PHOTOGRAMMETRY IN SWEDISH HYDROGRAPHIC SURVEYING

by Dr. P.O. FAGERHOLM,
Head of the Swedish Hydrographic Office.

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CHARACTERISTIC OF SWEDISH WATERS AND SURROUNDING SEAS

Sweden is no doubt regarded as a country fronted by archipelagoes with innumerable islands, rocks and shoals. This is not the general rule, however, as 40 per cent of the coast is open, 30 per cent is fronted by scattered islands and only the remaining 30 per cent is fringed by archipelagoes. The coast and archipelago waters are in the main rather shoaly and have an uneven bottom topography. This was created by the last glaciation which formed moraines and drums between hard ridges of the bedrock. The ridges have not yet been fully abraded.

As a rule the seas outside the coastal waters are relatively shoaly and extensive offshore surveying is therefore necessary. Nowadays this survey is performed by means of a movable Decca chain belonging to the Hydrographic Department of the Royal Board of Shipping and Navigation.

(See Fig. 1 and 2)

The general character of the coast and archipelago waters makes surveys time-consuming and expensive. Though it is more than 300 years since our first chart was published, we consider to-day that only 25 per cent of our waters are satisfactorily surveyed taking into account the increasing draught of modern ships.

THE CLIMATE OF SWEDEN FROM THE SURVEYORS' POINT OF VIEW

(See Fig. 3)

The temperate Gulf Stream gives the country a maritime climate with higher mean temperatures than would be expected in these high latitudes. The diagrams give mean temperature, cloud amount, wind force, and formation of ice at five characteristic places. Owing to the relatively large amount of clouds, air photography can take place at an average of only 20 days each year. The curves of temperature and ice formation show that our survey season must be limited to about five months. Therefore, the survey work must be transferred to office work as far as possible and the remaining part of the survey work must be rationalized to the utmost. In this respect photogrammetry is extremely helpful.

THE GEODETIC FRAMEWORK OF SWEDISH COASTAL AREAS

(See Fig. 4)

The Swedish first order triangulation, which is being performed by the Geographical Survey Office, consists of a series of first order frames which have been completed with second order area nets. The Hydrographic Office has for a long time been responsible for filling up with the second-order framework in

coastal areas. As the coast and isles are relatively low and densely wooded, the geodetic determination of positions of minor control points has been hard work, which is now being eliminated by a photogrammetric framework.

Previous survey methods

As regards the determination of positions of minor control points and coast lines, previous Swedish methods seem to have corresponded with those of other countries. The work was complicated, however, by the fringed coast areas.

The course of photogrammetric work

Airphotographing. (See Fig. 5)

The strips are planned in relation to the coast, islands and islets in such a way that :

The pictures can be oriented in precision stereo plotters ;

Photogrammetric triangulation between existing geodetic points is not interfered with by water surfaces ;

Sun reflections do not interfere within important areas ;

High trees normally do not hide the coast line.

We are now gradually turning from photography with a Zeiss RMK 20.30.30. (f=200 mm) from an altitude of 4000 m at a scale of 1 :20000 to photography with a wild Rc 5a with Aviogon objective (f = 150 mm) from an altitude of 6000 m at scale 1 :40000. Owing to different sizes of pictures, the coverage does not increase quadratically proportionately to the picture scales but from 35 square km to 80 square km.

Furthermore, we recently began to try photographing from an altitude of 10000 m at scale 1 :65000. Every picture covers an area of 15 by 15 km, that is to say 225 square km.

Before air photography we build or paint signals on existing geodetic triangulation points. This increases essentially the accuracy of the photogrammetric procedure.

We photograph only in light or moderate winds in order to avoid breakers along the coast.

According to our experience infrared photography gives a very sharp and good coastline and no sun reflection. But infrared photographs also have some disadvantages, which cause us to use the ordinary panchromatic material. The disadvantages of infraphotography are :

1. Rather poor reproduction of bushes, grass patches, etc., which might be used as minor control points;

2. No reproduction of ledges and shoals, knowledge of which would be of great value to surveyors;

3. Poorer reproduction of triangulation station signals.

(See Fig. 6a, 6b, 6c, 6d)

From a theoretical study we have found that the most appropriate combination of film and filter is orthochromatic film and green filter for obtaining as good a reproduction of the bottom as possible. In the Gulf of Bothnia, however, this combination has failed as the water is coloured brown by waste from sulphate factories and sludge.

Fig. 1.

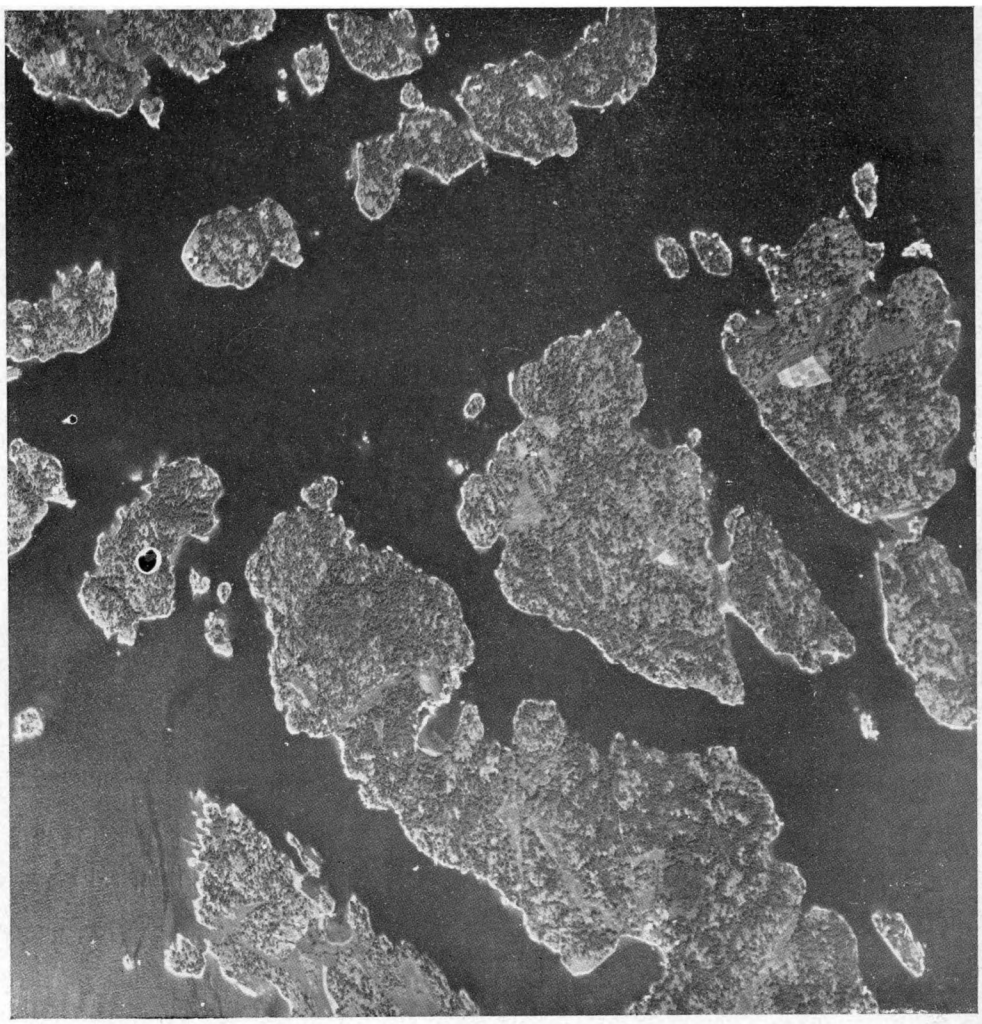


Fig. 2.

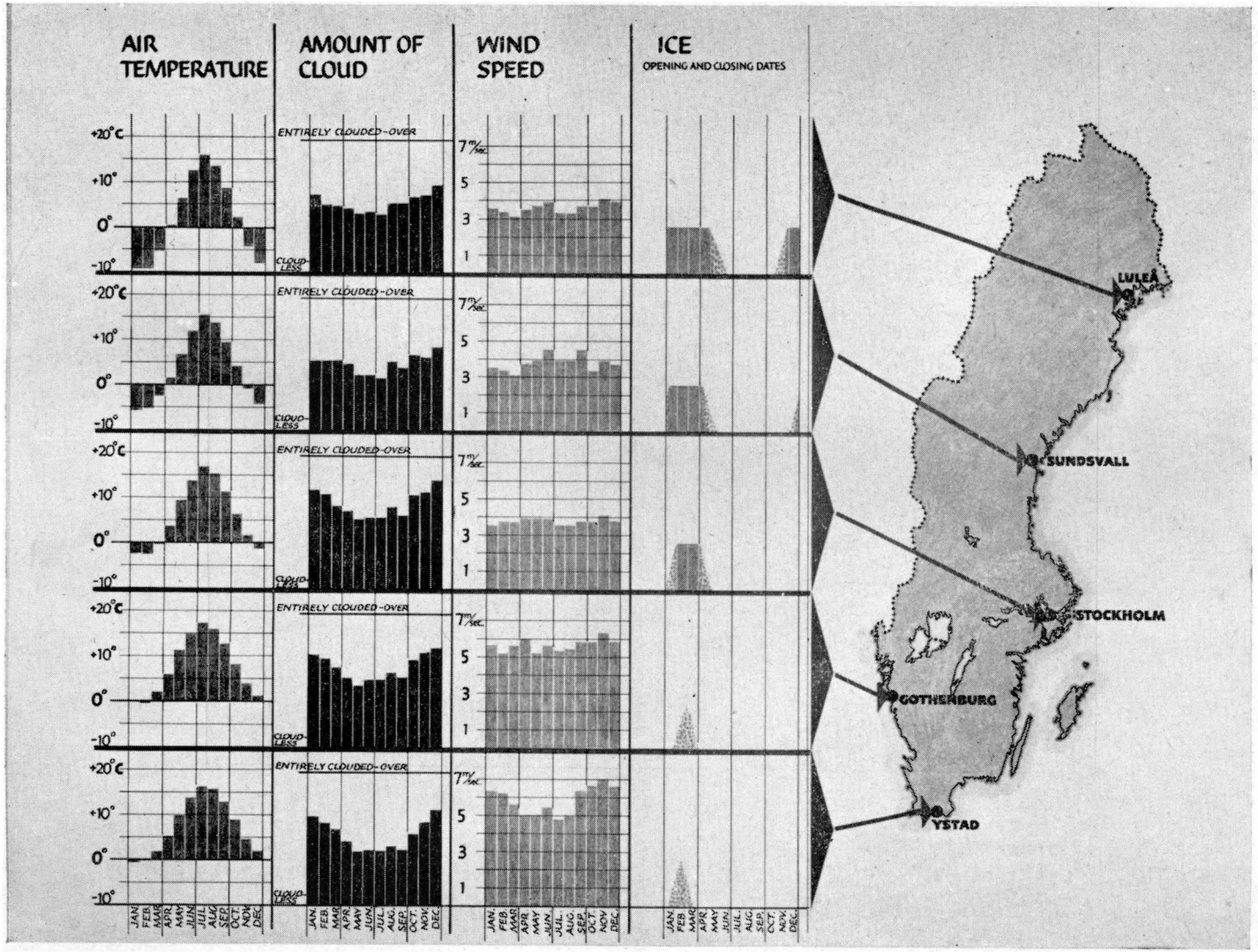

AIR TEMPERATURE
AMOUNT OF CLOUD
WIND SPEED
ICE
OPENING AND CLOSING DATES
+20°C
+10°
0°
-10°
ENTIRELY CLOUDED-OVER
CLOUD-LESS
7 m/sec
5
3
1
JAN.
FEB.
MAR.
APR.
MAY
JUN.
JUL.
AUG.
SEP.
OCT.
NOV.
DEC.
LULEÅ
SUNDSVALL
STOCKHOLM
GOTHENBURG
YSTAD

Fig. 3.

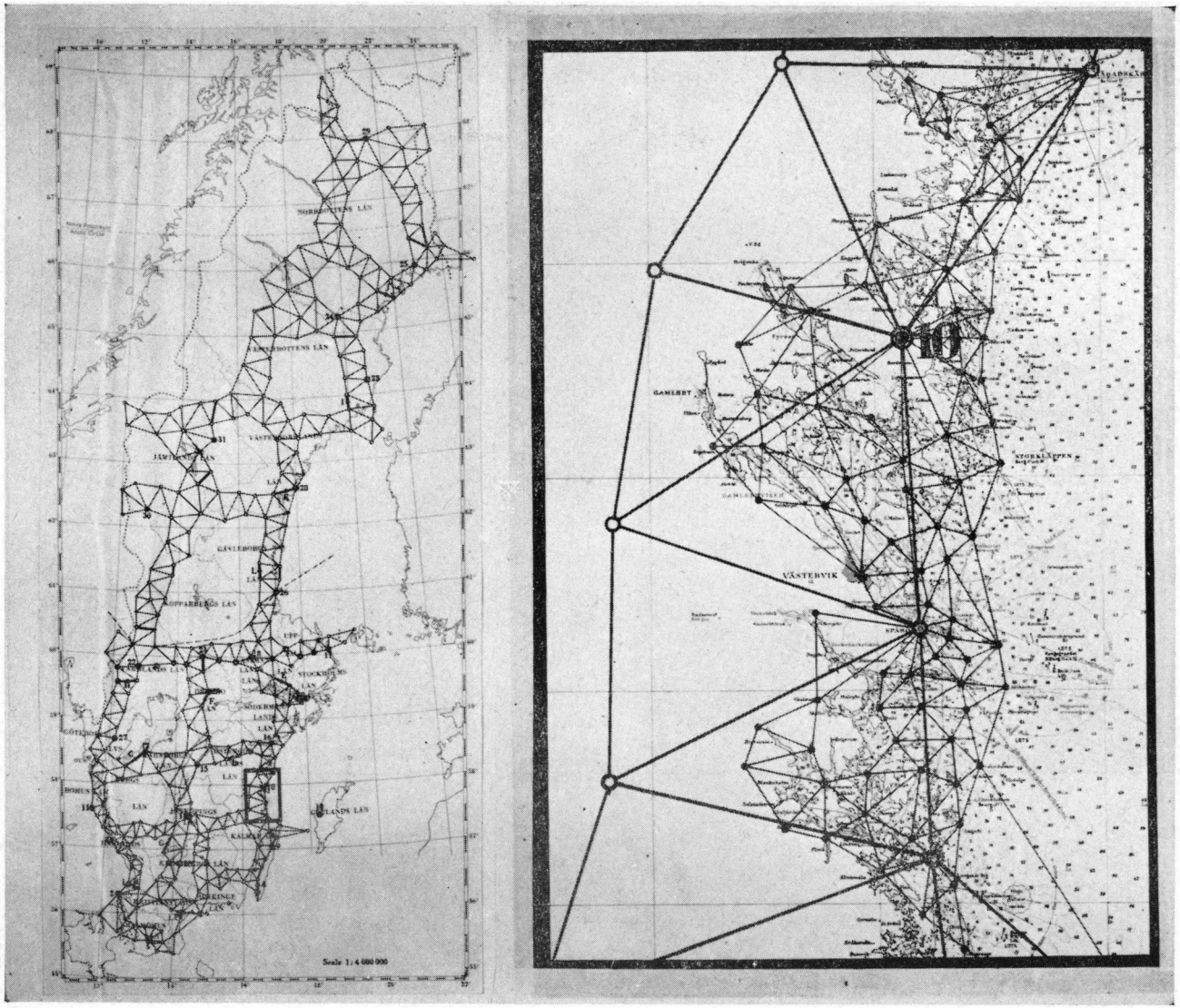

Scale 1:4 000 000
GÄVLEBORGS LÄN
KOPPARBERGS LÄN
STOCKHOLMS LÄN
GOTLANDS LÄN
GAMLEBY
VÄSTERVIK
STORA SJÖFEN

Fig. 4.

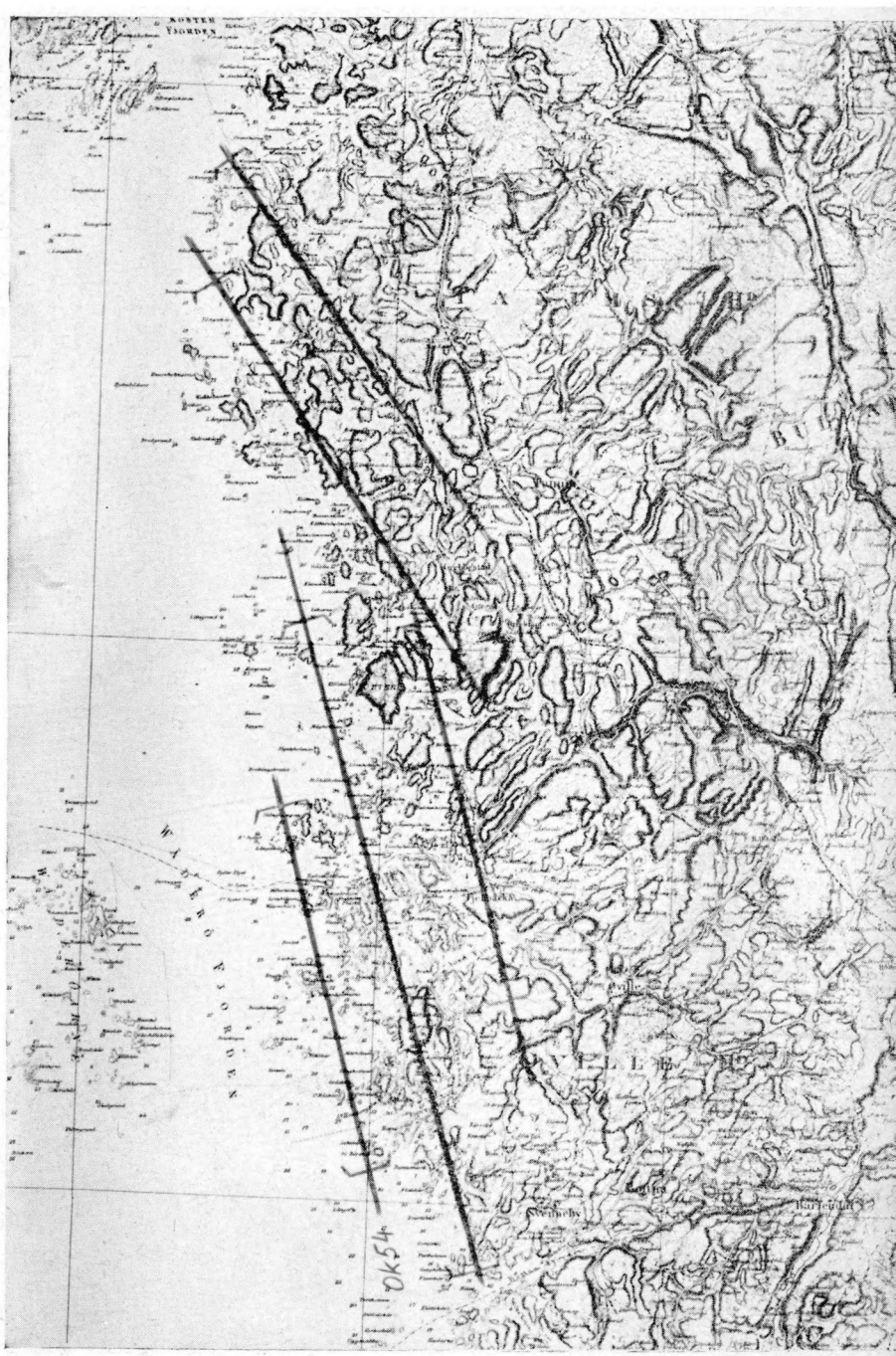


Fig. 5.

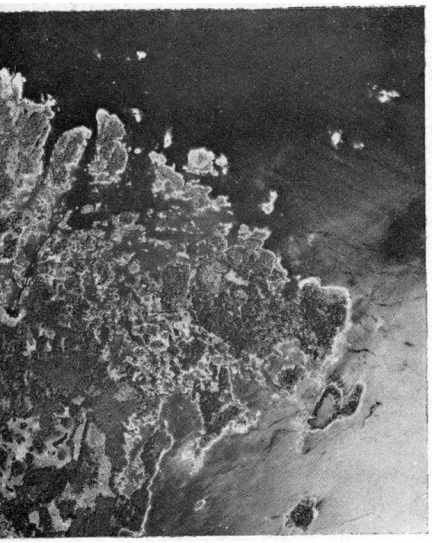


Fig. 6 a

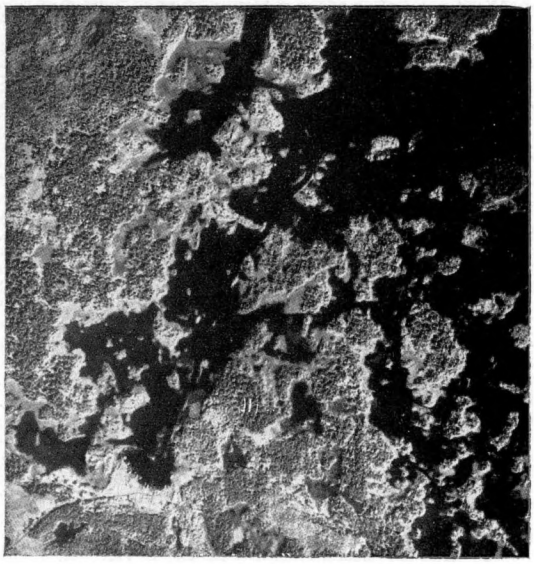


Fig. 6 b

Fig. 6 c

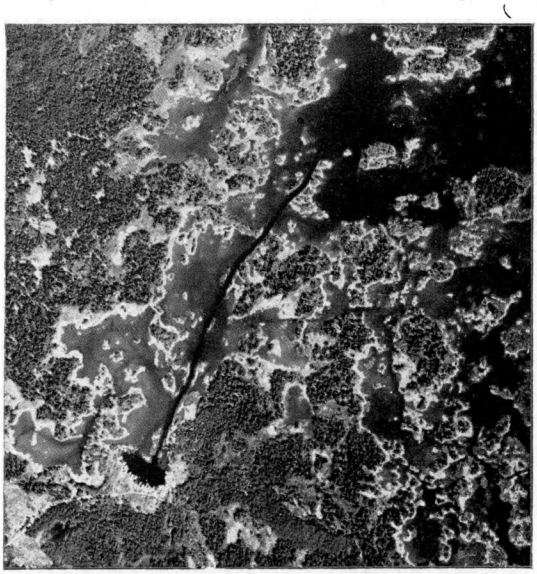


Fig. 6 d

Colour photography from moderate altitudes can in particularly fair weather give additional information, especially concerning demarcation between reed and land. We have as yet no sufficient experience of colour photography to be able to state whether colour pictures are of any considerable importance.

As soon as the photographic flight is finished the triangulation stations are identified on the pictures. This can be performed in the office by means of sketches and descriptions.

Photogrammetric plotting.

This takes place in the precision Wild A7 or A8 stereo plotter or Zeiss Stereoplanigraph. When the geodetic framework is sparse we first make a photogrammetric triangulation. The «Ekelund method» with its independent models is well suited for this work and it gives very good accuracy.

The quality of the stereomodels for triangulation and plotting is controlled by measuring vertical parallaxes and by calculating the orientation corrections in

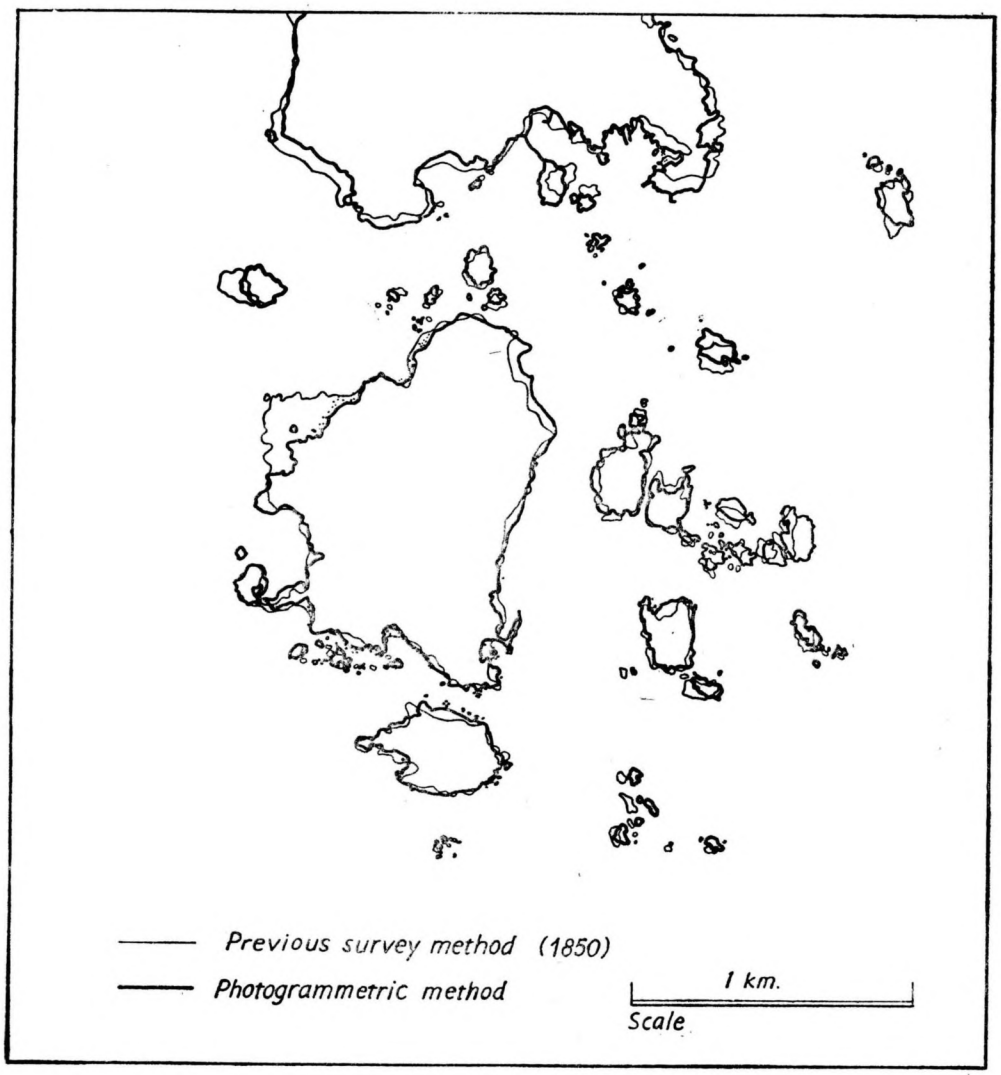


Fig. 7.

accordance with the «Hallert method». The mean square error is greatly diminished by adjusting models numerically. When evaluating the very high altitude photography, which we are now experimenting, we will use the aforesaid numerical adjustment method in order to obtain maximum precision. We reckon that we will be able to reduce the mean square error to about ± 1 m as far as sharp details are concerned. We also plan to apply pure numerical methods for calculation of the point-coordinates from stereocomparator measurements in the pictures. The reason for this is the wish to get the same accuracy from very-high altitude-photographs (10000 m.) as now from photographs taken from 4000 or 6000 metres.

(See Fig. 7)

The next step is the plotting of coastline and minor control points. For the information of surveyors, ledges and rocks awash are also charted. Diffuse coastline is dotted. The coastline is plotted at a rate of about 600 metres per minute. When appropriate, height contours are also drawn for the purpose of producing future radar charts if such charts should be required.

We do not know as yet whether it is possible to determine, or rather to interpret minor control points on the very-high altitude pictures (1 : 65000). Should this procedure not be possible we intend to use pictures from lower altitudes for interpreting and pictures from 10000-metre altitudes for determining positions.

In about 1944 we started to use air photogrammetry for hydrographic surveying purposes in Sweden. At that time we had already explored minor control points and built or painted marks in the terrain in order to recognize the points on the pictures. This procedure, however, has been shown to be superfluous, as usually a sufficient number of good natural points exist. I will mention some natural control points, the positions of which can be determined in the stereoplotting instruments and which need not be marked for surveying purposes. These are, for instance, flagpoles, chimneys on factories, and houses of various sizes ; blocks of stone on island tops or ridges, trees standing by themselves, etc. Most of the control points however must be chosen by means of horizontal details as for instance bodies of water in small clefts, sandspots, a small bush, small grass grown plots, ridges of house roofs, etc. In these latter cases marks must be built on the points or eccentric to them in conjunction with the beginning of the sounding work.

The minor control points are chosen in the stereoplotting instrument by an assisting surveyor. He has to estimate their probable visibility from the sea and their appropriate placing as seen from the surveyor's point of view. The minor control points are pricked on enlarged air photos but they are also fully described in illustrated description booklets. As photogrammetric determination and description only require one to three minutes we can afford to make plenty of reserve points.

Photogrammetric material on survey expeditions.

When a survey vessel is sailing for an expedition, equipped for surveying, it has on board :

1. *Original sheets* on the scale of 1 : 10000. These consist of dimensionally stable material and show triangulation stations, photogrammetrically plotted control points, coastlines etc., and also contour lines. These sheets are kept on board and the ship's cartographer uses them for the initial assembling of concentrated data from the tremendously extensive soundings. The sheets also constitute our original material for the editing of new charts and for examinations regarding new channels, lighting, etc.

(See Fig. 8)

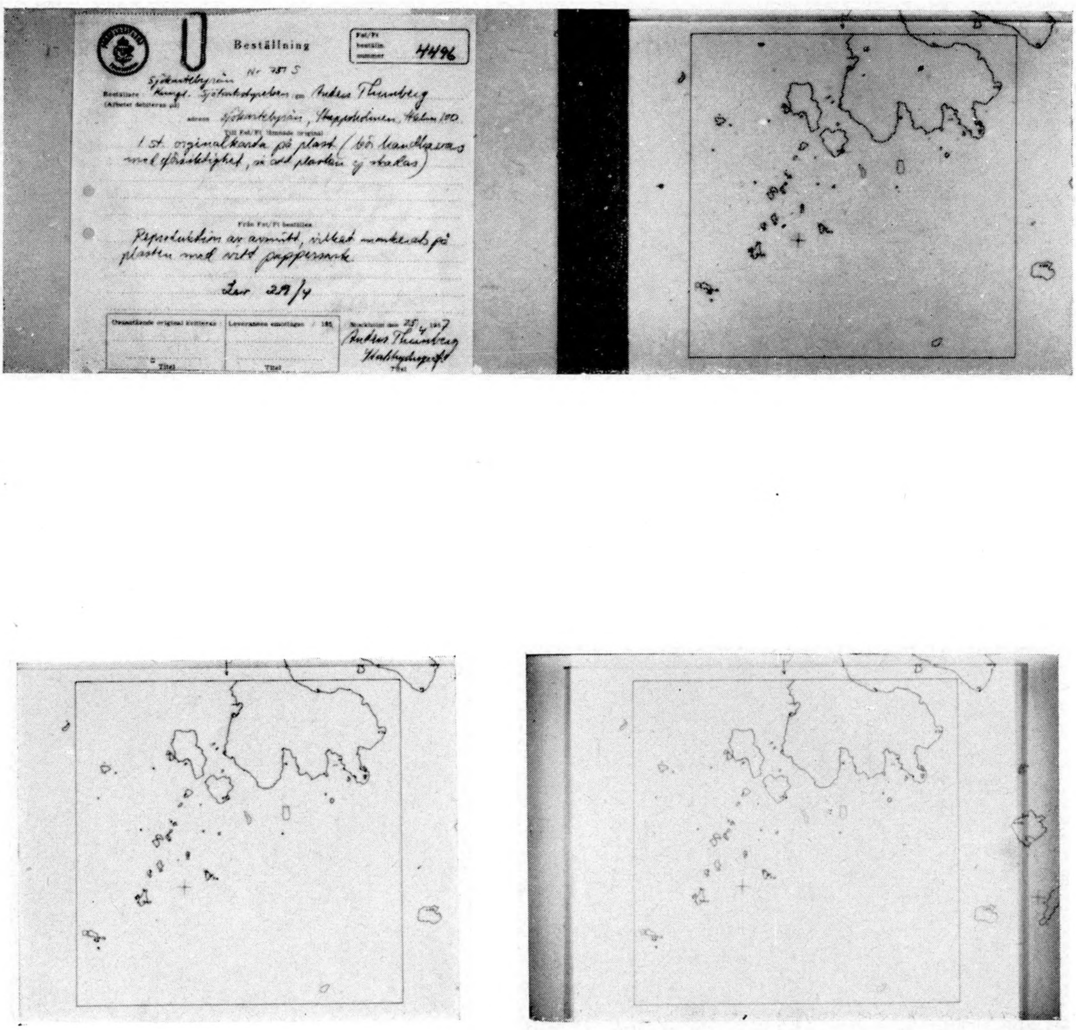

Beställning
4496
1 st. orginalkarta på plast (bör handhavas med försiktighet, så att plasten ej skadas)
Reproduktion av avsnitt, vilket monteras på plasten med vitt pappersark
Anders Thunberg

Fig. 8.

Fig. 9.

Punkternas signalering
The signals of the points

V 33 :

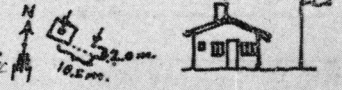
V 34 a : flstg. 10,5 m. i riktning mot sjöbodens V. hörn (mot V32)
flaggstaff 10,5 m. in the direction towards the western corner of the boat-house (V32)

V 35 :

V 36 : Ensam rönn
A single rowan-tree

V 37 : Flyttad 8 m. mot V36
Moved 8 m. towards V36

V 38 a : flstk.
flaggstaff



V 39 :

V 40 :

X 52 - 155 - 14
(The registration-number of the aerial photo.)

Nr	Description Beskrivning
V 33	Centrum av stort stenblock The centre of a large block of stone ungefär mitt på ön. in the middle of the island.
V 34	Västra taknocken på stuga The western ridge-pole of a cottage
V 35	Toppen på stort stenblock The top of a large block of stone
V 36	Liten topp å öns högsta punkt A small top at the highest point of the island.
V 37	Ensamt träd A single tree
V 38	Skorsten å hus The chimney of a house
V 39	Sten på toppen av ön A stone on the top of the island
V 40	Centrum av stenblock The centre of a block of stone

Fig. 10.

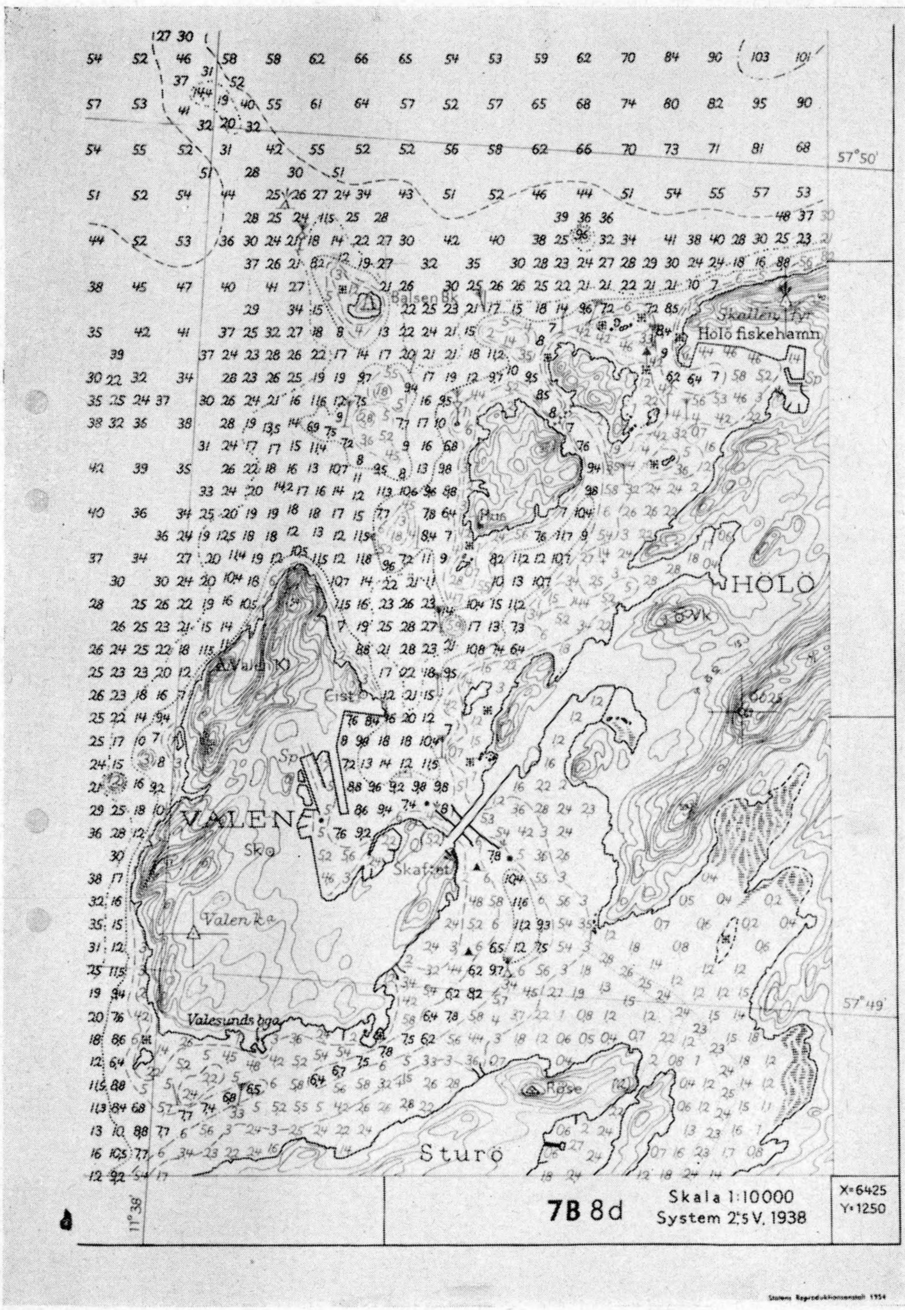

Holö fiskehamn
HOLÖ
VALEN
Sturö
7B 8d
Skala 1:10000
System 2,5 V. 1938
X=6425
Y=1250
57°50'
57°49'
11°38'

Fig. 11.

2. *Boat sheets* on the scale of 1 : 10000, consisting of plastic or of paper pasted on wooden frames. Most of the essential details of the original sheets have been transferred to the boat sheets. These are used on board the surveying boats for plotting (with the station pointer) of positions in the different types of sounding procedures.

(See Fig. 9)

3. *Air photo* enlargements, usually on the scale of 1 : 10000. They are marked with parallel lines 50 mm. apart in order to facilitate their viewing with a pocket stereoscope. On these enlargements all minor control points are pinpricked and lettered.

4. *Description booklets* containing all information, sketches etc. intended to facilitate the identification of photogrammetrically plotted control points.

(See Fig. 10)

Coastal water surveying

Upon arriving at the survey area the surveyors first have to build marks on control points which cannot themselves be used for measuring angles.

Next begins the echo sounding on course lines usually spaced 50 metres apart. The positions are obtained by quintant observations when running.

Shoal areas and areas with rough bottom topography are enclosed by small buoys, the positions of which are determined. Such areas are closely sounded on course lines so narrowly drawn that full coverage is guaranteed. In depths of less than 10 metres we space the course lines 6 metres apart.

Irregularities discovered are swept for least depth.

Results of the close soundings are successively recorded on investigation sheets on a scale of 1 : 500 - 1 : 5000.

The echo soundings on course lines and the investigations are recorded by the cartographer on the ship on the photogrammetric original sheet with ink of various colours.

(See Fig. 11)

Development of coastal water surveying

The method used in the survey of coastal waters will be further improved this summer when we plan to employ the « Fahrentholz frame ». This consists of 50 echo sounding microphones abreast, which are applied athwartships to a small vessel. If wind and sea permit, the vessel will proceed at a speed of 5 knots. We will thus achieve a complete representation of the depths within lanes of 50 metres. Positions will be determined from photogrammetric control points and full coverage will be secured by means of buoyage.

Gradually as electronic aids to navigation — such as the « Atlas radiolog », which will be tested in Sweden this summer — improve, the importance of a dense network of control points will essentially decrease. Then the photogrammetric charting will be required for representing the coast line and in some cases for determining the radio reference stations and check-points.