Columbia University
in the City of New York

LAMONT GEOLOGICAL OBSERVATORY
PALISADES, NEW YORK

VEMA CRUISE NO. 16
GEOMAGNETIC MEASUREMENTS

by

James R. Heirtzler

Technical Report No. 2
CU-3-61-Nonr-Geology

July 1961

LAMONT GEOLOGICAL OBSERVATORY

(Columbia University)

Palisades, New York

VEMA CRUISE NO. 16 GEOMAGNETIC MEASUREMENTS

by

James R. Heirtzler

Technical Report No. 2

CU-3-61-Nonr - Geology

July 1961

CONTENTS

I. INTRODUCTION

Since 1948, Lamont Geological Observatory has had a program for measuring the total intensity of the geomagnetic field in marine areas. Most of the measurements were made with a towed magnetometer by the Research Vessel VEMA on its regular cruises. Many measurements, however, have been made from other ships, on Arctic ice stations, and during 1955 and 1957, and from PBY aircraft.

The intent of the program was to obtain total intensity profiles to assist in the analysis of detailed geological features. Within recent years it has become evident that this data is of interest to individuals in other disciplines than structural geology. This report is the first attempt to present the entire data from a VEMA cruise. It is necessary that there be a departure from the tradition of presenting data and interpretation together. The data is so extensive that a reasonably complete analysis would make the data generally unavailable for a long period of time. Also, the data of a single cruise is frequently of value only when included with the data of other cruises so that trends can be observed. Accordingly, it would be impossible to make a complete analysis of the results of a single cruise.

It is expected that data from other cruises will be presented by this group in a similar format.

The VEMA-16 cruise departed New York on October 1, 1959, and returned to that port on September 21, 1960, completing a voyage of approximately 40,000 nautical miles. The ship circumnavigated the globe from west to east, usually sailing in mid-southern latitudes. Figure 1 shows the entire track. The magnetometer program began at San Juan and continued with only one major interruption (just before Buenos Aires) when the towed member was lost and a replacement could not be effected for several days.

The figures which constitute the body of this report show the total magnetic intensity values in gammas (10^5 gammas = 1 oersted) as a function of track distance in nautical miles from the last major port. The regional magnetic field and the time-varying part of the magnetic field have not been removed. Each profile sheet shows the depth to bottom in fathoms (corrected according to Mathew's Tables) and the 3-hour magnetic K-index from the nearest magnetic observatory. Breaks in the record are identified by the following codes:

- A Magnetometer under repair
- B Fluxgate magnetometer off scale
- C Ship hove to and drifting
- D Ship circling
- E Changing recording paper
- 129 (for example) the number of the station when ship stopped for other marine measurements.

These profile sheets are divided into seven sections. Each section is prefaced with a more detailed navigational chart.

II. INSTRUMENTATION

Two different types of magnetometers were used on this cruise. One type, the fluxgate, was the type that has been used for many years at Lamont. The other type, which will be used exclusively in the future, is the proton precession magnetometer. Two different fluxgate heads were used and each was calibrated separately. Table I gives the times when each of the instruments was used. Local times are used in this report. The relation of local to GMT is given in another part of this document.

TABLE I

INSTRUMENTS USED

Interval	Instrument
Beginning of record to 1336, 17 Jan. 1960	Fluxgate No. 1
1930, 17 Jan. to 1630, 9 May	Proton Precession
1730, 10 May to 0100, 24 May	Fluxgate No. 1
0215, 30 May to 1015, 31 May	Fluxgate No. 2
1400, 31 May to 0745, 6 June	Proton Precession
1640, 6 June to 1400, 9 June	Fluxgate No. 2
2215, 16 June to 1400, 17 June	Proton Precession
1430, 19 June to 1115, 10 July	Fluxgate No. 2
1600, 10 July to 1814, 14 July	Proton Precession
0000, 15 July to End of record	Fluxgate No. 2

1. Fluxgate Magnetometer

The fluxgate, or saturable core, magnetometer was a modification of the AN/ASQ-3A airborne magnetometer. Early modifications of this instrument for geophysical use are described by Rumbaugh and Alldredge (1949) and for towed marine use by Heezen, et. al. (1953). Additional modifications to stabilize the electronic components have been made in recent years.

2. Proton Precession Magnetometer

To simplify the instrumentation and reduction of data, and to provide for greater accuracy without calibration, a proton precession magnetometer has been developed by the Lamont group over the last four to five years. The instrument is not greatly different from other proton precession magnetometers in common use.

The total magnetic field intensity (F) is a function of the proton precession frequency (f) and is given by:

$$F = (2\pi/g)f$$

where g is the proton gyromagnetic ratio. The value of g, adopted by the International Association of Geomagnetism and Aeronomy in 1960 (Nelson, 1960), is 2.67513×10^4 radians/gauss second. Much of the data reported in this report was reduced before that value was adopted and the value of g used here was 2.67531×10^4 radians/gauss second. The use of this latter value causes the reported readings to be low by a maximum of 5 gammas at high geomagnetic latitudes.

3. Accuracy

A summary of the maximum error of the magnetometer readings is as follows:

		Maximum error
<u>Fluxgate (with first head used)</u>		
Absolute Errors		
Ship's permanent field		5 gamma
Coil constant error		150
	Total	155 gamma
Relative Errors		
Ship's induced field		5 gamma
Balance point drift		50
Misc. reading errors		5
	Total	60 gamma
<u>Fluxgate (with second head used)</u>		
Absolute Errors		
Ship's permanent field		5 gamma
Coil constant error		10
	Total	15 gamma
Relative Errors		
Ship's induced field		5 gamma
Balance point drift		50
Misc. reading errors		5
	Total	60 gamma
<u>Proton Precession</u>		
Absolute Errors		
Ship's permanent field		5 gamma
Relative Errors		
Ship's induced field		5 gamma
Rounding off in computations		5
Finite counting time of frequency meter		5
Error in gyromagnetic ratio		5
	Total	20 gamma

It is seen that the instrument with the largest possible error is the first fluxgate. Most of this instrument's error comes from its coil constant calibration. The coil was calibrated against another coil which was in turn calibrated against a proton precession magnetometer. The calibration between the two coils had to be made by comparing readings with a previous cruise at common track points. Although this was done for magnetically undisturbed localities, the daily and secular variations can only be estimated.

With the fluxgate, the balance point drift was checked about once in two hours and some interpolation and extrapolation was necessary. On a few occasions a 50 gamma instrument excursion could have occurred. Such occasions were rare and the balance point usually drifted in a smooth fashion and caused no more than about 10 gamma error.

The presence of the ship should contribute less than 10 gammas error. For iron naval vessels the total dipole moment of the vessel is no more than 10^8 cgs units (Fromm, 1952), half of this being induced and half permanent. With the most unfavorable situation, a field of 5 gamma would be created 400 ft from the vessel by induced magnetization. The direction of the permanent magnetization has not been determined, and it may contribute a constant error as large as 5 gamma. The magnetometers were towed with a 400 ft cable. The magnetometership distance was, somewhat, less than 400 ft when the vessel was making a sharp turn or circling in a tight circle and some erroneous readings are evident during this type maneuver.

III. NOTES ON TIME-VARYING GEOMAGNETIC PHENOMENA

To assist in the distinction of magnetic anomalies caused by the time-varying magnetic field, from anomalies caused by earth structure, the 3-hour K-index is shown. In accord with conventional usage the K-index is an integer on the scale 0,1,2,......9 indicating the difference between maximum and minimum values of one of the magnetic intensity vector components during the 3-hour period. The fluctuation range of the horizontal component is frequently used by the magnetic observatory. The K value assigned for a given gamma range is specified by the individual magnetic observatory code. For the observatories mentioned in this report, Table II gives the gamma range of the K-values. All excursions exceeding the upper limit for K = 8 are assigned a K = 9. Inspection of this table shows those K values which may cause appreciable anomalies. It should be pointed out that the K value may be assigned for a magnetic excursion that takes place in a few minutes. Also, a constant and sustained deviation from the local mean magnetic value would be manifest as a low K number even though an anomalous geomagnetic condition exists.

The diurnal quiet variation (Sq) of the geomagnetic intensity can be predicted fairly accurately and of the order of 100 gammas in equatorial regions (maximum near noon), but

TABLE II

MAGNETIC OBSERVATORY K-INDICES

Station	Gamma Range for K Values				
	K=0	1	2	3	4
Fredericksburg	0-5	5-10	10-20	20-40	40-70
San Juan	0-3	3-6	6-12	12-24	24-42
Vassouras	0-6	6-12	12-24	24-48	48-84
Hermanus	0-3	3-6	6-12	12-24	24-40
Gnangara	0-3.5	3.5-7	7-14	14-28	28-49
Toolangi	0-5	5-10	10-20	20-40	40-70
Macquarie Island	0-15	15-30	30-60	60-120	120-210
Amberley	0-5	5-10	10-20	20-40	40-70
Argentine Islands	0-5	5-10	10-20	20-40	40-70
Trelew	0-4	4-8	8-16	16-30	30-50

Less than 50 gammas

Station	Gamma Range for K Values				
	K=5	6	7	8	9
Fredericksburg	70-120	120-200	200-330	330-500	500
San Juan	42-72	72-120	120-198	198-300	300
Vassouras	84-144	144-240	240-396	396-600	600
Hermanus	40-70	70-120	120-200	200-300	300
Gnangara	49-84	84-140	140-231	231-350	350
Toolangi	70-120	120-200	200-330	330-500	500
Macquarie Island	120-360	360-600	600-990	990-1500	1500
Amberley	70-120	120-200	200-330	330-500	500
Argentine Islands	70-120	120-200	200-330	330-500	500
Trelew	50-85	85-140	140-230	230-350	350

is considerably less as one approaches the polar latitudes. In mid-latitudes, this variation is about 20 gammas. By convention the 3-hour part of the Sq variation is removed from the magnetic record before the K index is determined. Unpredictable disturbances (S_D and Dst) usually occur with larger amplitudes in the auroral zones than at mid-latitudes.

K indices shown on profile sheets have been displayed as functions of local time. The times that particular magnetic observatory data was used, are shown in Table III.

TABLE III

MAGNETIC OBSERVATORIES USED

Local Time Interval	Magnetic Observatory Providing K-Indices
2 Nov. to 15 Nov. (0100)	San Juan
15 Nov. (0100) to 6 Dec. (0100)	Vassouras
6 Dec. (0100) to 31 Jan. (1500)	Hermanus
31 Jan. (1500) to 9 March (2100)	Gnangara
9 March (2100) to 23 March (0800)	Toolangi
23 March (0800) to 2 April (2300)	Macquarie Island
2 April (2300) to 23 April (1400)	Amberley
23 April (1400) to 19 May (0300)	Argentine Islands
19 May (0300) to 17 June (1400)	Trelew
17 June (1400) to 14 July (1430)	Vassouras
14 July (1430) to 27 July (0800)	San Juan
27 July (0800) to End	Fredericksburg

Total intensity values from observatories would have been more useful than K indices, but it was felt that the small increase in accuracy did not merit the increased format and computational difficulties.

IV. TIME ZONES USED

The local time maintained by the scientific party on the ship is used on the magnetic profile sheets for the indication of day and 3-hour K-index intervals. To change local time to GMT, Table IV should be consulted.

TABLE IV

TIME ZONES

Local clock time interval	To local times add or subtract the following number of hours to get GMT
before 0000, Nov. 10	+4
0100, Nov. 10 to 0000, Nov. 25	+3
0100, Nov. 25 to 0000, Dec. 3	+2
0100, Dec. 3 to 0000, Dec. 10	+1
0100, Dec. 10 to 0000, Dec. 16	0
0100, Dec. 16 to 0000, Dec. 20	-1
0100, Dec. 20 to 0000, Jan. 7	-2
0100, Jan. 7 to 0000, Jan. 15	-3
0100, Jan. 15 to 0000, Feb. 3	-4
0100, Feb. 3 to 0000, Feb. 9	-5
0100, Feb. 9 to 0000, Feb. 18	-6
0100, Feb. 18 to 0000, Feb. 21	-7
0100, Feb. 21 to 0000, Mar. 5	-8
0030, Mar. 5 to 0000, Mar. 8	-8.5
0030, Mar. 8 to 0000, Mar. 10	-9
0030, Mar. 10 to 0000, Mar. 29	-9.5
0030, Mar. 29 to 0000, Apr. 2	-10
0100, Apr. 2 to 0000, Apr. 5	-11
0100, Apr. 5 to 2400, first Apr. 13	-12
0000, second Apr. 13 to 0000, Apr. 19	+12
0100, Apr. 19 to 0000, Apr. 22	+11
0100, Apr. 22 to 0000, Apr. 24	+10
0100, Apr. 24 to 0000, Apr. 27	+9
0100, Apr. 27 to 0000, Apr. 30	+8
0100, Apr. 30 to 0000, May 1	+7
0030, May 1 to 0000, May 2	+6.5
0030, May 2 to 0000, May 3	+6
0030, May 3 to 0000, May 4	+5.5
0030, May 4 to 0000, May 6	+5
0100, May 6 to 0000, May 7	+4
0100, May 7 to 1400, Sept. 18	+3
1300, (second time) Sept. 18 to end of voyage	+4

ACKNOWLEDGMENTS

Istvan Gereben operated the magnetometer during the entire cruise. Carolyn Peppin supervised the data reduction and drafting work. Julius Hirshman, assisted by George Peter, assembled the apparatus and assured its operation. The Submarine Geology section at Lamont supplied the record of bottom topography. Other members of the scientific party of the VEMA provided assistance in the recording of the data.

Financial support for the work was provided by the Office of Naval Research, Contract Nonr 266(48), the National Science Foundation, Grant 4151, and Columbia University Higgins Research Fund.

REFERENCES

Fromm, W. E., "The Magnetic Airborne Detector" from Advances in Electronics IV, Academic Press, Inc. New York, 1952.

Nelson, J. H., Journal Geoph. Res., 65, 11, (Nov. 1960) p. 3826.

Rumbaugh, L. H., and L. R. Alldredge, Trans. Amer. Geoph. Union, 30, p. 836-848, 1949.

Heezen, B. C., M. Ewing, and E. T. Miller, Deep-Sea Res., 1, p. 25-33, 1953.

JULIANEHAAB
ARGENTIA
HALIFAX
NEW YORK
FREDERICKSBURG
SAN JUAN
RECIFE
VASSOURAS
RIO DE JANEIRO
BUENOS AIRES
TRELEW
USHUAIA
ARGENTINE ISLANDS
CAPETOWN
HERMANUS
MAURITIUS
GNANGARA
FREMANTLE
ADELAIDE
TOOLANGI
AMBERLEY
WELLINGTON
MACQUARIE I.

FIGURE 1

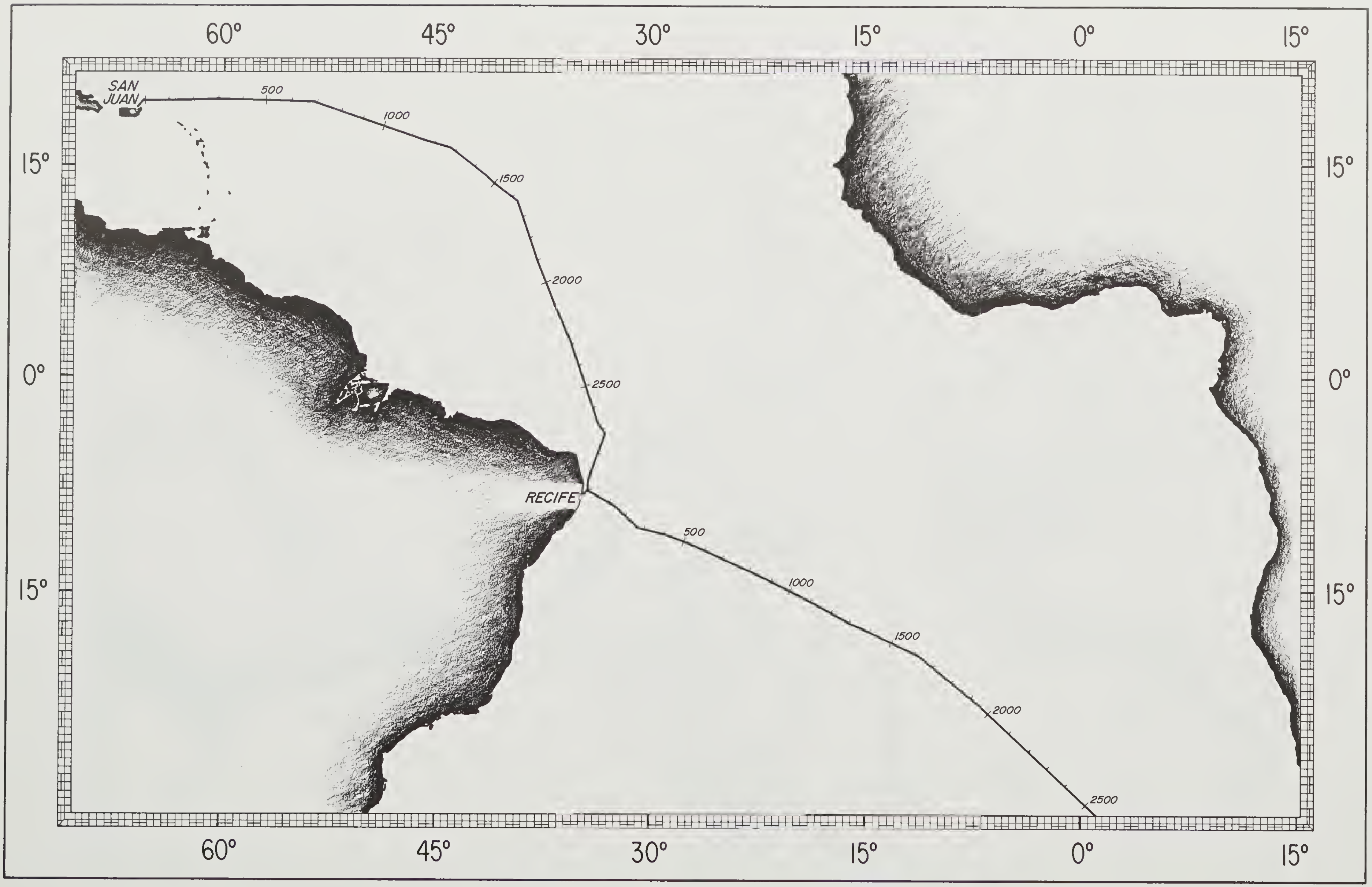

60°
45°
30°
15°
0°
15°
SAN
JUAN
500
1000
1500
2000
2500
RECIFE
500
1000
1500
2000
2500

FIGURE 2

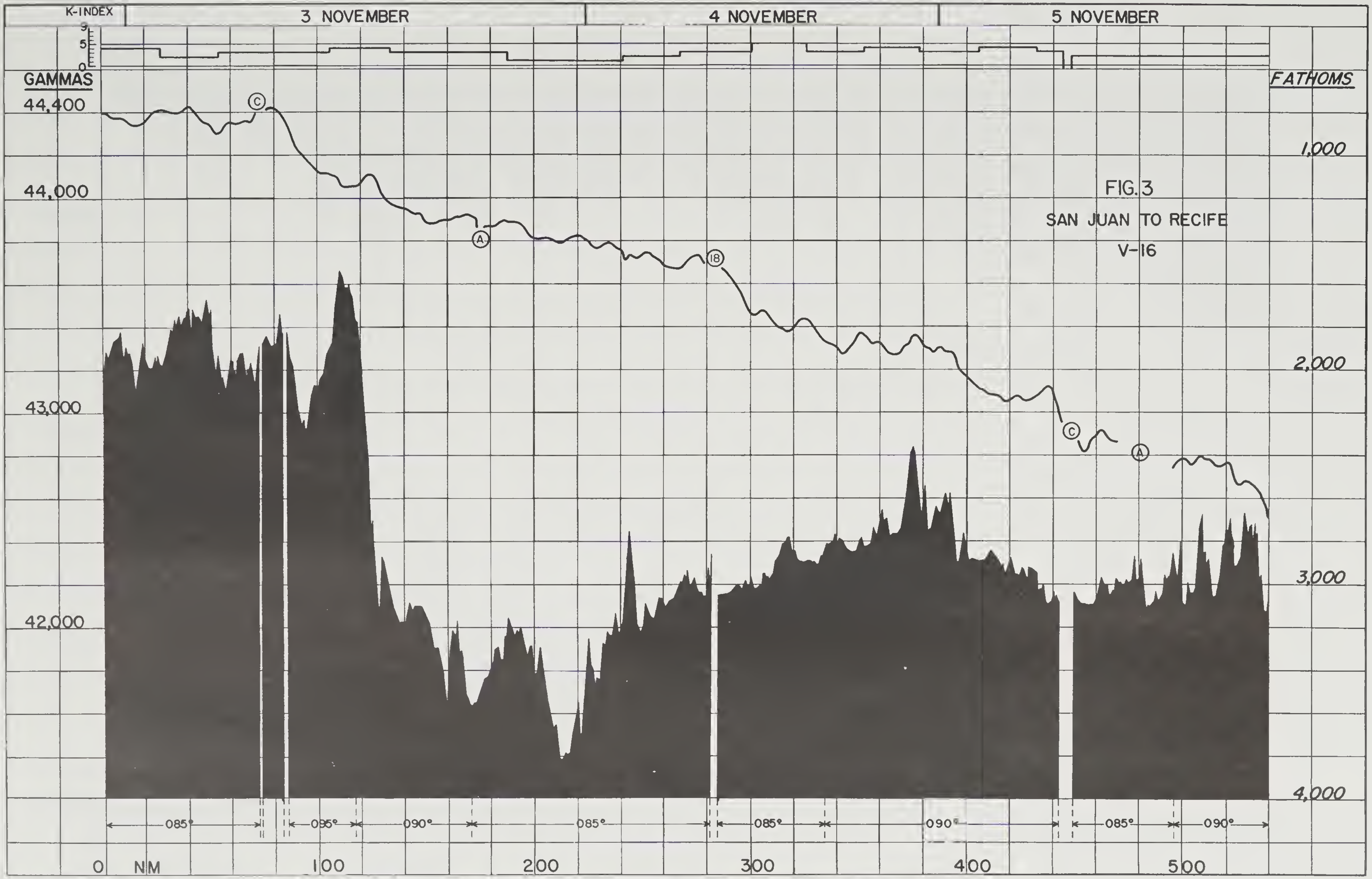
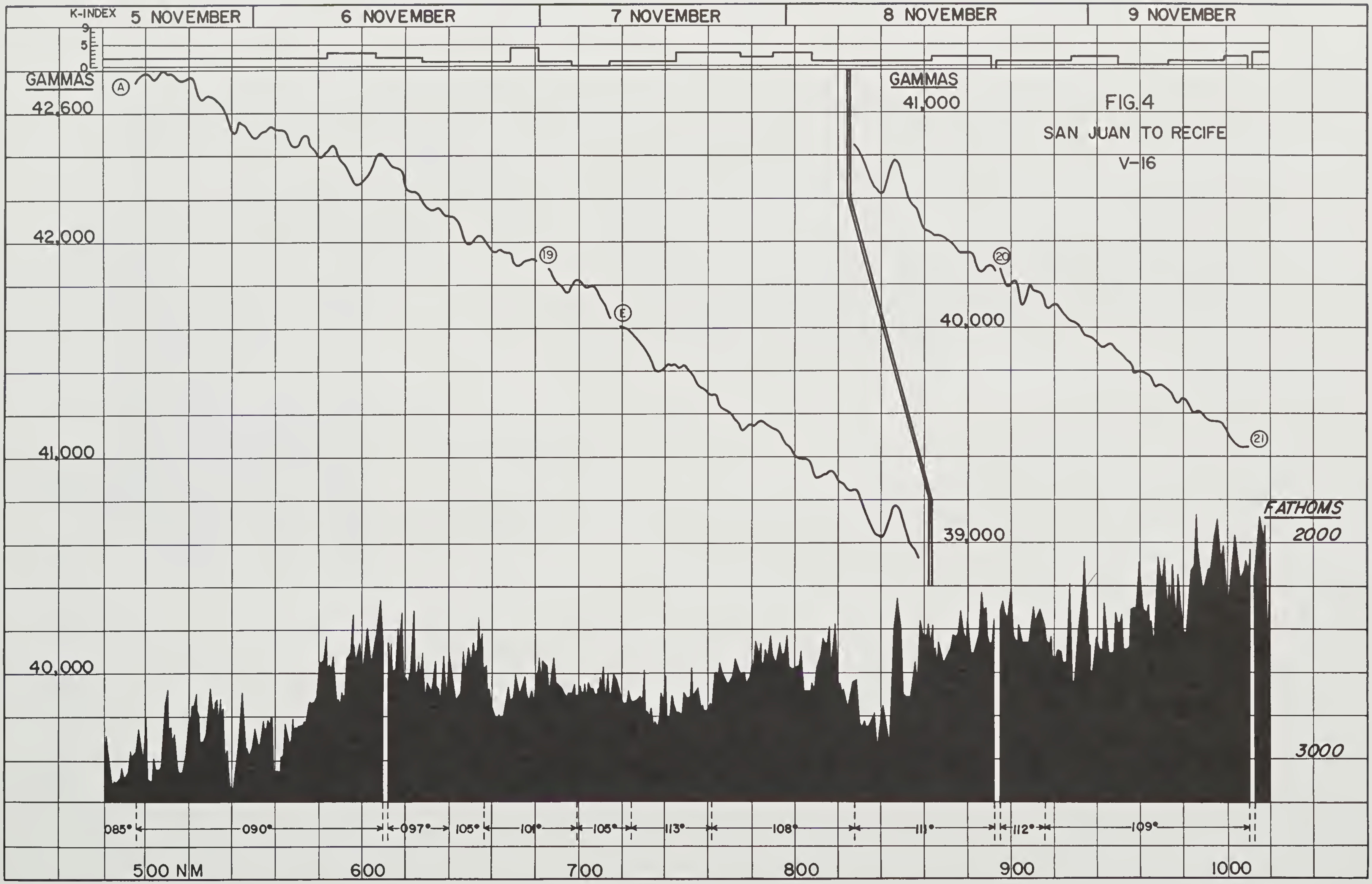


FIG. 3
SAN JUAN TO RECIFE
V-16



K-INDEX
5 NOVEMBER
6 NOVEMBER
7 NOVEMBER
8 NOVEMBER
9 NOVEMBER
9
5
0
GAMMAS
42,600
42,000
41,000
40,000
GAMMAS
41,000
40,000
39,000
FIG.4
SAN JUAN TO RECIFE
V-16
FATHOMS
2000
3000
085°
090°
097°
105°
101°
105°
113°
108°
111°
112°
109°
500 NM
600
700
800
900
1000

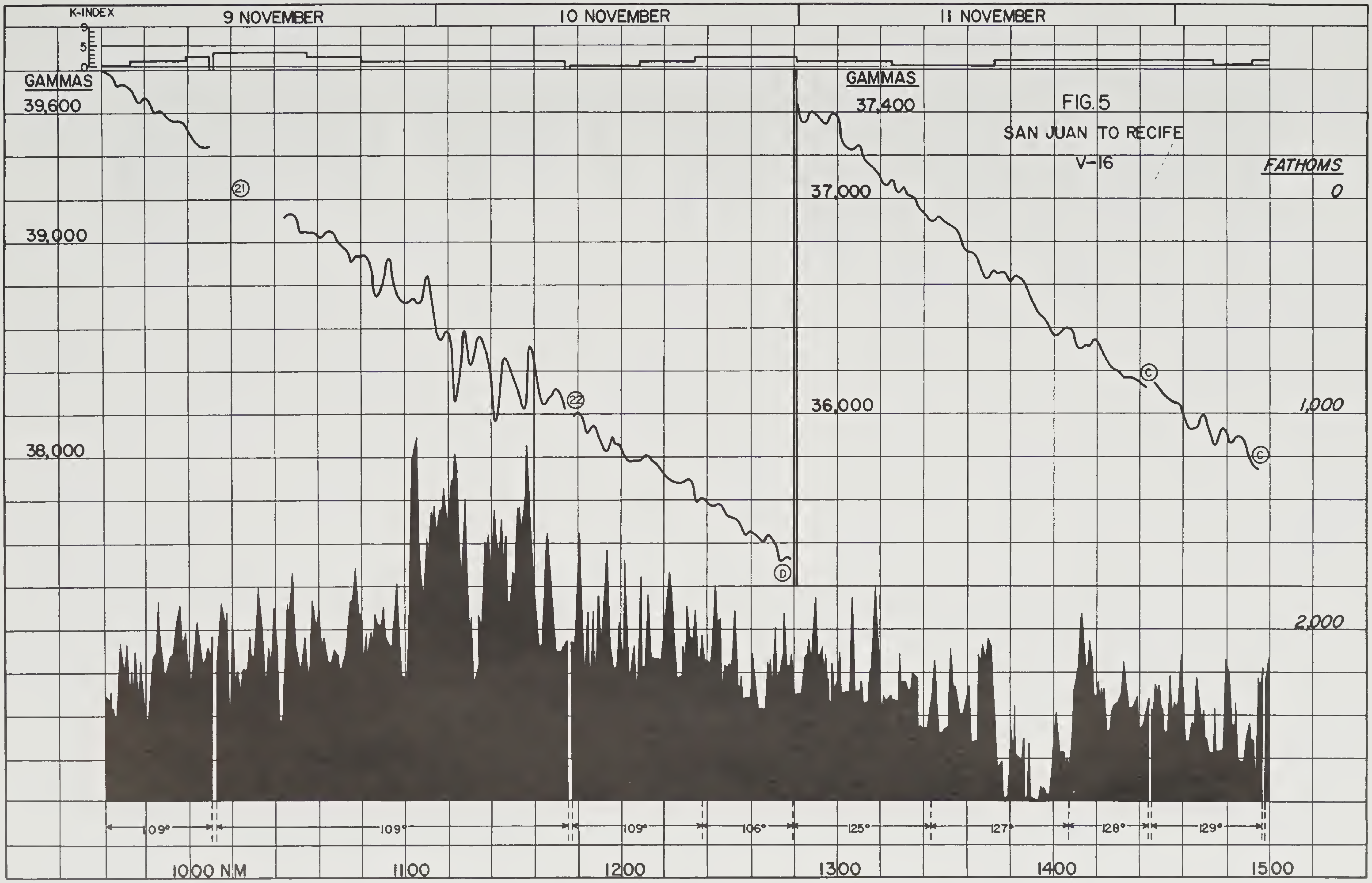
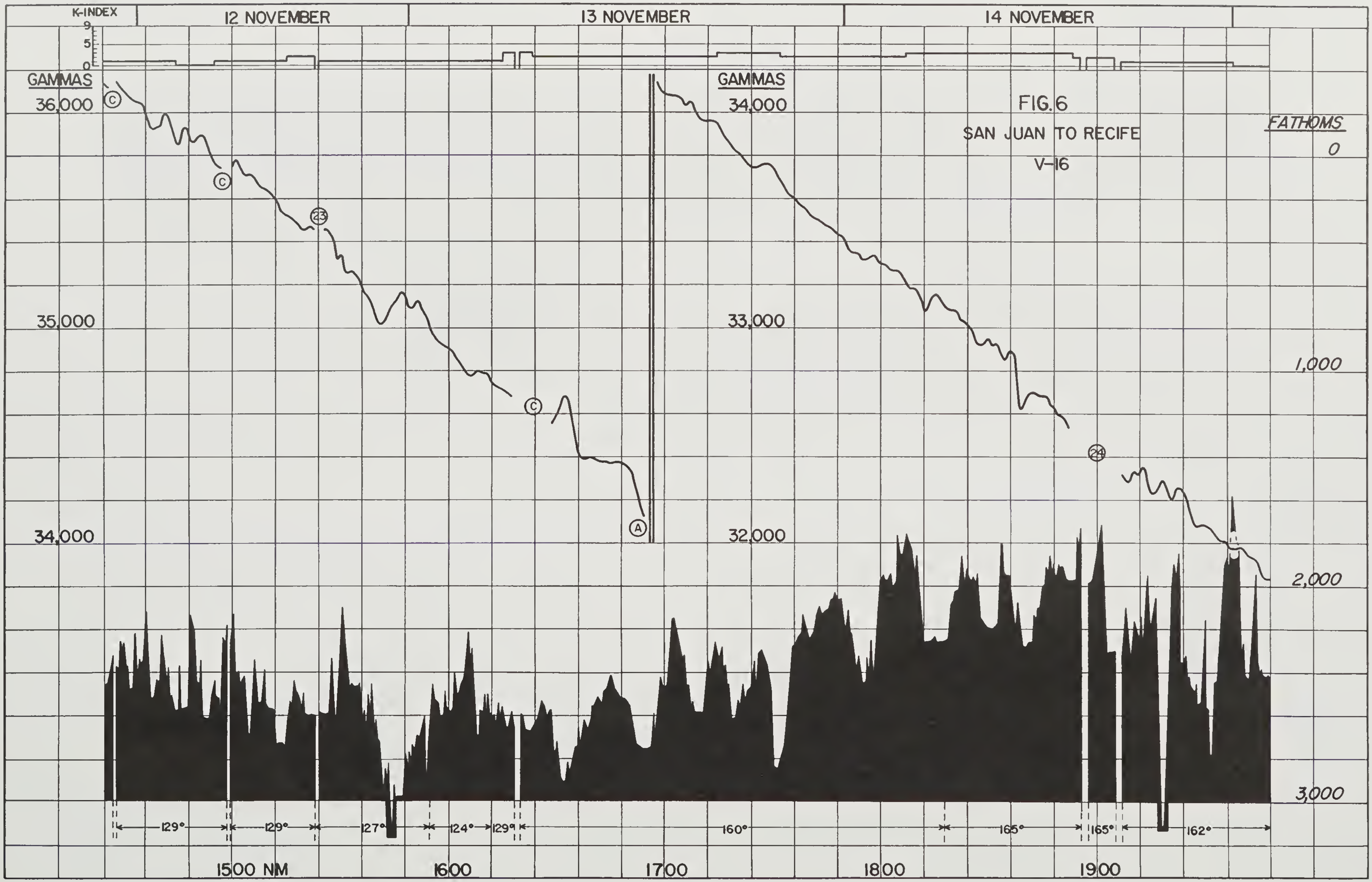


FIG. 5
SAN JUAN TO RECIFE
V-16



K-INDEX
9
5
0
12 NOVEMBER
13 NOVEMBER
14 NOVEMBER
GAMMAS
36,000
35,000
34,000
GAMMAS
34,000
33,000
32,000
FIG. 6
SAN JUAN TO RECIFE
V-16
FATHOMS
0
1,000
2,000
3,000
C
C
23
C
A
24
129°
129°
127°
124°
129°
160°
165°
165°
162°
1500 NM
1600
1700
1800
1900

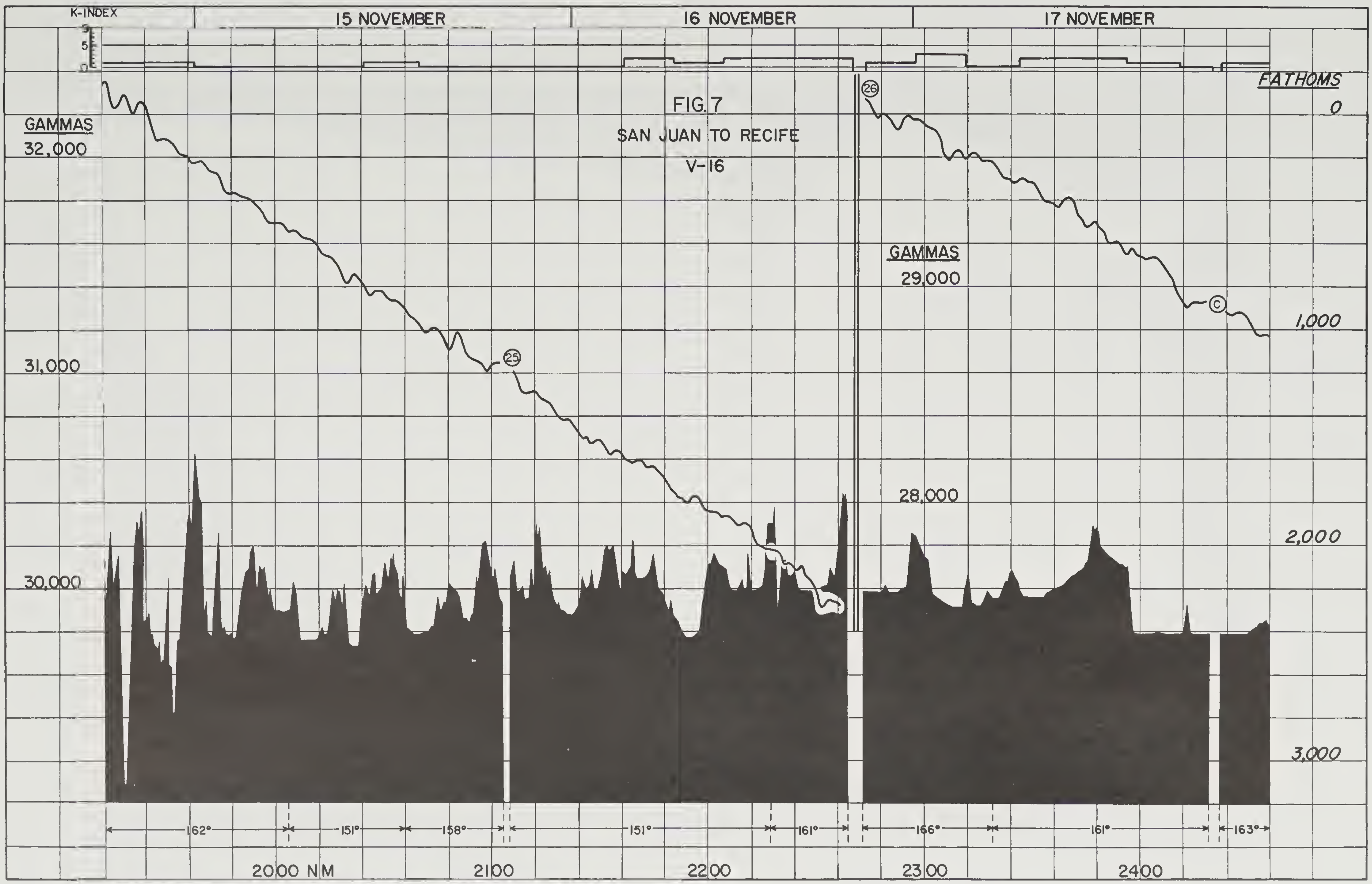
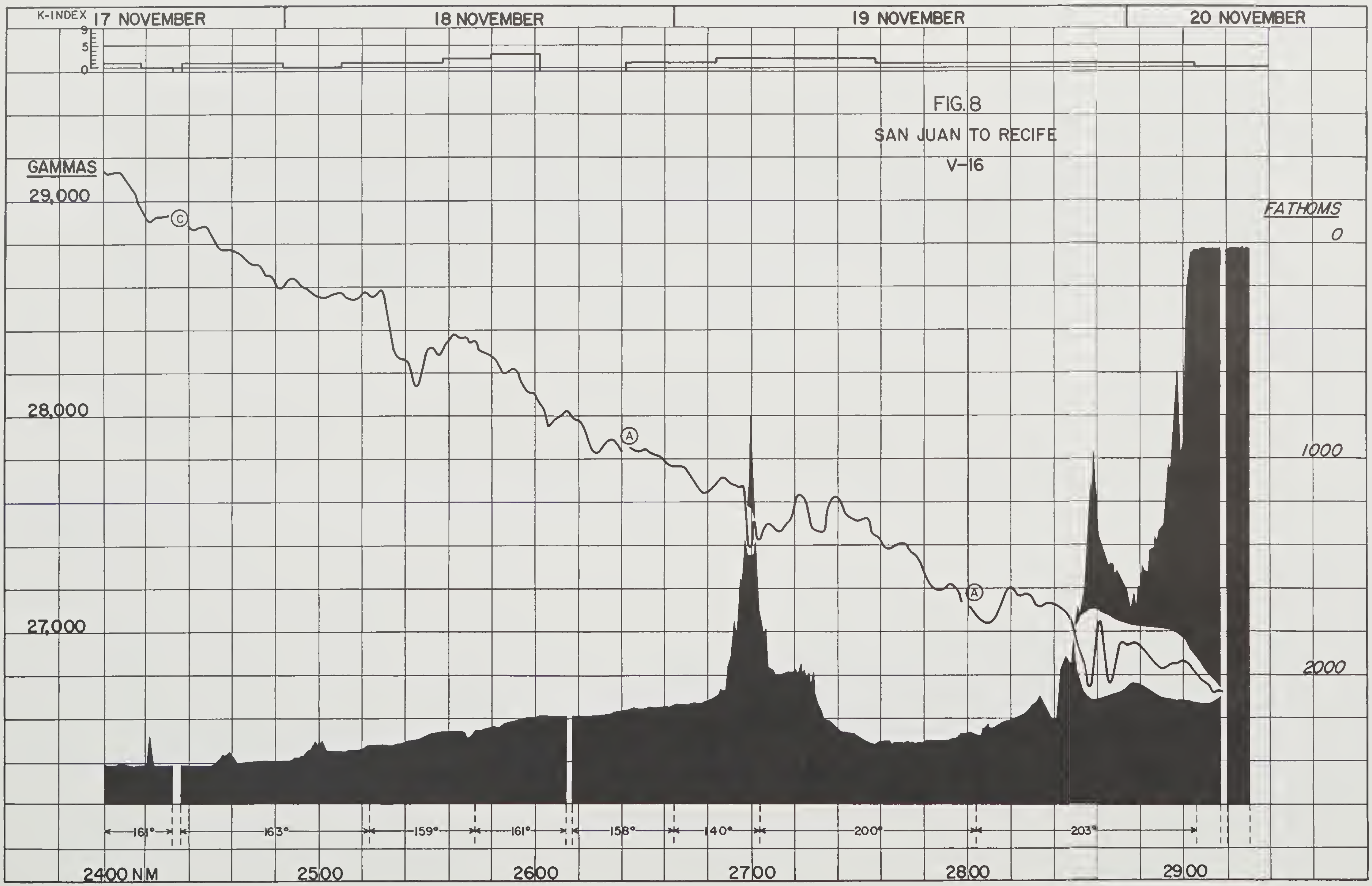


FIG. 7
SAN JUAN TO RECIFE
V-16


K-INDEX
17 NOVEMBER
18 NOVEMBER
19 NOVEMBER
20 NOVEMBER
9
5
0
FIG. 8
SAN JUAN TO RECIFE
V-16
GAMMAS
29,000
28,000
27,000
FATHOMS
0
1000
2000
161°
163°
159°
161°
158°
140°
200°
203°
2400 NM
2500
2600
2700
2800
2900

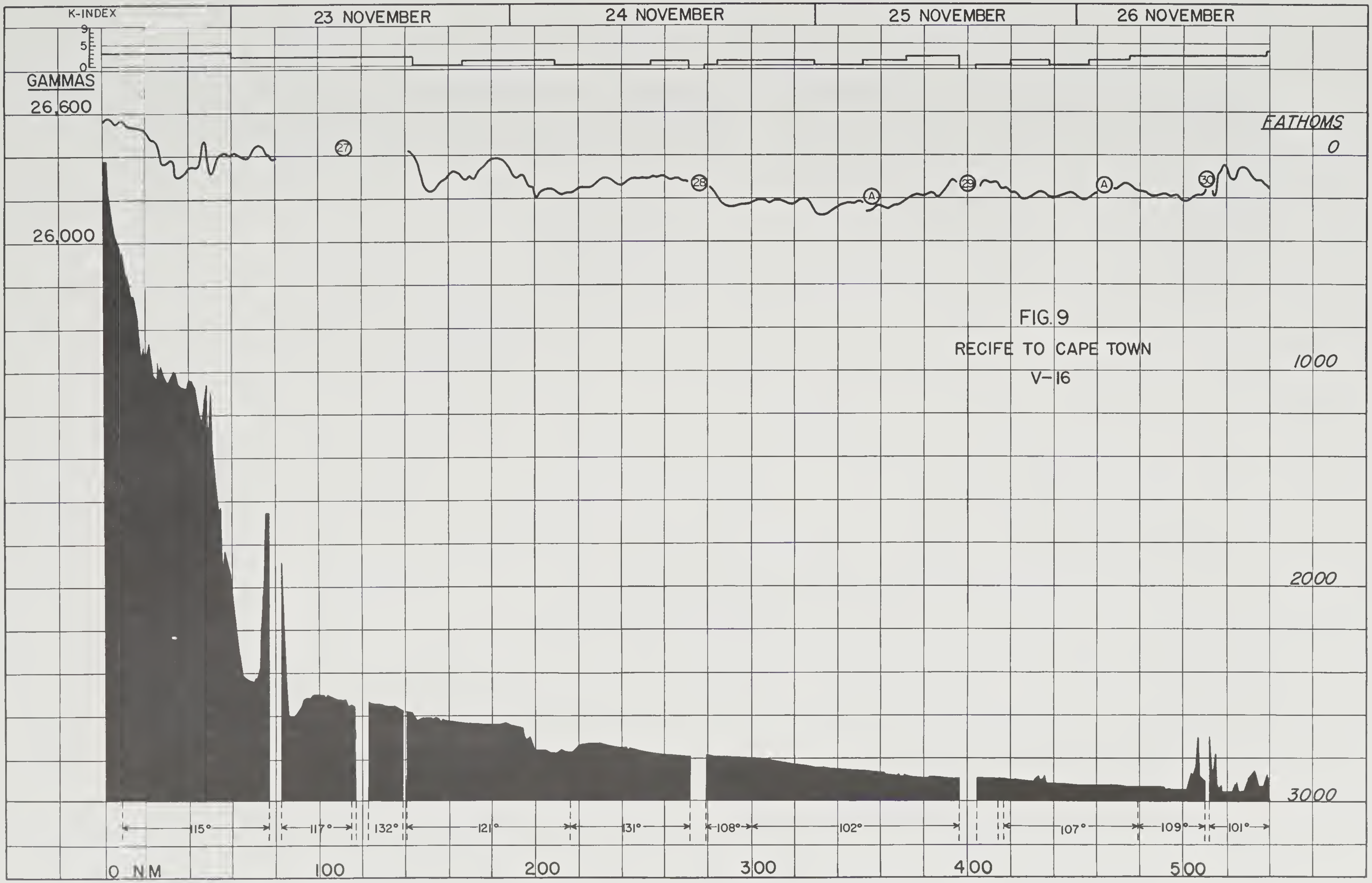
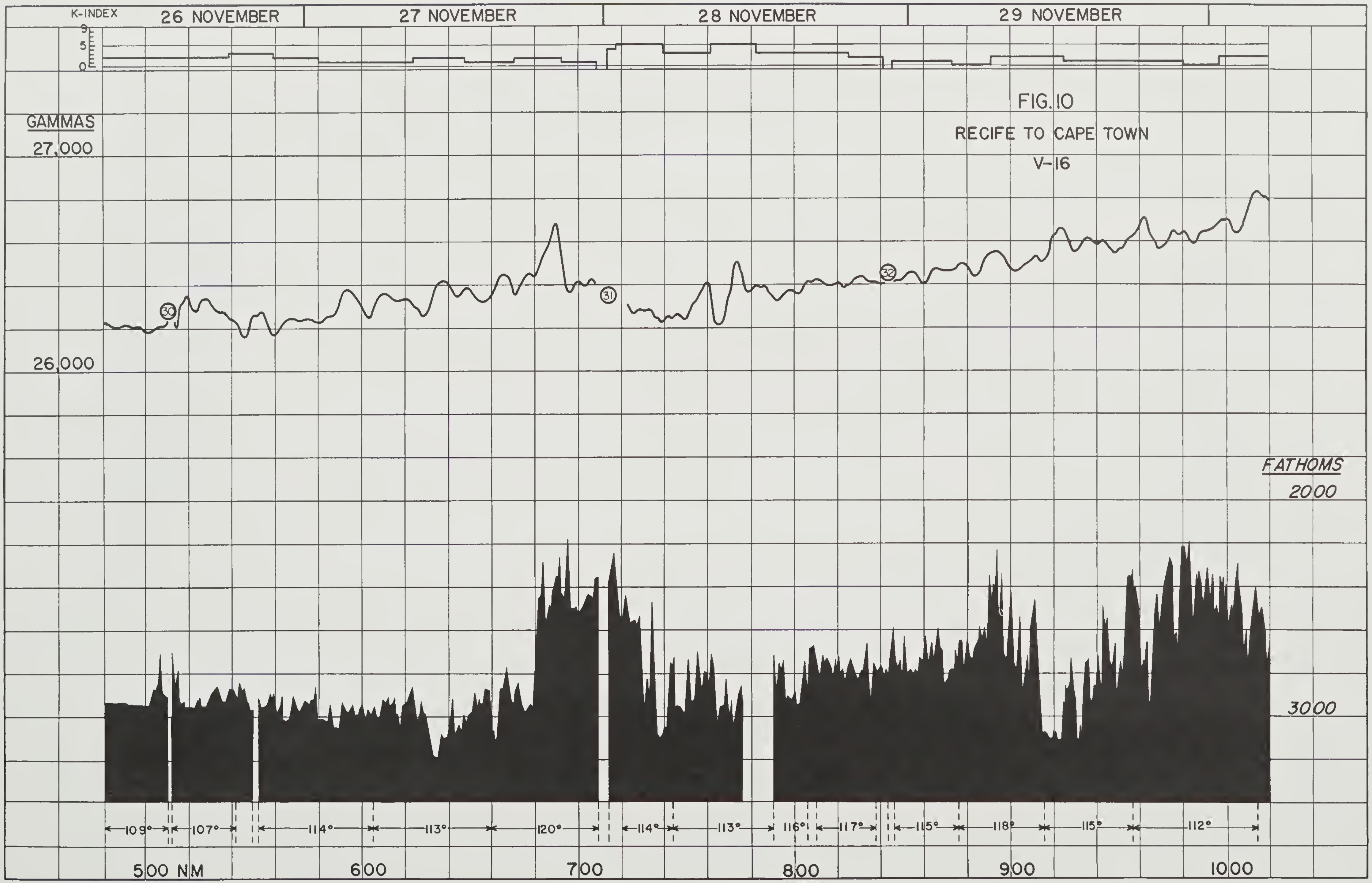


FIG. 9
RECIFE TO CAPE TOWN
V-16


K-INDEX
26 NOVEMBER
27 NOVEMBER
28 NOVEMBER
29 NOVEMBER
9
5
0
FIG. 10
RECIFE TO CAPE TOWN
V-16
GAMMAS
27,000
26,000
30
31
32
FATHOMS
2000
3000
109°
107°
114°
113°
120°
114°
113°
116°
117°
115°
118°
115°
112°
500 NM
600
700
800
900
1000

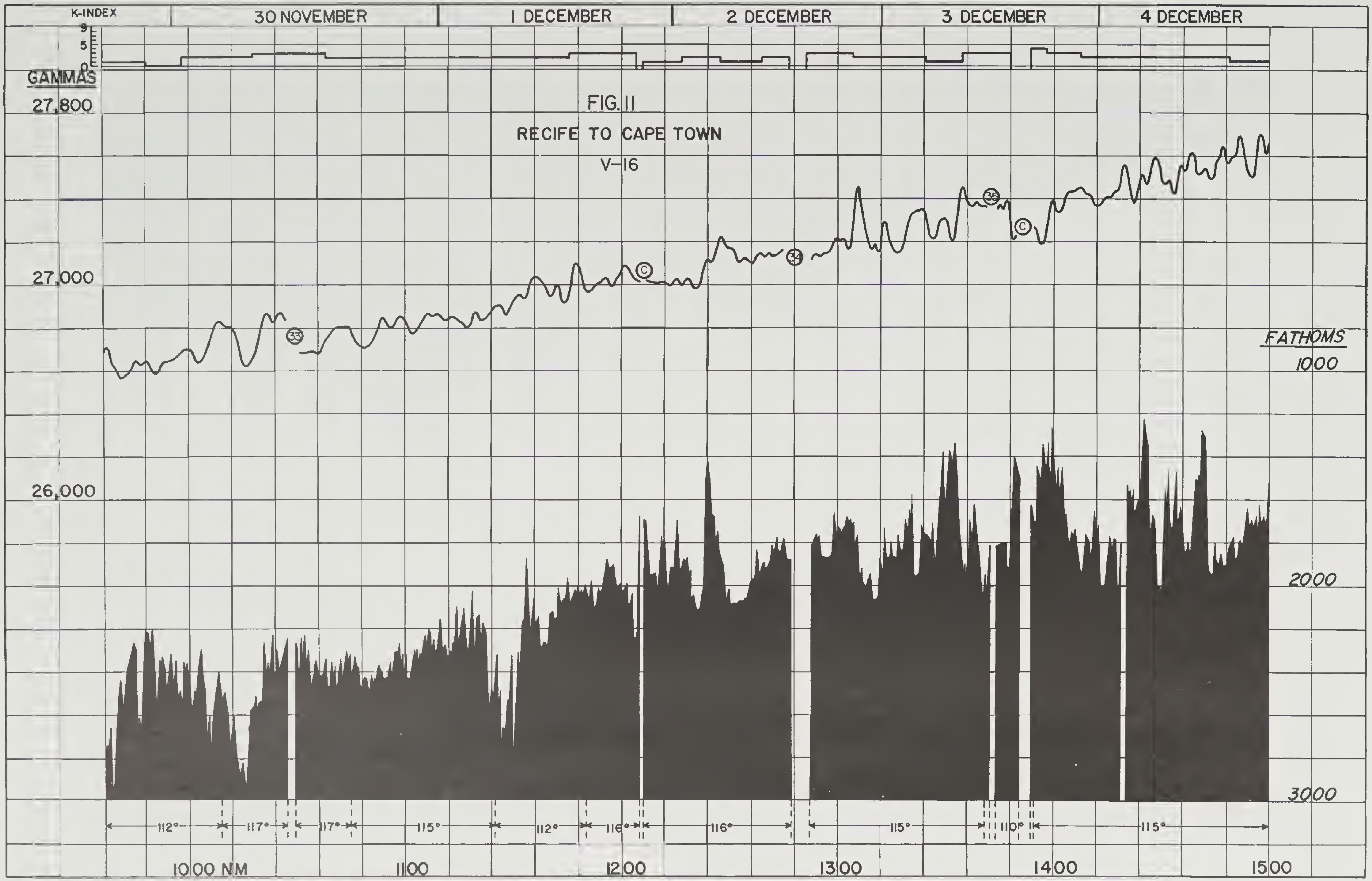


FIG. 11
RECIFE TO CAPE TOWN
V-16

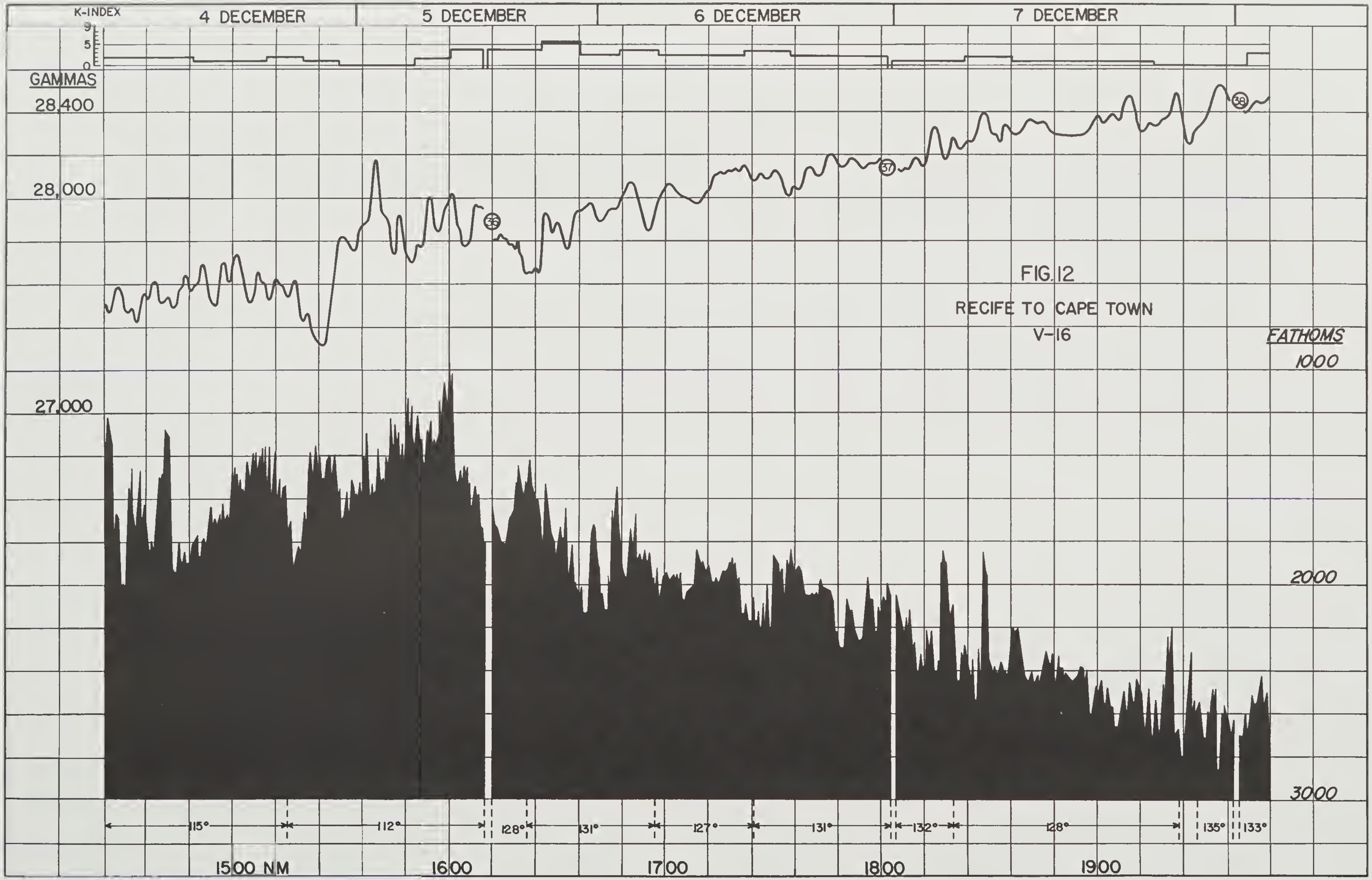


FIG. 12
RECIFE TO CAPE TOWN
V-16

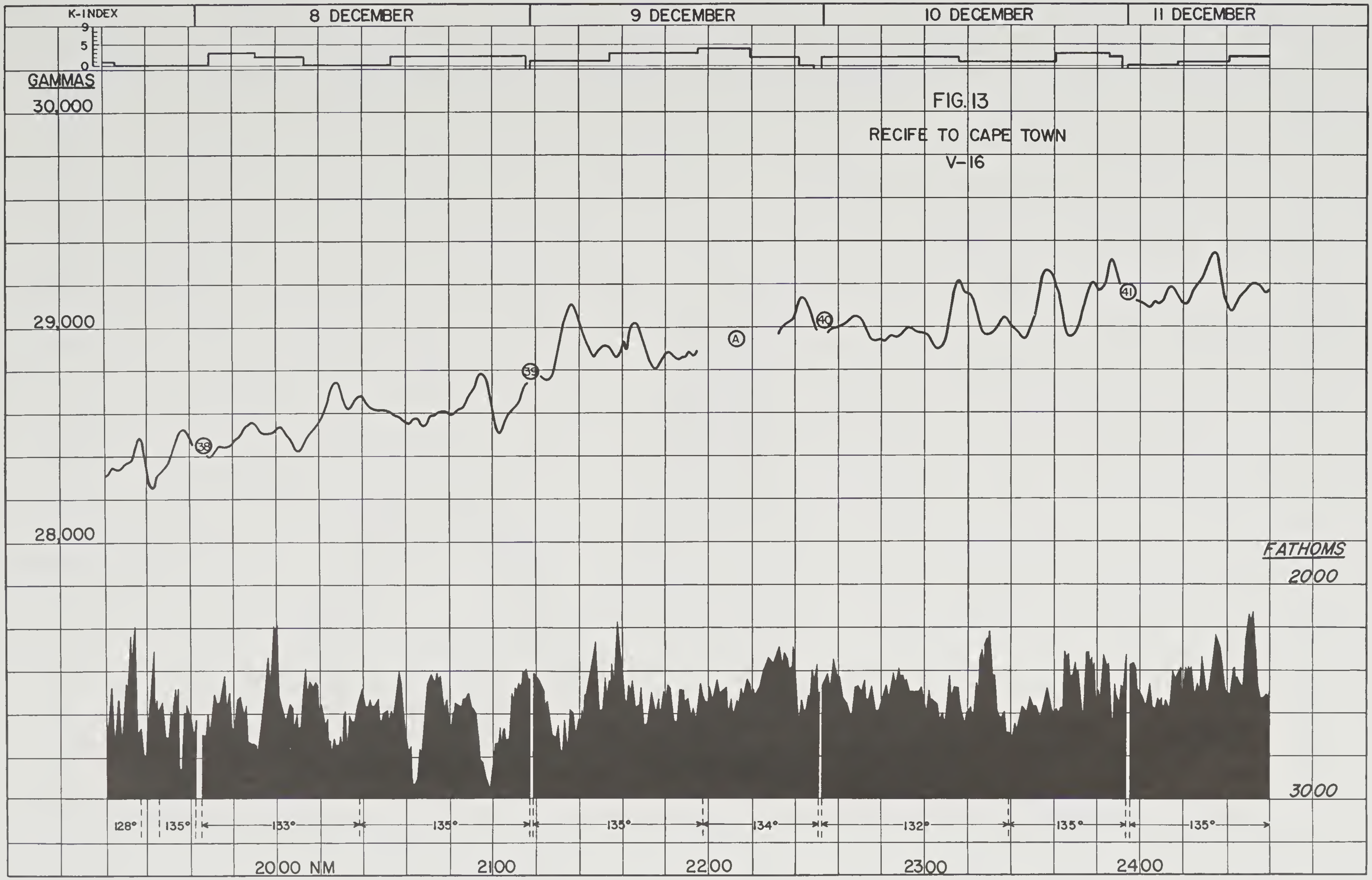


FIG. 13
RECIFE TO CAPE TOWN
V-16


0°
15°
30°
45°
60°
75°
15°
30°
45°
MAURITIUS
CAPETOWN
0
500
1000
1500
2000
2500
3000
3500

FIGURE 14

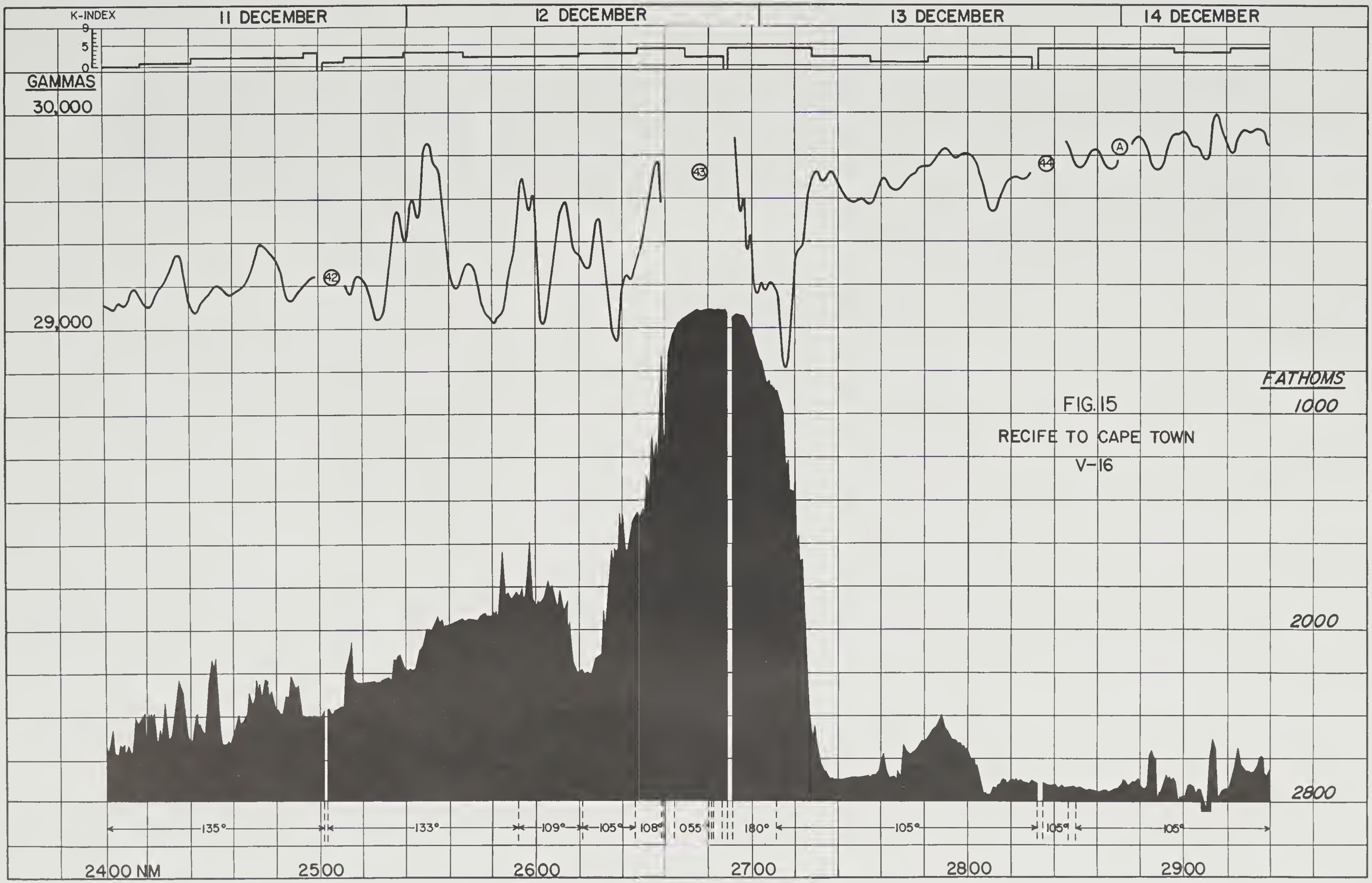


FIG. 15
RECIFE TO CAPE TOWN
V-16

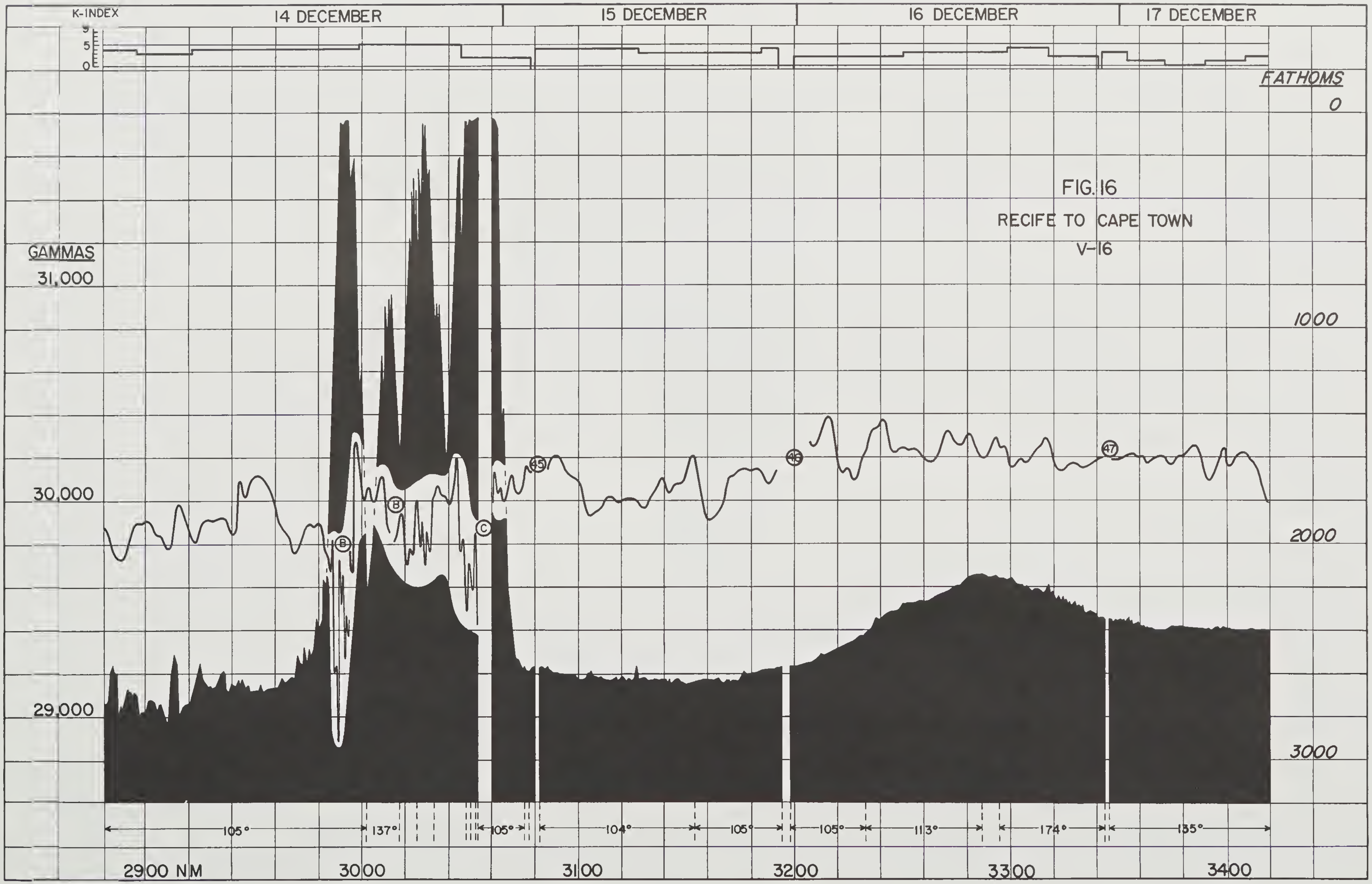


FIG. 16
RECIFE TO CAPE TOWN
V-16

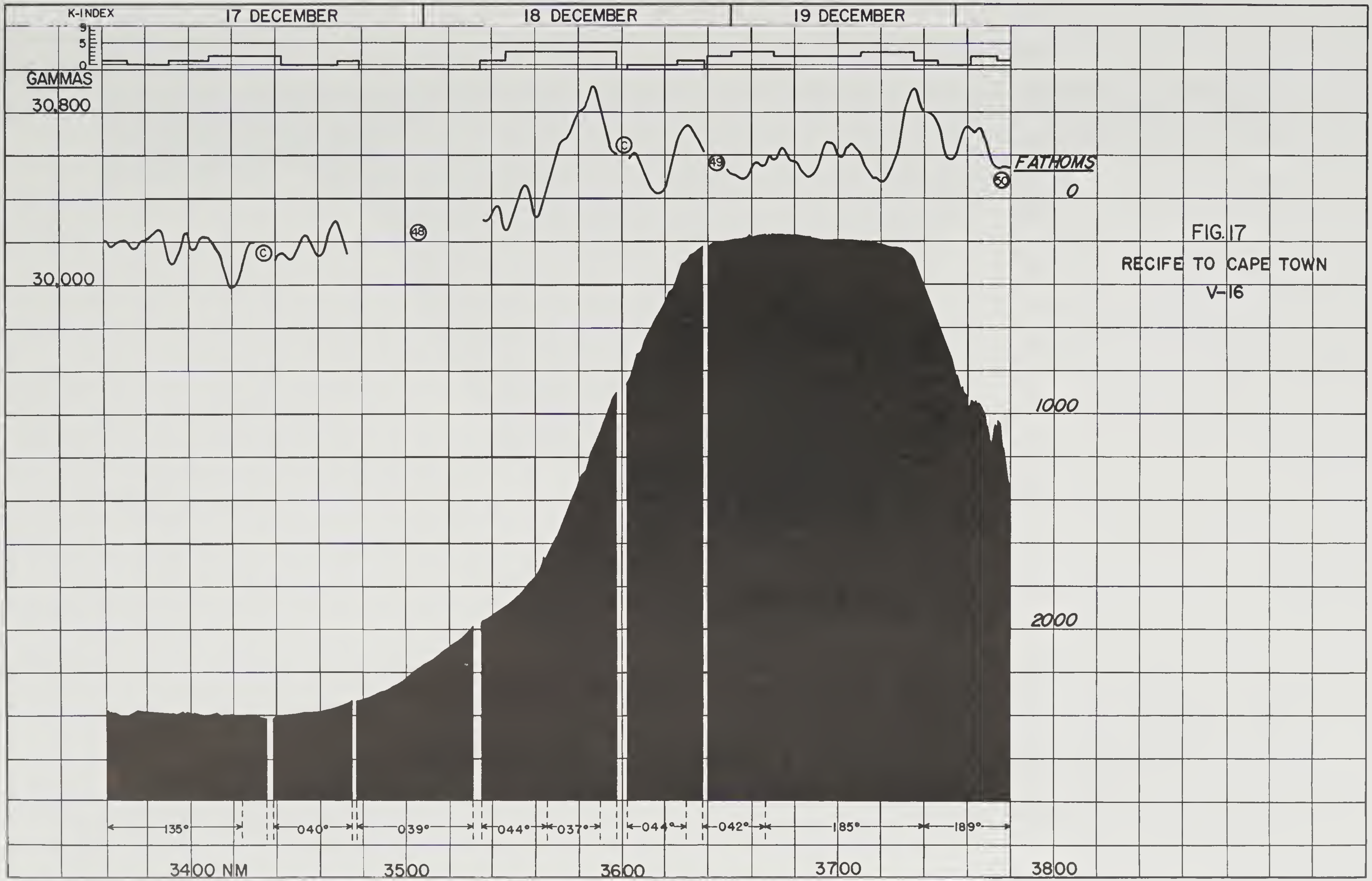


FIG. 17
RECIFE TO CAPE TOWN
V-16

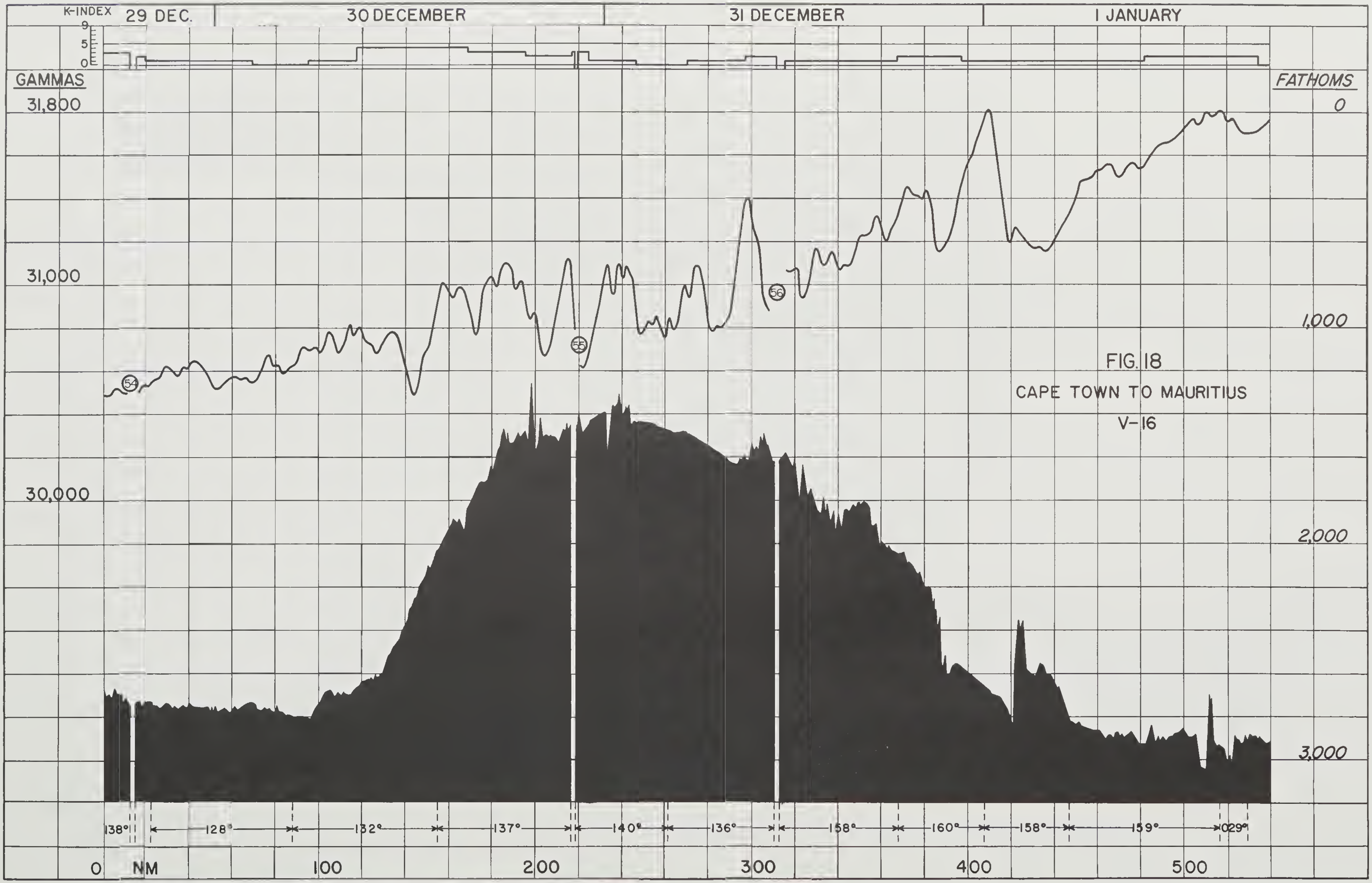


FIG. 18
CAPE TOWN TO MAURITIUS
V-16

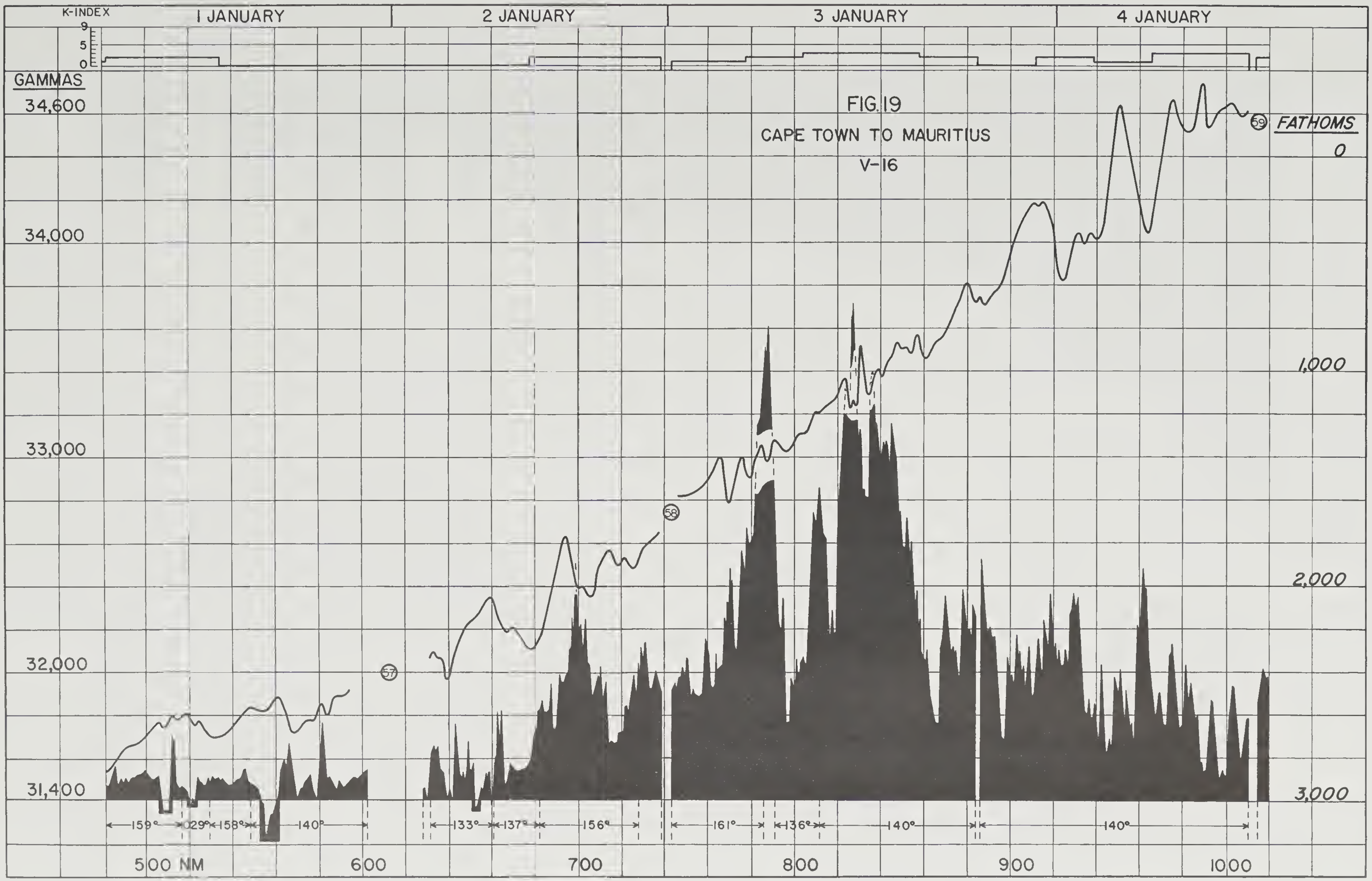


FIG. 19
CAPE TOWN TO MAURITIUS
V-16
K-INDEX
9
5
0
1 JANUARY
2 JANUARY
3 JANUARY
4 JANUARY
GAMMAS
34,600
34,000
33,000
32,000
31,400
FATHOMS
0
1,000
2,000
3,000
57
58
59
159°
029°
158°
140°
133°
137°
156°
161°
136°
140°
140°
500 NM
600
700
800
900
1000

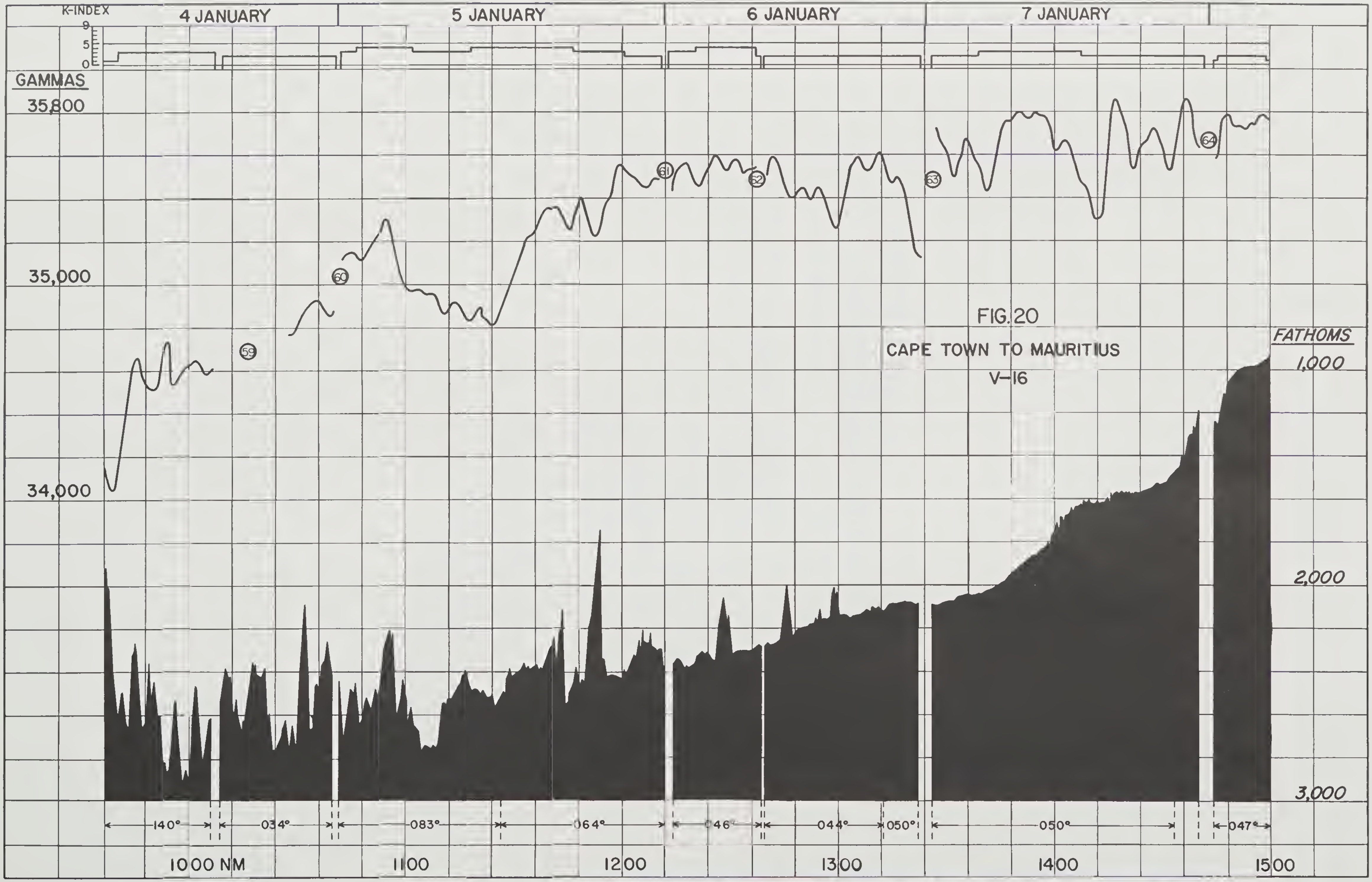


FIG. 20
CAPE TOWN TO MAURITIUS
V-16

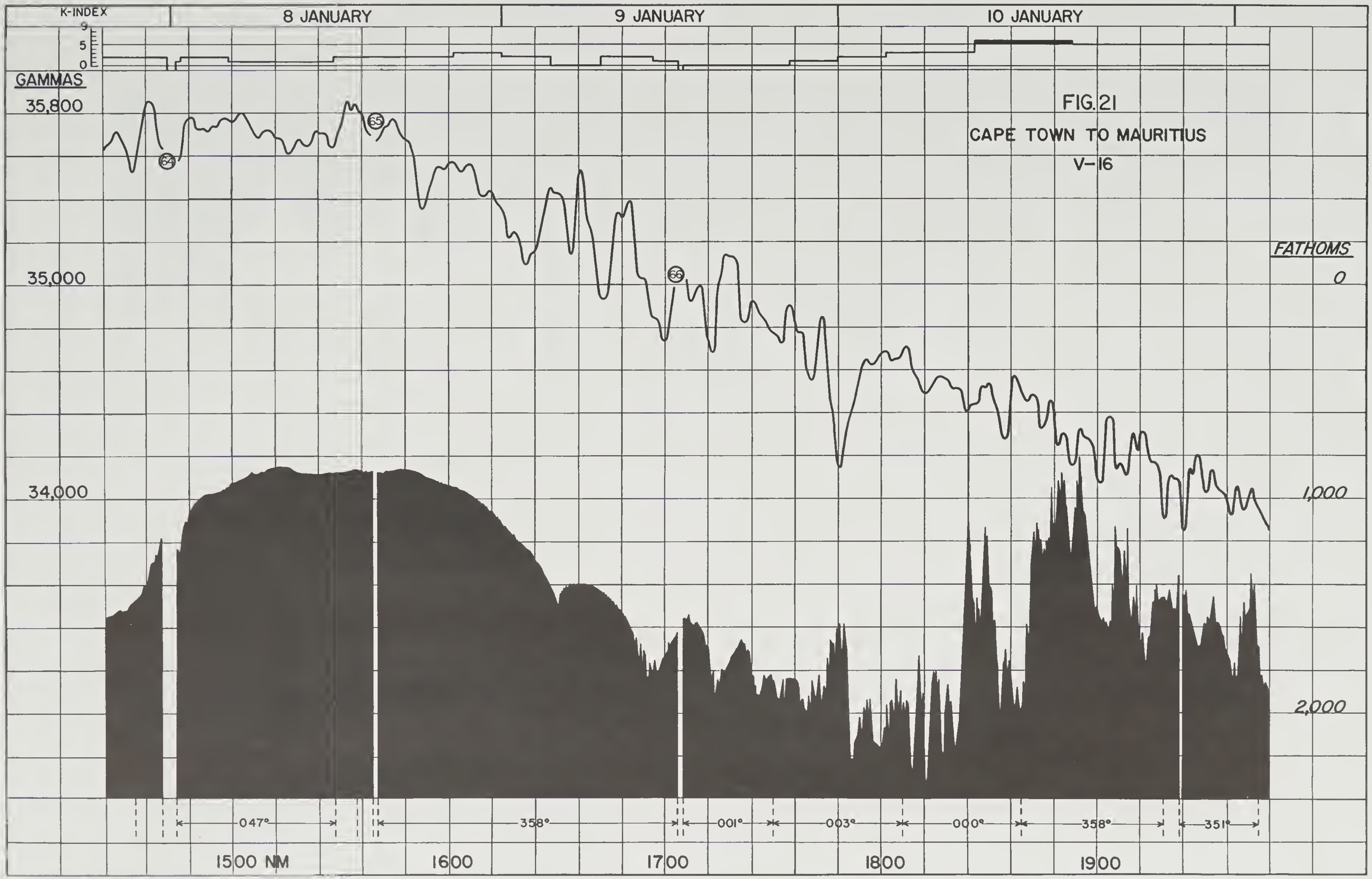
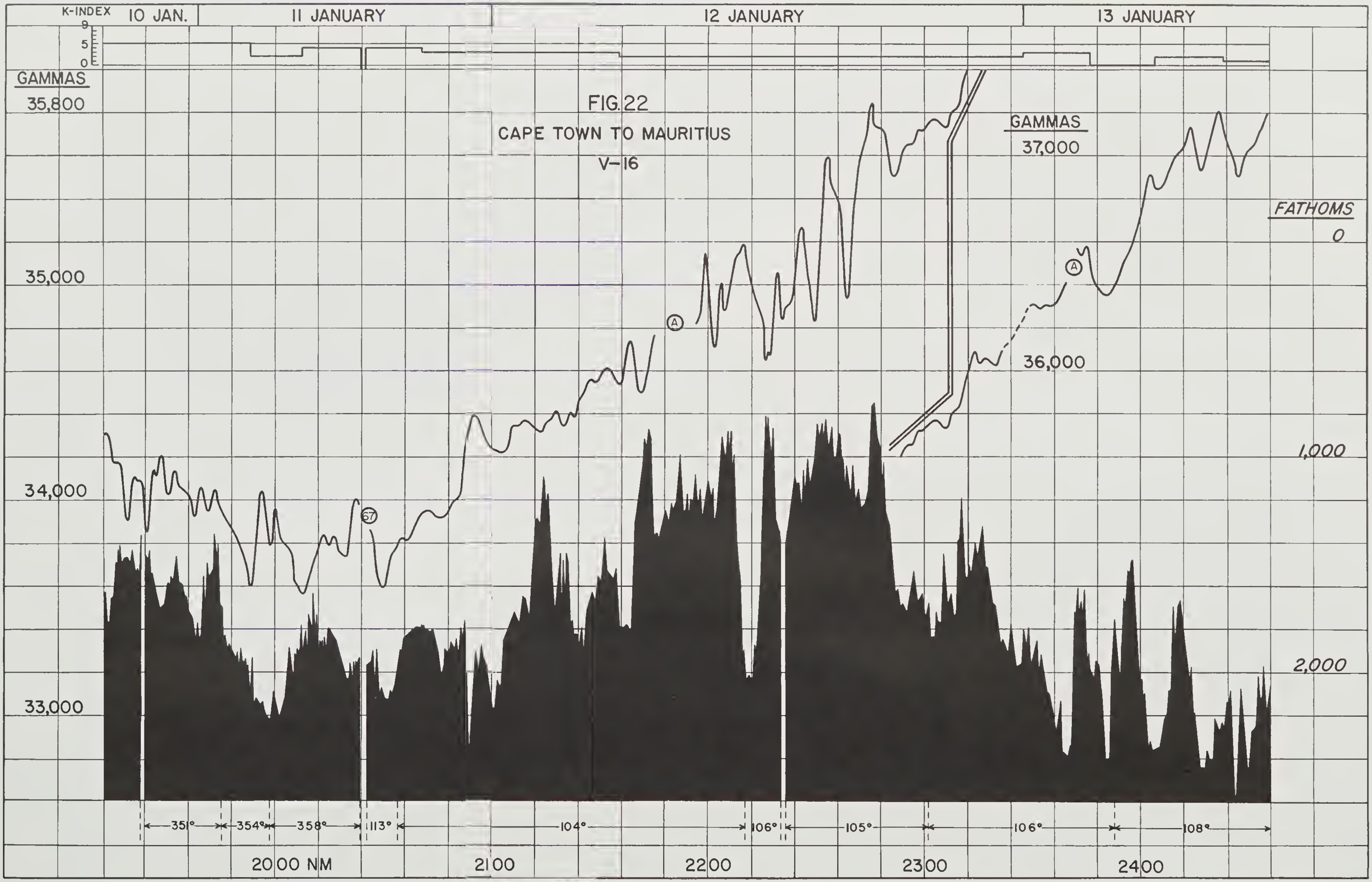


FIG. 21
CAPE TOWN TO MAURITIUS
V-16


K-INDEX
10 JAN.
11 JANUARY
12 JANUARY
13 JANUARY
9
5
0
GAMMAS
35,800
35,000
34,000
33,000
CAPE TOWN TO MAURITIUS
V-16
GAMMAS
37,000
36,000
FATHOMS
0
1,000
2,000
67
A
A
351°
354°
358°
113°
104°
106°
105°
106°
108°
2000 NM
2100
2200
2300
2400
FIG. 22

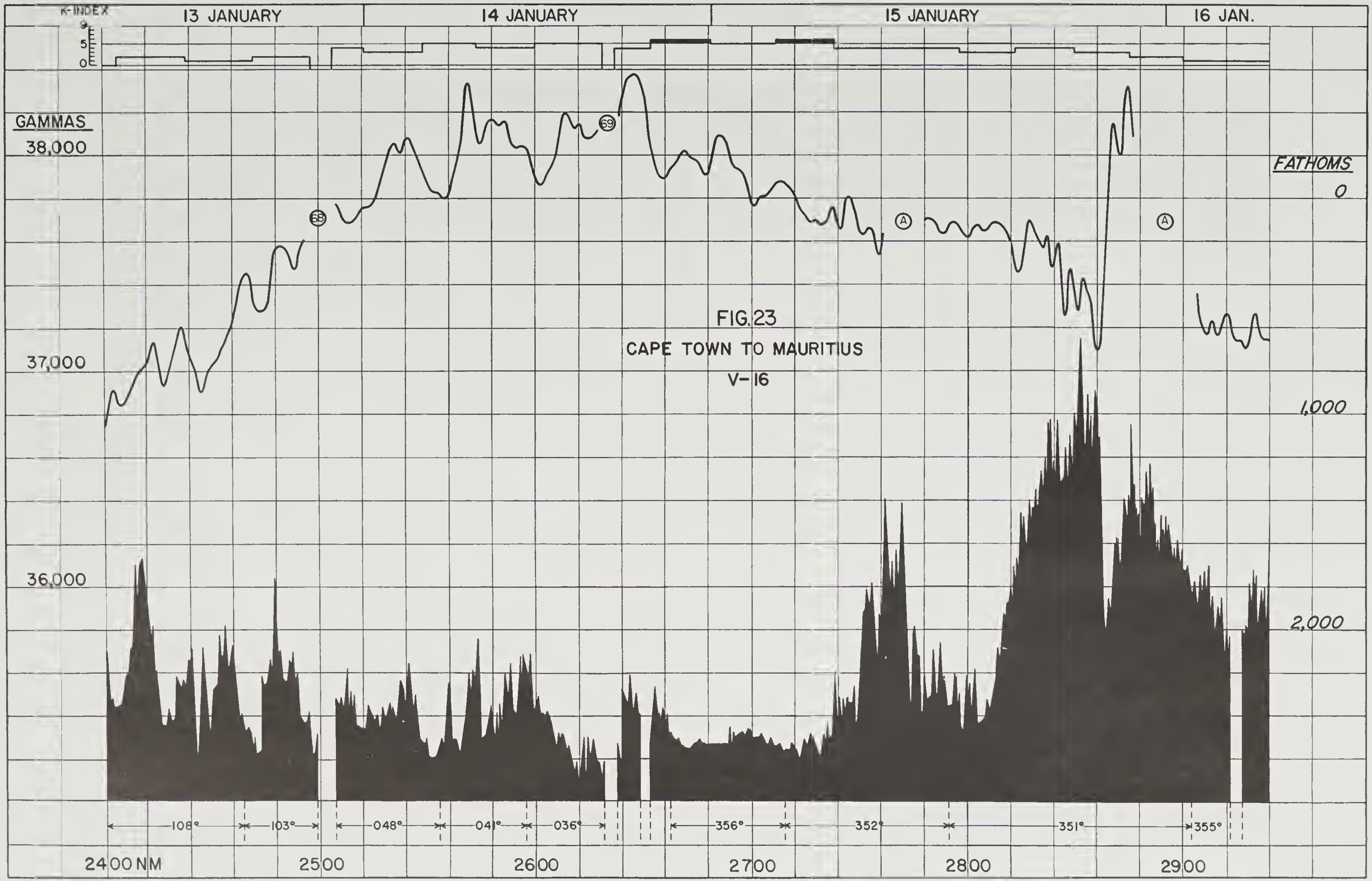


FIG. 23
CAPE TOWN TO MAURITIUS
V-16

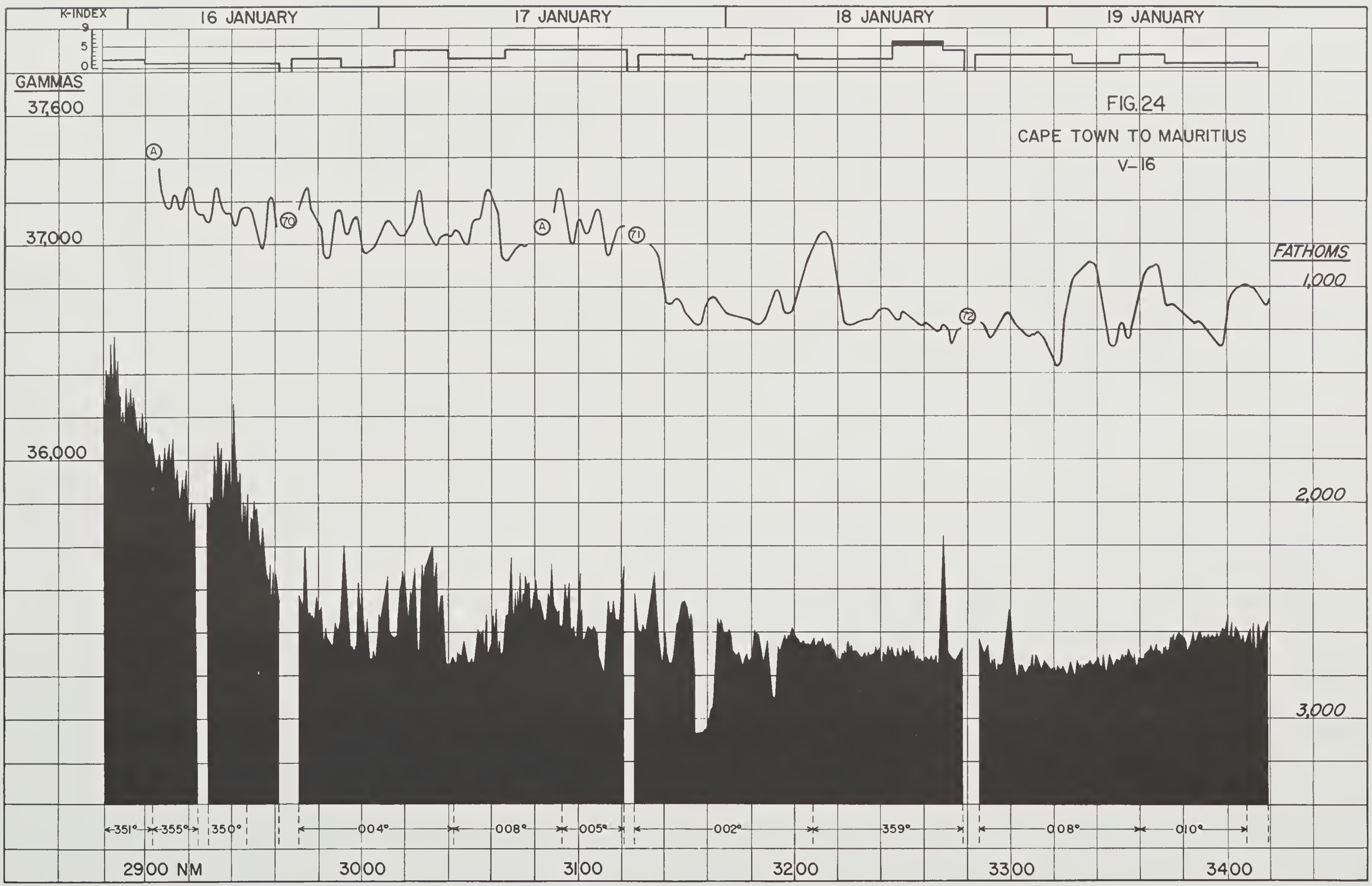


FIG. 24
CAPE TOWN TO MAURITIUS
V-16

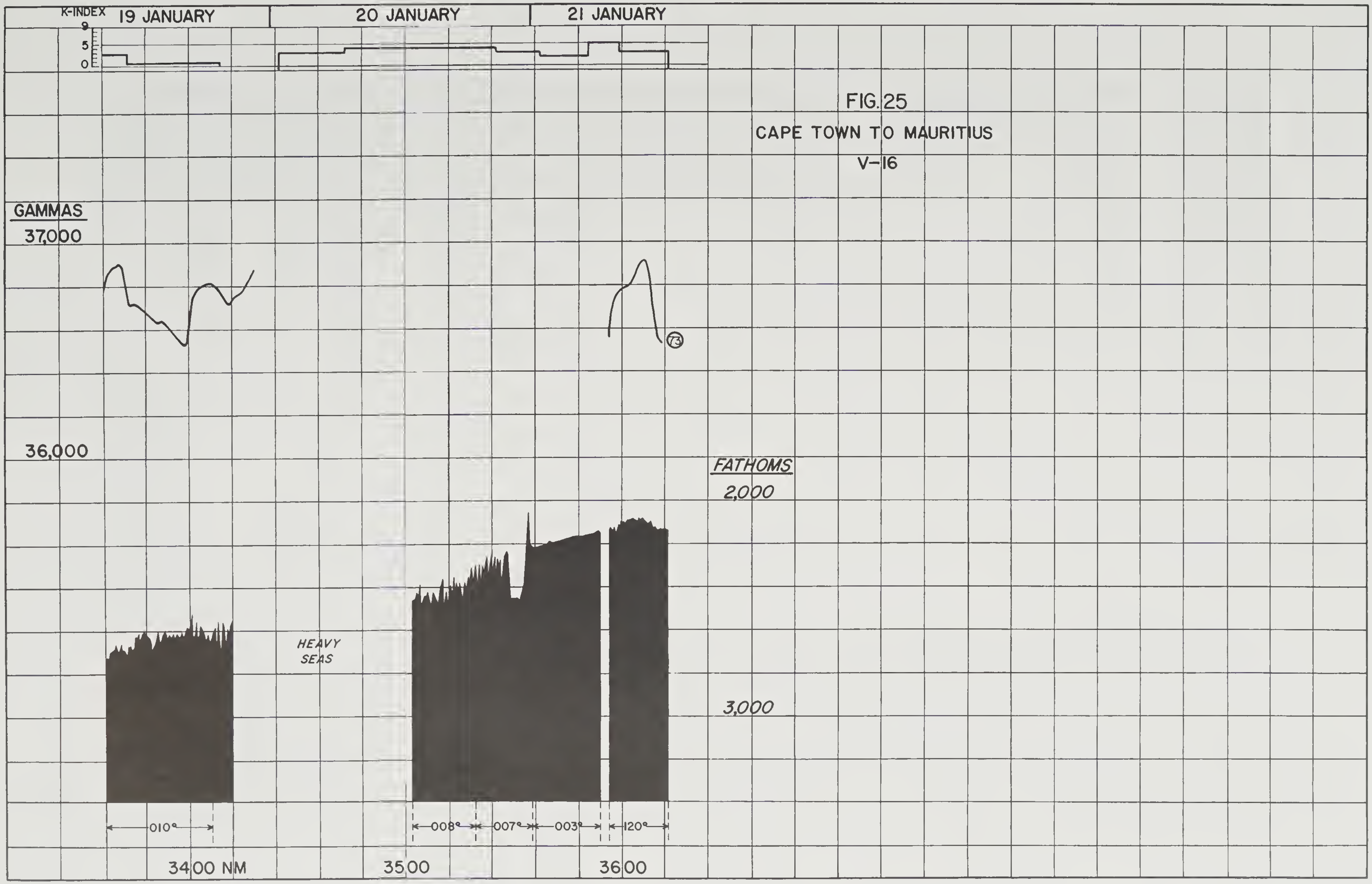


FIG. 25
CAPE TOWN TO MAURITIUS
V-16

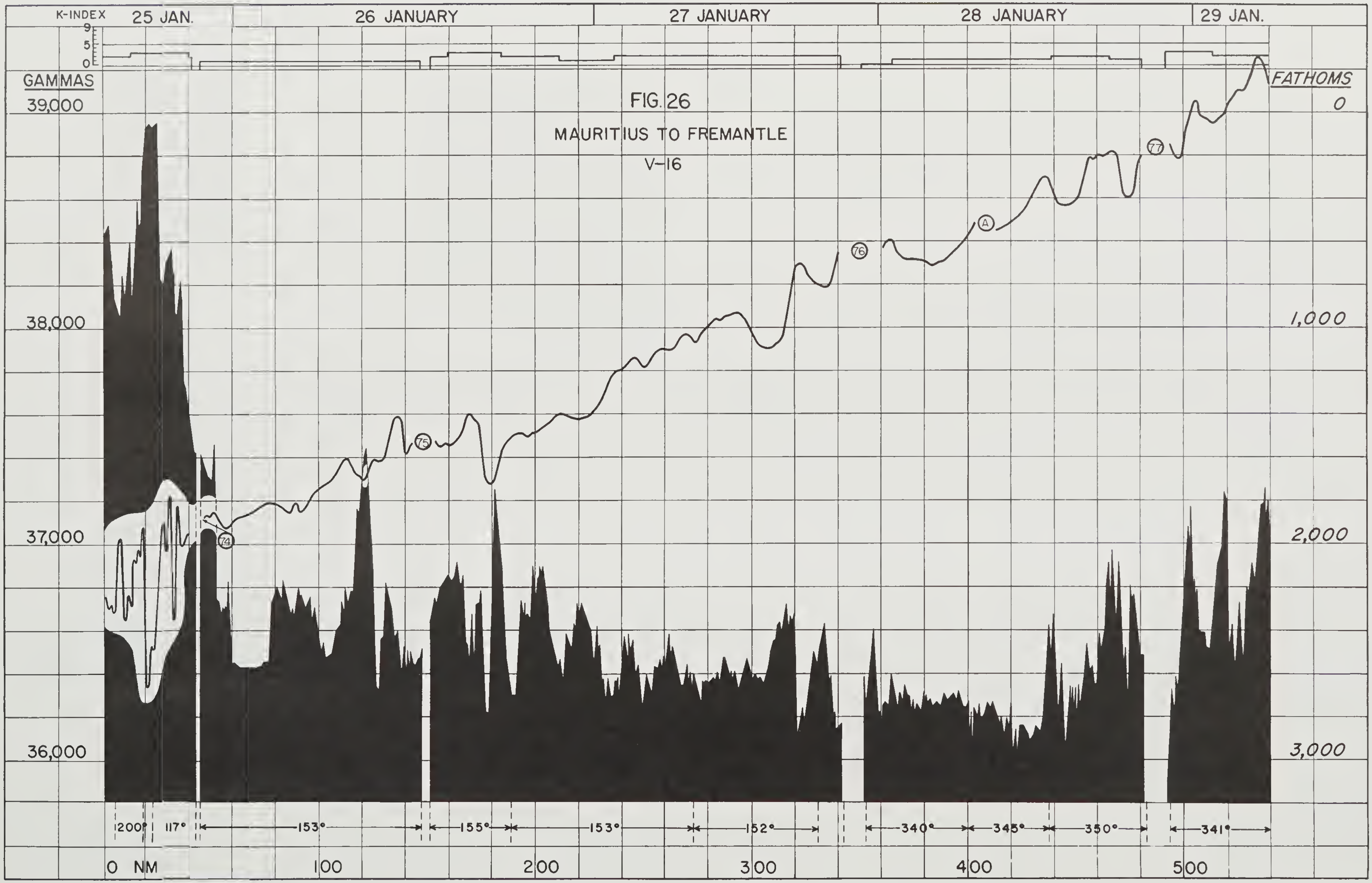


FIG. 26
MAURITIUS TO FREMANTLE
V–16

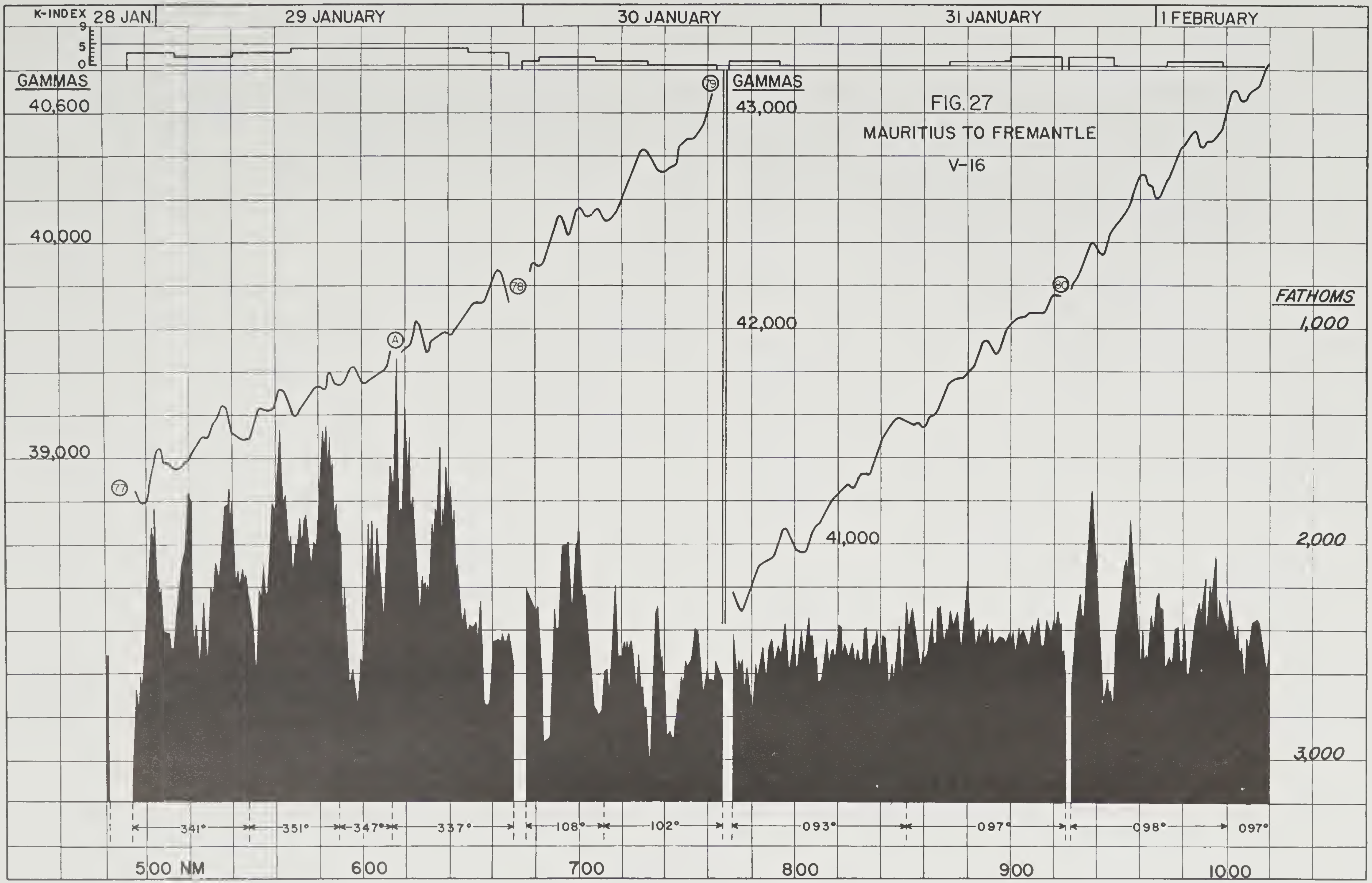


FIG. 27
MAURITIUS TO FREMANTLE
V-16

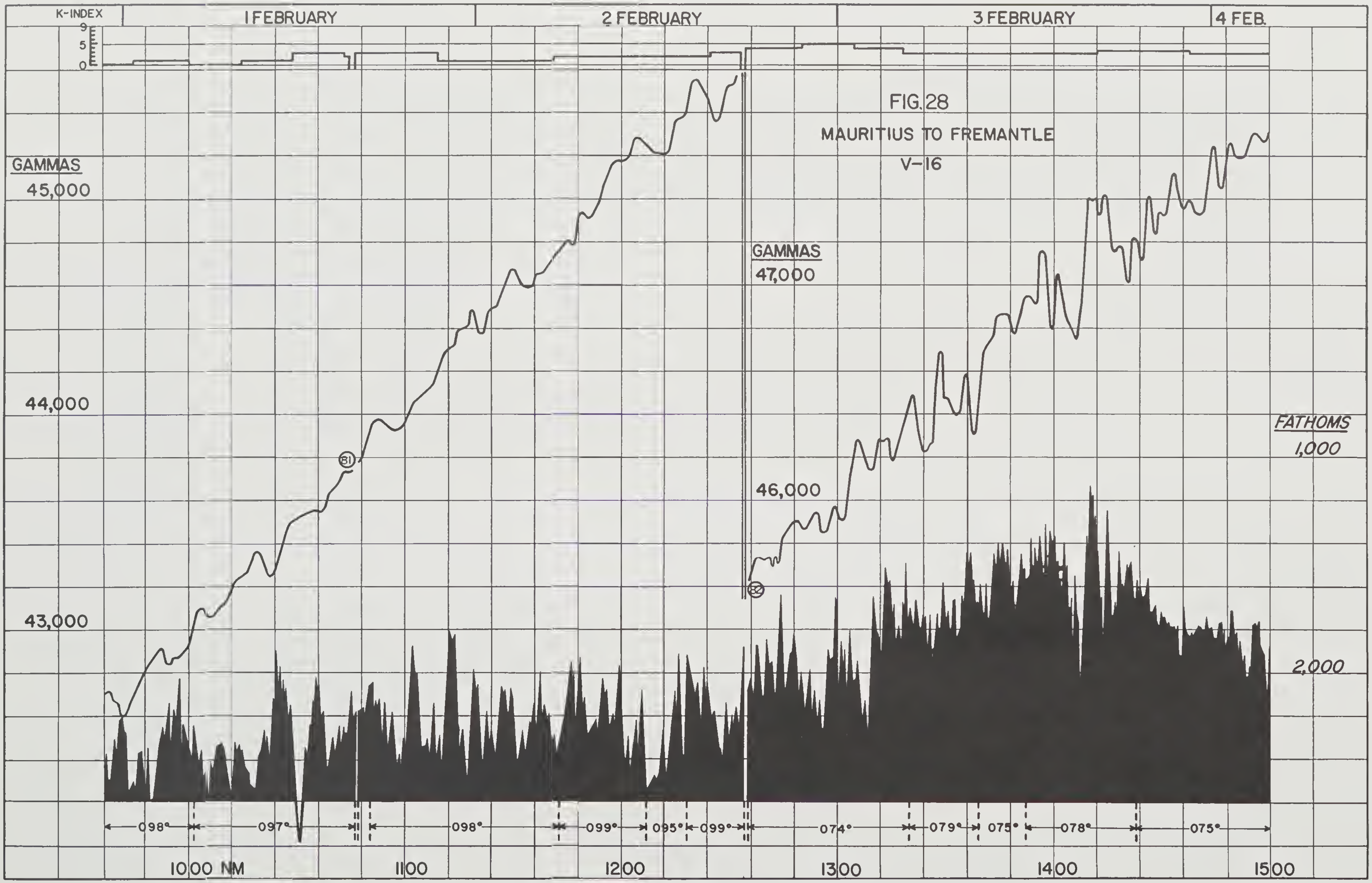


FIG. 28
MAURITIUS TO FREMANTLE
V-16

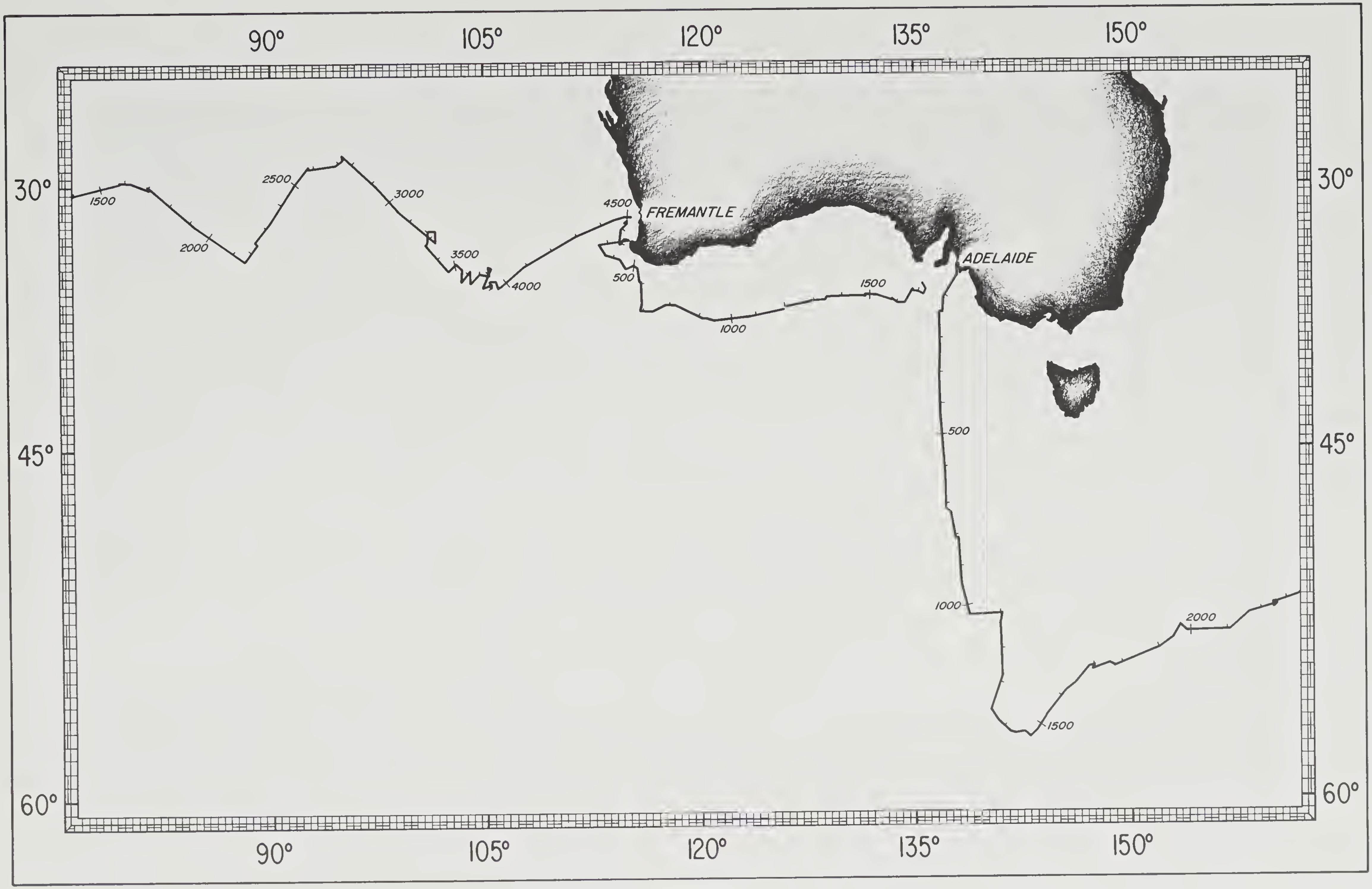
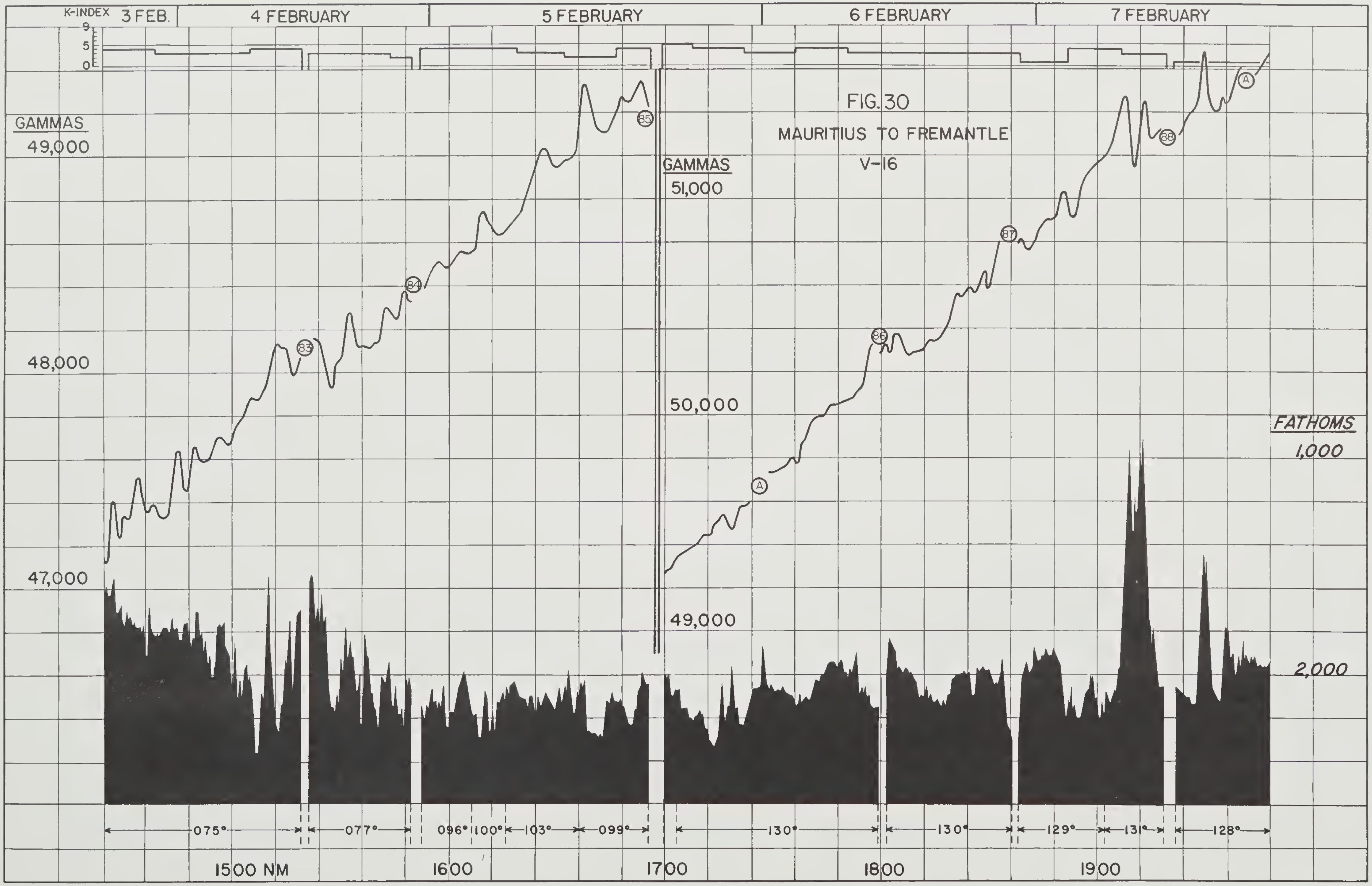

90°
105°
120°
135°
150°
30°
45°
60°
1500
2000
2500
3000
3500
4000
4500
FREMANTLE
500
1000
1500
ADELAIDE
500
1000
1500
2000

FIGURE 29



K-INDEX
9
5
0
3 FEB.
4 FEBRUARY
5 FEBRUARY
6 FEBRUARY
7 FEBRUARY
GAMMAS
49,000
48,000
47,000
GAMMAS
51,000
50,000
49,000
FIG. 30
MAURITIUS TO FREMANTLE
V-16
83
84
85
86
87
88
A
A
FATHOMS
1,000
2,000
075°
077°
096°
100°
103°
099°
130°
130°
129°
131°
128°
1500 NM
1600
1700
1800
1900

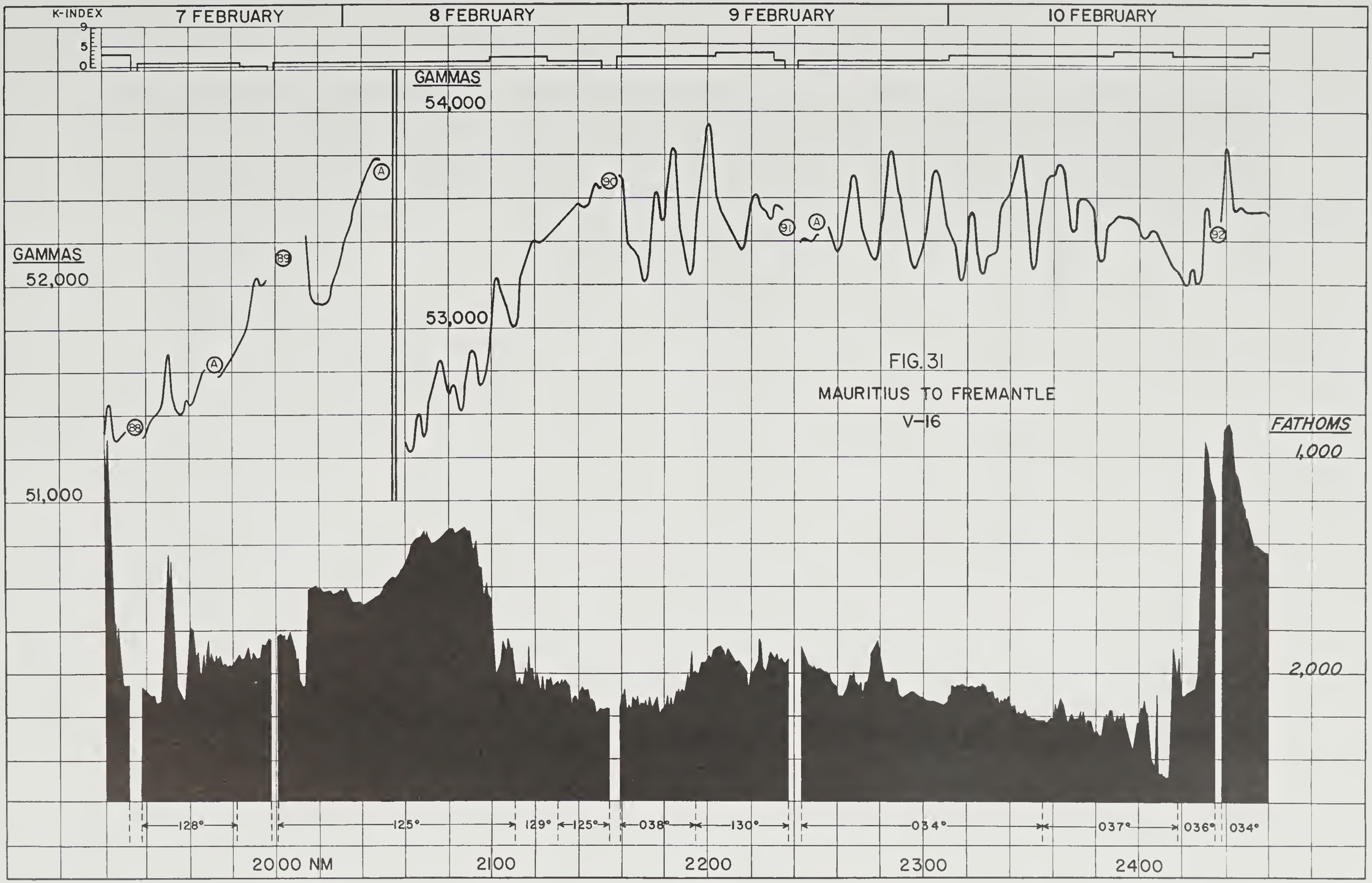
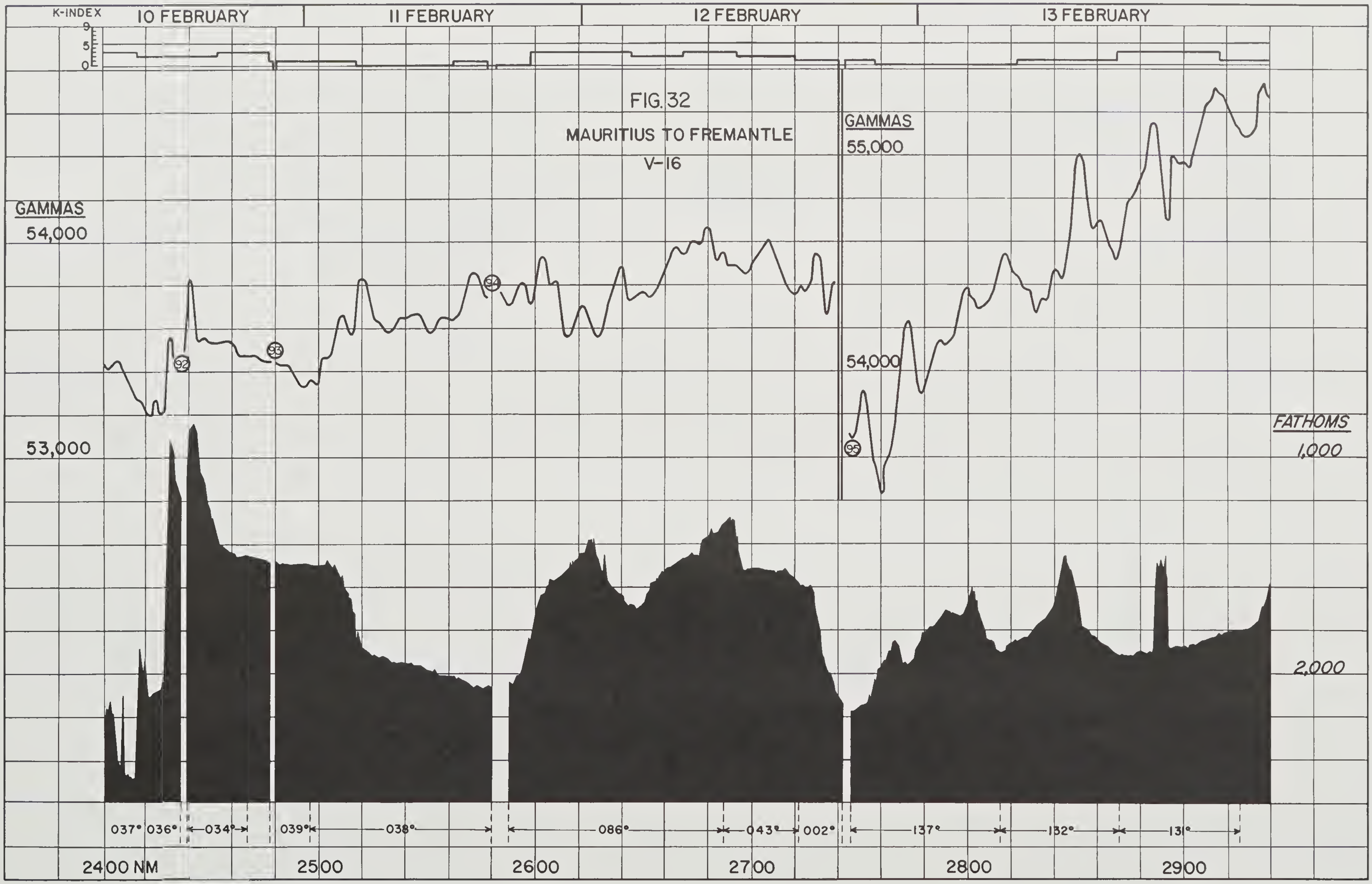


FIG. 31
MAURITIUS TO FREMANTLE
V-16


K-INDEX
10 FEBRUARY
11 FEBRUARY
12 FEBRUARY
13 FEBRUARY
9
5
0
FIG. 32
MAURITIUS TO FREMANTLE
V-16
GAMMAS
54,000
53,000
GAMMAS
55,000
54,000
FATHOMS
1,000
2,000
92
93
94
95
037° 036° 034° 039° 038° 086° 043° 002° 137° 132° 131°
2400 NM
2500
2600
2700
2800
2900

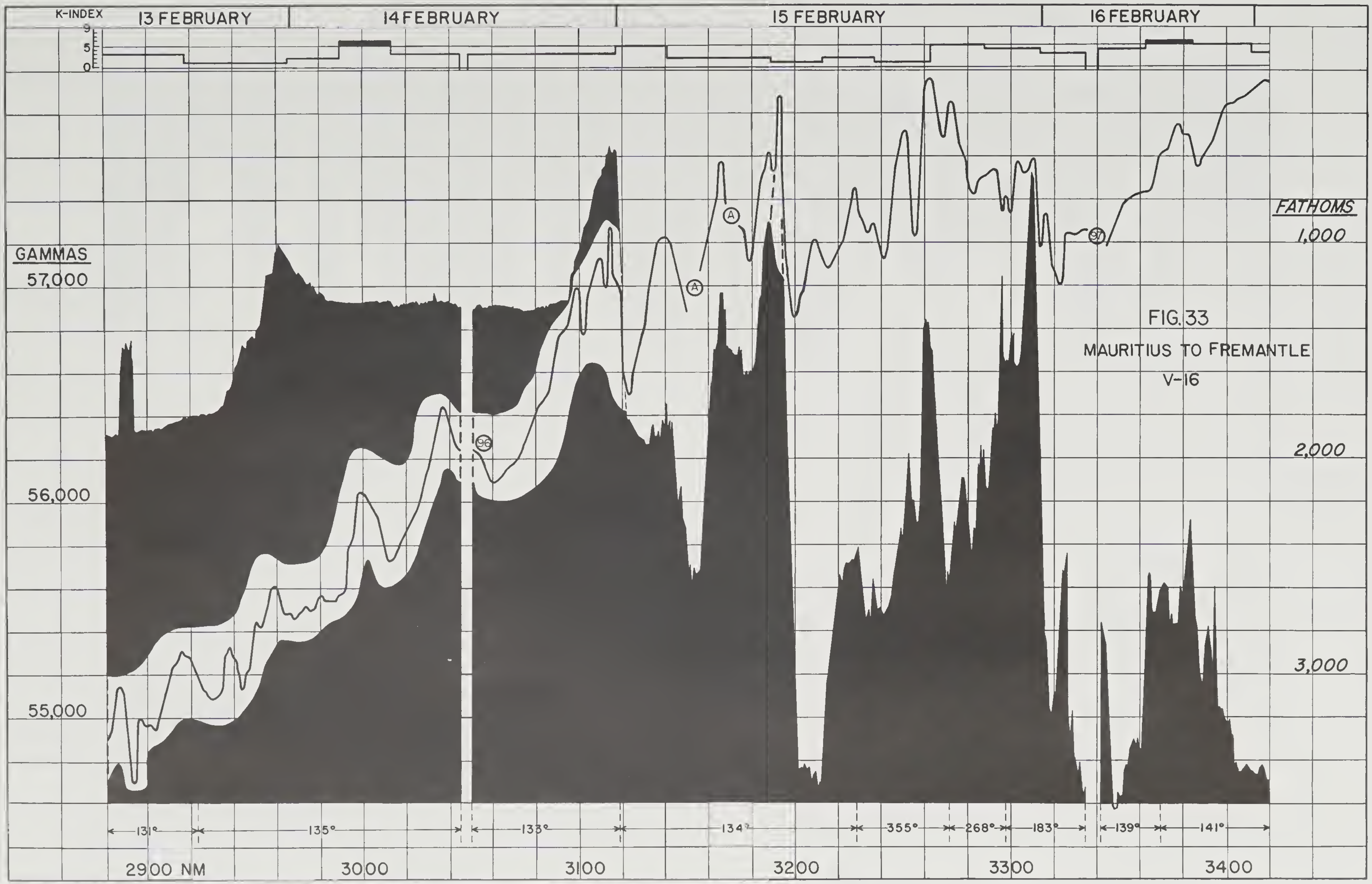


FIG. 33
MAURITIUS TO FREMANTLE
V-16

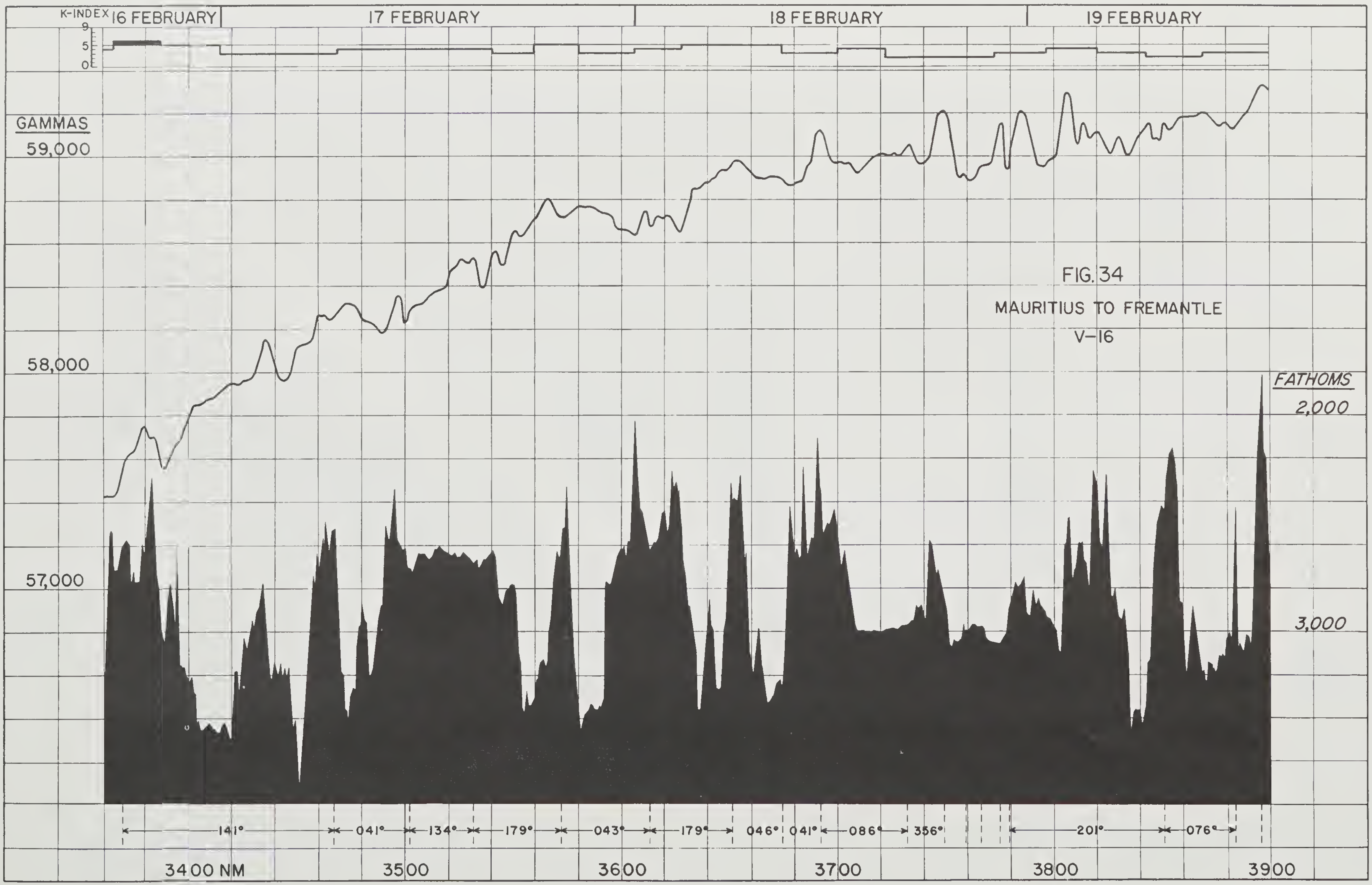
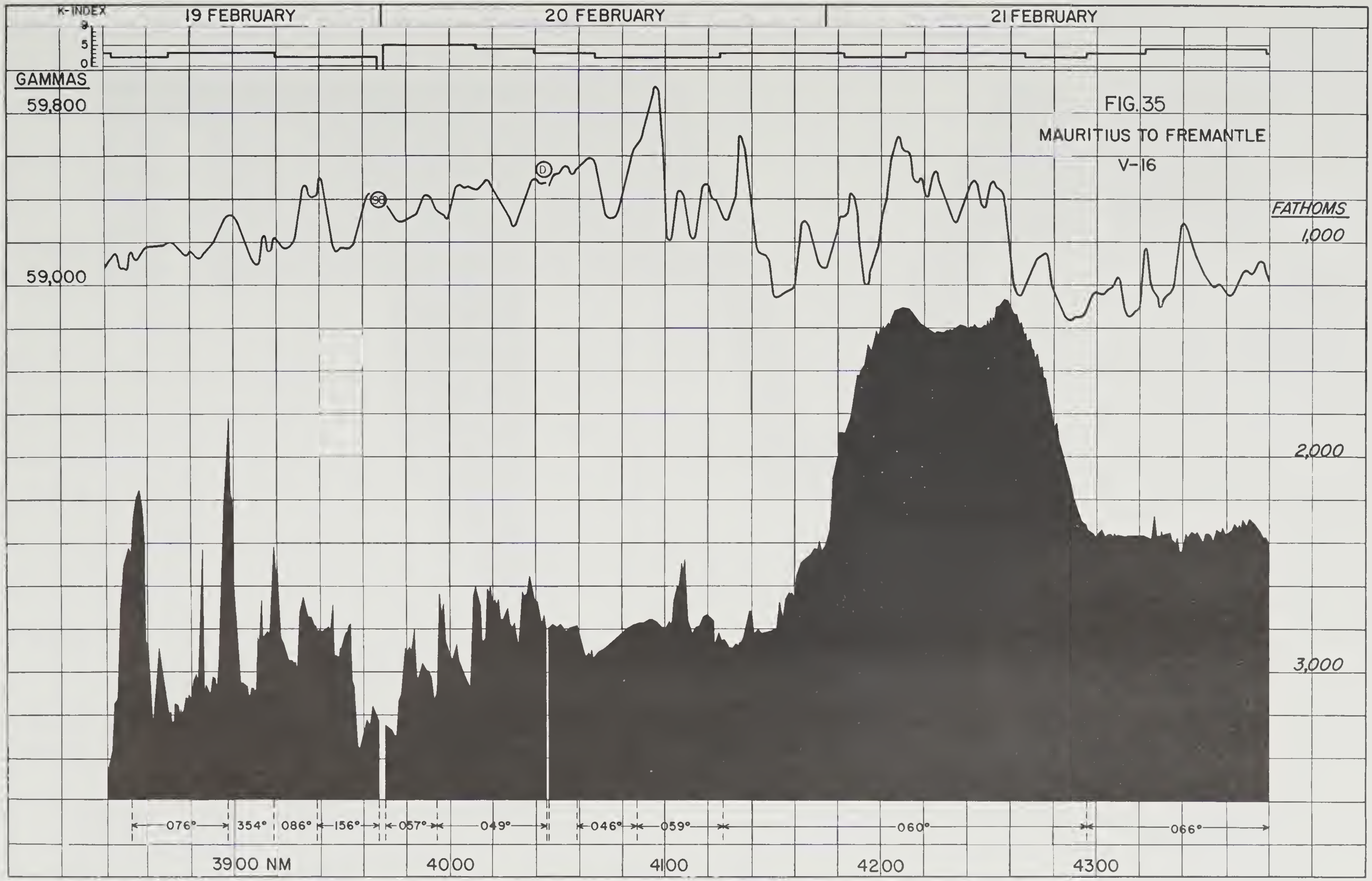


FIG. 34
MAURITIUS TO FREMANTLE
V–16


K-INDEX
9
5
0
19 FEBRUARY
20 FEBRUARY
21 FEBRUARY
GAMMAS
59,800
59,000
FIG. 35
MAURITIUS TO FREMANTLE
V-16
FATHOMS
1,000
2,000
3,000
076°
354°
086°
156°
057°
049°
046°
059°
060°
066°
3900 NM
4000
4100
4200
4300

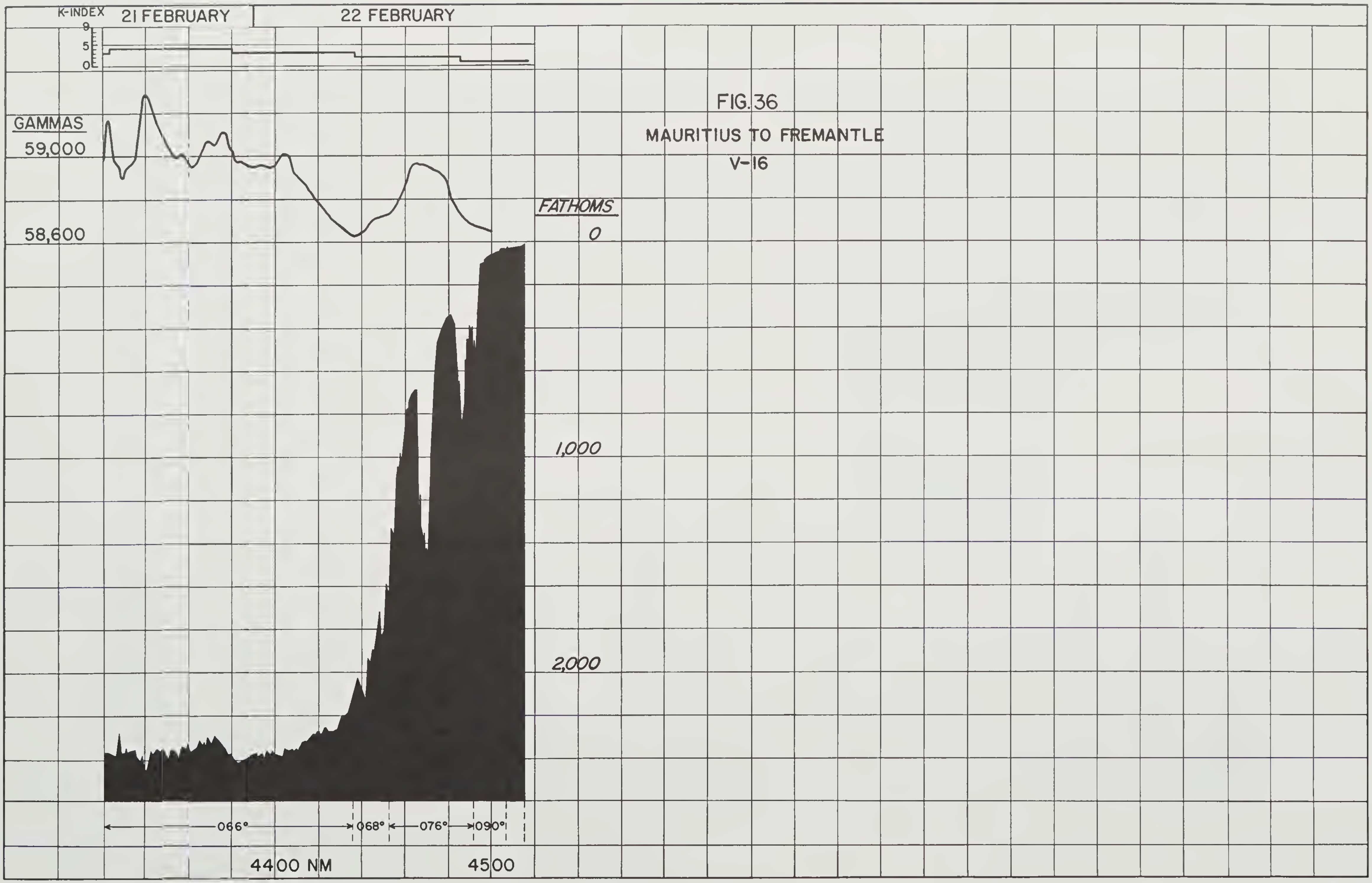


FIG. 36
MAURITIUS TO FREMANTLE
V-16

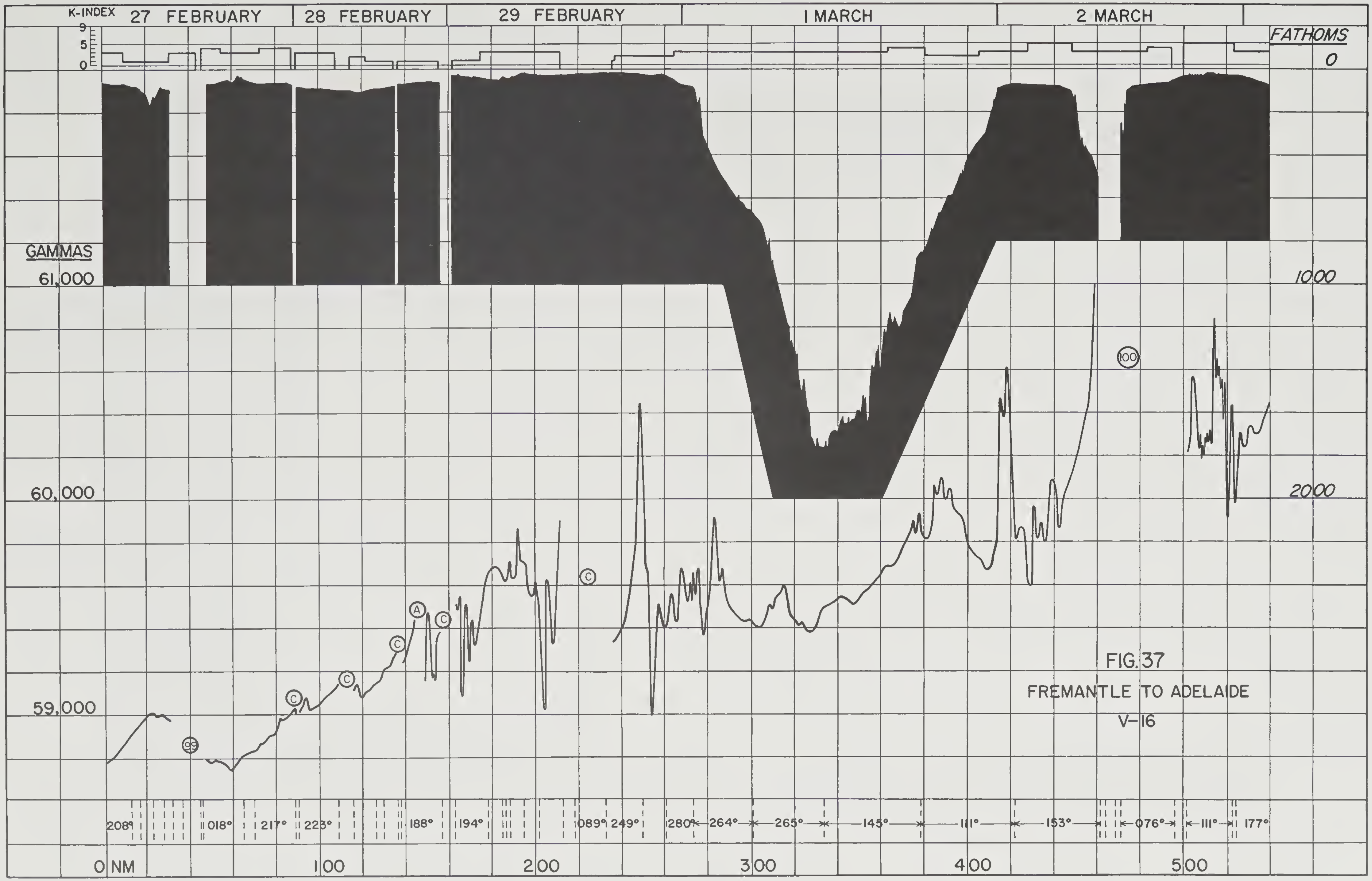


FIG. 37
FREMANTLE TO ADELAIDE
V-16

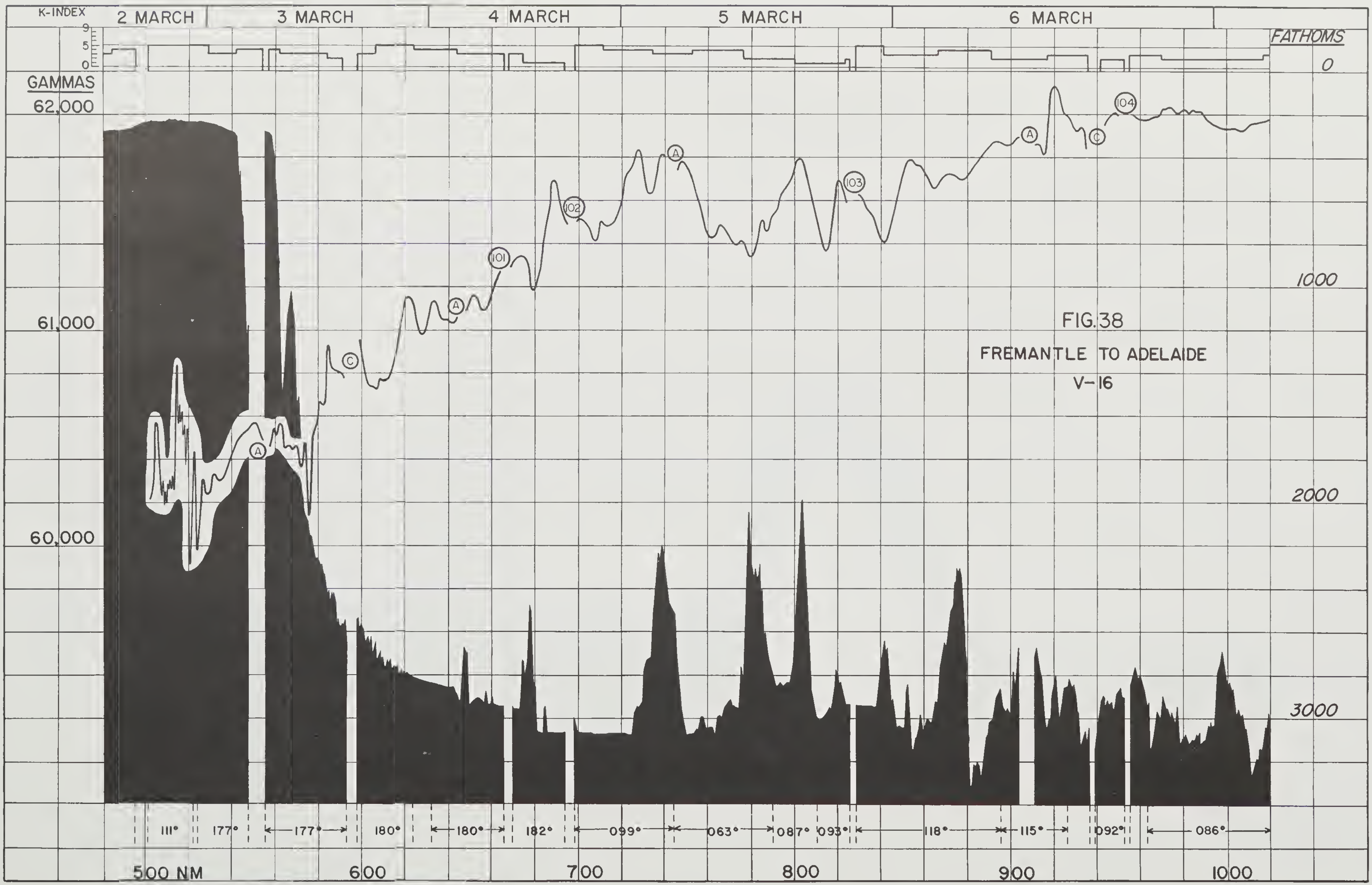


FIG. 38
FREMANTLE TO ADELAIDE
V–16

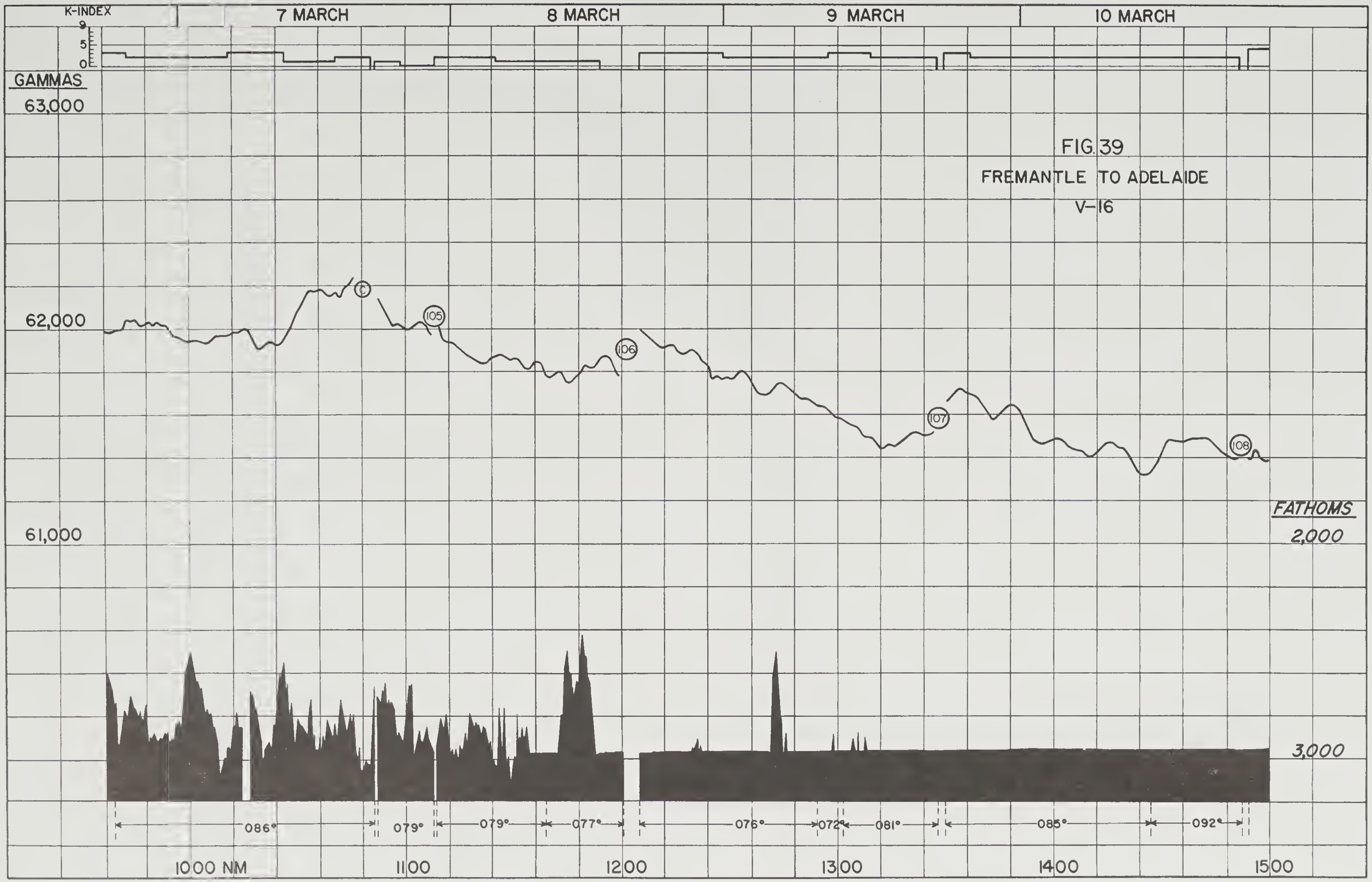


FIG. 39
FREMANTLE TO ADELAIDE
V-16
K-INDEX
9
5
0
7 MARCH
8 MARCH
9 MARCH
10 MARCH
GAMMAS
63,000
62,000
61,000
FATHOMS
2,000
3,000
C
105
106
107
108
086°
079°
079°
077°
076°
072°
081°
085°
092°
1000 NM
1100
1200
1300
1400
1500

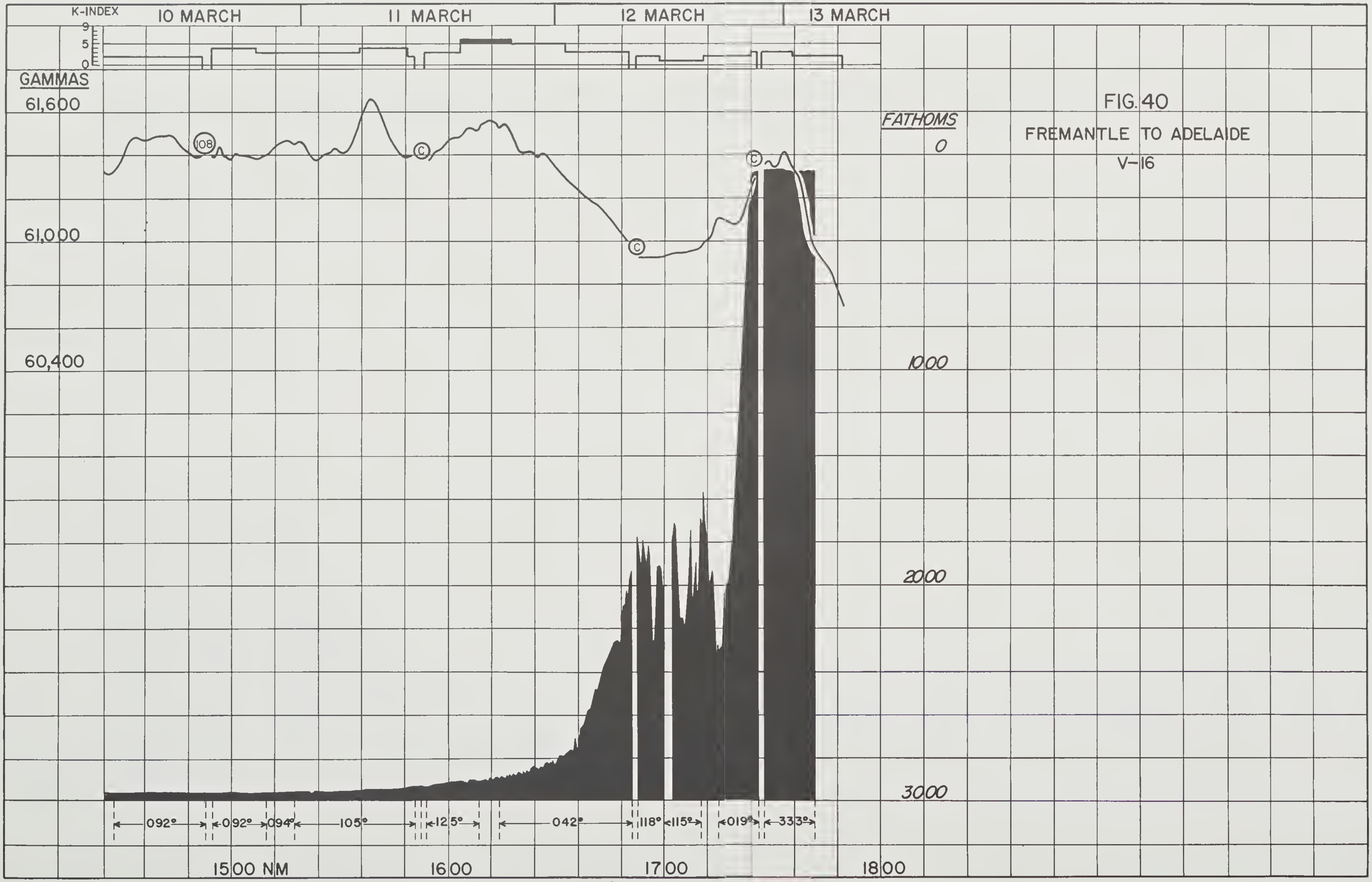


FIG. 40
FREMANTLE TO ADELAIDE
V-16

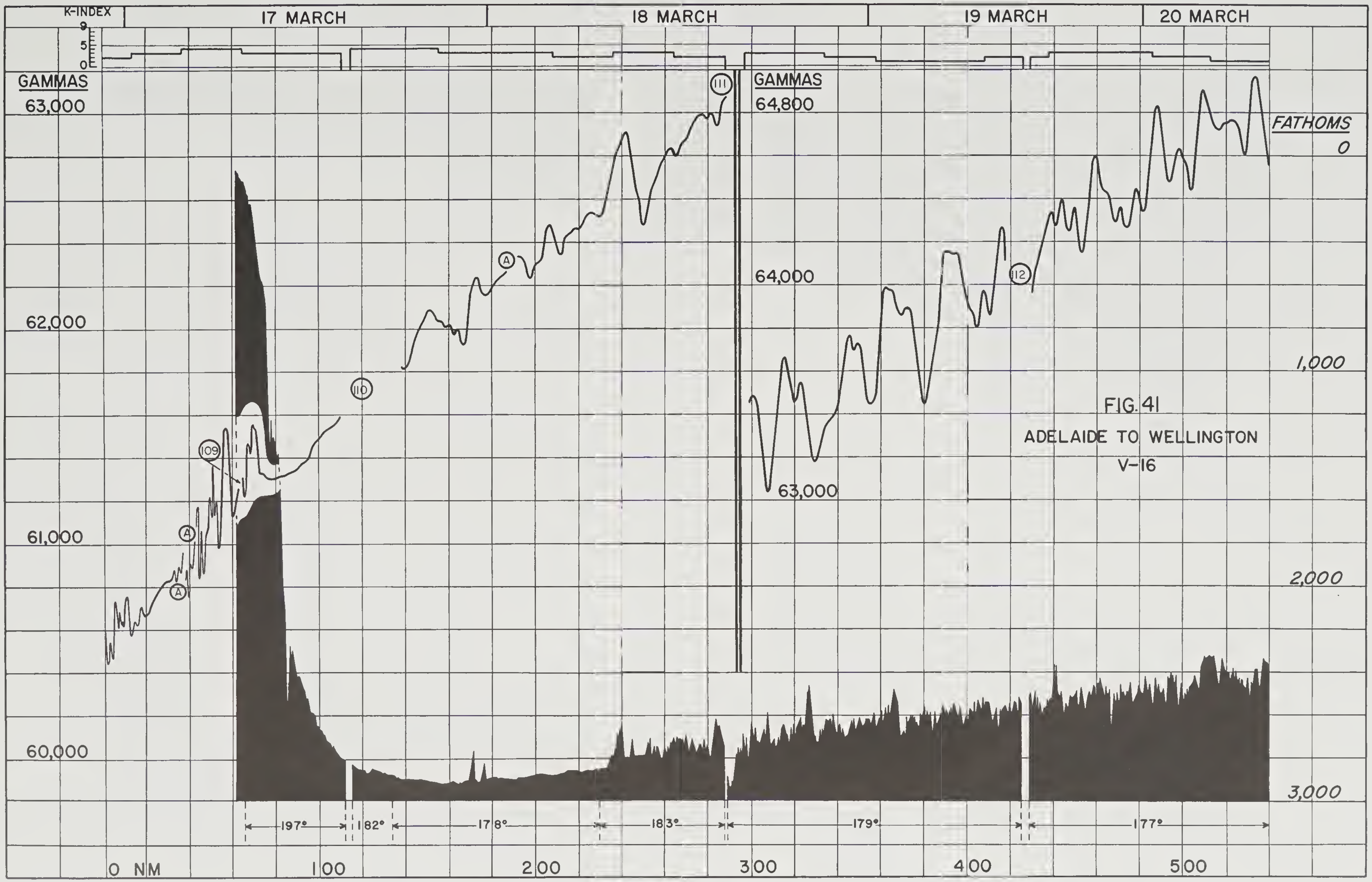


FIG. 41
ADELAIDE TO WELLINGTON
V-16

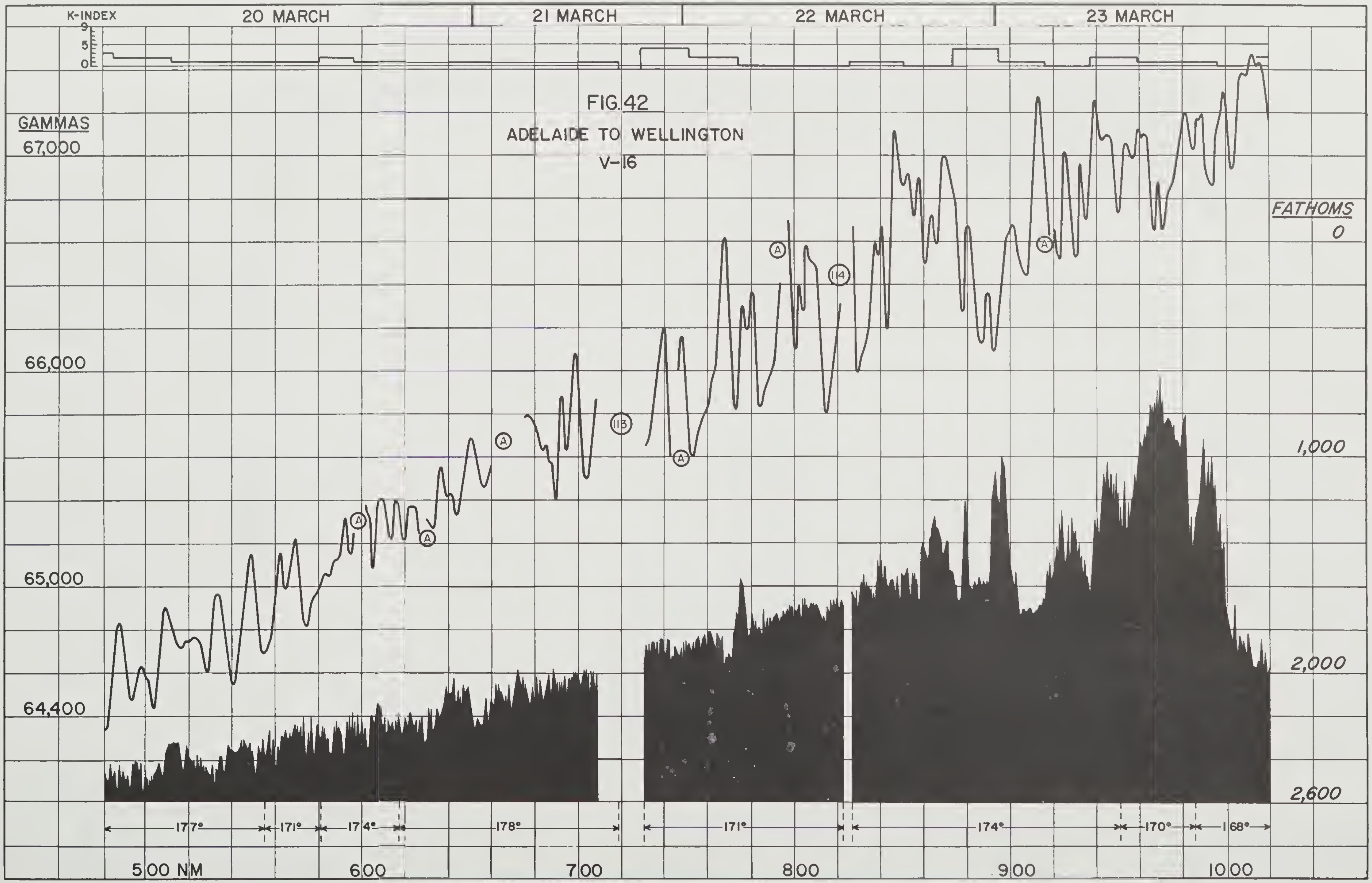


FIG. 42
ADELAIDE TO WELLINGTON
V-16

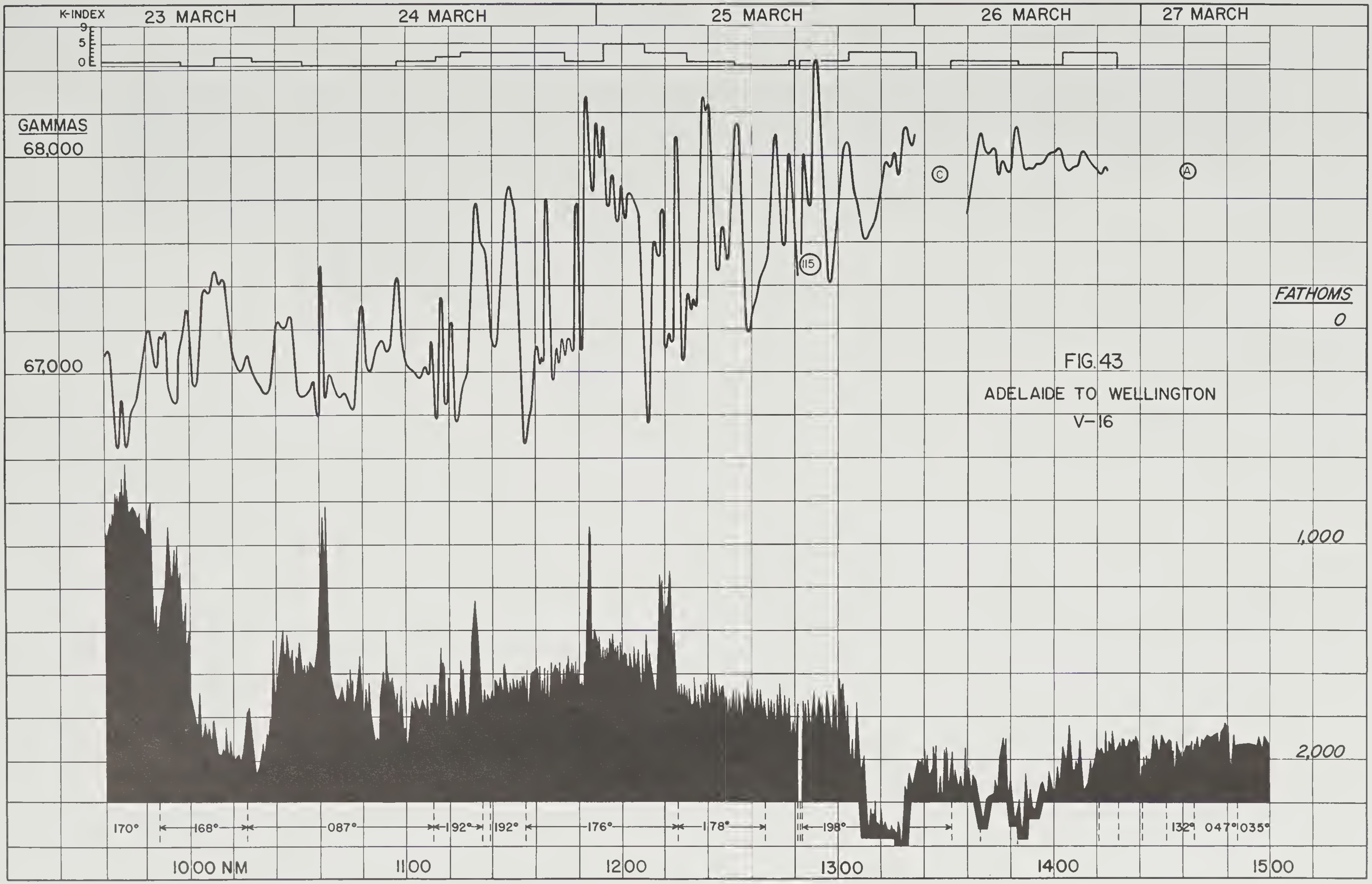


FIG. 43
ADELAIDE TO WELLINGTON
V-16

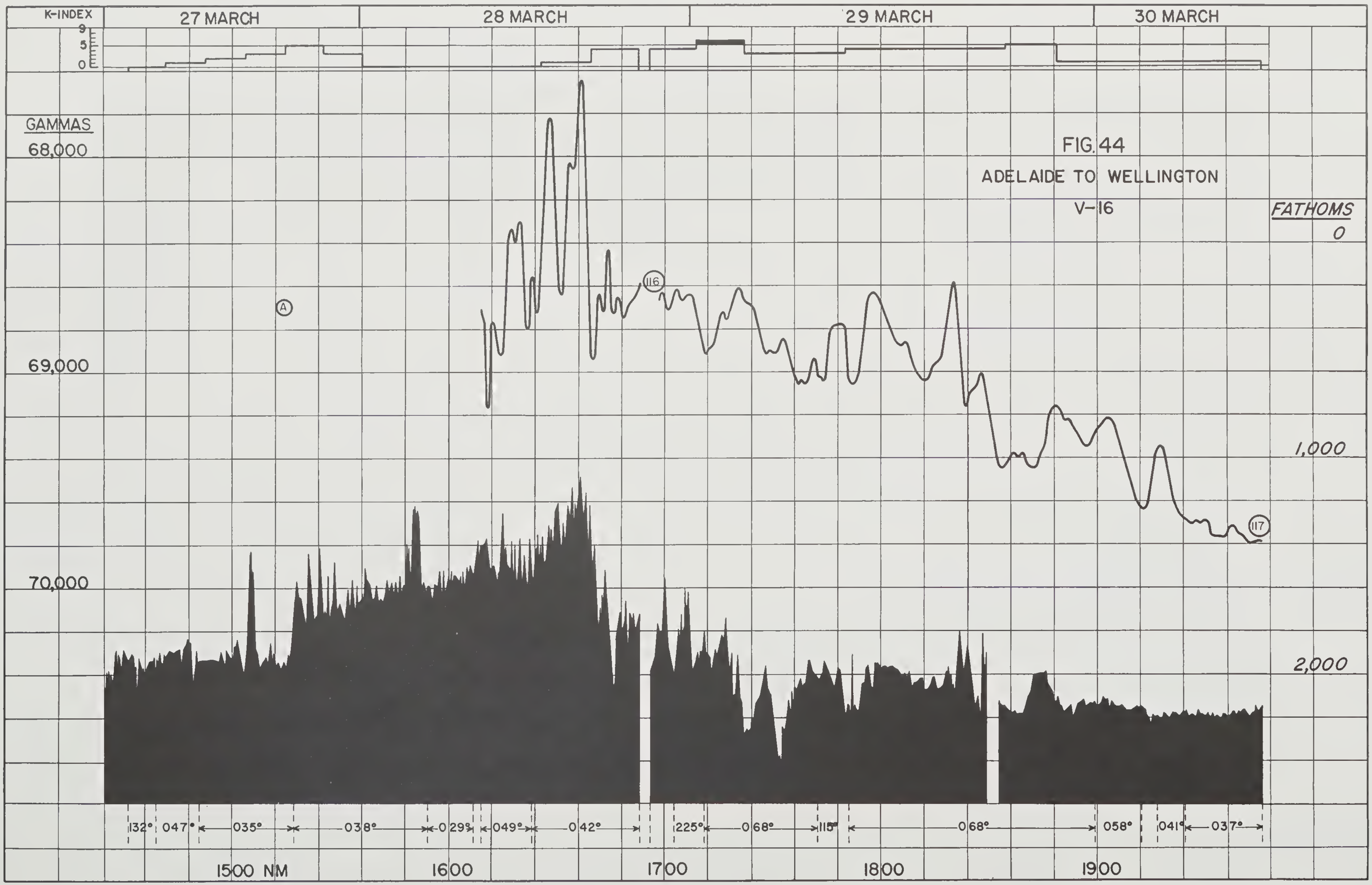


FIG. 44
ADELAIDE TO WELLINGTON
V-16

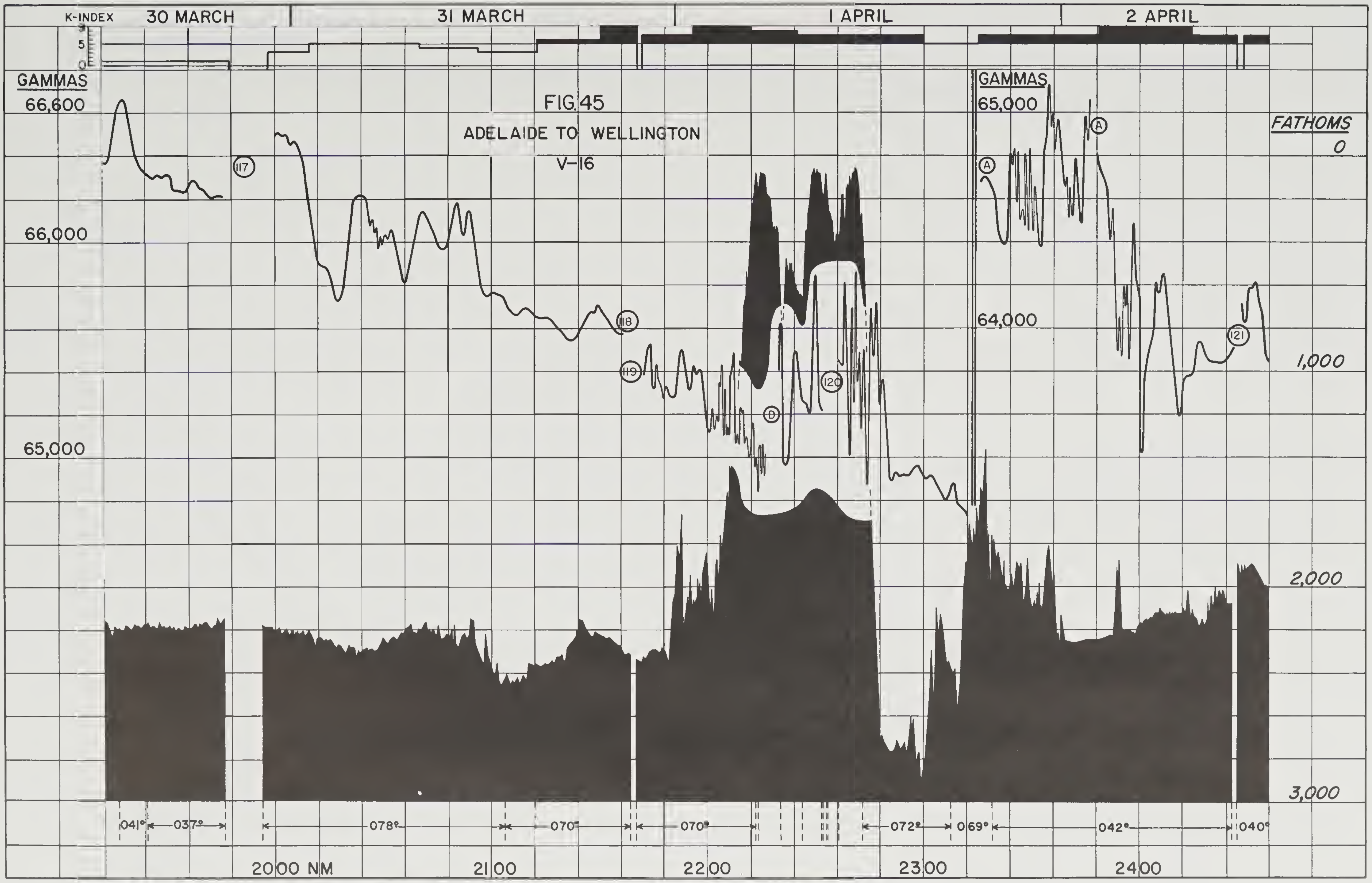


FIG. 45
ADELAIDE TO WELLINGTON
V-16

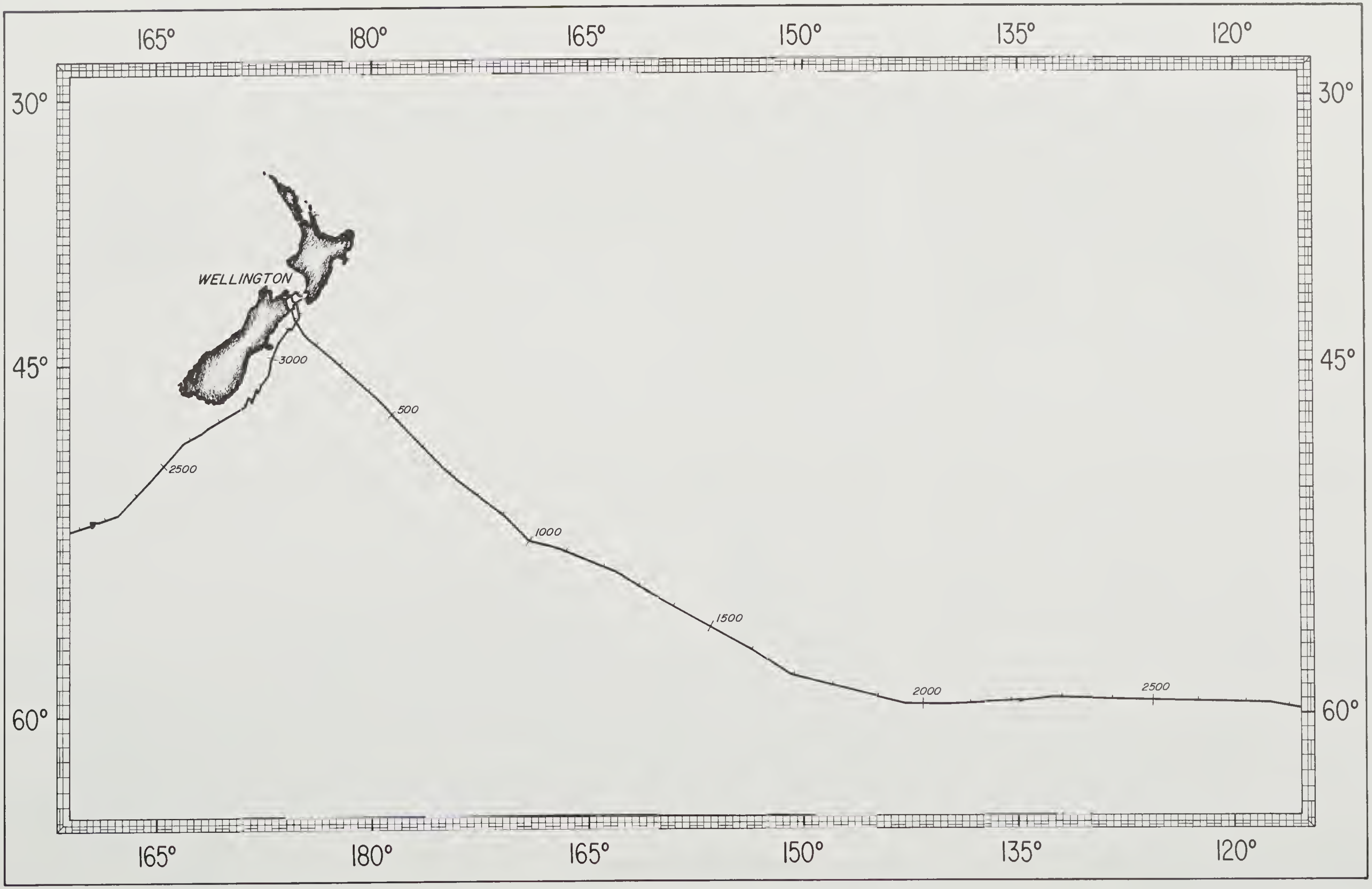

165°
180°
165°
150°
135°
120°
30°
45°
60°
WELLINGTON
3000
500
2500
1000
1500
2000
2500

FIGURE 46

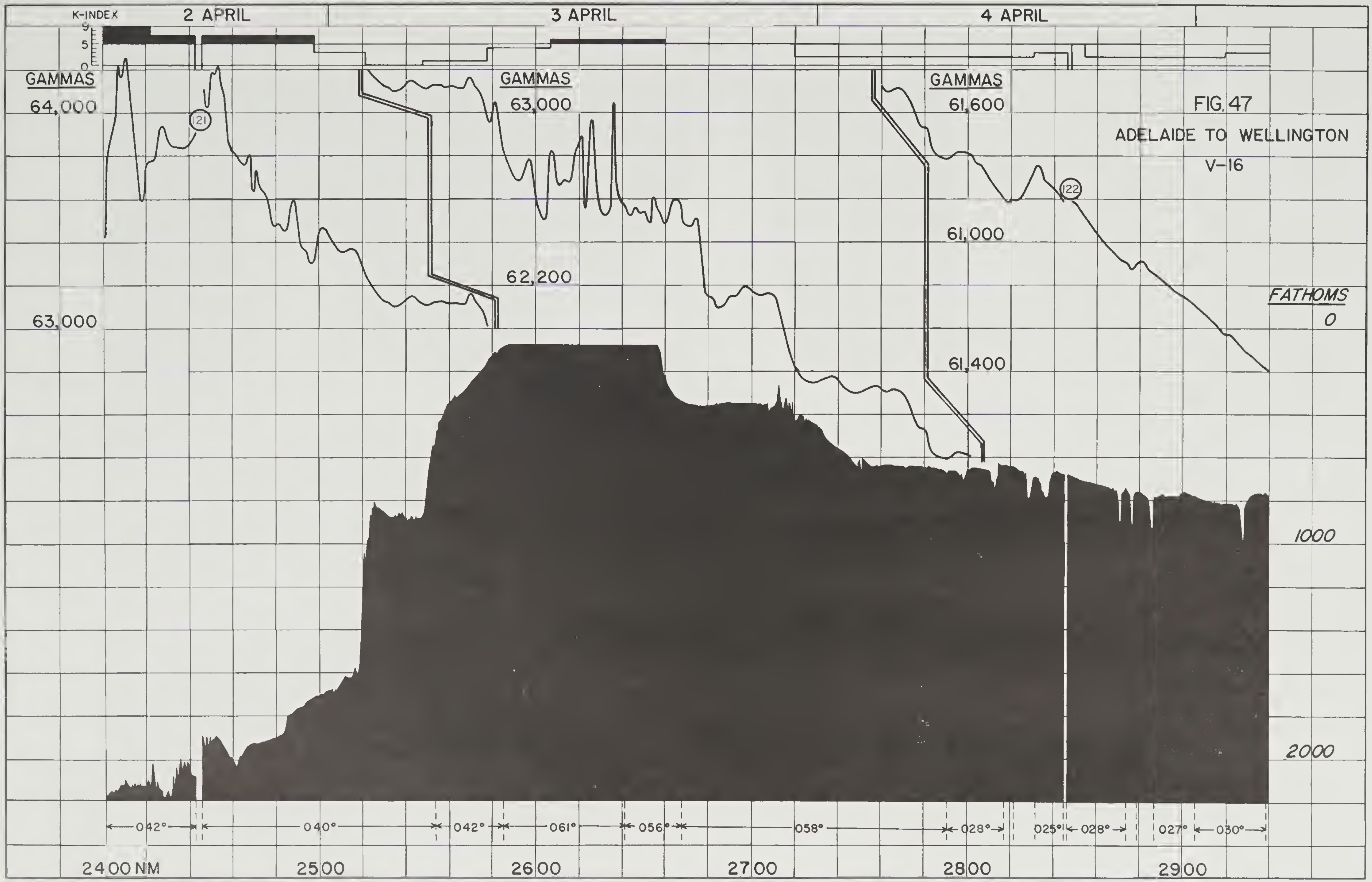


FIG. 47
ADELAIDE TO WELLINGTON
V-16

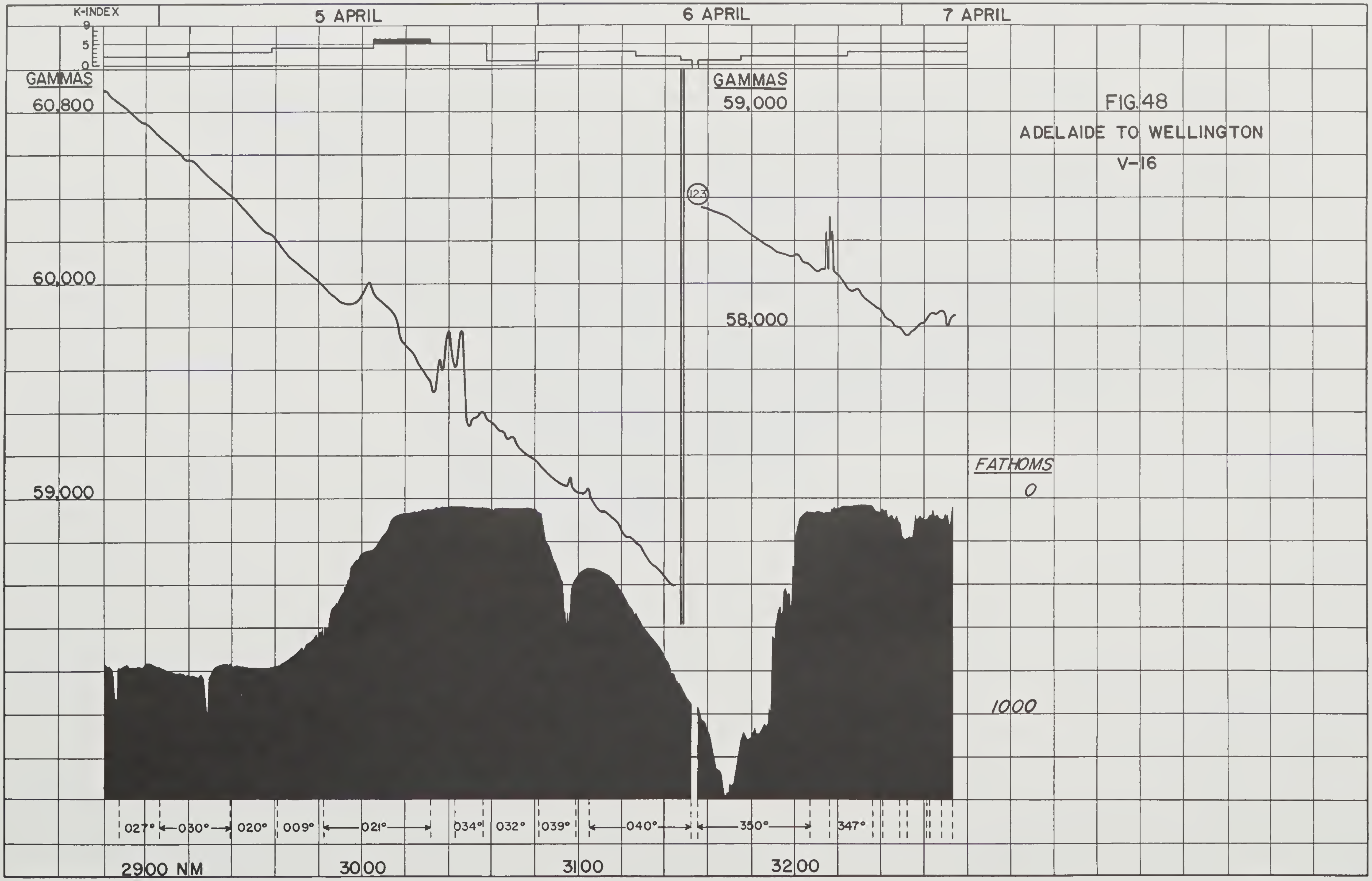


FIG. 48
ADELAIDE TO WELLINGTON
V-16
K-INDEX
9
5
0
5 APRIL
6 APRIL
7 APRIL
GAMMAS
60,800
60,000
59,000
GAMMAS
59,000
58,000
123
FATHOMS
0
1000
027°
030°
020°
009°
021°
034°
032°
039°
040°
350°
347°
2900 NM
3000
3100
3200

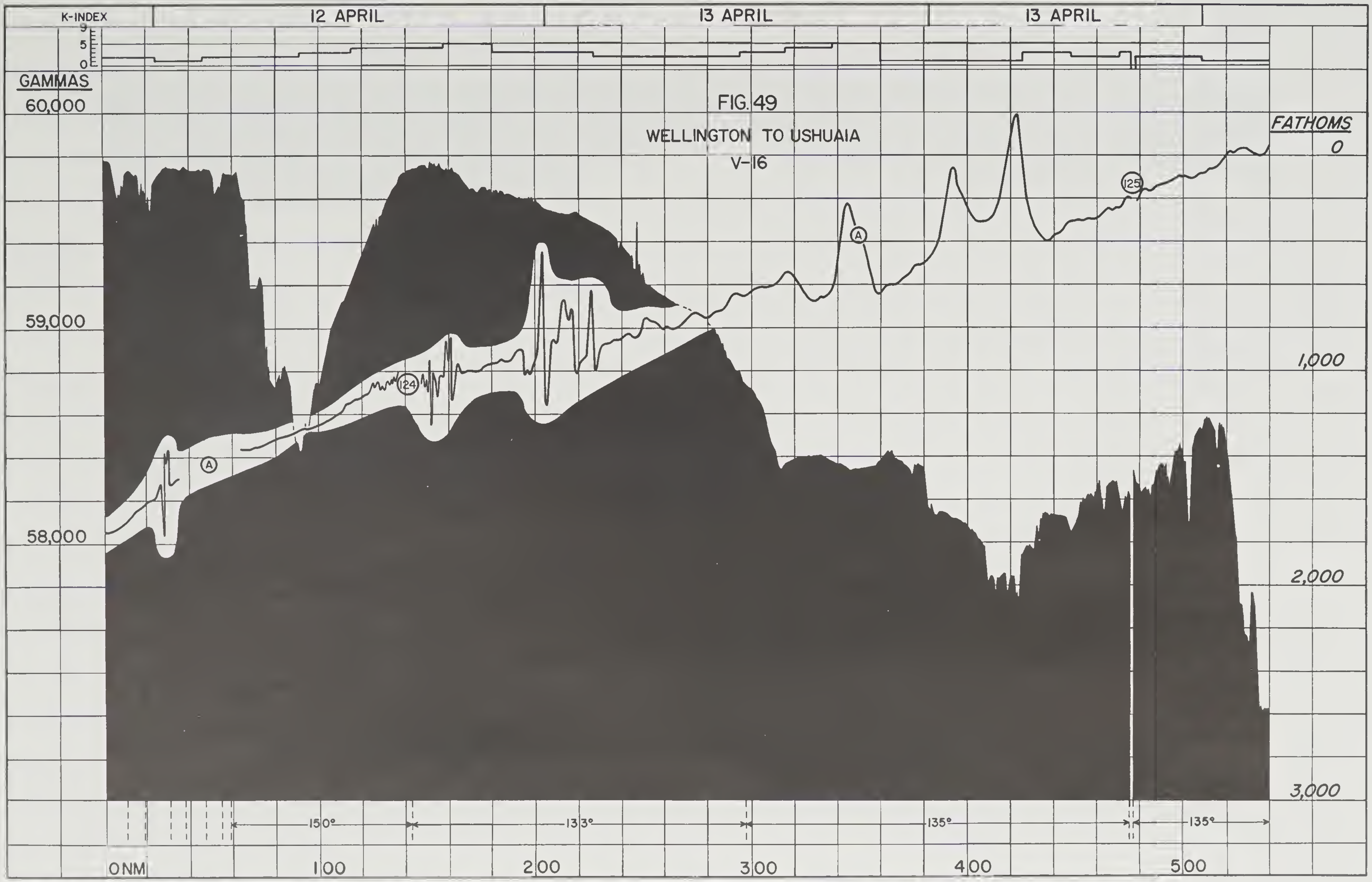


FIG. 49
WELLINGTON TO USHUAIA
V-16

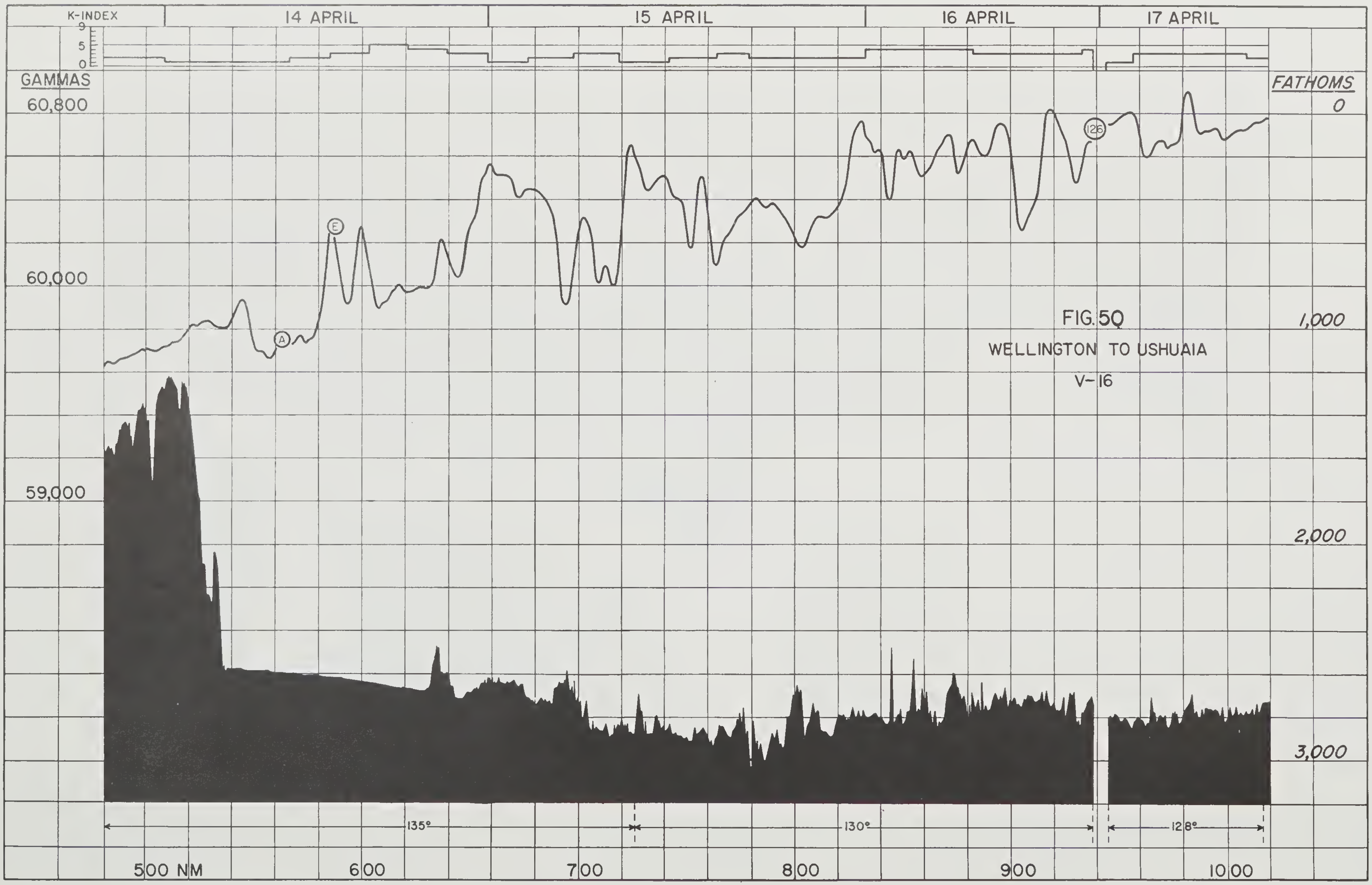
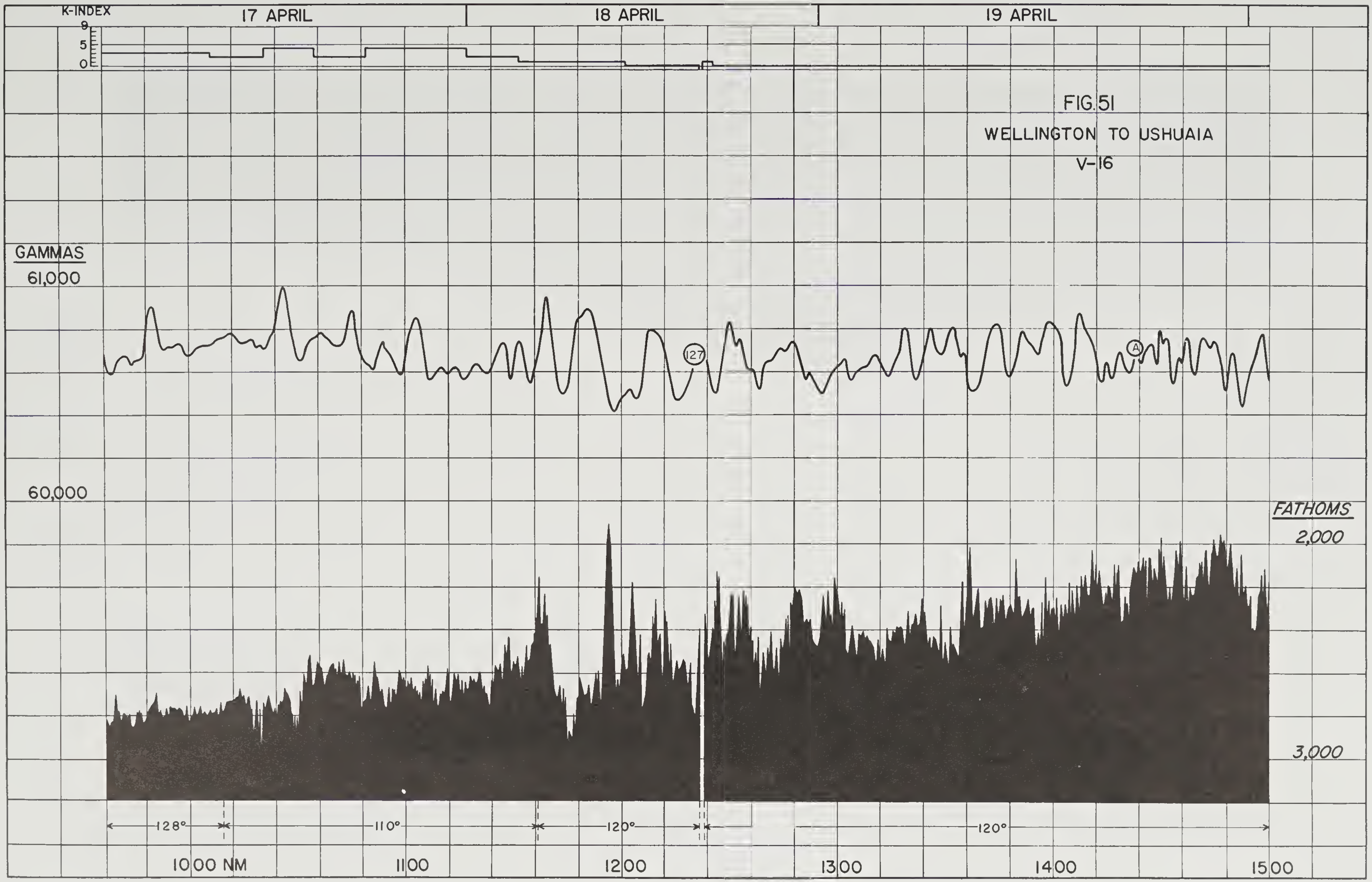


FIG. 50
WELLINGTON TO USHUAIA
V-16


K-INDEX
9
5
0
17 APRIL
18 APRIL
19 APRIL
FIG. 51
WELLINGTON TO USHUAIA
V-16
GAMMAS
61,000
60,000
127
A
FATHOMS
2,000
3,000
128°
110°
120°
120°
1000 NM
1100
1200
1300
1400
1500

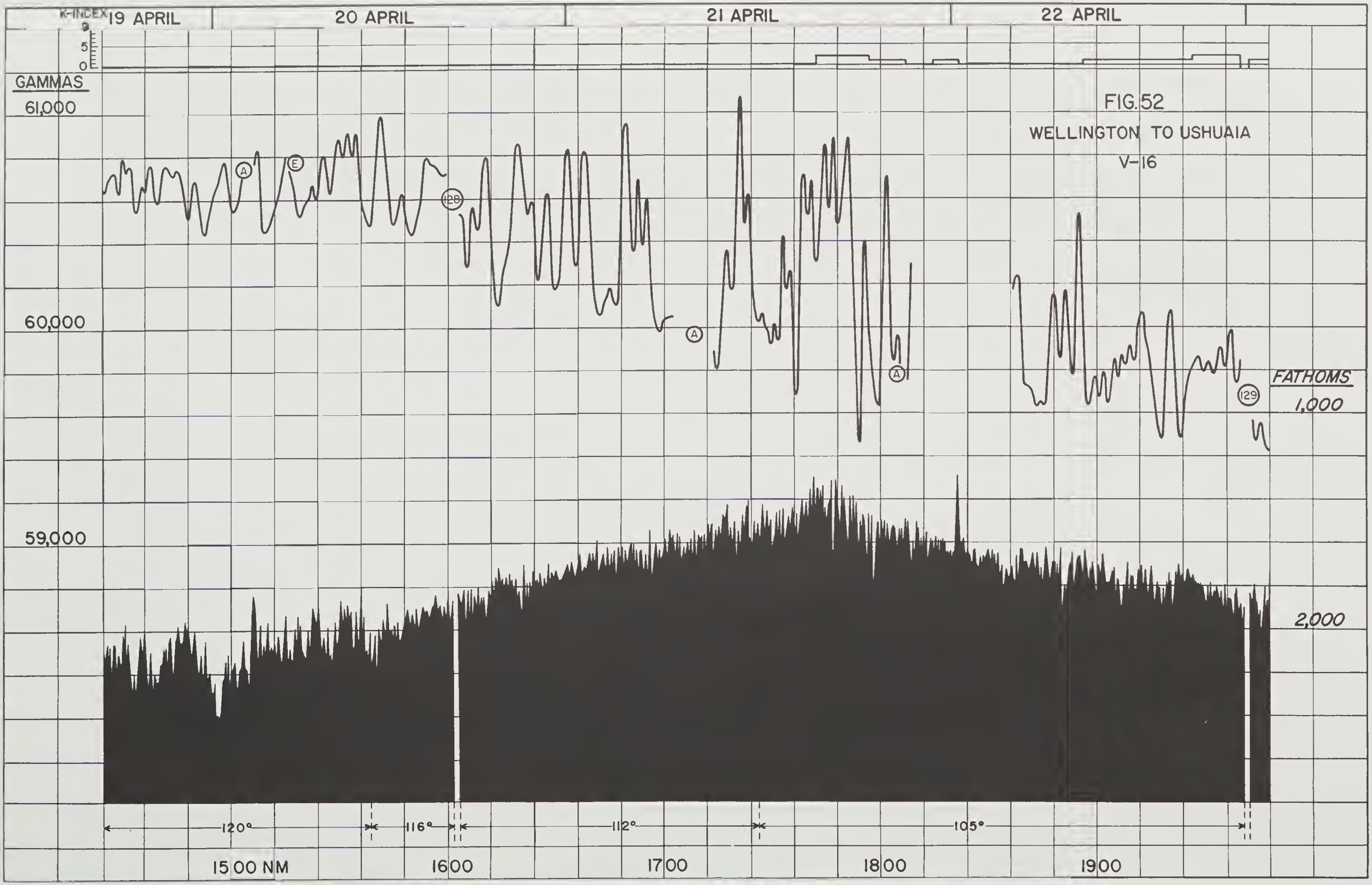


FIG. 52
WELLINGTON TO USHUAIA
V-16

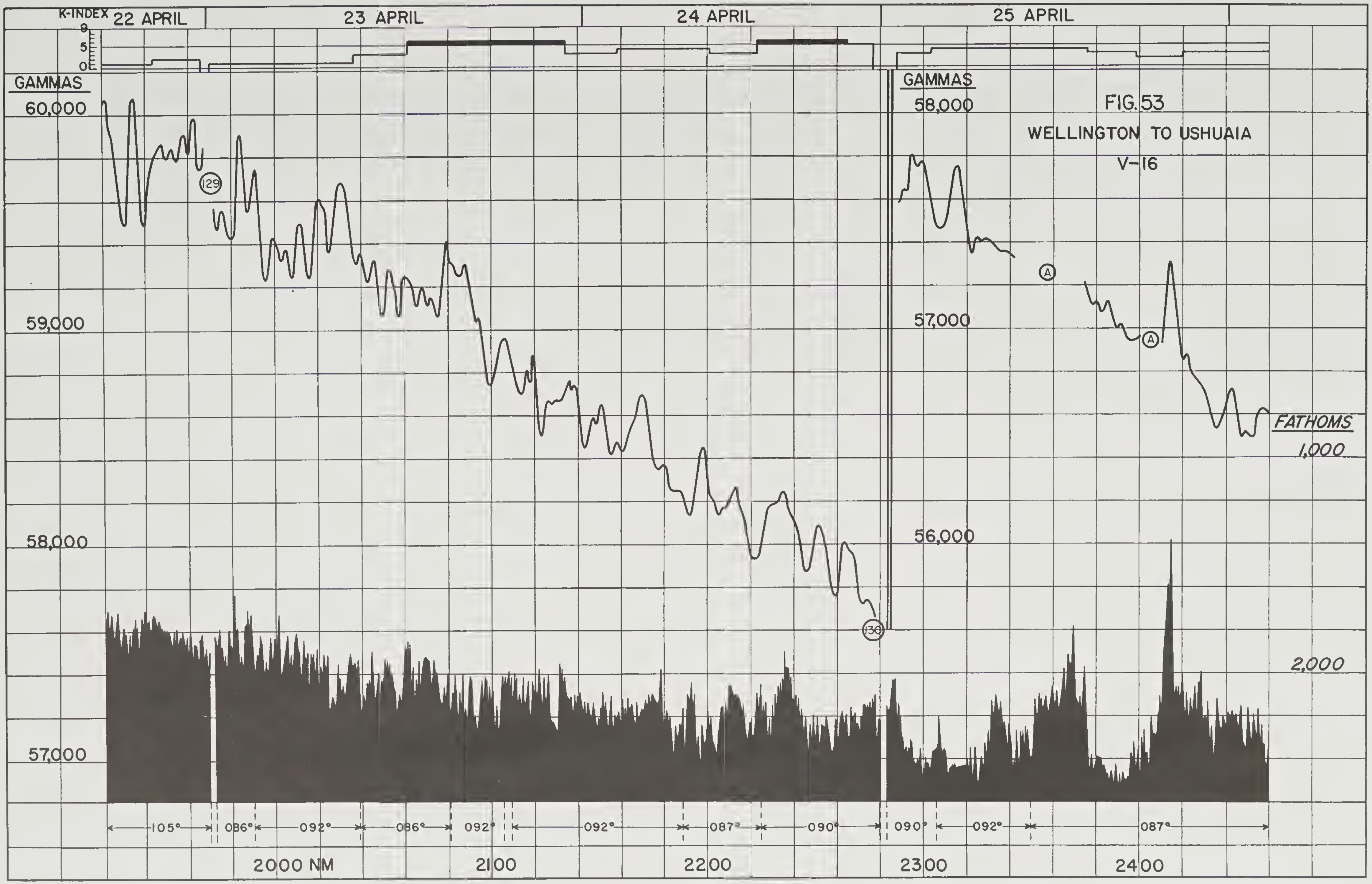
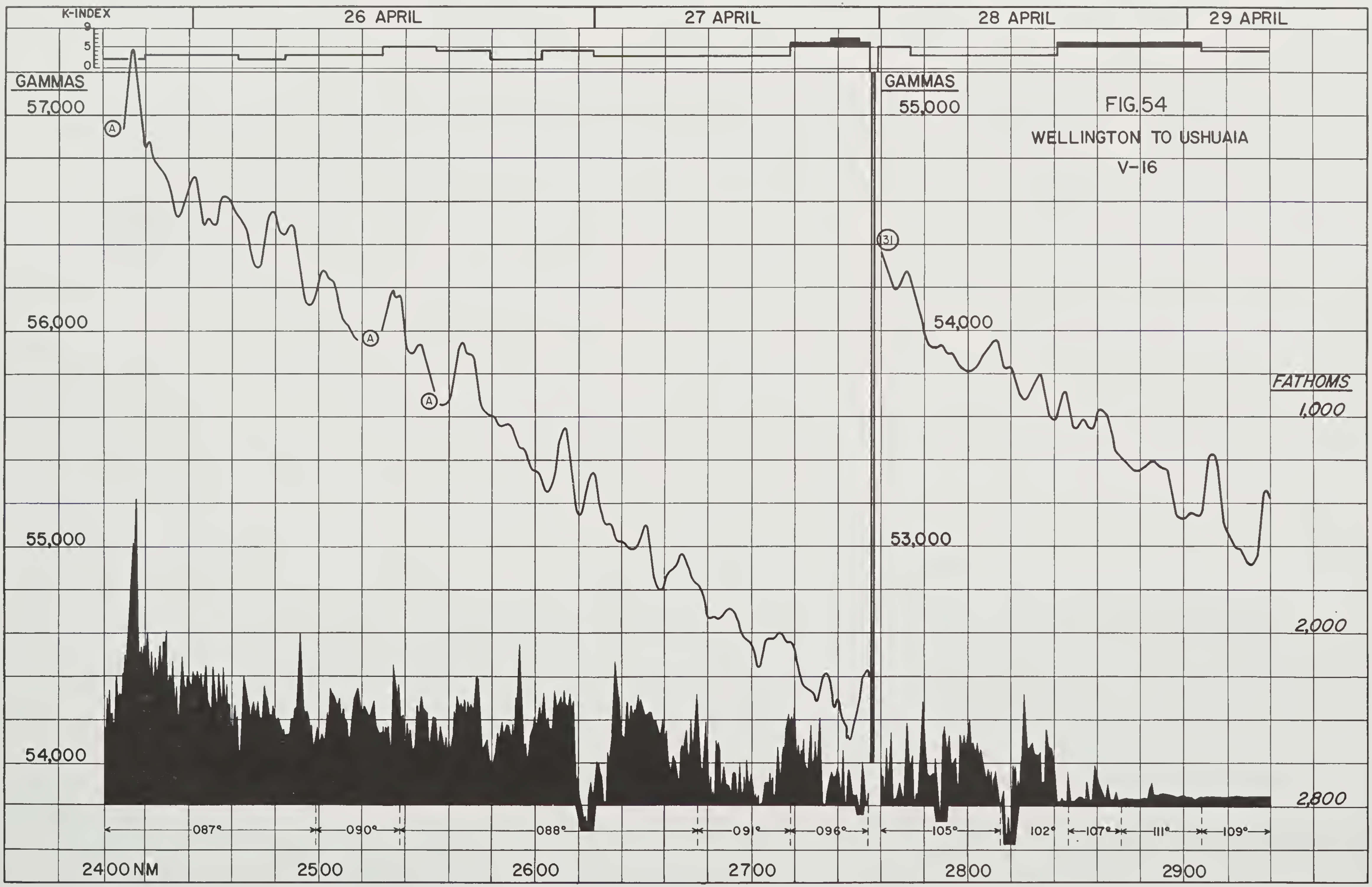
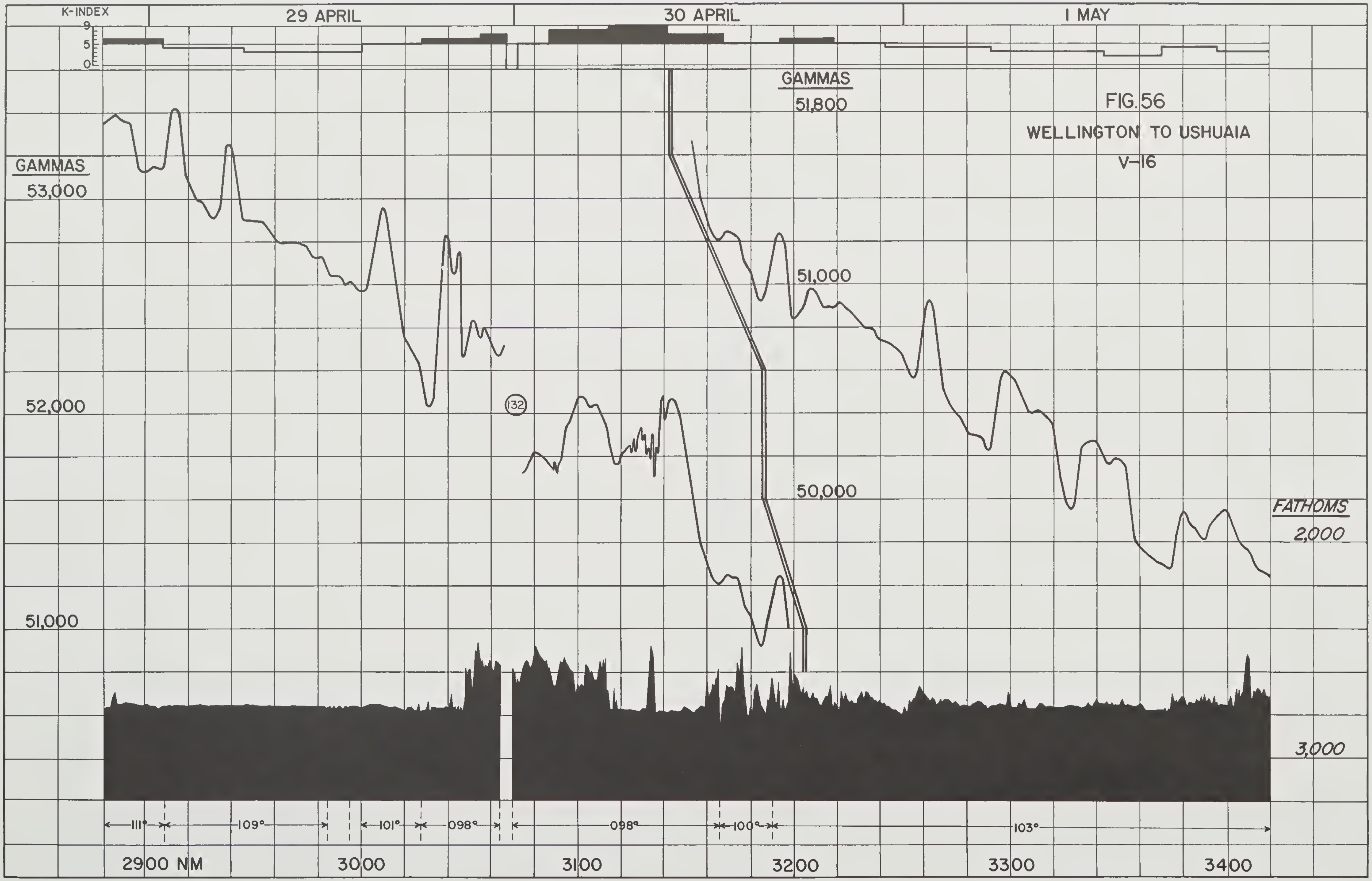


FIG. 53
WELLINGTON TO USHUAIA
V-16


K-INDEX
9
5
0
26 APRIL
27 APRIL
28 APRIL
29 APRIL
GAMMAS
57,000
56,000
55,000
54,000
GAMMAS
55,000
54,000
53,000
FIG.54
WELLINGTON TO USHUAIA
V-16
FATHOMS
1,000
2,000
2,800
A
A
A
131
087°
090°
088°
091°
096°
105°
102°
107°
111°
109°
2400 NM
2500
2600
2700
2800
2900


105°
90°
75°
60°
45°
30°
45°
60°
BUENOS
AIRES
USHUAIA
1000
500
0
3000
1500
2500
2000
1000
500
0
4500
4000
3000
3500

FIGURE 55


K-INDEX
9
5
0
29 APRIL
30 APRIL
1 MAY
GAMMAS
53,000
52,000
51,000
GAMMAS
51,800
51,000
50,000
FIG. 56
WELLINGTON TO USHUAIA
V-16
(132)
FATHOMS
2,000
3,000
111°
109°
101°
098°
098°
100°
103°
2900 NM
3000
3100
3200
3300
3400

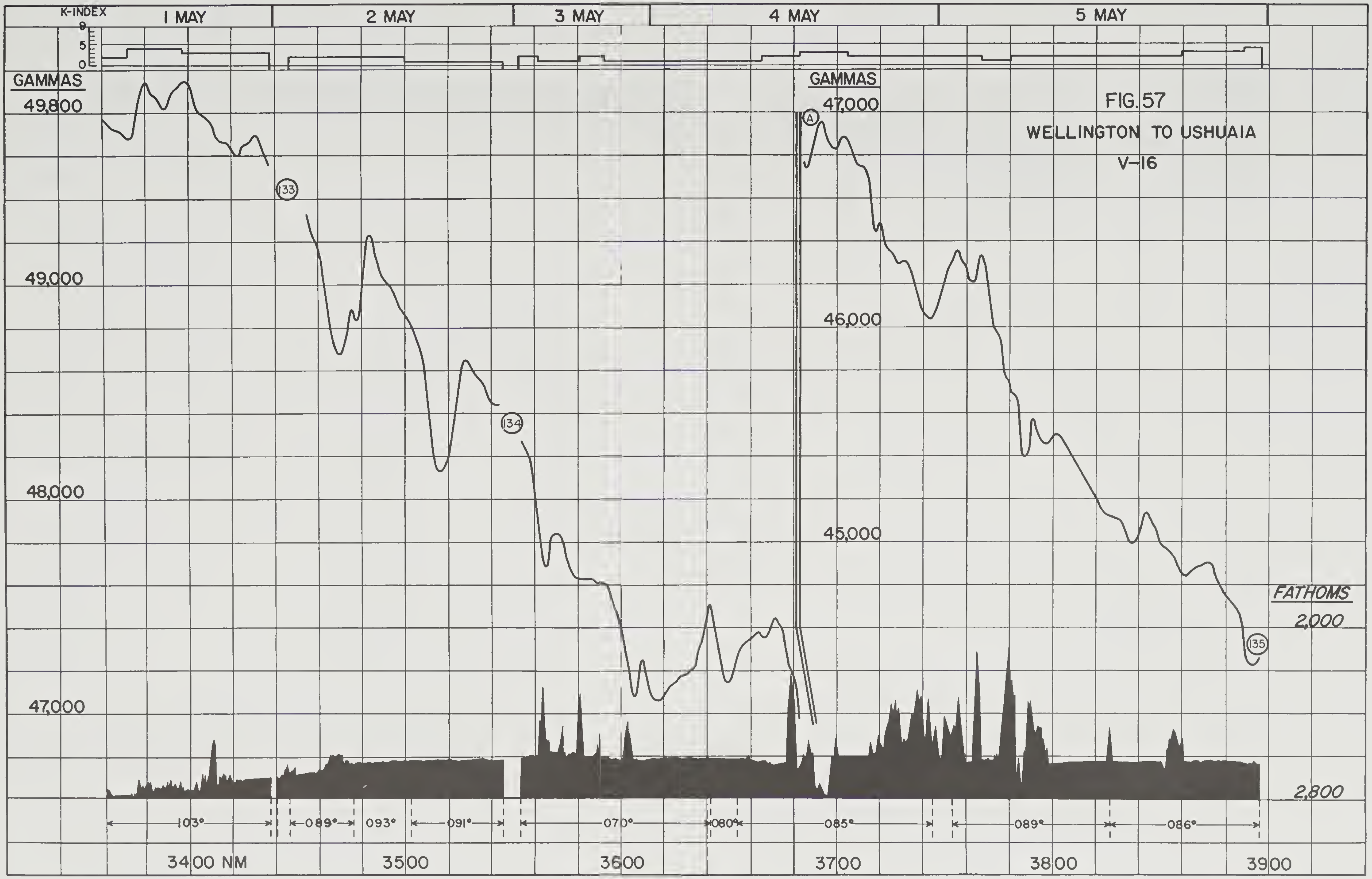


FIG. 57
WELLINGTON TO USHUAIA
V-16

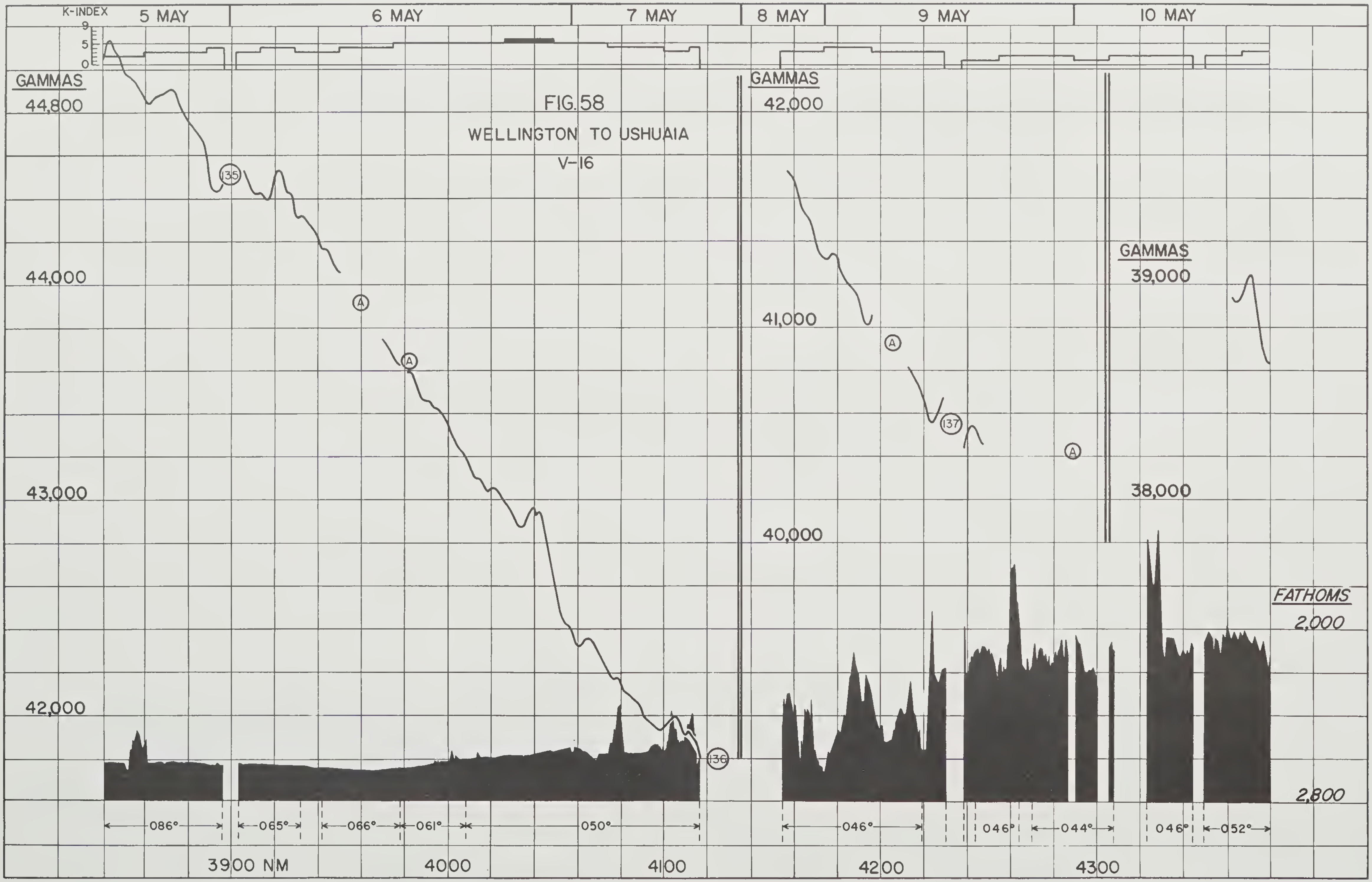


FIG. 58
WELLINGTON TO USHUAIA
V-16

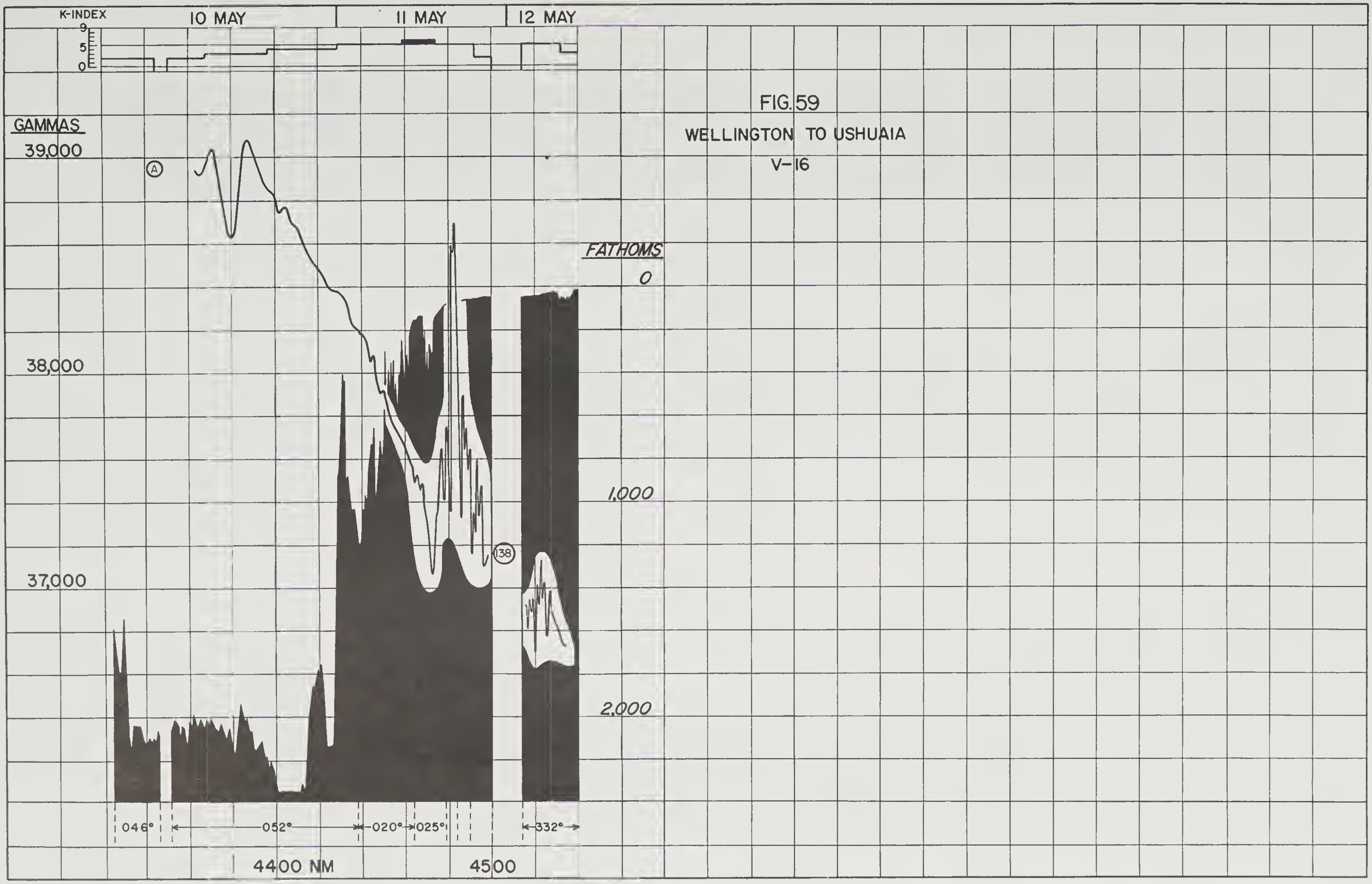


FIG. 59
WELLINGTON TO USHUAIA
V-16

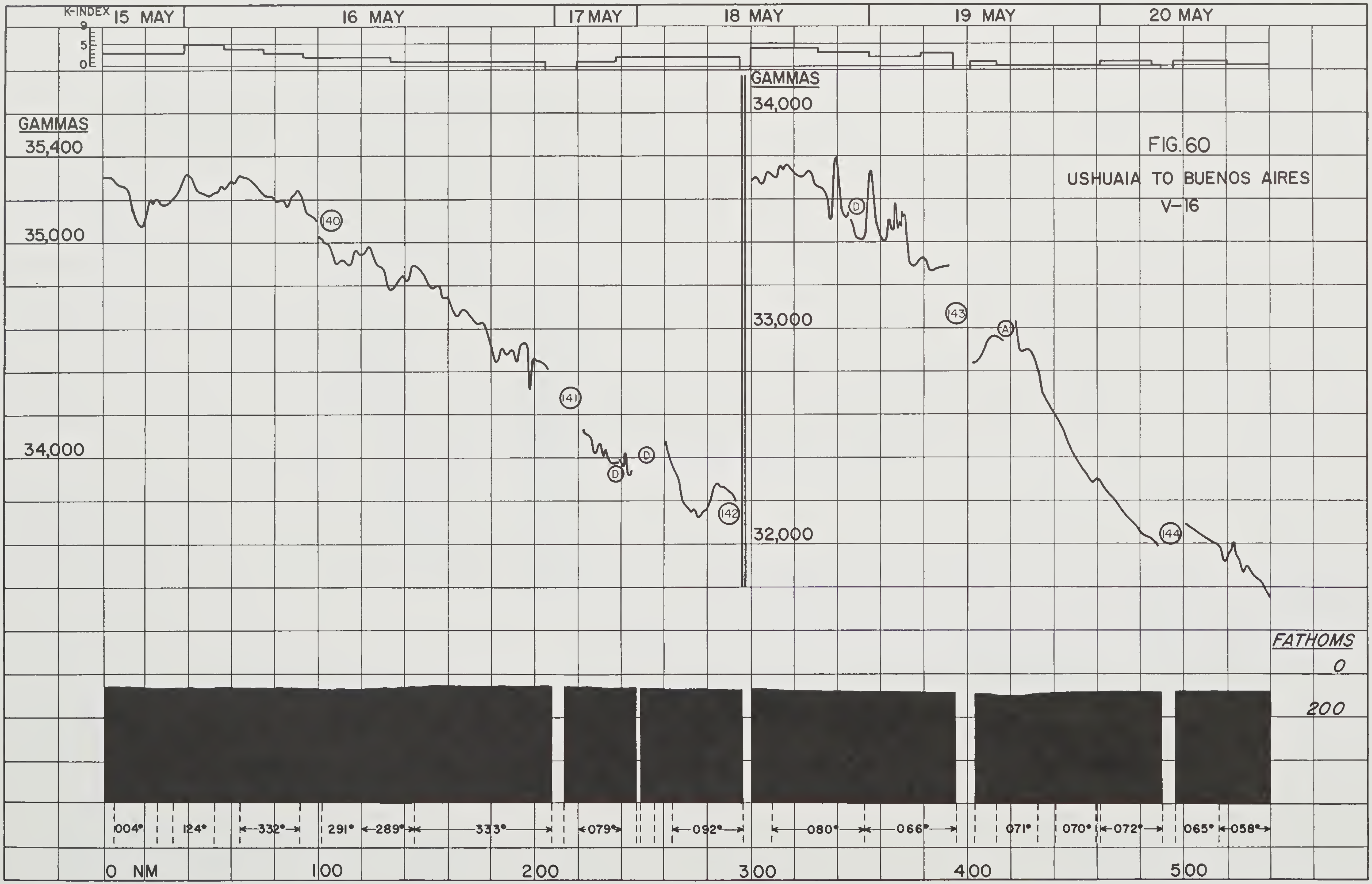


FIG. 60
USHUAIA TO BUENOS AIRES
V-16

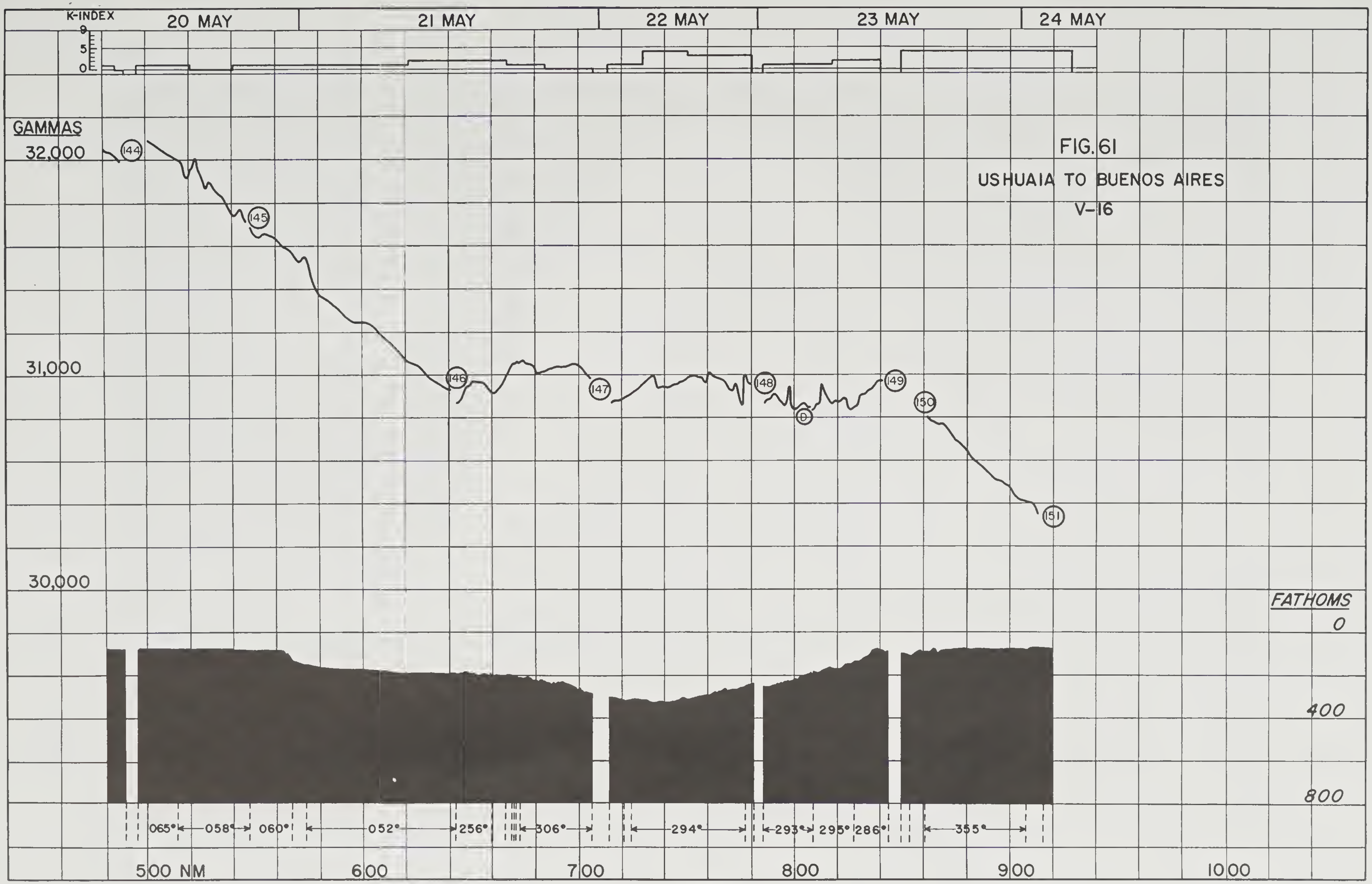


FIG. 61
USHUAIA TO BUENOS AIRES
V-16
K-INDEX
9
5
0
20 MAY
21 MAY
22 MAY
23 MAY
24 MAY
GAMMAS
32,000
31,000
30,000
144
145
146
147
148
149
150
151
D
FATHOMS
0
400
800
065°
058°
060°
052°
256°
306°
294°
293°
295°
286°
355°
500 NM
600
700
800
900
1000

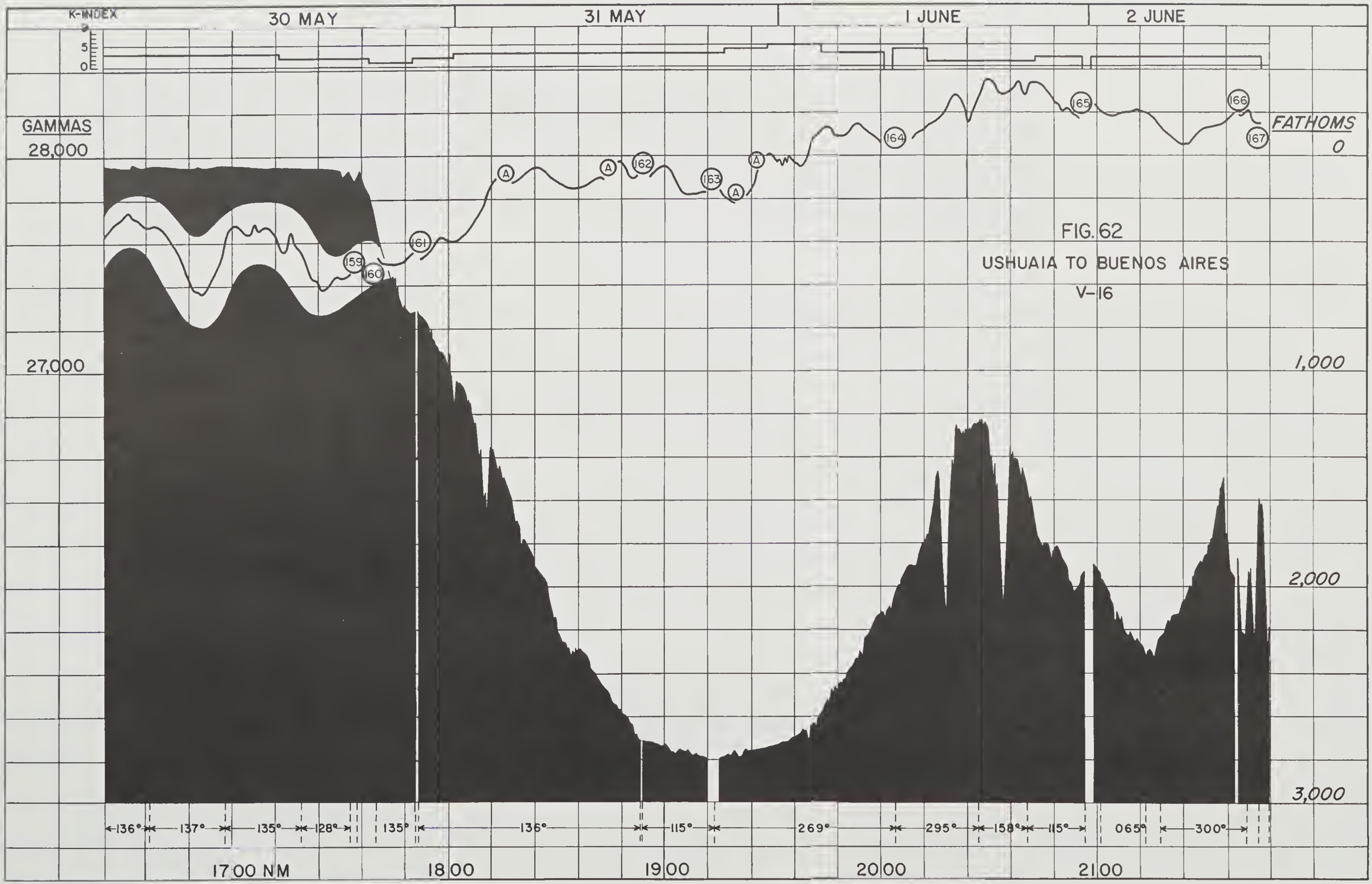


FIG. 62
USHUAIA TO BUENOS AIRES
V-16

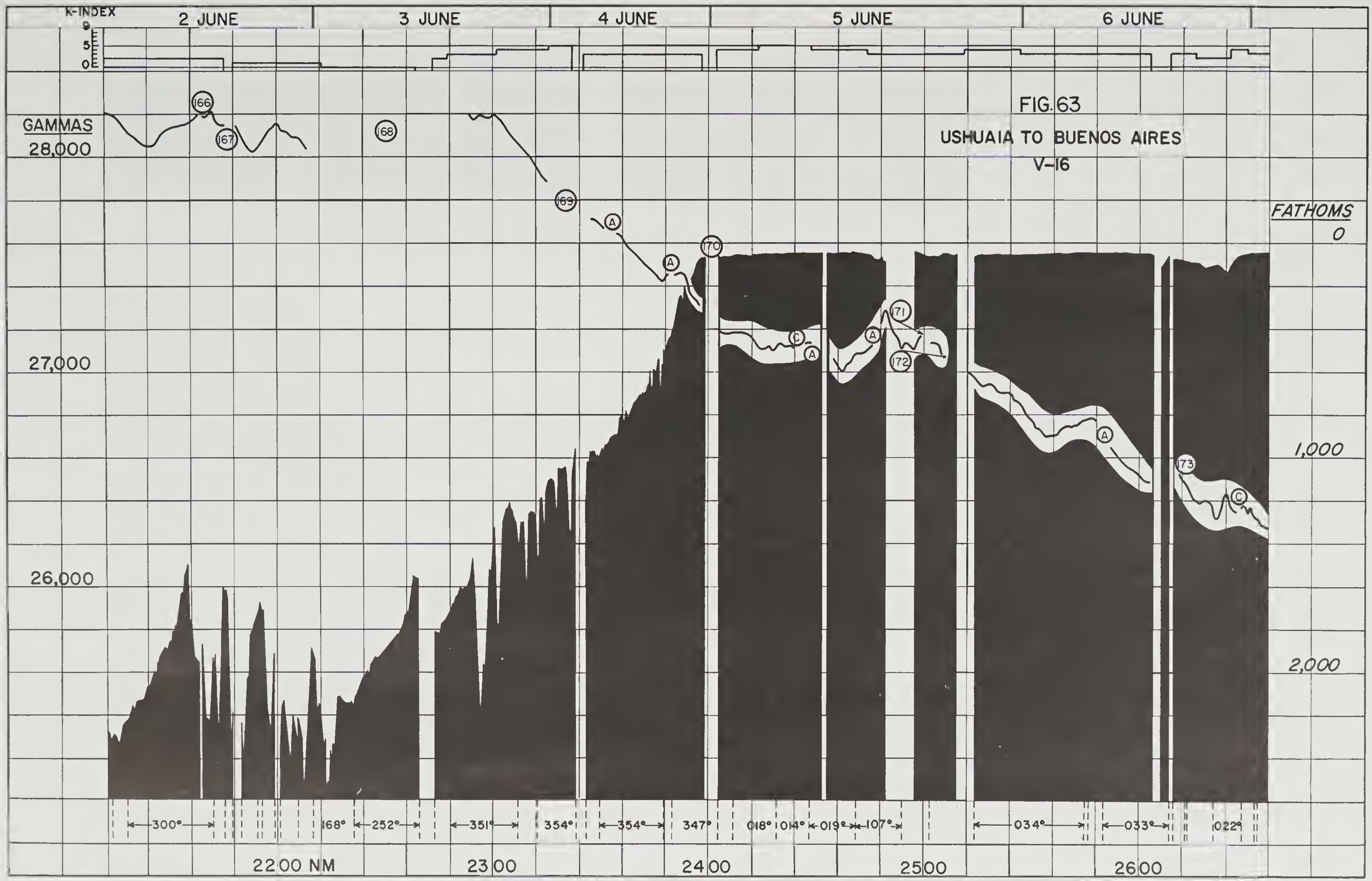


FIG. 63
USHUAIA TO BUENOS AIRES
V-16

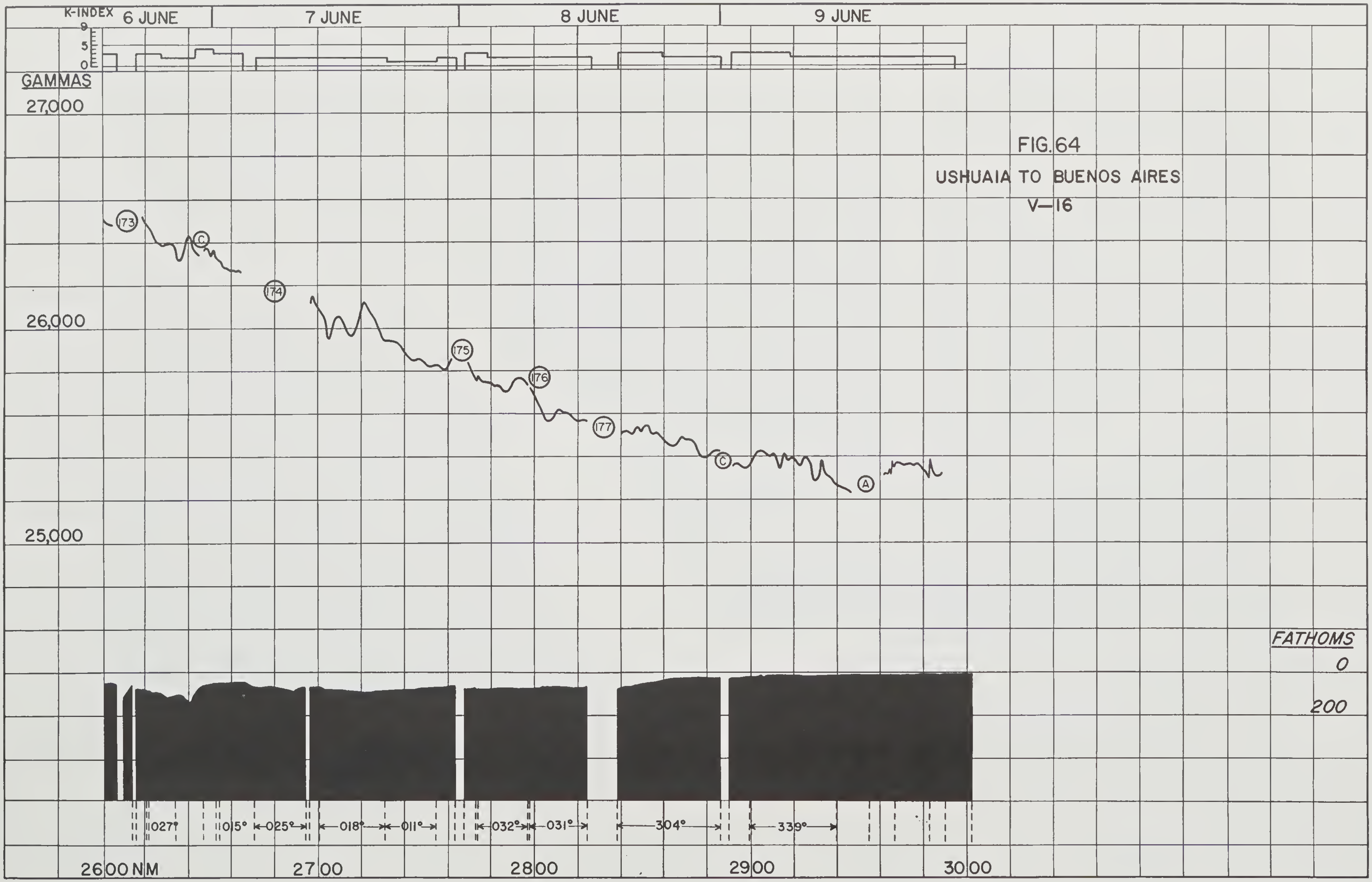
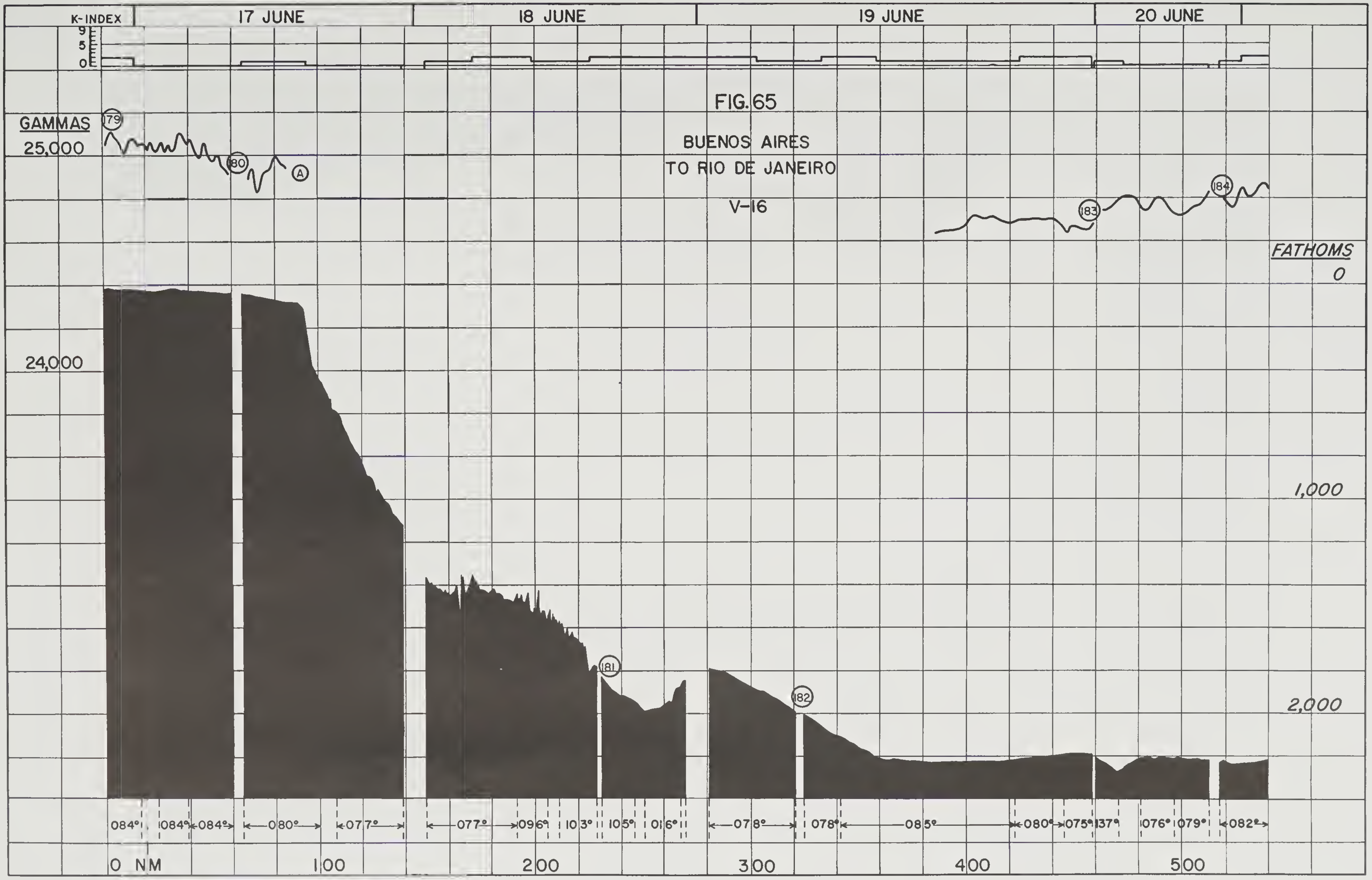
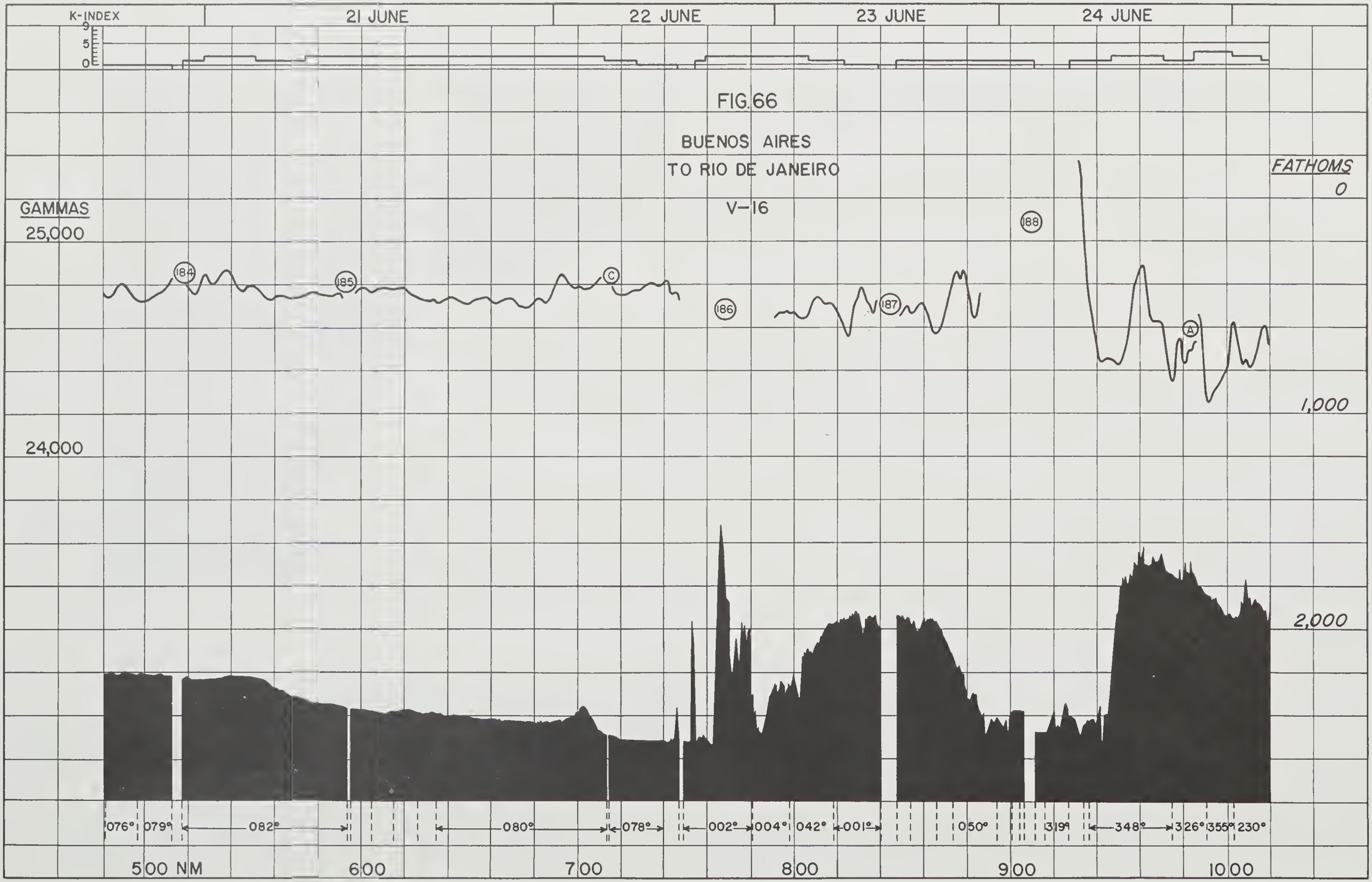


FIG. 64
USHUAIA TO BUENOS AIRES
V—16


K-INDEX
17 JUNE
18 JUNE
19 JUNE
20 JUNE
FIG. 65
BUENOS AIRES
TO RIO DE JANEIRO
V-16
GAMMAS
25,000
24,000
FATHOMS
0
1,000
2,000
179
180
A
181
182
183
184
084°
084°
084°
080°
077°
077°
096°
103°
105°
016°
078°
078°
085°
080°
075°
137°
076°
079°
082°
0 NM
100
200
300
400
500


K-INDEX
9
5
0
21 JUNE
22 JUNE
23 JUNE
24 JUNE
FIG. 66
BUENOS AIRES
TO RIO DE JANEIRO
V-16
GAMMAS
25,000
24,000
FATHOMS
0
1,000
2,000
184
185
C
186
187
188
A
076°
079°
082°
080°
078°
002°
004°
042°
001°
050°
319°
348°
326°
355°
230°
500 NM
600
700
800
900
1000

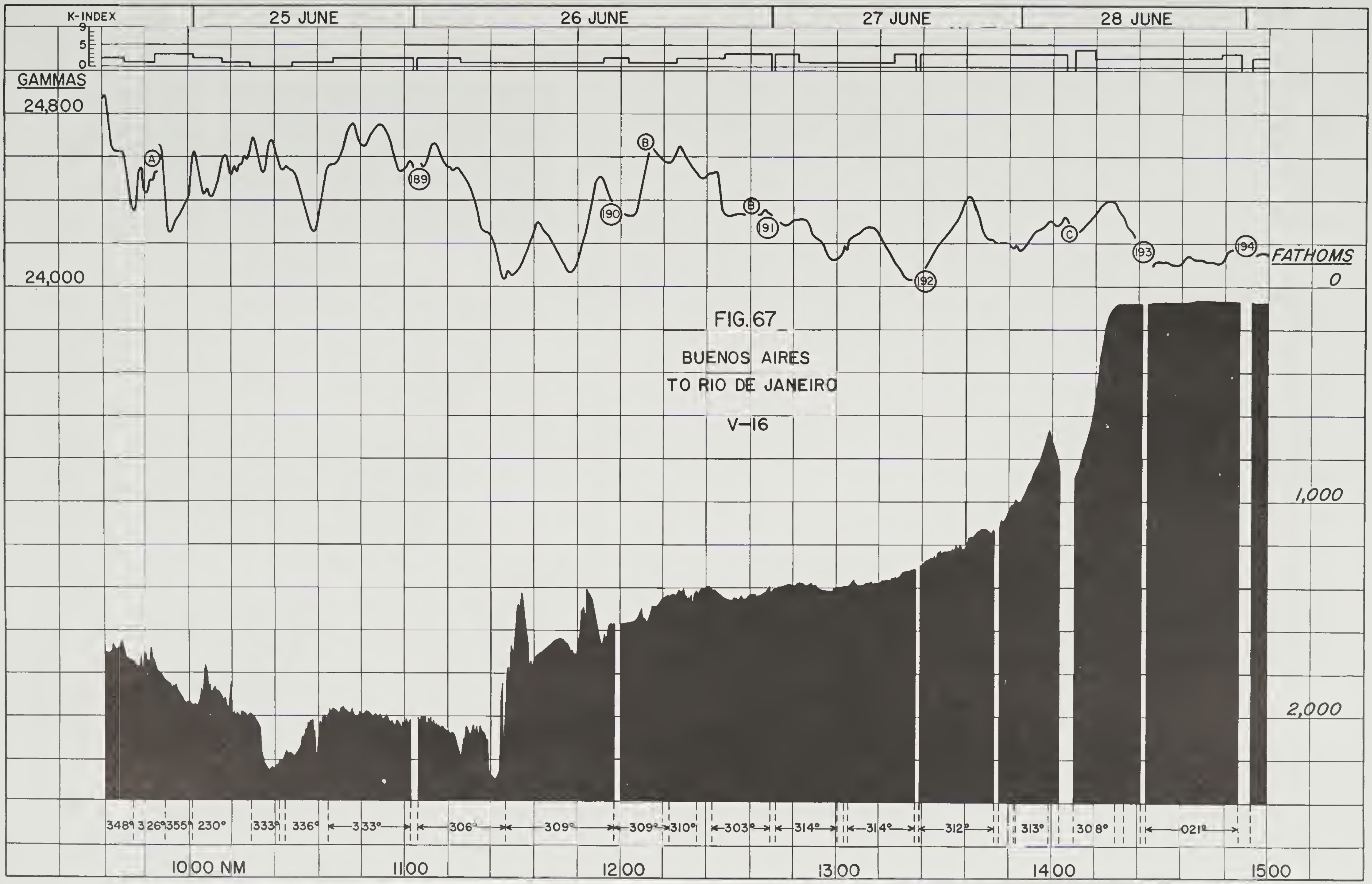


FIG. 67
BUENOS AIRES
TO RIO DE JANEIRO
V-16

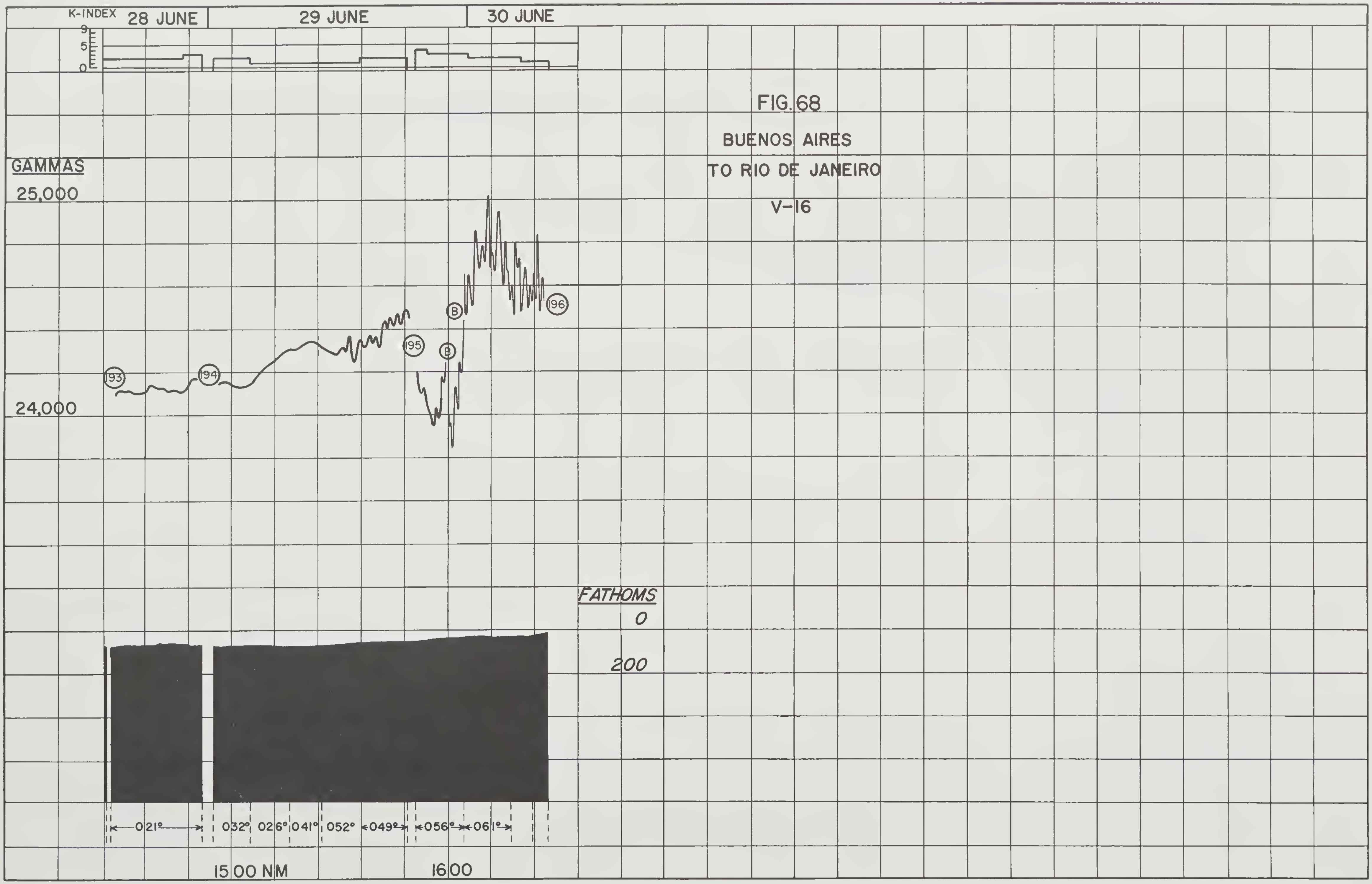


FIG. 68
BUENOS AIRES
TO RIO DE JANEIRO
V-16

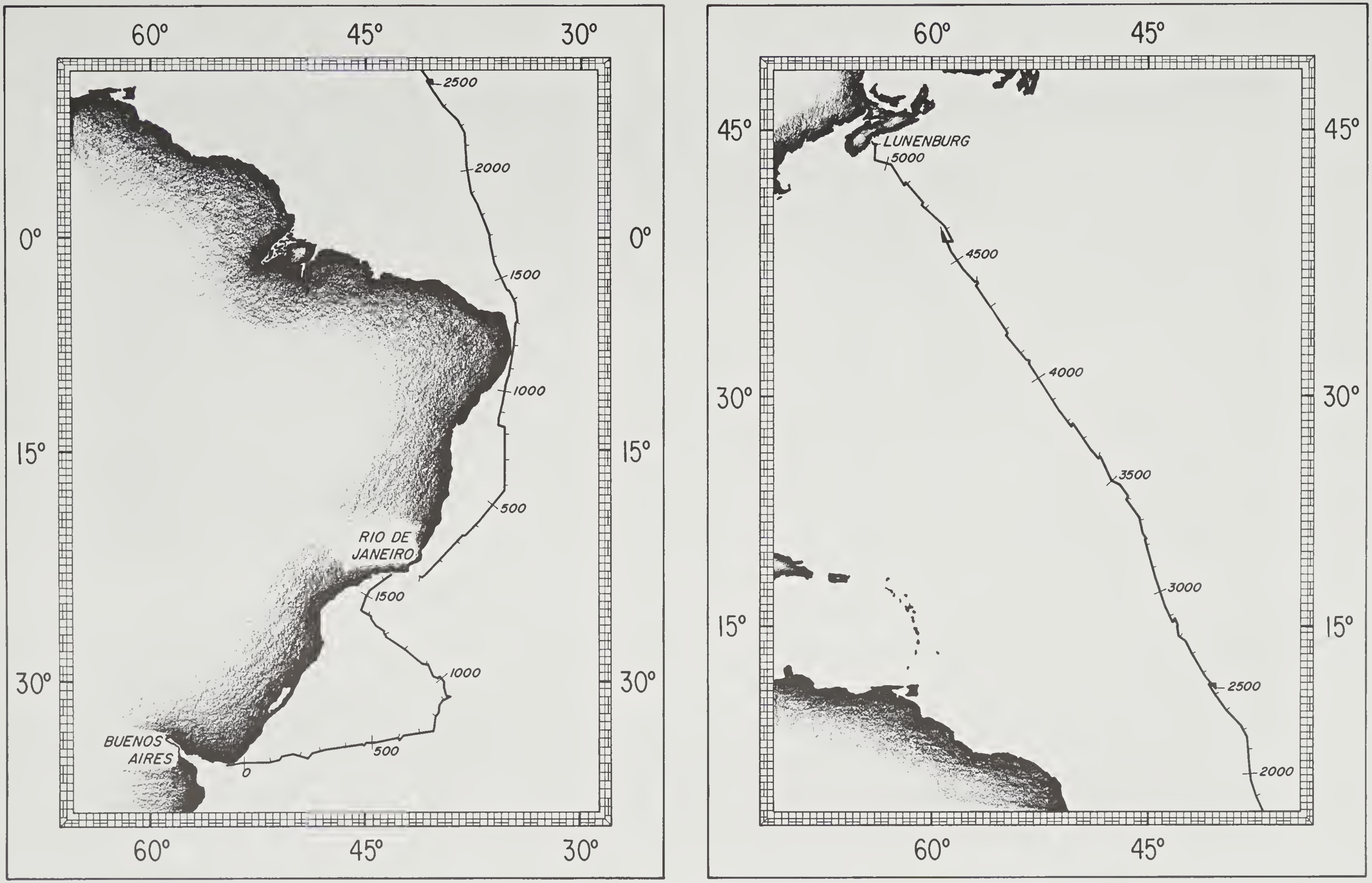

60°
45°
30°
0°
15°
2500
2000
1500
1000
500
RIO DE
JANEIRO
1500
1000
500
0
BUENOS
AIRES
LUNENBURG
5000
4500
4000
3500
3000
2500
2000

FIGURE 69

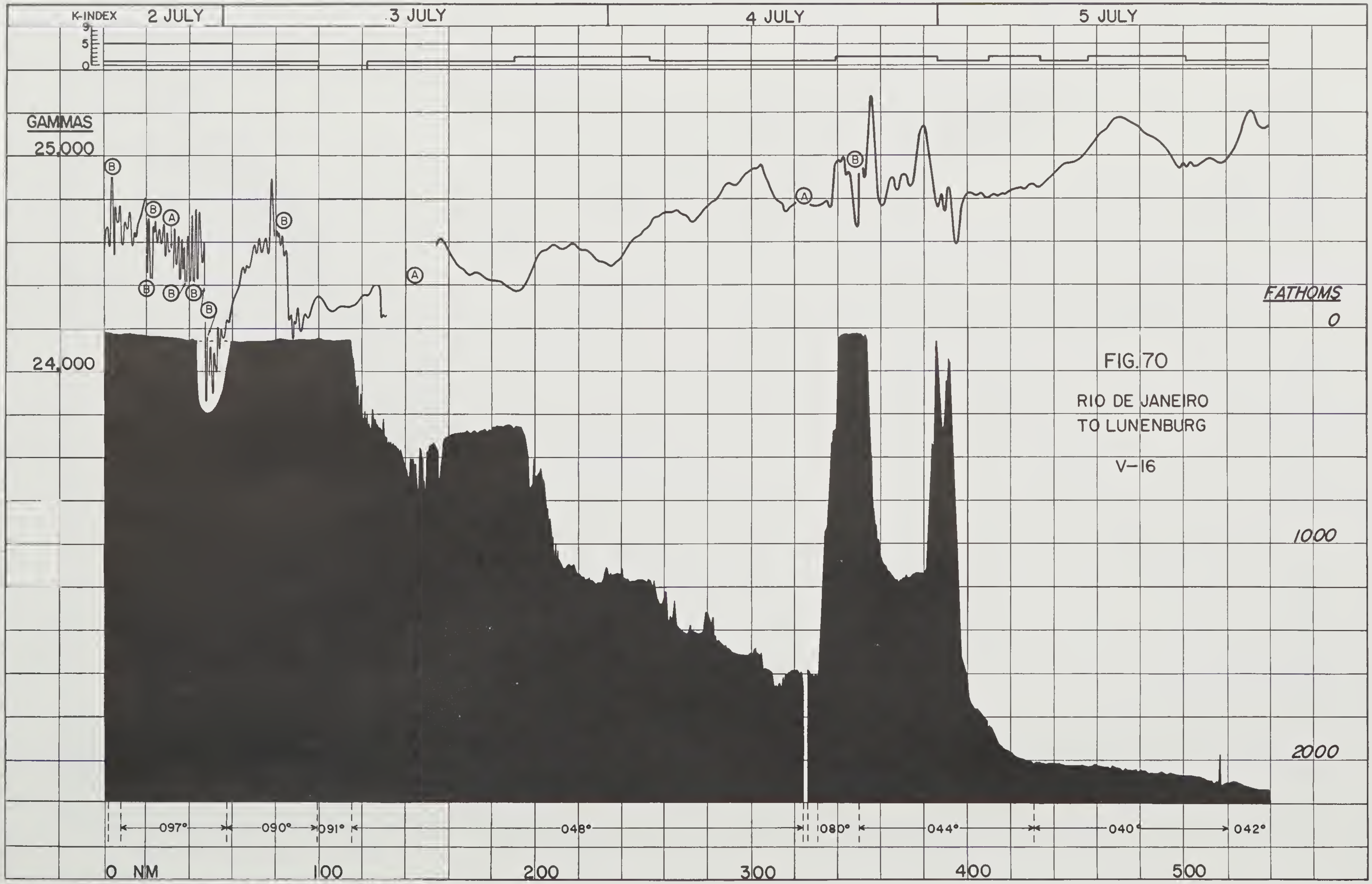


FIG. 70
RIO DE JANEIRO
TO LUNENBURG
V-16

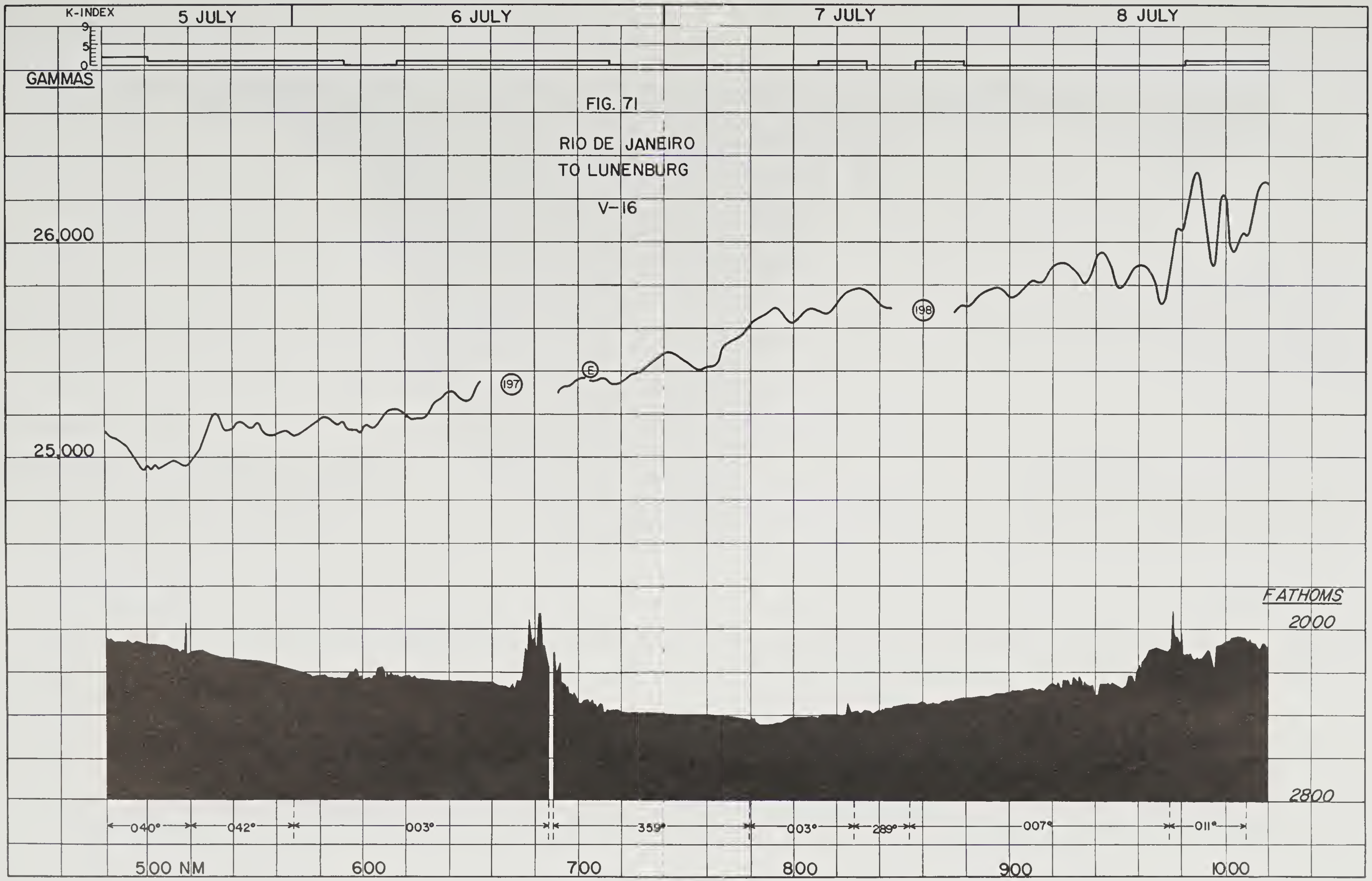


FIG. 71

RIO DE JANEIRO
TO LUNENBURG

V-16

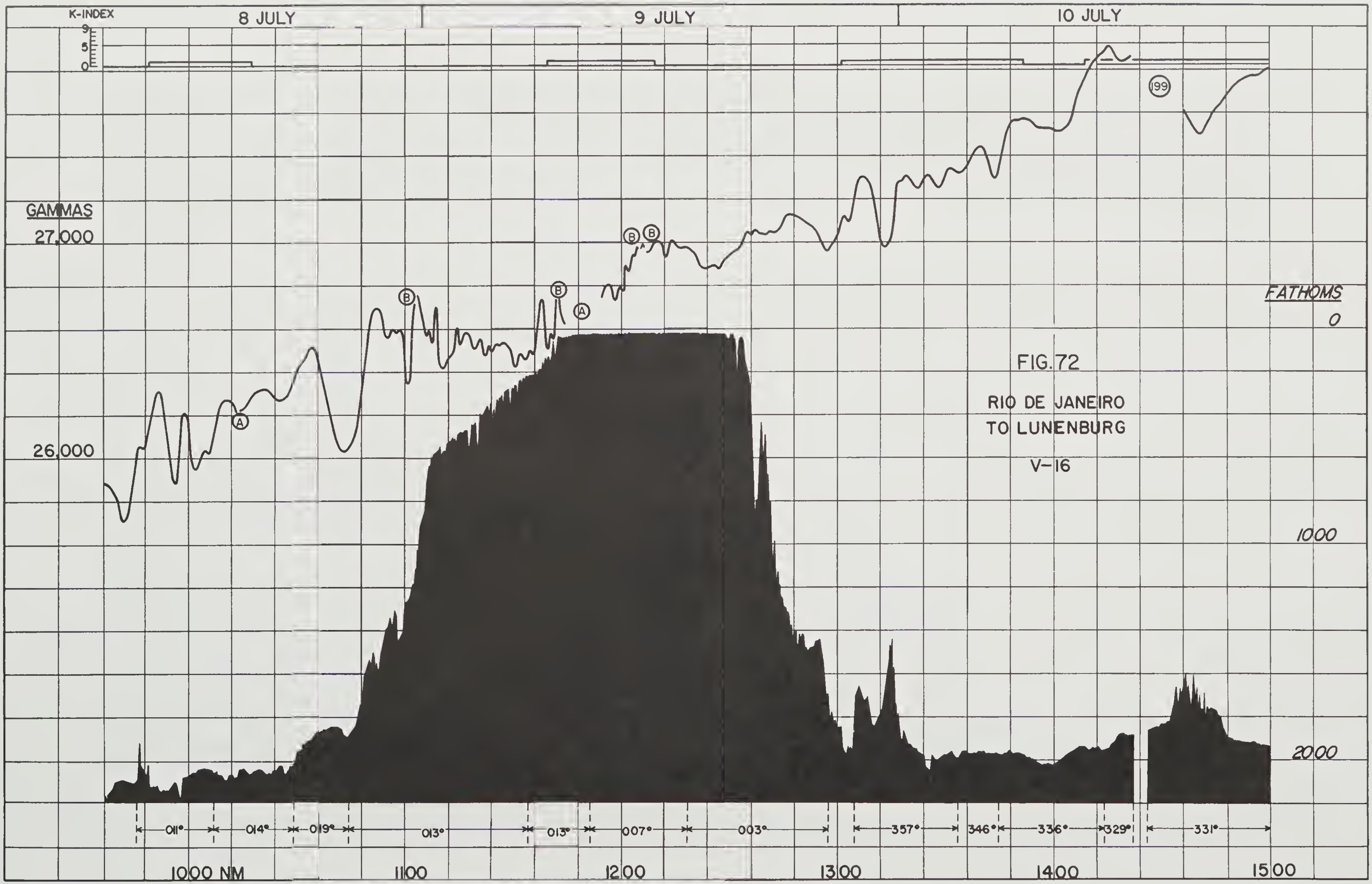
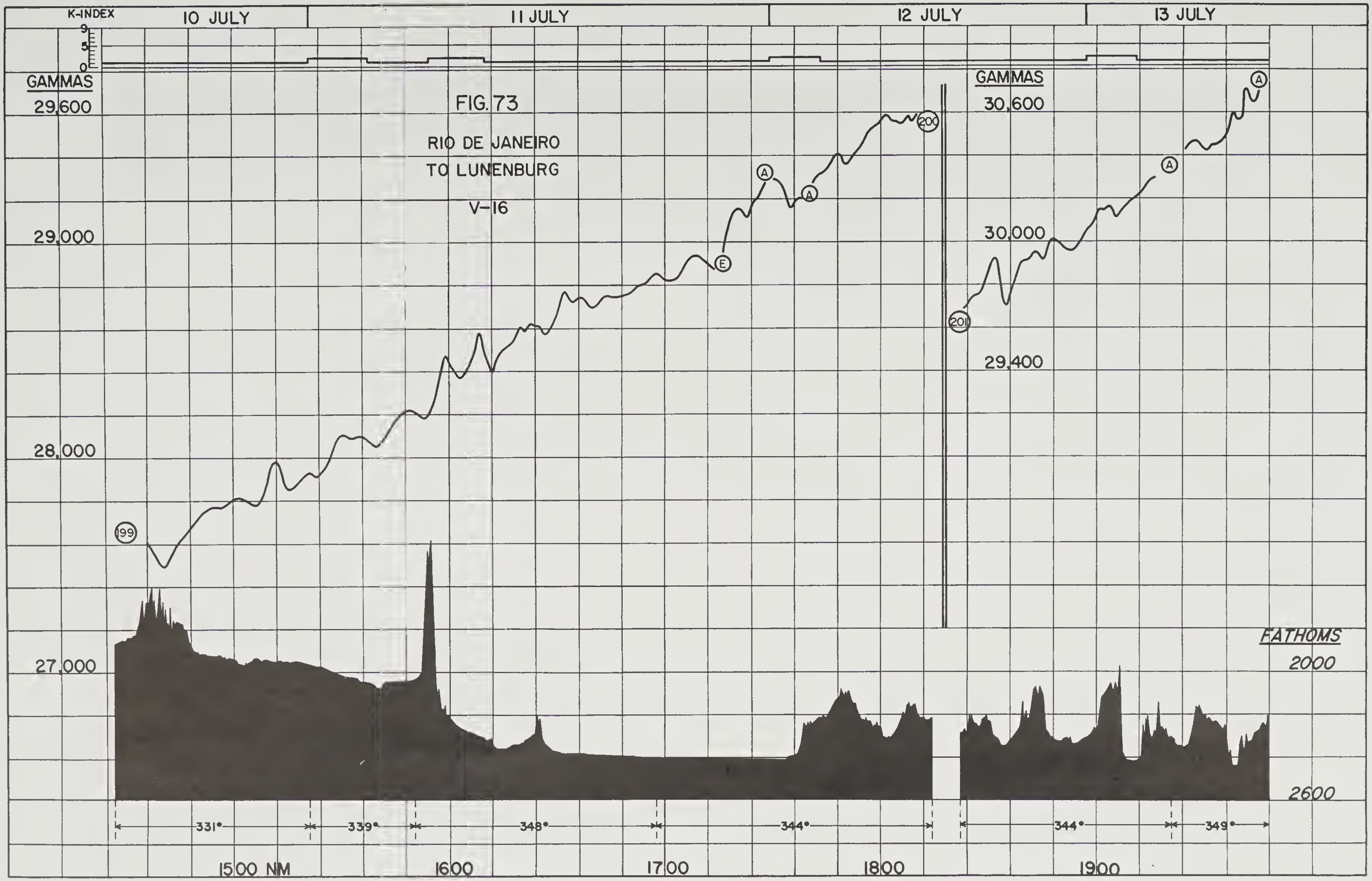


FIG. 72

RIO DE JANEIRO
TO LUNENBURG
V-16



K-INDEX
9
5
0
10 JULY
11 JULY
12 JULY
13 JULY
GAMMAS
29,600
29,000
28,000
27,000
FIG. 73
RIO DE JANEIRO
TO LUNENBURG
V-16
GAMMAS
30,600
30,000
29,400
199
200
201
A
E
FATHOMS
2000
2600
331°
339°
348°
344°
344°
349°
1500 NM
1600
1700
1800
1900

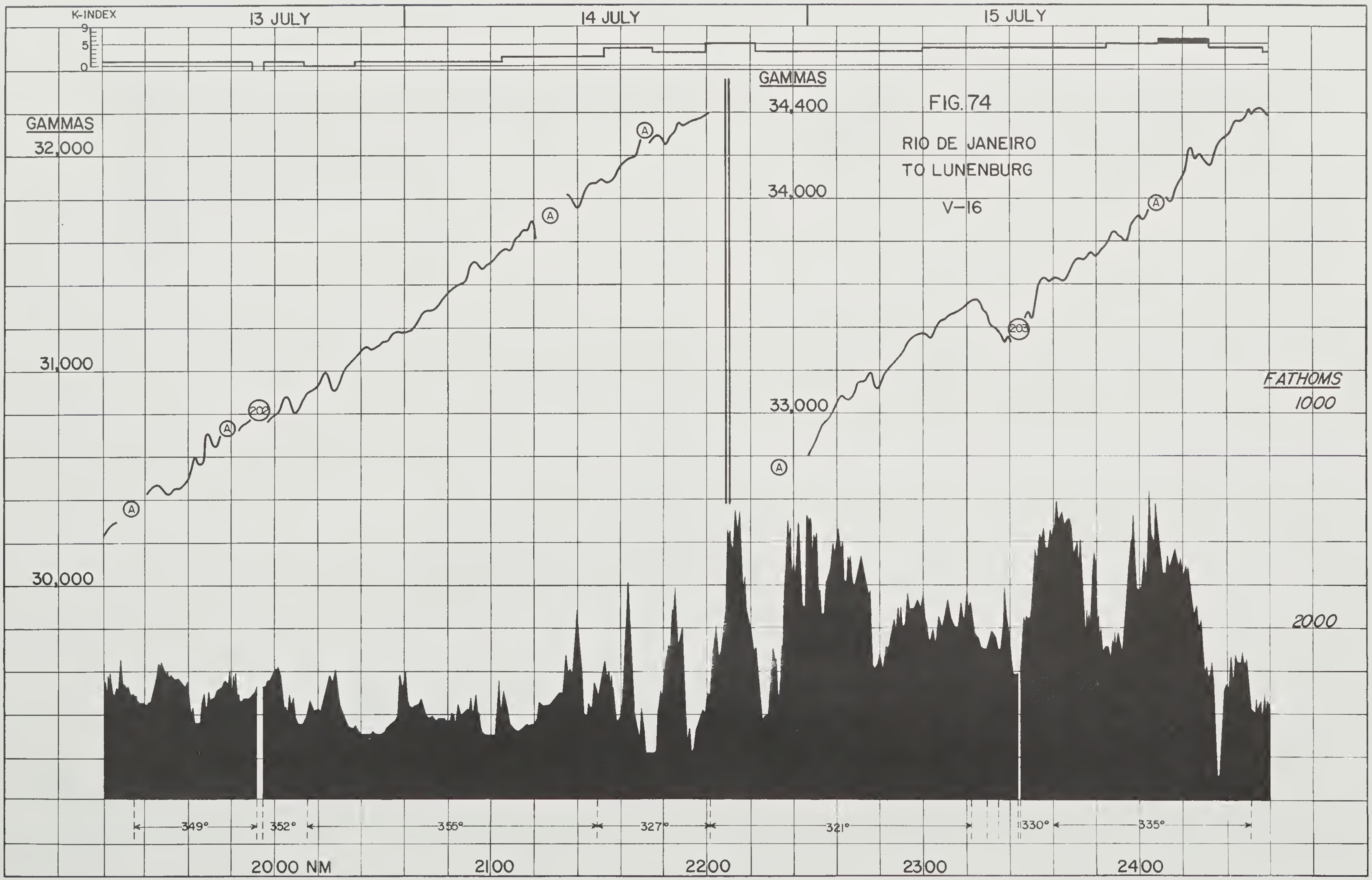
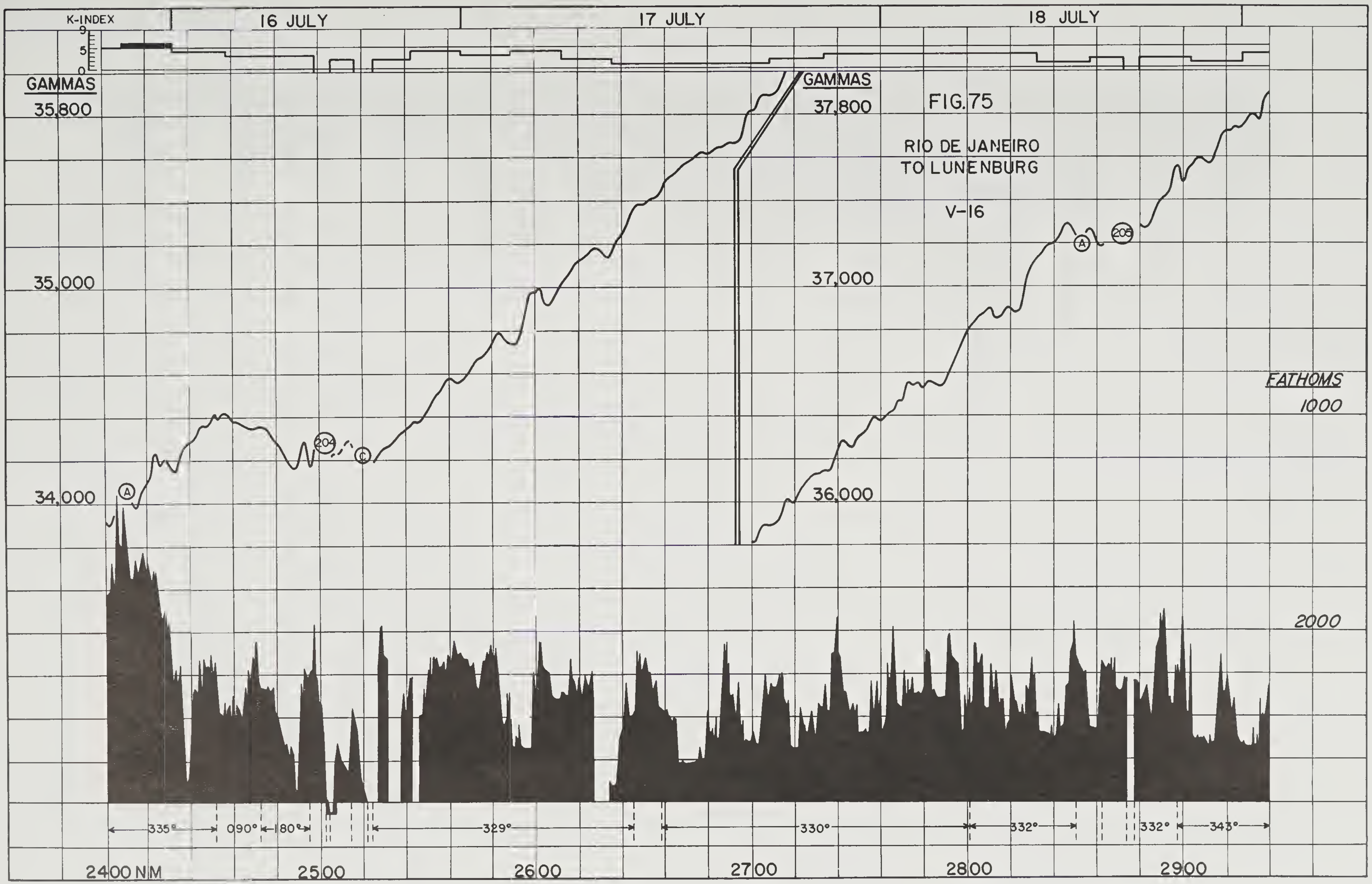
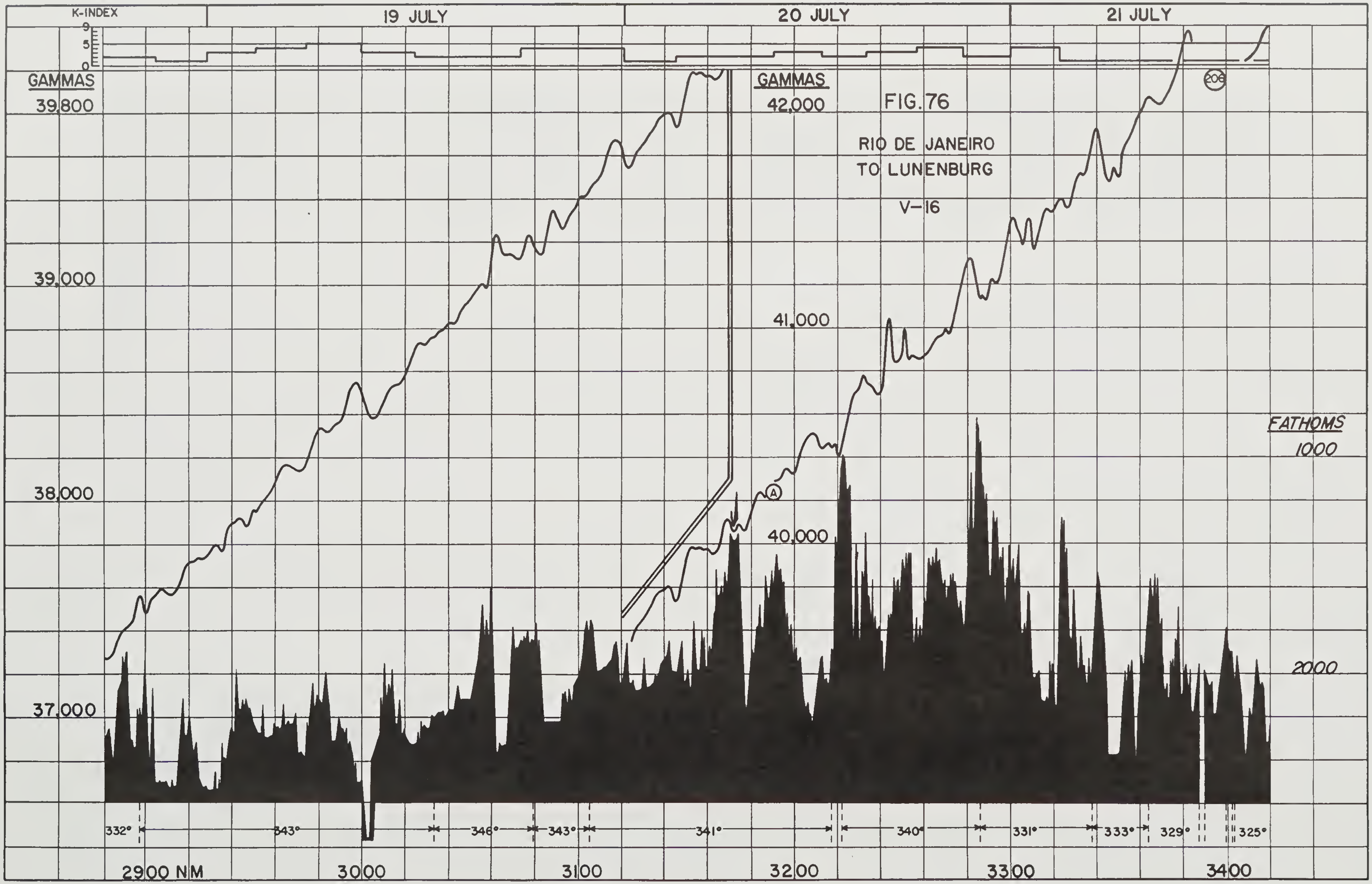
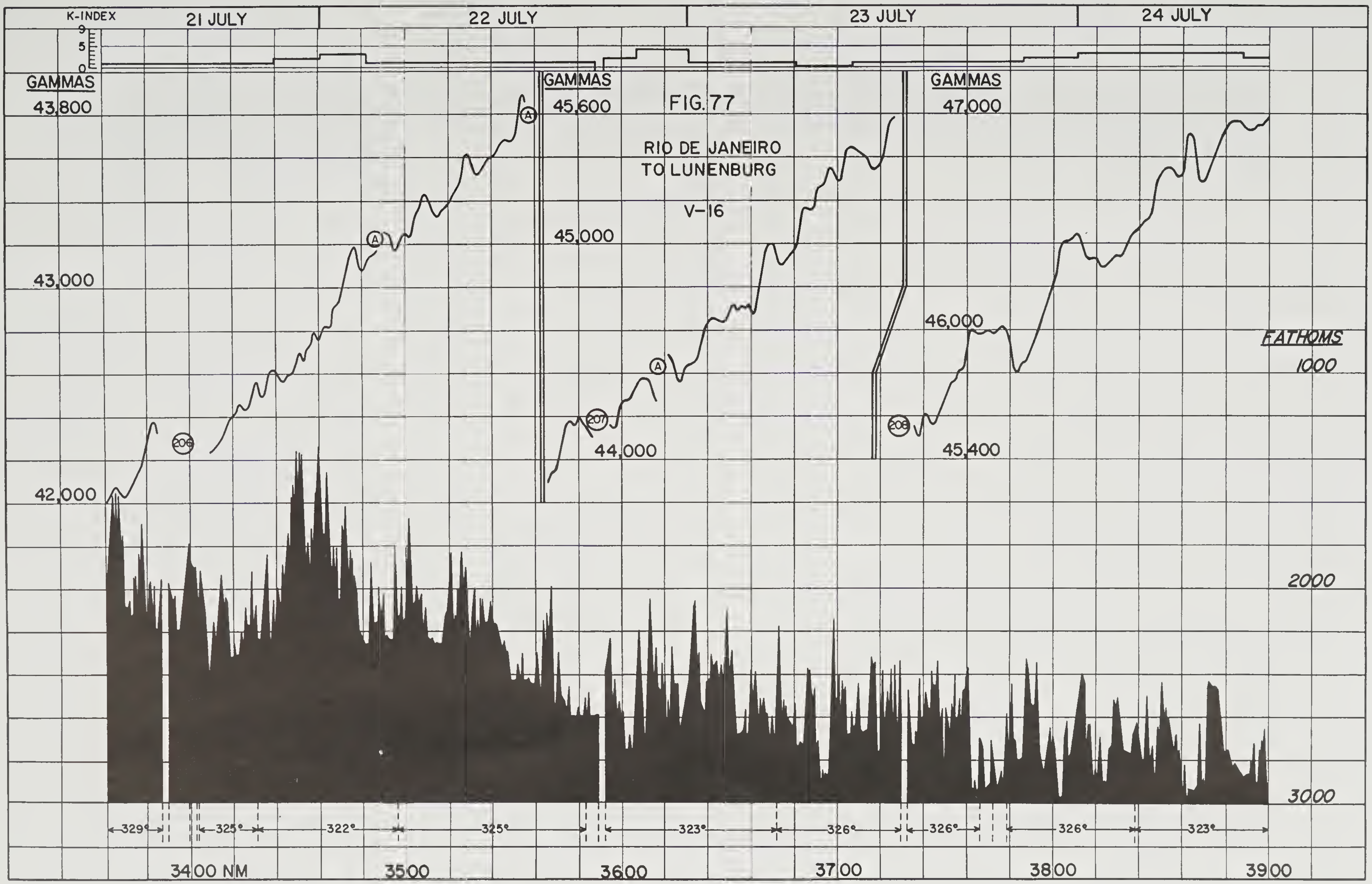


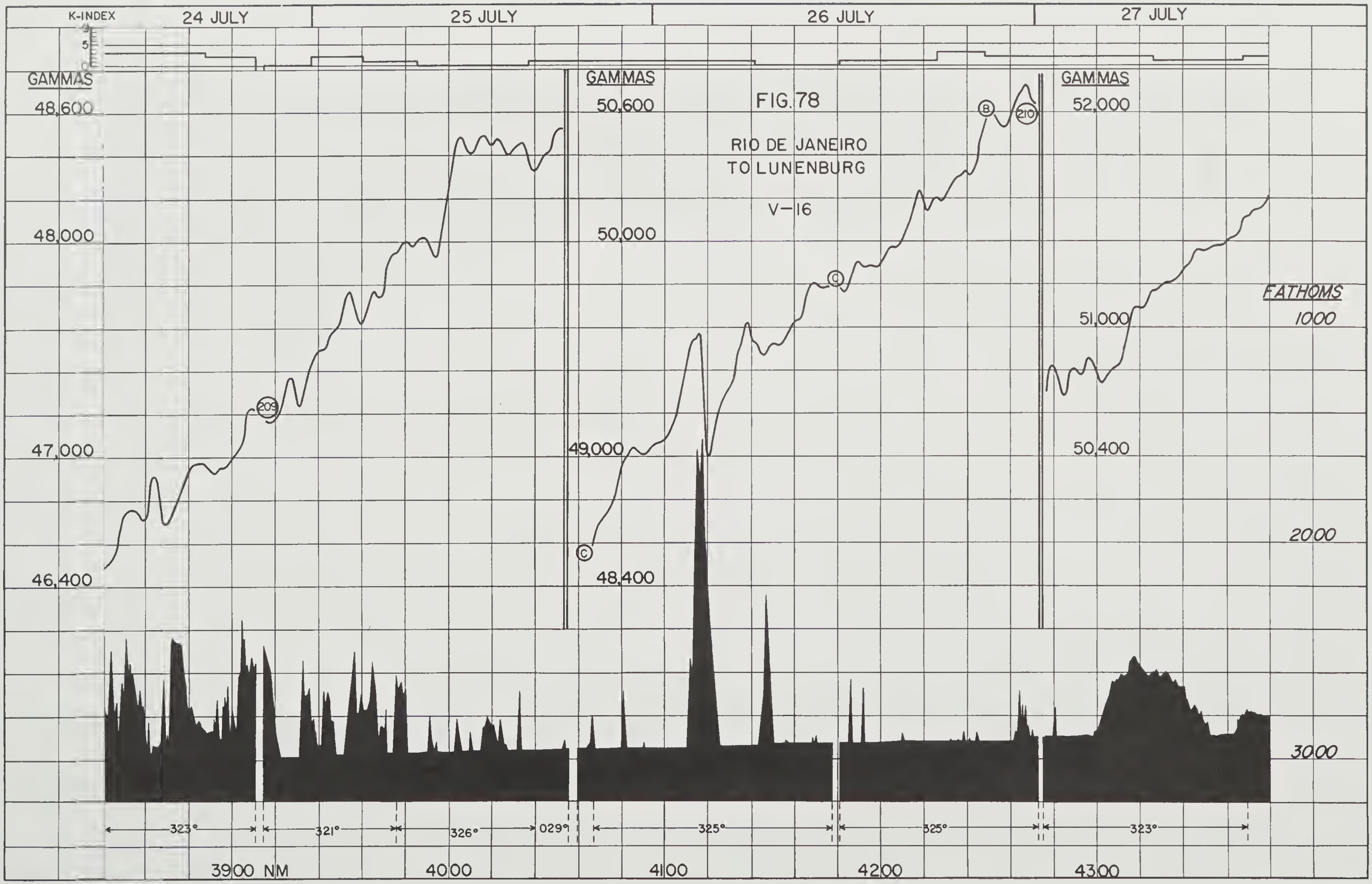
FIG. 74
RIO DE JANEIRO
TO LUNENBURG
V-16
K-INDEX
9
5
0
13 JULY
14 JULY
15 JULY
GAMMAS
32,000
31,000
30,000
GAMMAS
34,400
34,000
33,000
FATHOMS
1000
2000
A
202
203
349°
352°
355°
327°
321°
330°
335°
2000 NM
2100
2200
2300
2400

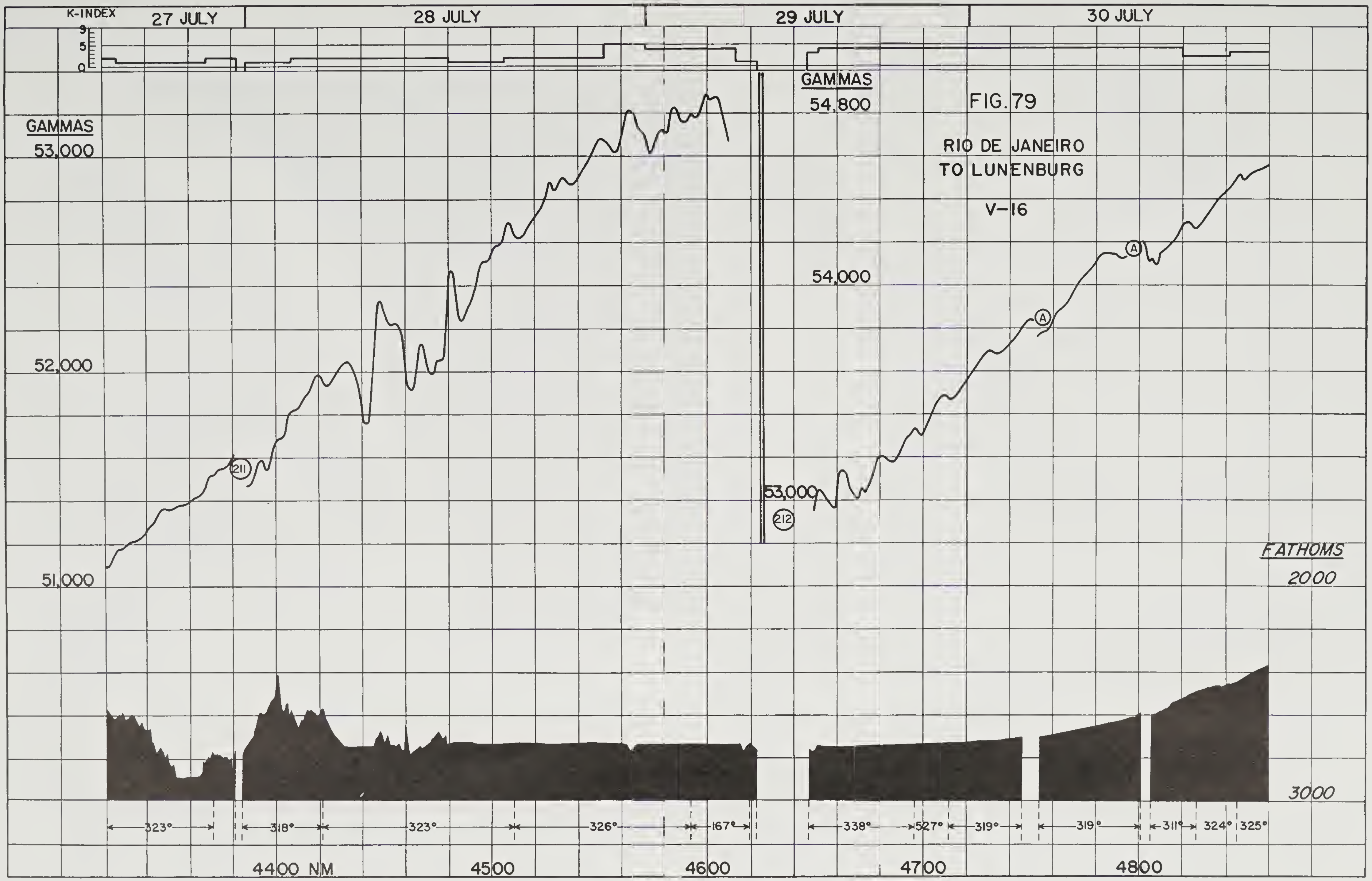

K-INDEX
9
5
0
16 JULY
17 JULY
18 JULY
GAMMAS
35,800
35,000
34,000
GAMMAS
37,800
37,000
36,000
RIO DE JANEIRO
TO LUNENBURG
V-16
A
204
C
A
205
FATHOMS
1000
2000
335°
090°
180°
329°
330°
332°
332°
343°
2400 NM
2500
2600
2700
2800
2900
FIG. 75

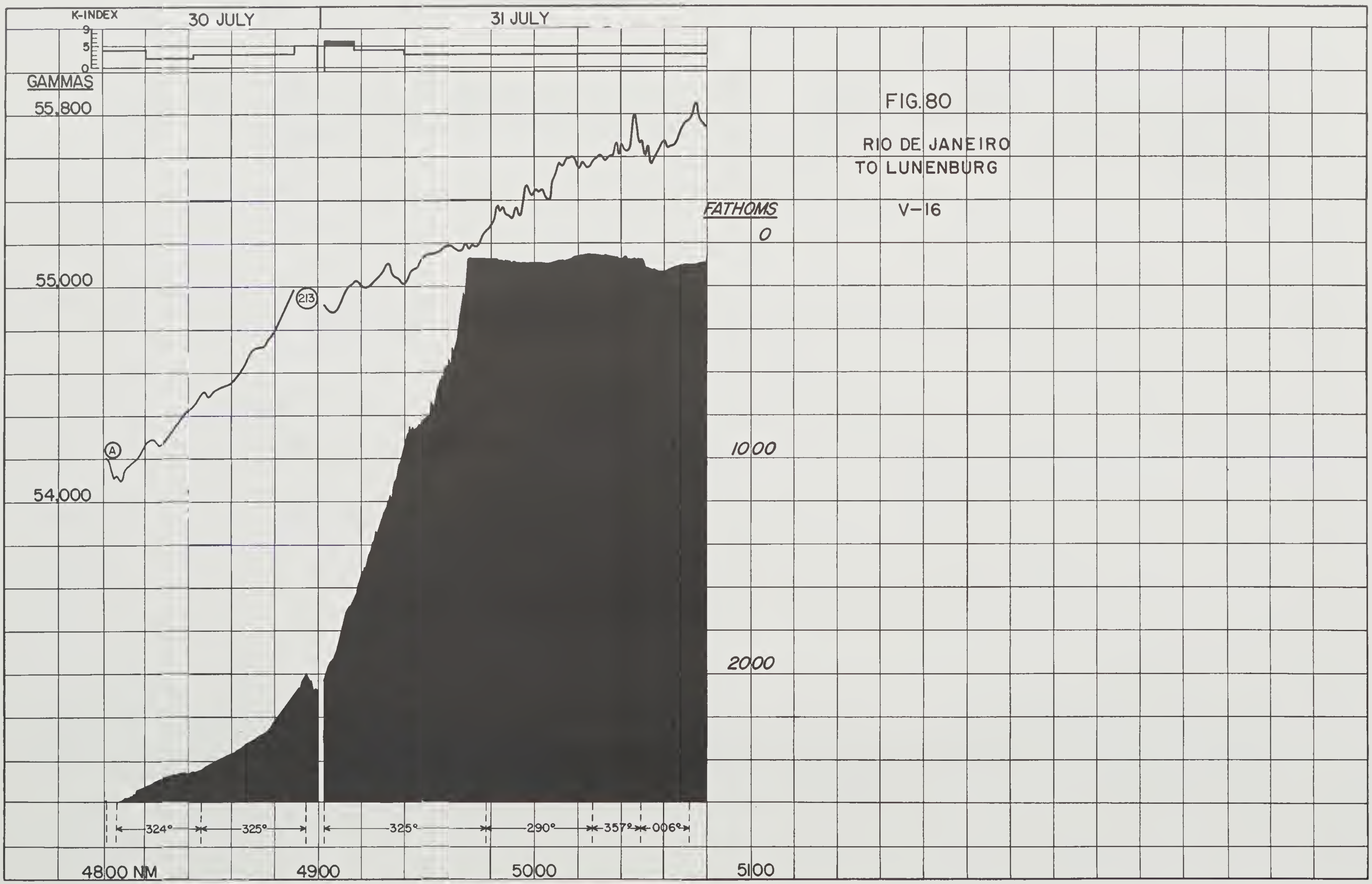

K-INDEX
19 JULY
20 JULY
21 JULY
GAMMAS
39,800
39,000
38,000
37,000
GAMMAS
42,000
41,000
40,000
FIG. 76
RIO DE JANEIRO
TO LUNENBURG
V-16
FATHOMS
1000
2000
332°
343°
346°
343°
341°
340°
331°
333°
329°
325°
2900 NM
3000
3100
3200
3300
3400



K-INDEX
21 JULY
22 JULY
23 JULY
24 JULY
9
5
0
GAMMAS
43,800
43,000
42,000
GAMMAS
45,600
45,000
44,000
GAMMAS
47,000
46,000
45,400
FIG. 77
RIO DE JANEIRO
TO LUNENBURG
V-16
A
206
207
208
FATHOMS
1000
2000
3000
329°
325°
322°
325°
323°
326°
326°
326°
323°
3400 NM
3500
3600
3700
3800
3900


K-INDEX
24 JULY
25 JULY
26 JULY
27 JULY
GAMMAS
48,600
48,000
47,000
46,400
GAMMAS
50,600
50,000
49,000
48,400
GAMMAS
52,000
51,000
50,400
FIG. 78
RIO DE JANEIRO
TO LUNENBURG
V-16
209
210
FATHOMS
1000
2000
3000
323°
321°
326°
029°
325°
325°
323°
3900 NM
4000
4100
4200
4300


K-INDEX
27 JULY
28 JULY
29 JULY
30 JULY
GAMMAS
53,000
52,000
51,000
GAMMAS
54,800
54,000
53,000
211
212
A
A
RIO DE JANEIRO
TO LUNENBURG
V-16
FATHOMS
2000
3000
323°
318°
323°
326°
167°
338°
527°
319°
319°
311°
324°
325°
4400 NM
4500
4600
4700
4800
FIG. 79



K-INDEX
9
5
0
30 JULY
31 JULY
GAMMAS
55,800
55,000
54,000
A
213
FATHOMS
0
1000
2000
324°
325°
325°
290°
357°
006°
4800 NM
4900
5000
5100
RIO DE JANEIRO
TO LUNENBURG
V-16

FIG. 80

75°
60°
45°
JULIANEHAAB
1000
500
ARGENTIA
400
100
LUNENBURG
5000
4500

75°
60°
45°
JULIANEHAAB
0
500
1000
700
1100
800
1200
900
1500
2000
LUNENBURG
100
NEW YORK
700
500
600

FIGURE 81

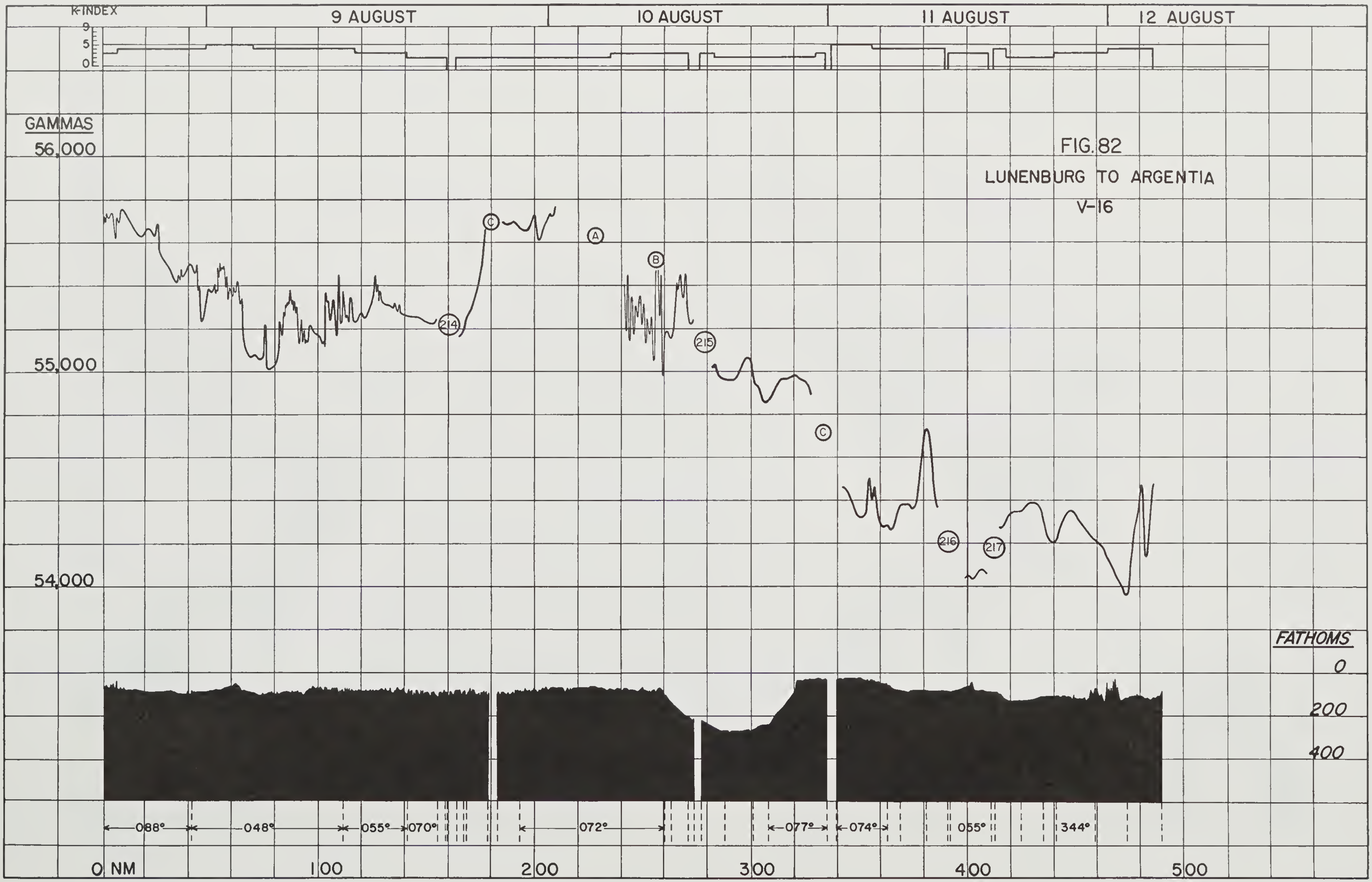


FIG. 82
LUNENBURG TO ARGENTIA
V-16

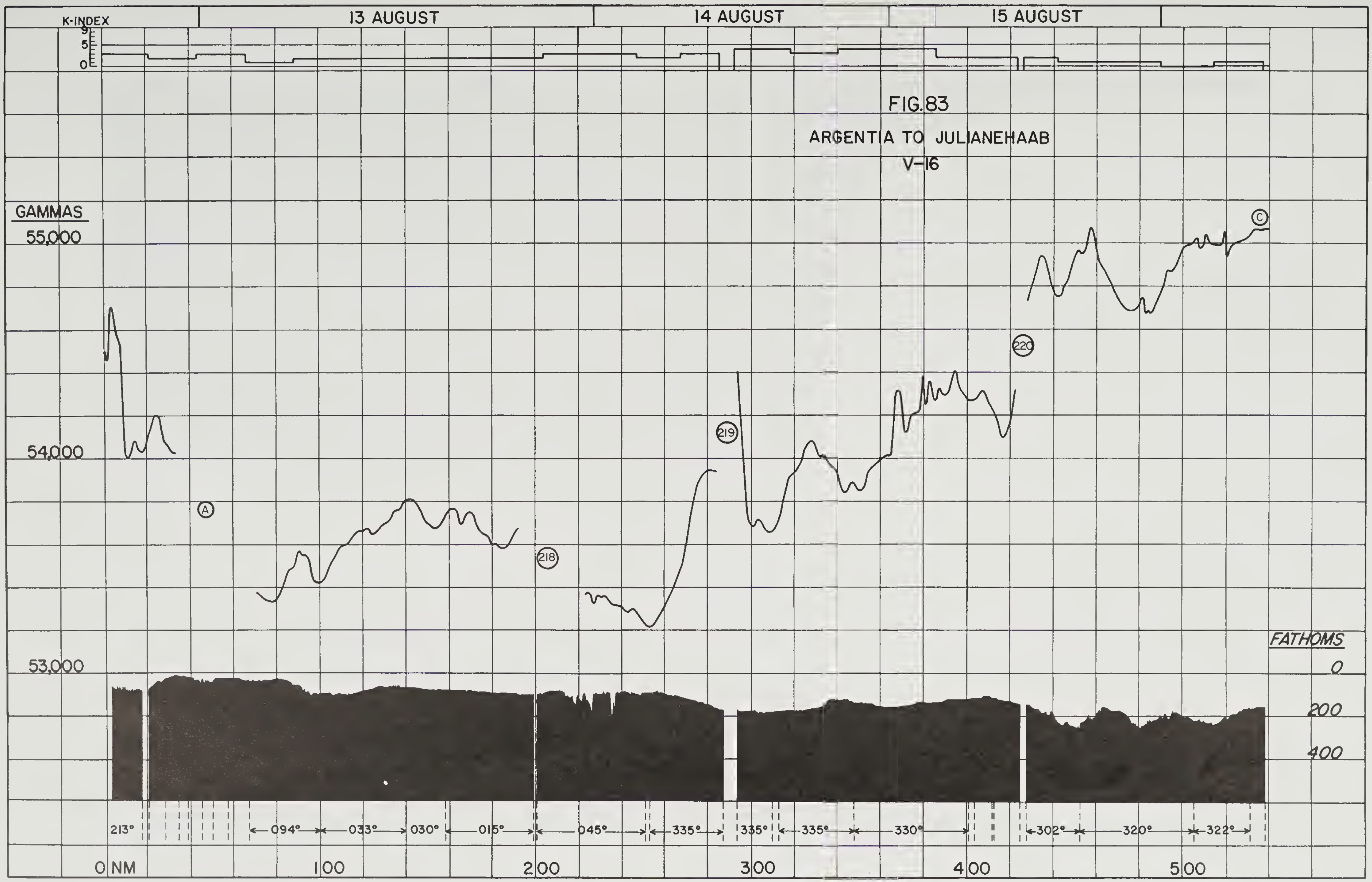


FIG.83
ARGENTIA TO JULIANEHAAB
V-16
K-INDEX
9
5
0
13 AUGUST
14 AUGUST
15 AUGUST
GAMMAS
55,000
54,000
53,000
FATHOMS
0
200
400
A
218
219
220
C
213°
094°
033°
030°
015°
045°
335°
335°
335°
330°
302°
320°
322°
0 NM
100
200
300
400
500

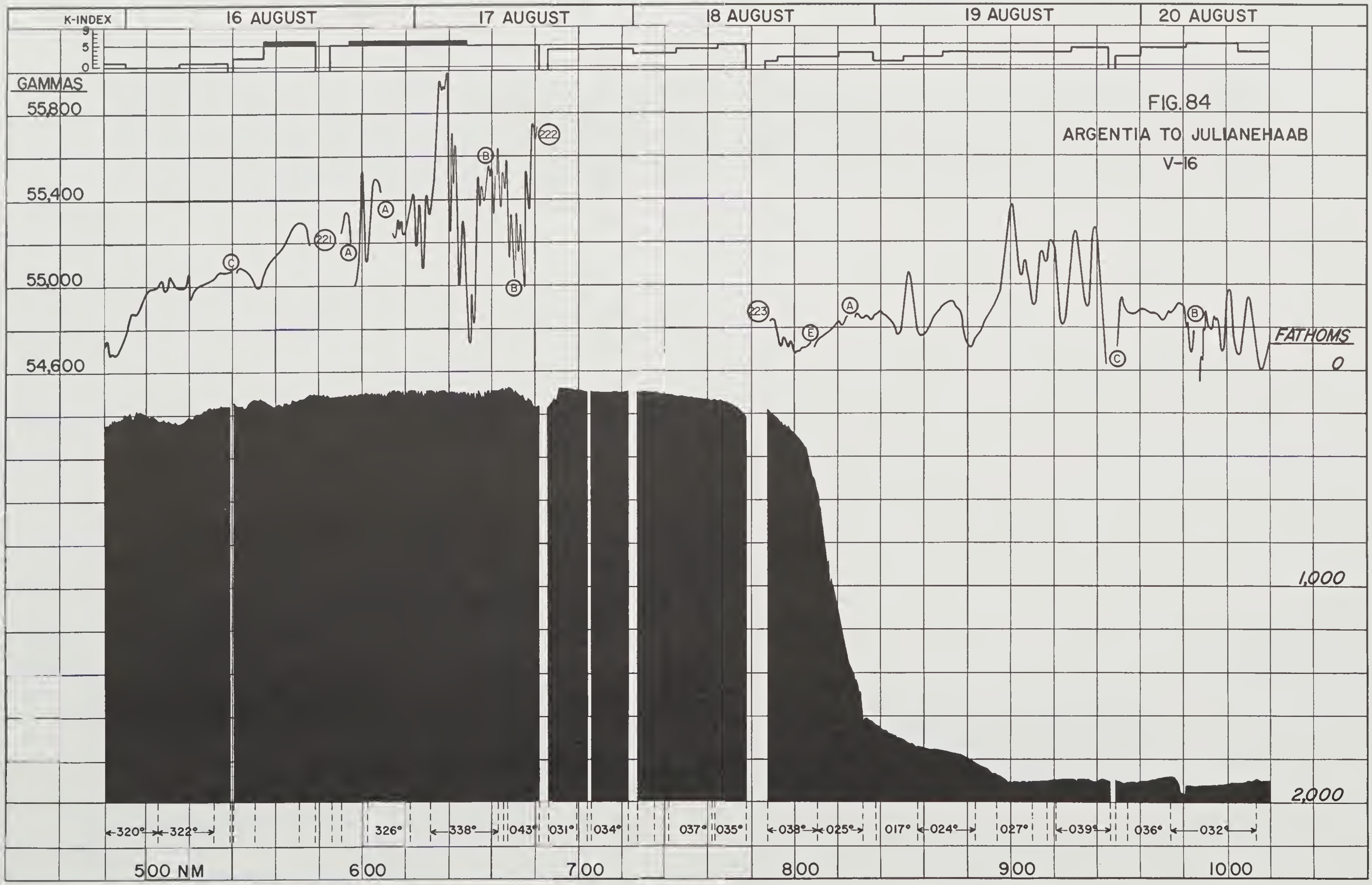


FIG. 84
ARGENTIA TO JULIANEHAAB
V-16

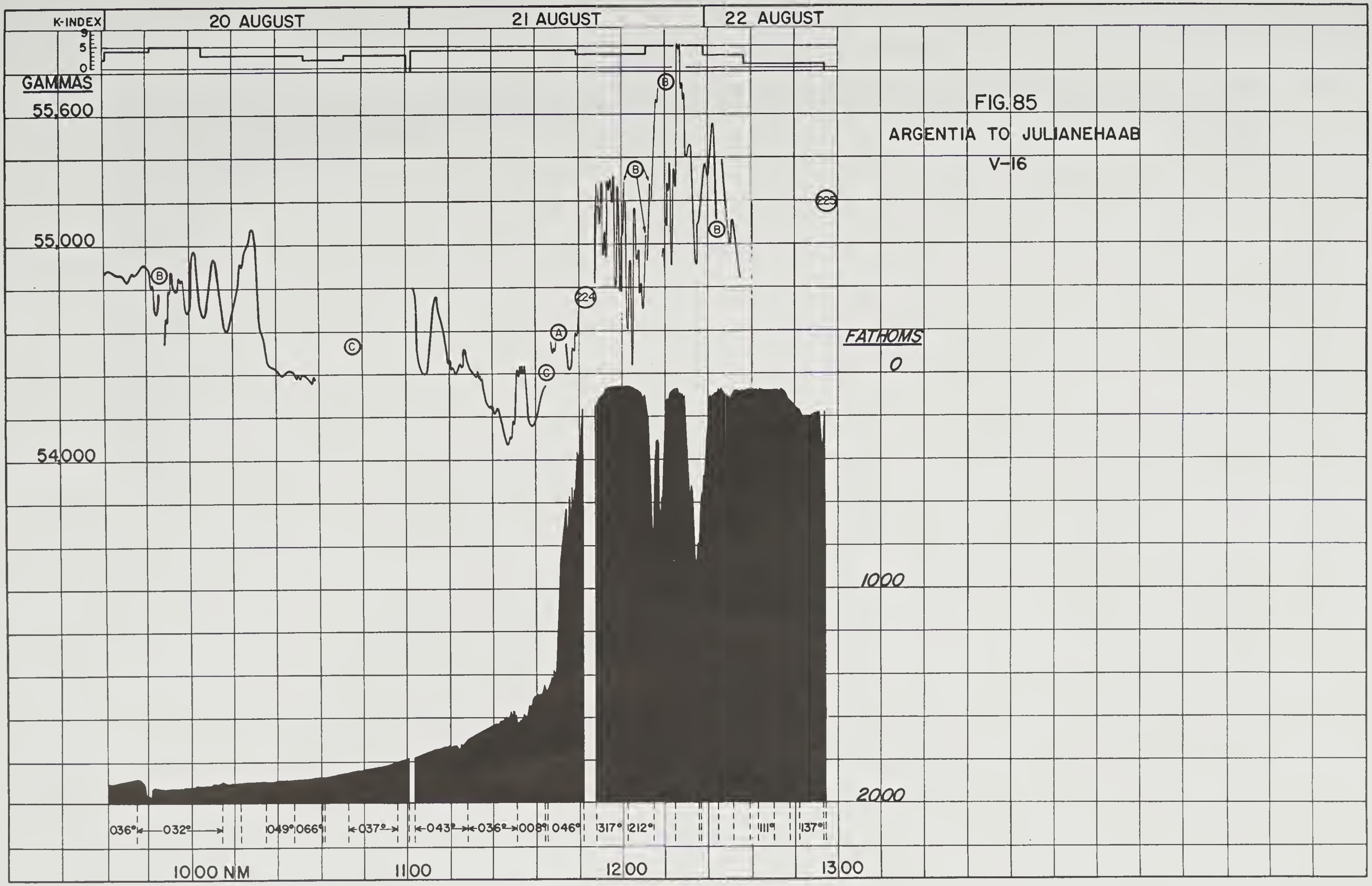


FIG. 85
ARGENTIA TO JULIANEHAAB
V-16

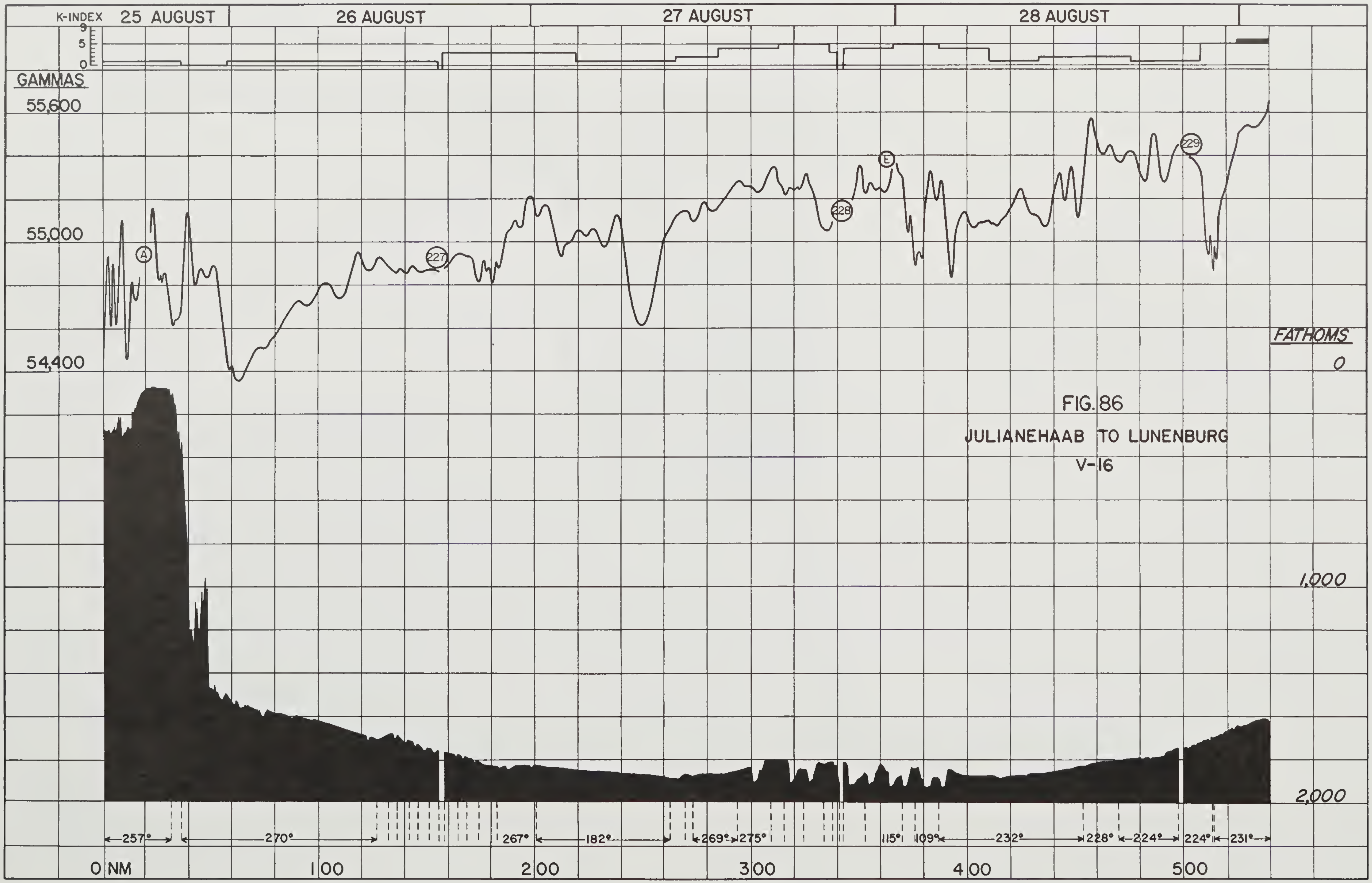
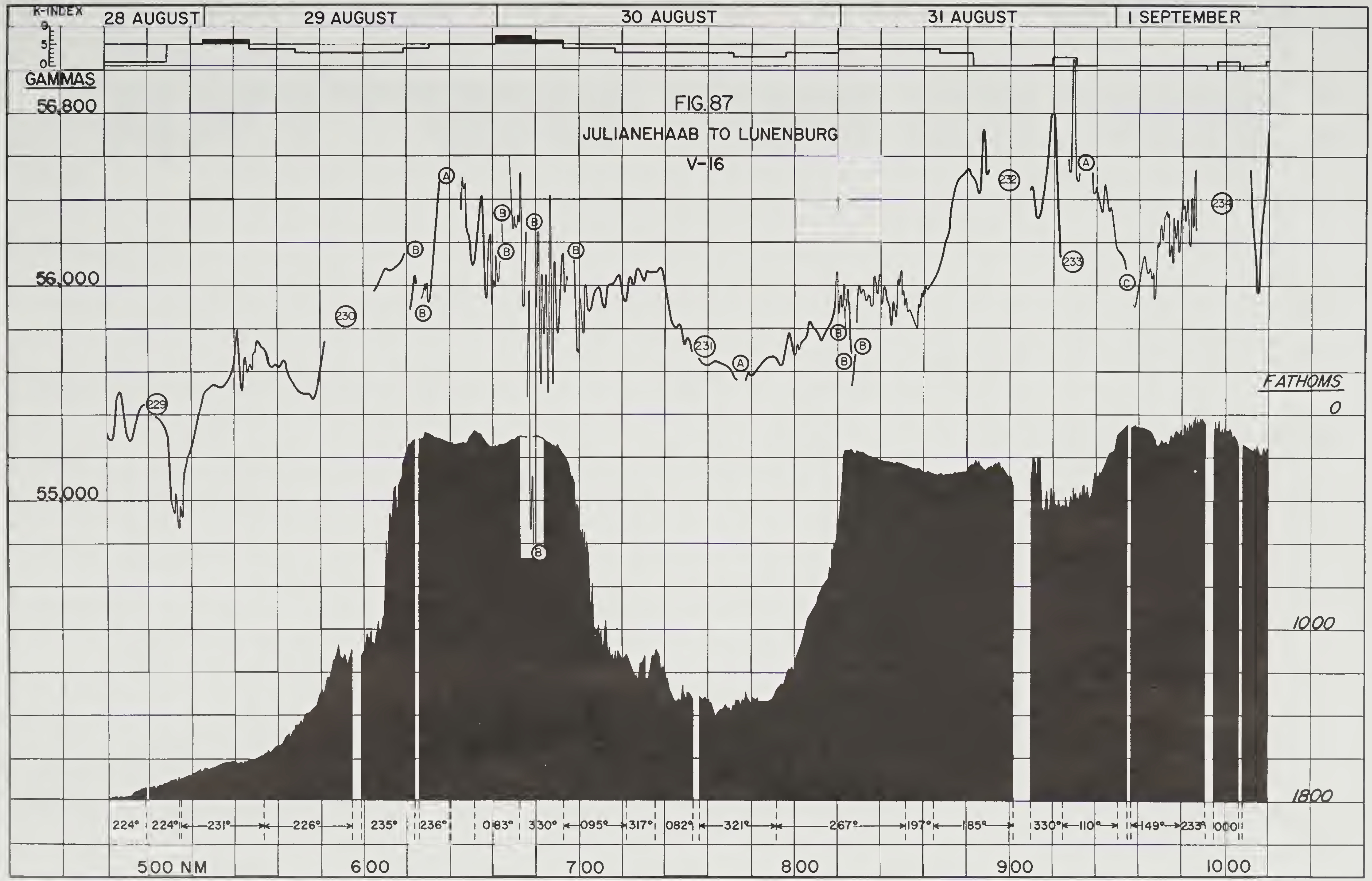


FIG. 86
JULIANEHAAB TO LUNENBURG
V-16

FIG. 87

JULIANEHAAB TO LUNENBURG

V-16



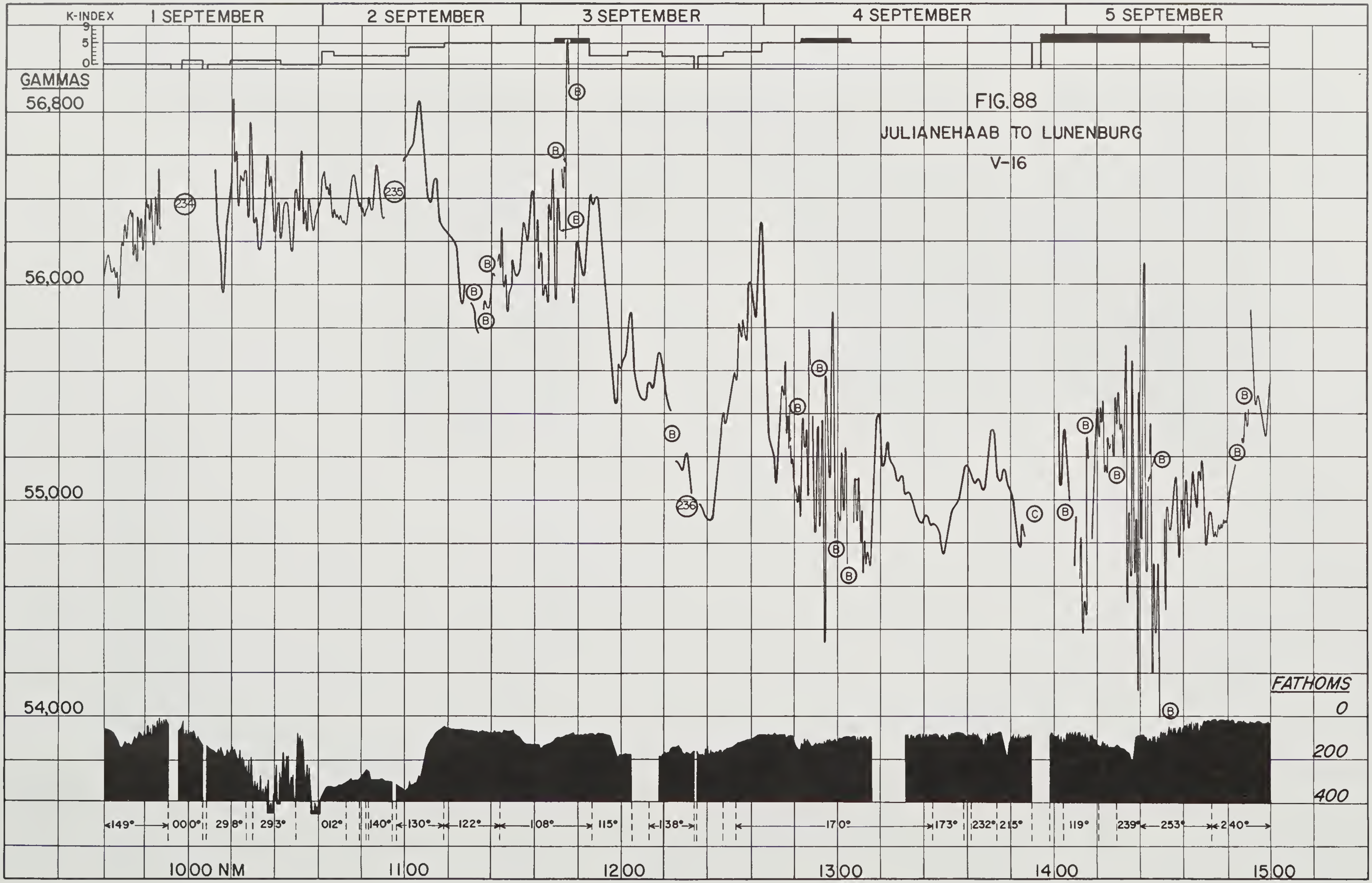


FIG. 88
JULIANEHAAB TO LUNENBURG
V-16

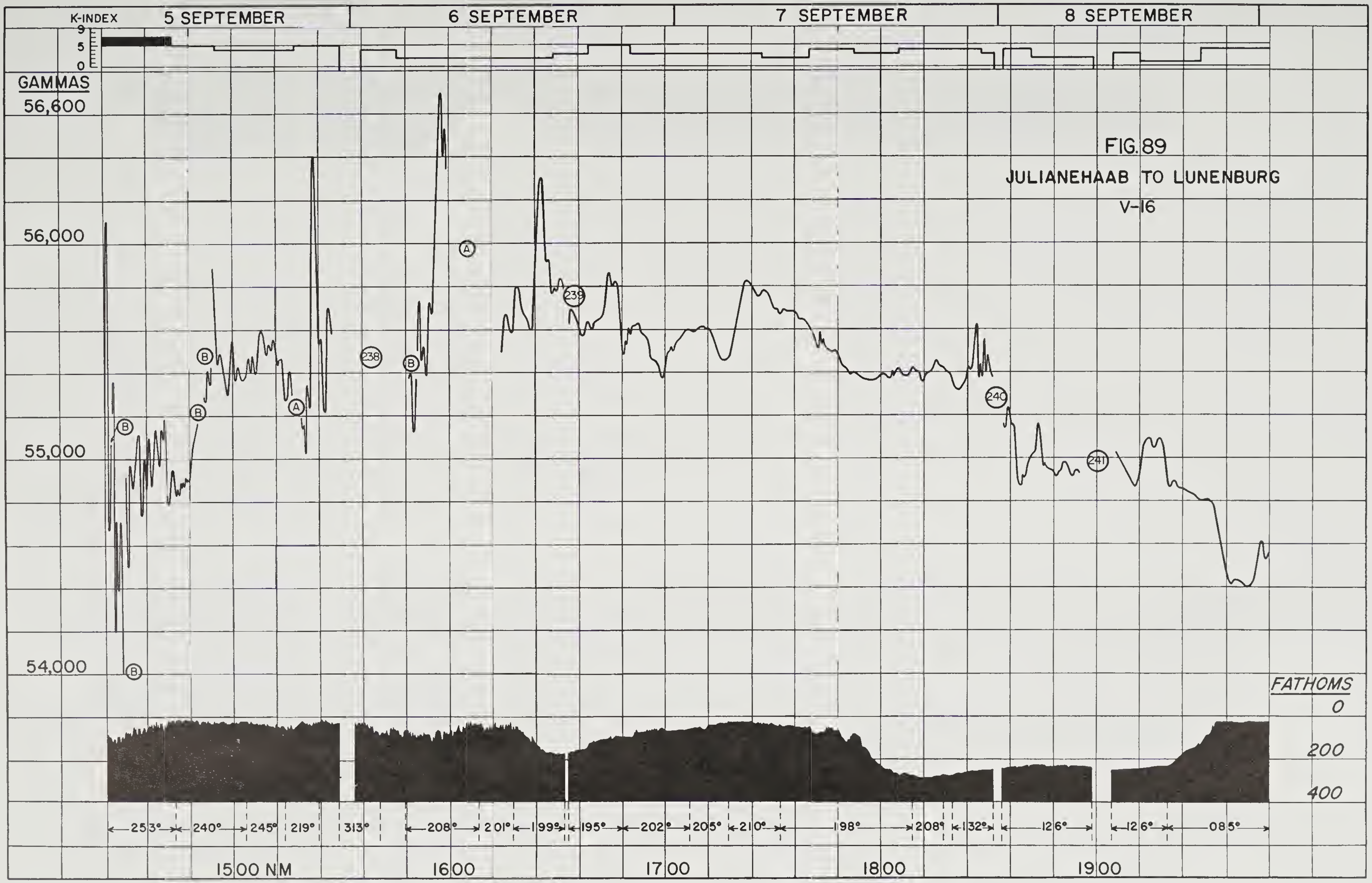


FIG. 89
JULIANEHAAB TO LUNENBURG
V-16
K-INDEX
9
5
0
5 SEPTEMBER
6 SEPTEMBER
7 SEPTEMBER
8 SEPTEMBER
GAMMAS
56,600
56,000
55,000
54,000
A
B
238
239
240
241
FATHOMS
0
200
400
253°
240°
245°
219°
313°
208°
201°
199°
195°
202°
205°
210°
198°
208°
132°
126°
126°
085°
1500 NM
1600
1700
1800
1900

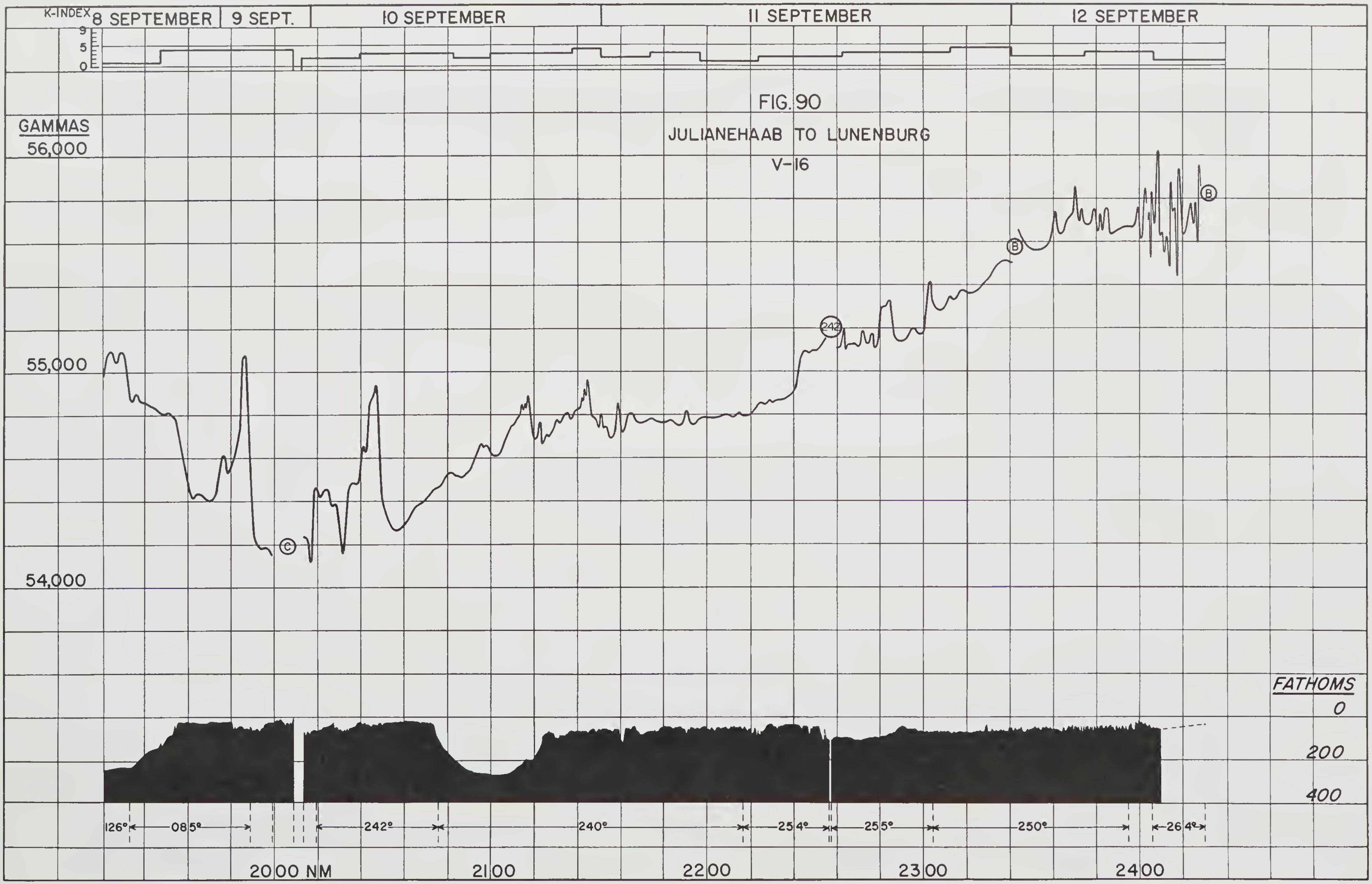


FIG. 90
JULIANEHAAB TO LUNENBURG
V-16

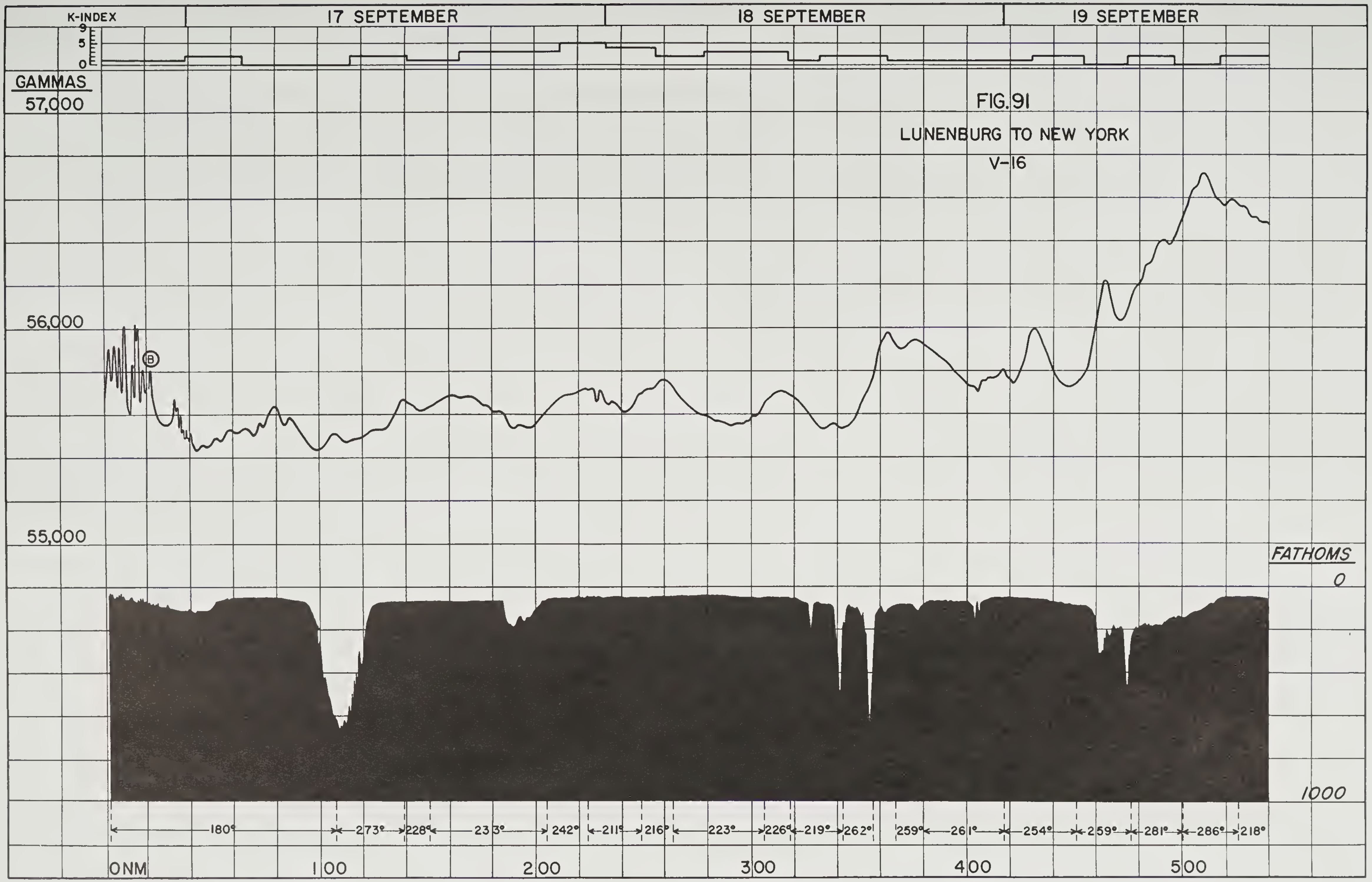


FIG. 91
LUNENBURG TO NEW YORK
V-16

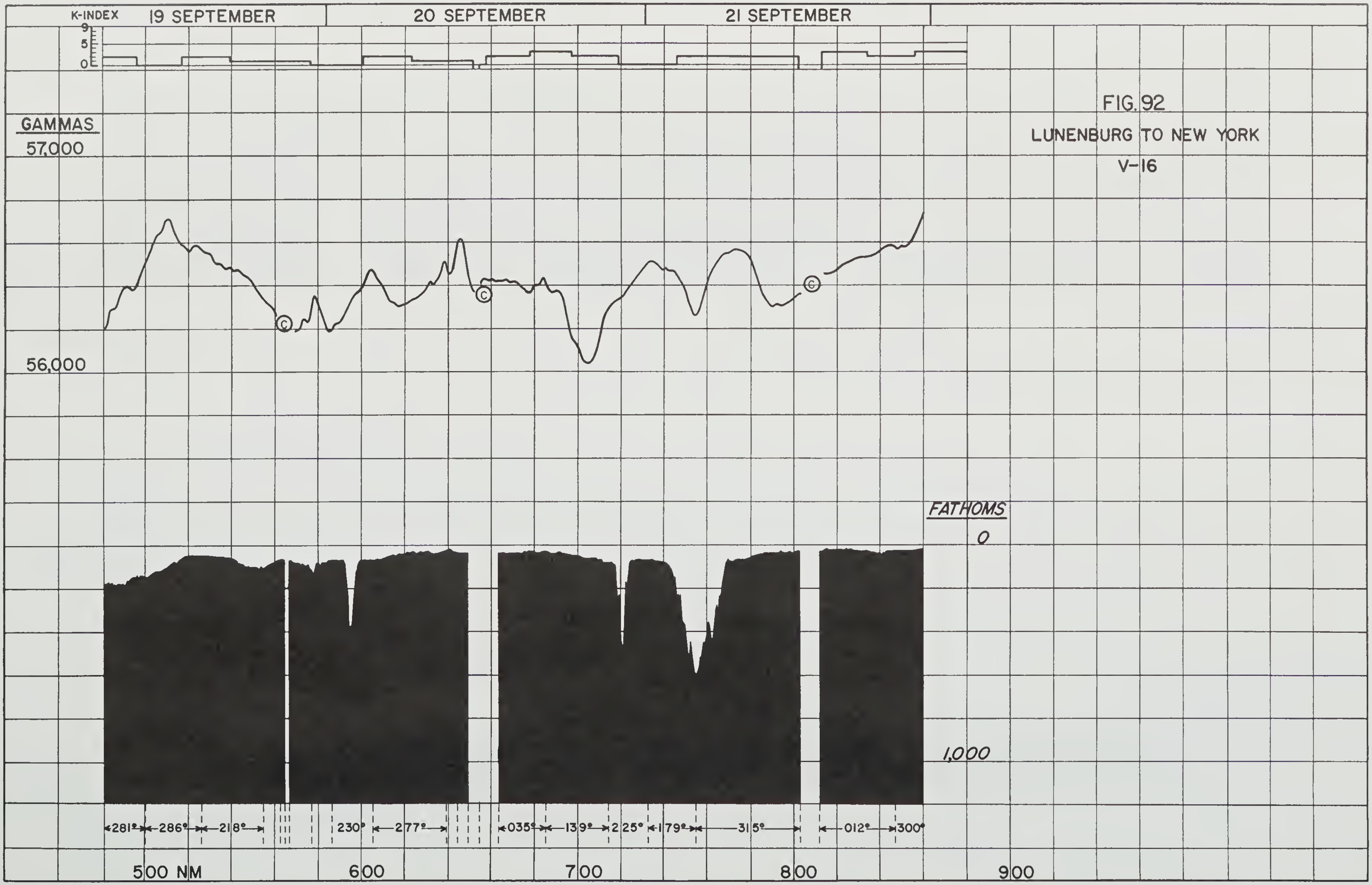


FIG. 92
LUNENBURG TO NEW YORK
V-16