DETERMINATION OF FIXED ERRORS IN NAVIGATIONAL (AND HYDROGRAPHIC) DECCA CHAINS

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Due to variations in electrical ground conductivity, which causes variations in phase propagation velocity, the Decca patterns show some irregularities. This is especially the case when conductivity over land is bad and differs substantially from that over water, as in Sweden and other countries with moraine and surface rock geology.

When the Swedish Hydrographic Office started its first Decca surveys with its own hyperbolic survey chain these unforeseen disturbances caused a great deal of trouble. With the assistance of Mr. Hugo LARSSON as consultant to the H.O., a method of surveying and interpolation of the fixed error curves was developed. (See International Hydrographic Review, November 1949 and May 1956).

The same system in principle was used in the next two positions of the survey chain, and also for the Baltic navigational chain when it was established in 1957.

There was much discussion in Sweden, and there still is in other countries, as to whether Decca lattices on navigational charts should be corrected for the constant *fixed error* or *land corrections*, as we call them, by altering their sign. In spite of the fact that considerable survey resources (ship's time) have to be used for the field work, and the fair drawing of the lattices becomes somewhat more complicated, the National Board of Shipping and Navigation has found it advisable to raise the quality of the system in order to assist the navigator, as well as to eliminate the risk of adding corrections when they should be subtracted or vice versa. Consequently we do not accept the halfway idea of making sparsely distributed fixed error determinations, and of presenting them in tables.

The next (and last) position of our survey chain (1959-60) was in the Bay of Bothnia where, as usual, the Finnish and Swedish survey ships cooperated very closely, using the same chain and the same control station. After establishing the Decca stations the first task was to determine the

land corrections — in this case with the following somewhat modified procedure for the calculations. The method was worked out by Mr. A. THUNBERG, head of the Research and Development Section of the H. O. The entire operation was supervised from the survey point of view by Mr. F. WESTERBERG. The kind asistance of Mr. Hugo LARSSON in the interpretation of the results was most beneficial to their high quality.

The sextant angles (and the trig. station numbers) were sent by radio every evening from the Finnish and Swedish ships to the control station, and written-up as records. The records were brought to a nearby telex-station, punched into a telex-tape and sent by wire to Stockholm. In a data-processing centre a big electronic computer (Facit EDB) was fed with a special programme — coordinates for all trig. stations in the area and the telex data. The figures in the column to the right (fig. 2*a* and 2*b*) in every data group were *check sums*, computed on board the ships in order to verify correct data transmission by radio and telex. The output (on telex-code) was the theoretical Decca values for the checking points as well as the half axes of an "error parallelogram", assuming a unit error in each sextant angle of 1 minute of arc. This was certainly too low a value ! The telex-tape was transmitted by telephone line to the telex station near the control station and the results sent the last part of the way by radio to the ships. In the ships, in this manner, the values could, when needed, be available within a few hours and be compared with the decometer readings. The need for extra checking points could consequently be analysed before the ship proceeded along the coast.

When, together with Finland, two new navigational Decca chains were established in 1961-62, covering the Gulf and Bay of Bothnia, it was decided to continue with the principle of determining fixed errors and printing charts with corrected Decca lattices. In order to assist the navigators when passing the narrows between the Gulf of Bothnia and the Bay of Bothnia, it was also decided to produce a new chart (scale 1/125 000) over that Finnish-Swedish area, but *only* a Decca chart. This chart (D 515) has been produced jointly by the H. O.'s of the two countries. As it contains specific cartographic details it has been separately produced.

It was decided to carry out a Finnish-Swedish determination of land corrections according to a common plan, and with the calculations (electronically) performed in Sweden. Finland used the traditional resection system with sextant angles taken from the ships. Sweden planned to use that system to a certain extent, but also to use Hydrodist and shore-based theodolites.

There were two shore groups, each one with one Hydrodist remote, one theodolite and one VHF set. With this set-up redundant observations could normally be taken, which is rather seldom the case in hydrographic surveys, in contrast to geodetic and topographic surveys. Furthermore this set-up gave a good safety margin for instrument trouble, bad visibility, moving time for shore groups, etc. The major benefit of Hydrodist was its high accuracy (± 1 m), which could be obtained very far out (maximum about 70 km) where, even if land marks and shore fixes had been visible,

INPUT DATA SENT FROM THE SURVEY SHIPS BY RADIO AND TELEX TO THE COMPUTER CENTER IN STOCKHOLM. RESECTION WITH SEXTANT ANGLES.

U/ /Följer data till uppdragsnummer 0885. Mätningarna utförda av Nautilus den 25.6 1962 inom område 1 och avse deccakedja 5. Röd blankett.//

U/ + 1731① + 10② + 46③ + 59④ + 48② + 78③ + 51④ + 33② + 984⑤ + 779⑤ + 166⑤ /- 3985⑥/

U/ + 1800 + 46 + 65 + 27 + 32 + 55 + 28 + 58 + 368 + 113 + 759 /- 3351 /

U/ + 1821 + 46 + 70 + 21 + 32 + 69 + 58 + 58 + 970 + 005 + 237 /- 3387 /

{Information about ship, date, Decca-chain, etc.

{Data from one sextant-observ. and corresponding Decca-readings

① Observation-time
② Number of the three fix-points used
③ Measured angles (degrees)
④ Measured angles (minutes)
⑤ Decimals in the Decca-readings (red, green, purple)
⑥ Check-sum

OUTPUT DATA FROM THE ELECTRONIC COMPUTER

Följer data till uppdragsnummer 0885. Mätningarna utförda av Nautilus den 25.6 1962 inom område 1 och avse deccakedja 5. Röd blankett.

1731⑦	140,891⑧	164,732⑧	4,338⑧
	-0,984⑨	-0,779⑨	0,166⑨
	-0,093⑩	-0,047⑩	0,172⑩
	6,5⑪ 55,9⑫	5,1⑪	383,8⑫
1800	143,314	163,061	4,920
	0,368	0,113	0,759
	-0,054	-0,052	0,161
	5,3 378,1	4,5	68,0
1821	144,945	160,972	5,424
	0,970	0,005	0,237
	-0,025	-0,033	0,187
	4,5 362,7	2,7	62,0

{Information about ship, date, Decca-chain, etc. Repeated on the output data sheet.

{Results for one sextant-fix with corresponding Decca-readings.

⑦ Observation time
⑧ Computed hyperbola-numbers
⑨ Decimals in the Decca-readings
⑩ "Land-corrections"
⑪ Half-axes of the "error-parallellogram".
⑫ The directions (centigrades) of the half-axes.

FIG. 1*a*.

INPUT DATA SENT FROM THE SURVEY SHIPS BY RADIO AND TELEX TO THE COMPUTER CENTER IN STOCKHOLM. POSITION DETERMINATION WITH HYDRODIST, THEODOLITES OR HYDRODIST + THEODOLITE.

```
          U/ /GKL den 21.6. Kedja 5 Grön blankett.//

U/  + 951① + 202② + 0848,960④ + 0② + 0④ + 0② + 0④
    + 010⑥ + 312⑥ + 584⑥ + 202③ + 18437⑤ + 0③ + 0⑤/-869658⑦/

U/  + 1017  + 202  + 0551,920  + 0  + 0  + 0  + 0
    + 870  + 662  + 522  + 202  + 19112  + 19  + 24298  /-598824/

U/  + 1117  + 0  + 0  + 0  + 0  + 0  + 0
    + 294  + 027  + 665  + 202  + 24726  + 19  + 26186  /-53236/

U/  + 1144  + 0  + 0  + 19  + 1452,299  + 0  + 0
    + 445  + 466  + 587  + 202  + 22387  + 19  + 20195  /-1497763/

U/  + 1231  + 0  + 0  + 0  + 0  + 0  + 0
    + 226  + 125  + 900  + 202  + 33593  + 19  + 27216  /-63512/

U/  + 1453  + 36  + 0479,971  + 58  + 0292,620  + 0  + 0
    + 341  + 827  + 0  + 0  + 0  + 0  + 0  /-775306/
```

{ Information about ship, date, Decca-chain, etc.

{ Data from one theodolite + Hydrodist observation

① Observation time
② Trig-point number (theodolite-station ashore)
③ Trig-point number (Hydrodist-station ashore)
④ Geodetic azimuth observed towards the ship
⑤ Distance to the ship
⑥ Decimals in the Decca-readings (red, green, purple)
⑦ Check-sum.

OUTPUT DATA FROM THE ELECTRONIC COMPUTER

951⑧	10010⑨	44.897⑩	56.227⑩	0.090⑩	
		10⑪	312⑪	584⑪	
		- 113⑫	- 85⑫	- 494⑫	- ⑬
1017	10011	39.760	60.598	0.137	
		870	662	522	
		- 110	- 64	- 385	2.65
1144	01011	35.454	67.431	1.225	
		445	466	587	
		9	- 35	- 362	0.98
1231	00011	0.261	32.065	38.081	
		226	125	900	
		35	- 60	181	-
1453	11000	21.326	29.894		
		341	827		
		- 15	67		

⑧ Observation time
⑨ Five characters indicating the combination of theodolite and Hydrodist-observations
⑩ Computed hyperbola numbers
⑪ Decimals in the Decca-readings
⑫ "Land-corrections"
⑬ The distance in metres between X- and Y- coordinates computed two different ways, if redundant observations are taken.

FIG. 1*b*.

FORM TO BE USED IN DETERMINATION OF LAND CORRECTIONS

RESECTION WITH SEXTANT-ANGLES

Decca chain number 5

Surveying ship: Nautilus

Date 25/6/1962

Trigpoints:
No: 10, 46, 48, 32, 33, 58

Name: ....

TIME	LEFT TRIGPOINT NUMBER	LEFT ANGLE °	LEFT ANGLE ′	CENTRAL TRIGPOINT NUMBER	RIGHT ANGLE °	RIGHT ANGLE ′	RIGHT TRIGPOINT NUMBER	DECCA-READINGS (DECIMALS) RED	GREEN	PURPLE	CHECK-SUM
U/+ 1731	10	+ 46	+ 59	+ 48	+ 78	+ 51	+ 33	+ 984	+ 779	+ 166	/- 3985 /
U/+	+	+	+	+	+	+	+	+	+	+	/- /
U/+	+	+	+	+	+	+	+	+	+	+	/- /
U/+ 1800	+ 46	+ 65	+ 27	+ 32	+ 55	+ 28	+ 58	+ 368	+ 113	+ 759	/- 3351 /
U/+	+	+	+	+	+	+	+	+	+	+	/- /
U/+	+	+	+	+	+	+	+	+	+	+	/- /
U/+ 1821	+ 46	+ 70	+ 21	+ 32	+ 69	+ 58	+ 58	+ 970	+ 005	+ 237	/- 3387 /
U/+	+	+	+	+	+	+	+	+	+	+	/- /
U/+	+	+	+	+	+	+	+	+	+	+	/- /
U/+	+	+	+	+	+	+	+	+	+	+	/- /
U/+	+	+	+	+	+	+	+	+	+	+	/- /
U/+	+	+	+	+	+	+	+	+	+	+	/- /
U/+	+	+	+	+	+	+	+	+	+	+	/- /
U/+	+	+	+	+	+	+	+	+	+	+	/- /
U/+	+	+	+	+	+	+	+	+	+	+	/- /
U/+	+	+	+	+	+	+	+	+	+	+	/- /
U/+	+	+	+	+	+	+	+	+	+	+	/- /
U/+	+	+	+	+	+	+	+	+	+	+	/- /
U/+	+	+	+	+	+	+	+	+	+	+	/- /
U/+	+	+	+	+	+	+	+	+	+	+	/- /
U/+	+	+	+	+	+	+	+	+	+	+	/- /
U/+	+	+	+	+	+	+	+	+	+	+	/- /
U/+	+	+	+	+	+	+	+	+	+	+	/- /
U/+	+	+	+	+	+	+	+	+	+	+	/- /

FIG. 2a

FORM TO BE USED IN DETERMINATION OF LAND CORRECTIONS.

THEODOLITE AND HYDRODIST.

Decca chain number : 5
Surveing ship : G. KL
Date : 21/6/1962

Trigpoints :
N° .... Name : ....

TIME	THEODOLITE OBSERVATIONS FROM ASHORE						OBSERVATIONS ON BOARD THE SHIP							CHECK SUM
	TRIGPOINT NUMBER	GEODETIC AZIMUTH	TRIGPOINT NUMBER	GEODETIC AZIMUTH	TRIGPOINT NUMBER	GEODETIC AZIMUTH	DECCA-READINGS (decim) RED	GREEN	PURPLE	HYDRODIST OBSERVATIONS TRIGPOINT N°	DISTANCE	TRIGPOINT N°	DISTANCE	
U/+ 951	+ 202	+ 0848,960	+ 0	+ 0	+ 0	+ 0	+ 010	+ 312	+ 584	+ 202	+ 18437	+ 0	+ 0	/— 869658 /
U/+	+	+	+	+	+	+	+	+	+	+	+	+	+	/— /
U/+ 1017	+ 202	+ 0551,920	+ 0	+ 0	+ 0	+ 0	+ 870	+ 662	+ 522	+ 202	+ 19112	+ 19	+ 24298	/— 598824 /
U/+	+	+	+	+	+	+	+	+	+	+	+	+	+	/— /
U/+ 1117	+ 0	+ 0	+ 0	+ 0	+ 0	+ 0	+ 294	+ 027	+ 665	+ 202	+ 24726	+ 19	+ 26186	/— 53236 /
U/+	+	+	+	+	+	+	+	+	+	+	+	+	+	/— /
U/+ 1144	+ 0	+ 0	+ 19	+ 1452,299	+ 0	+ 0	+ 445	+ 466	+ 587	+ 202	+ 22387	+ 19	+ 20195	/— 1497763 /
U/+	+	+	+	+	+	+	+	+	+	+	+	+	+	/— /
U/+ 1231	+ 0	+ 0	+ 0	+ 0	+ 0	+ 0	+ 226	+ 125	+ 900	+ 202	+ 33593	+ 19	+ 27216	/— 63512 /
U/+	+	+	+	+	+	+	+	+	+	+	+	+	+	/— /
U/+ 1453	+ 36	+ 0479,971	+ 58	+ 0292,620	+ 0	+ 0	+ 341	+ 827	+ 0	+ 0	+ 0	+ 0	+ 0	/— 775306 /
U/+	+	+	+	+	+	+	+	+	+	+	+	+	+	/— /
U/+	+	+	+	+	+	+	+	+	+	+	+	+	+	/— /
U/+	+	+	+	+	+	+	+	+	+	+	+	+	+	/— /
U/+	+	+	+	+	+	+	+	+	+	+	+	+	+	/— /
U/+	+	+	+	+	+	+	+	+	+	+	+	+	+	/— /
U/+	+	+	+	+	+	+	+	+	+	+	+	+	+	/— /
U/+	+	+	+	+	+	+	+	+	+	+	+	+	+	/— /
U/+	+	+	+	+	+	+	+	+	+	+	+	+	+	/— /
U/+	+	+	+	+	+	+	+	+	+	+	+	+	+	/— /
U/+	+	+	+	+	+	+	+	+	+	+	+	+	+	/— /
U/+	+	+	+	+	+	+	+	+	+	+	+	+	+	/— /
U/+	+	+	+	+	+	+	+	+	+	+	+	+	+	/— /
U/+	+	+	+	+	+	+	+	+	+	+	+	+	+	/— /
U/+	+	+	+	+	+	+	+	+	+	+	+	+	+	/— /
U/+	+	+	+	+	+	+	+	+	+	+	+	+	+	/— /

FIG. 2b

the position accuracy of the sextant resection would be fairly low. The high accuracy is obviously not needed for safe navigation *but* is of great value for the interpretation of the errors and interpolation of the correction curves.

The operation proceeded according to plan under the operational leadership of Captain STARE, head of the Survey Section, and was quite successful. The number of check points (in groups of 3 or 5) was 595 Swedish and 591 Finnish. About 400 Hydrodist distances were measured and 360 theodolite readings (angles) taken. The operation lasted from 28/V to 24/VII in 1962, and the following ships were engaged :

From the Swedish H. O. :

Gustav af Klint, (650 tons), with Hydrodist (15/VI-24/VII);
Nils Strömcrona, (150 tons), with sextants only (28/V-24/VII);
Tärnan, (60 tons), mainly as a transport ship.

From the Finnish H. O. :

Nautilus, (30/V-19/VII);
Hyöky, (31/V-19/VII);
Airisto, as extra control station (1/VI-19/VII).

The plotting and interpretation of the results (Finnish and Swedish) were made in the Swedish H. O. in Stockholm, and not on board. The ships were given orders by radio when to proceed, or when to repeat a check measurement, etc.

Fig. 1*a* and 1*b* show the results from electronic computation of land corrections.

Fig. 2*a* and 2*b* show the forms used.

Fig. 3*a-e* show the final results of the operation — the correction curves for the two chains.

As consultant in the *analysis* Mr. Hugo LARSSON has been an indispensable help. He has been assisted by Captain STARE and cartographer SJÖLIN.

As this fixed-error survey may be one of the major ones, it has been thought to be of interest to other H.O.'s, as well as to other institutions and persons. Of course, the results of this survey, as well as its practical accomplishment, contain a lot more experience and details which might be of interest to others, but time and personal resources do not permit the production of an extensive report.

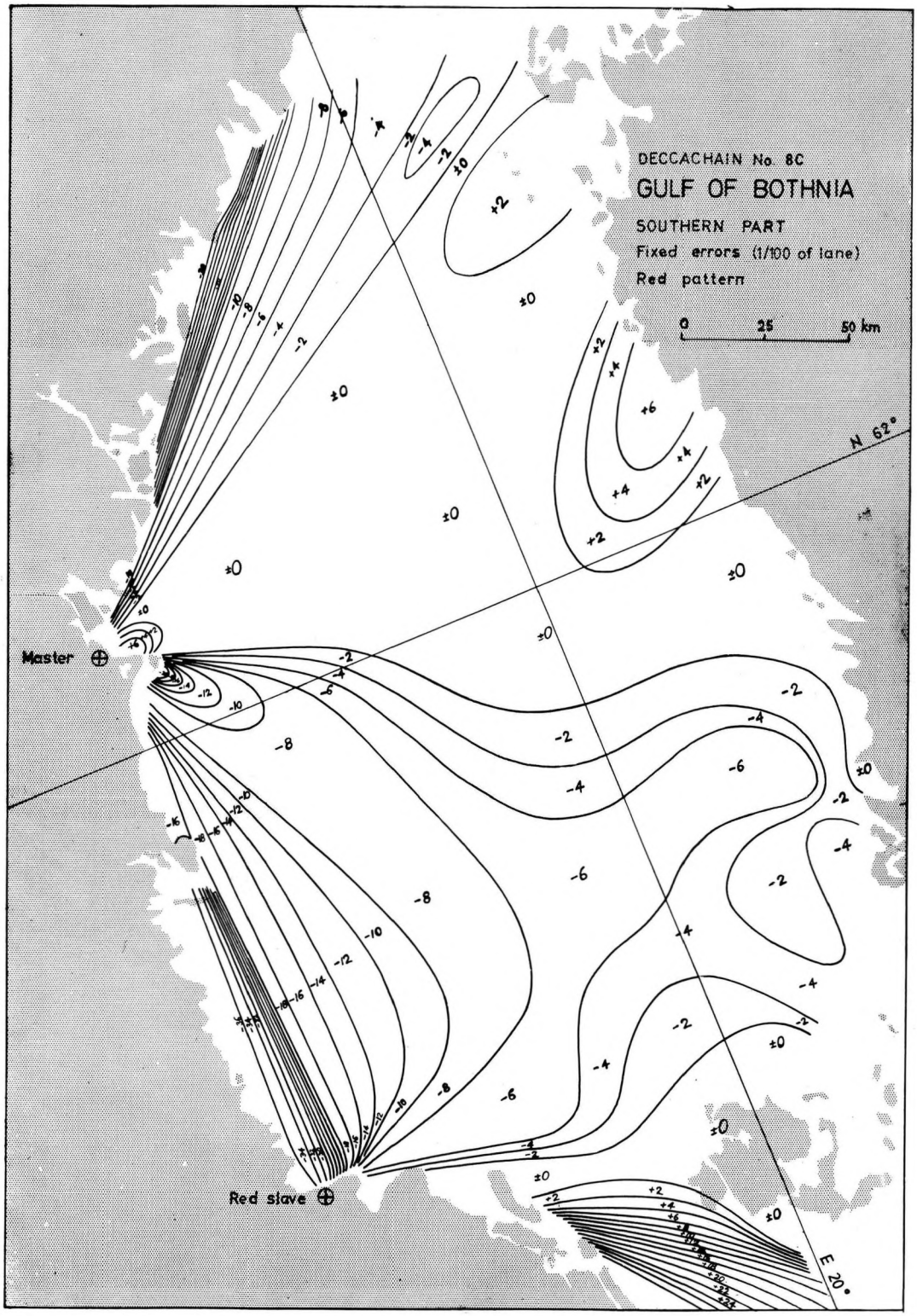
DECCACHAIN No. 8C
GULF OF BOTHNIA
SOUTHERN PART
Fixed errors (1/100 of lane)
Red pattern
0 25 50 km
N 62°
E 20°
Master
Red slave

FIG. 3a

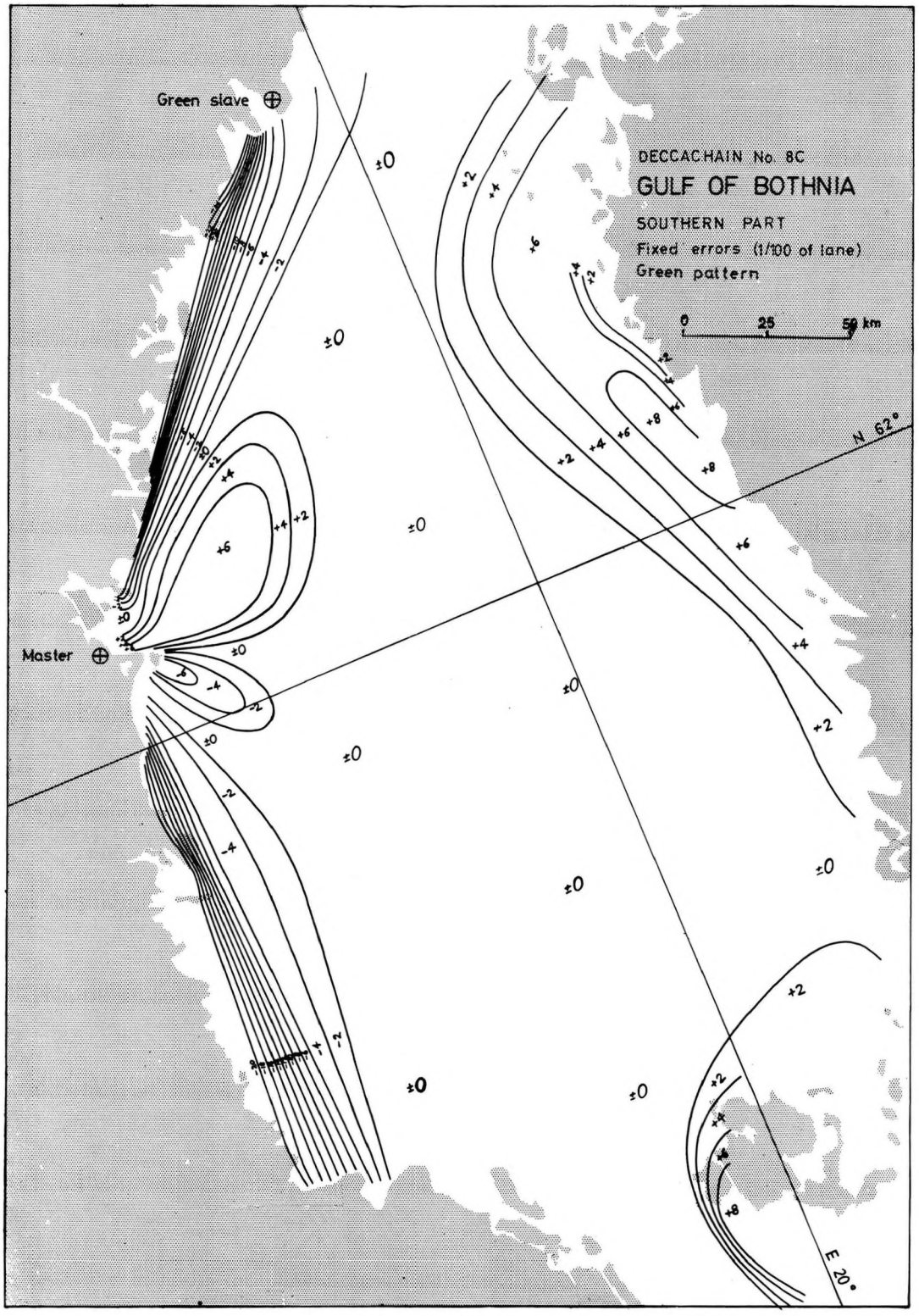
Green slave
Master
DECCA CHAIN No. 8C
GULF OF BOTHNIA
SOUTHERN PART
Fixed errors (1/100 of lane)
Green pattern
0
25
50 km
N 62°
E 20°
±0
+2
+4
+6
+8
-2
-4

FIG. 3b

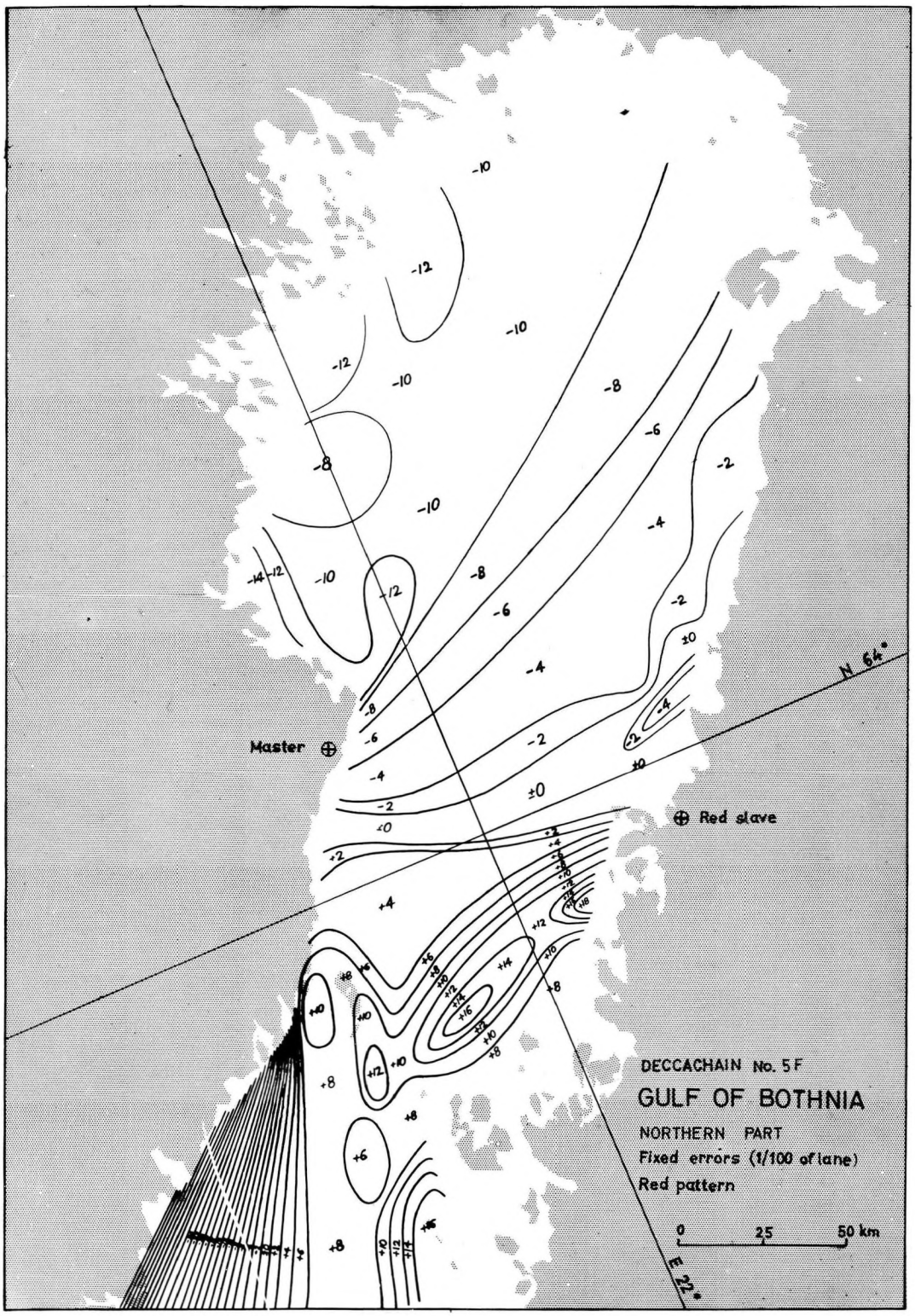
Master
Red slave
N 64°
E 22°
DECCACHAIN No. 5F
GULF OF BOTHNIA
NORTHERN PART
Fixed errors (1/100 of lane)
Red pattern
0
25
50 km

FIG. 3c

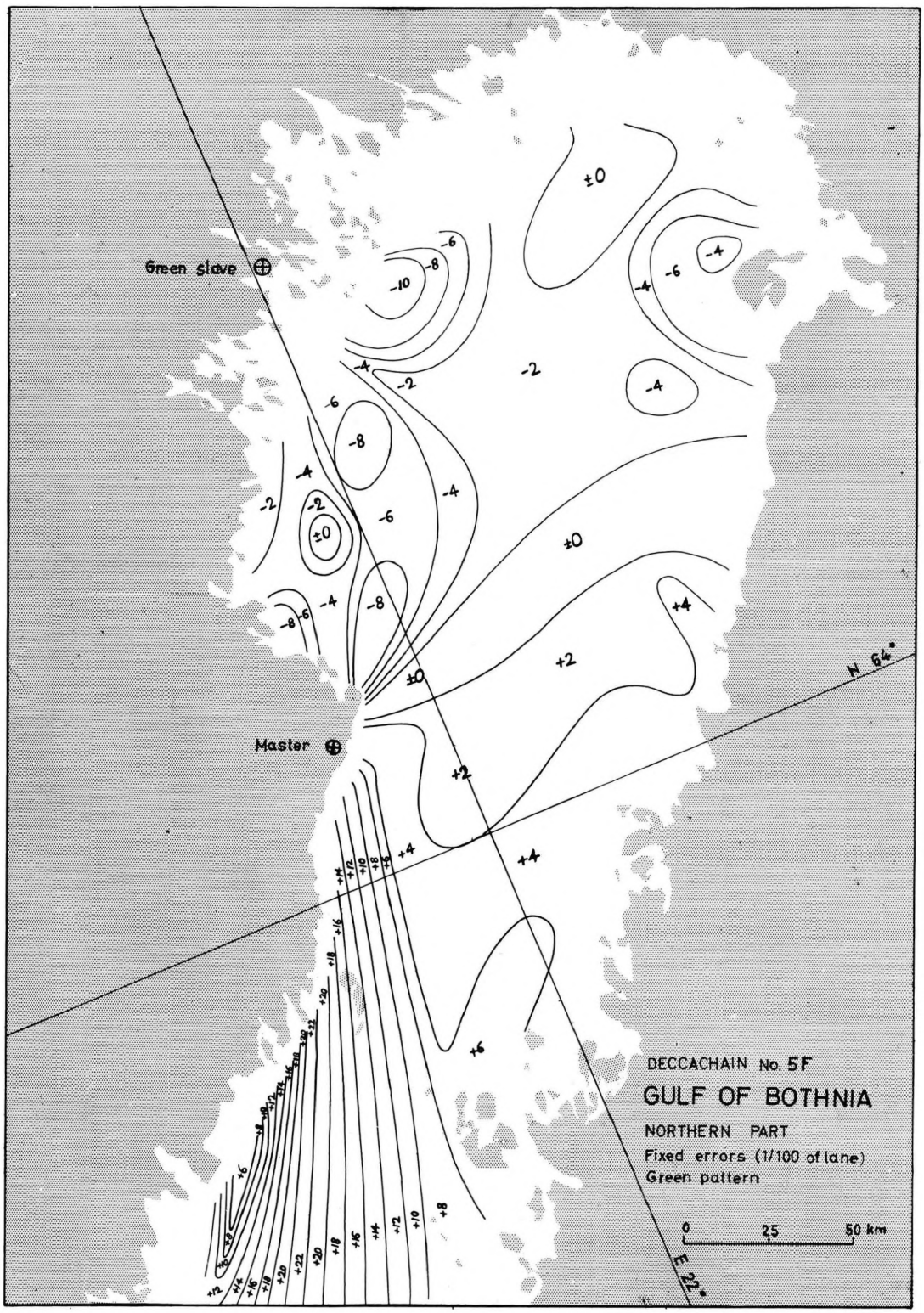
Green slave
Master
N 64°
E 22°
DECCACHAIN No. 5F
GULF OF BOTHNIA
NORTHERN PART
Fixed errors (1/100 of lane)
Green pattern
0 25 50 km

FIG. 3d

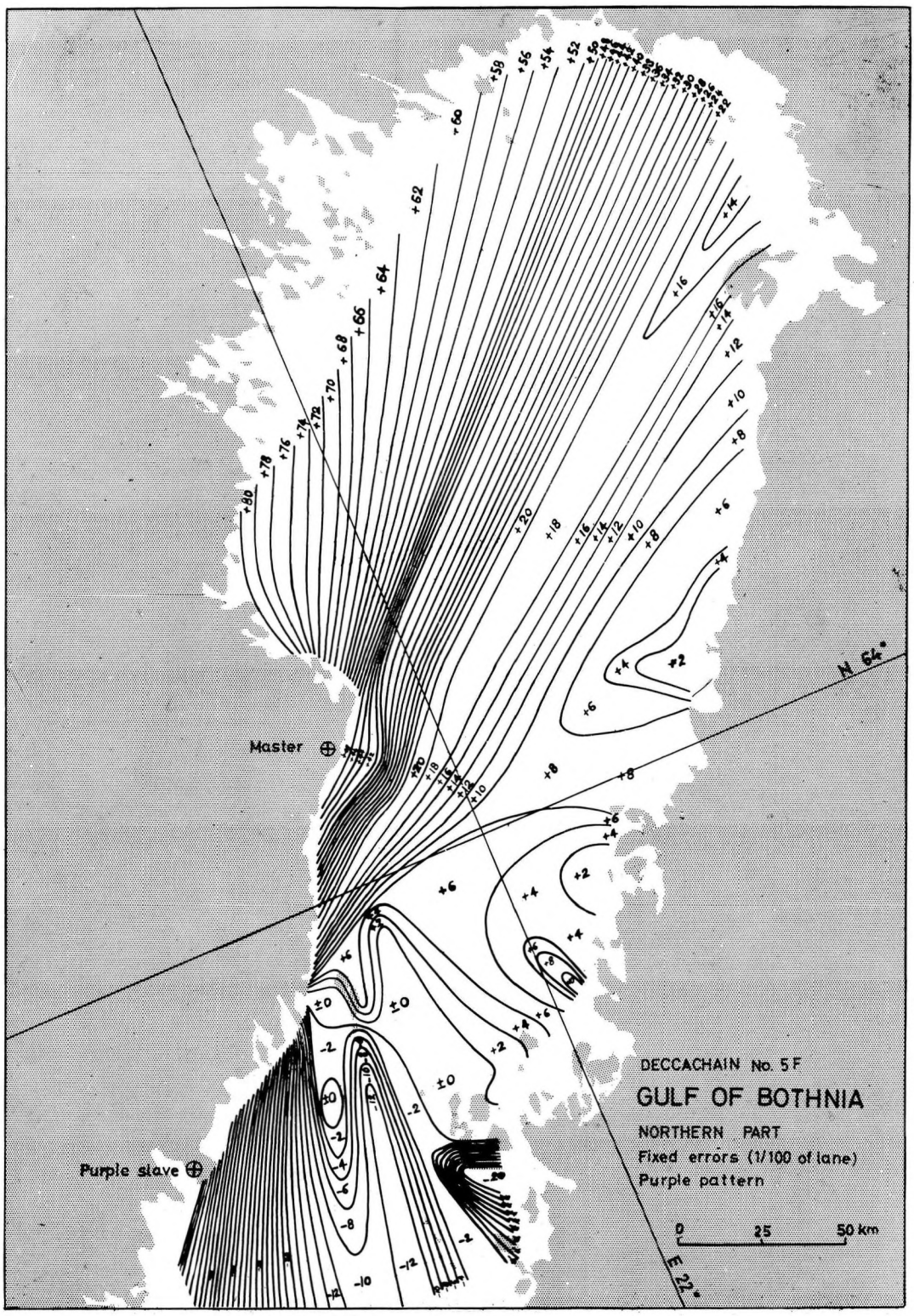
Master
Purple slave
DECCACHAIN No. 5F
GULF OF BOTHNIA
NORTHERN PART
Fixed errors (1/100 of lane)
Purple pattern
0 25 50 km
N 64°
E 22°

FIG. 3e