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REFERENCE NO. 72-95

SEISMIC REFLECTION, MAGNETIC, AND GRAVITY PROFILES OF THE EASTERN ATLANTIC CONTINENTAL MARGIN AND ADJACENT DEEP-SEA FLOOR
I. CAPE FRANCIS (SOUTH AFRICA), TO CONGO CANYON (REPUBLIC OF ZAIRE)

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TECHNICAL REPORT

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Approved for Distribution J. R. Heirtzler
J. R. Heirtzler, Chairman
Department Geology & Geophysics

INTRODUCTION

One of the programs of the International Decade of Ocean Exploration (IDOE) is a four-year geophysical and geological study of the Eastern Atlantic Continental Margin and the adjacent deep-sea floor. It was designed to learn more of the date and manner by which Africa became separated from South America and the subsequent history and development of the African continental margin and adjoining deep-sea floor. The traverses also serve to outline large sedimentary basins that may be potential reservoirs of petroleum. Subsequent more detailed exploration and eventual exploitation of these basins may be conducted or controlled by the adjacent African nations under whose jurisdiction the areas belong. This report is a compilation of the geophysical traverses made from Cape Francis (South Africa) to the Congo Canyon (Republic of Zaire) during the first half of 1972. Positions of these traverses are shown in Plates 1 and 2.

Computers had an exceptionally great role during this investigation, with five being used almost continuously aboard the ship. One computer served to digitize and process the gravity and magnetic measurements. The second, a special-purpose computer, is part of the satellite navigator. A third combined the output from the first two computers and from paper-tape records of the bathymetry so that plots could be drawn in map form and as distance profiles. The fourth and fifth computers are part of the seismic system, used to digitize and process the seismic data. For a more detailed description of the hardware and data processing aboard ship see the accompanying article by Groman and others.

DATA ACQUISITION

Bathymetric profiles of the sea floor were obtained with a 3.5 kHz transducer and recorded on 48-cm wet paper at a 400 fathoms (1 second) or 800 fathoms (2 seconds) sweep rate. The total-field magnetic intensity was determined with a proton precession magnetometer, and gravity measurements were made with a vibrating string gravimeter. Sound sources to obtain data on the shallow structure of the region include a 300 cu. in. air gun fired at 12-sec. intervals used in areas of thick sediment, and a 120, 40, or 10 cu. in. air gun used where the sediment blanket was thin or absent or when the larger gun was being repaired. Part of the time two guns were fired simultaneously. The air supply was delivered by a newly designed Diesel compressor capable of providing 2600 cu. in. per minute at 2000 pounds per sq. in. (200 cu. ft. per minute of free air). During most of one leg the large compressor was broken down and a small standby air compressor was able to support only the 10 cu. in. gun, which provided good information but at a ship speed of 4 to 5 knots rather than the usual 7 to 8.5 knots permitted by use of the large gun. Signals were received on two 30-m pressure-sensitive hydrophone arrays, each containing 200 sensing units and towed from booms at each side of the ship. The signals were summed, amplified, filtered at usually 20 to 80 Hz or 60 to 80 Hz, and recorded as analog plots on 28 x 40 cm sheets, one at 5-sec. sweep and the other at 2.5-sec. sweep. The signals also were automatically digitized and stored in digital form on magnetic tape for later computer processing to enhance signal relative to noise by stacking and to reduce multiple reflections from the water-bottom interface by deconvolution. Reduction of multiples was needed only on the continental shelf and upper continental slope, and stacking only in areas of thickest sediments beneath the continental shelf, slope, and rise; analog records proved sufficient for the deep-sea floor.

Radiosonobuoys were used an average of one each day to measure velocities of sound in the sedimentary strata, oceanic basement, and possibly oceanic crust (Layers 1, 2, and 3) by oblique reflection and refraction. The signals were amplified and recorded both in analog form on dry paper and on magnetic tape for subsequent refinement, reprinting, and computer processing. Various non-routine data such as bottom reflectivity and sound absorption in the bottom also were computed as time and interest permitted for special purposes. These data will be described in a future report.

INTERPRETATION OF SEISMIC REFLECTION PROFILES

The seismic recordings on 28 x 40 cm sheets were duplicated on a shipboard copier, the copies were assembled into strips for each traverse, and the various reflecting horizons were traced with colored pencils. These reflecting horizons were then transferred by eye to computer-plotted bathymetric profiles using the hour marks on the seismic and bathymetric records as guides. Where present, the oceanic basement and the pre-Mesozoic basement beneath the shelf and slope were accentuated with heavy lines. Similarly, the more prominent reflections within the sedimentary sequence above basement were also accentuated by heavy, but somewhat lighter lines, than those used for the basement. North of the Walvis Ridge, where salt piercement structures dominate the continental margin, these features have been indicated by a dotted pattern. The final plots shown in the accompanying plates consist of a top panel displaying the magnetic and gravity (Free air and Bouguer) anomalies along the ship's track, and a lower panel showing bathymetry and the line interpretation of the seismic profile. All of these profiles are adjusted for distance along the ship's track. For those interested in obtaining copies of the original seismic reflection, magnetic, gravity, bathymetry and navigational data they can be obtained from:

Marine Geology and Geophysics Group, Code D62
NOAA
Environmental Data Service
Washington, D. C. 20235

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DATA PROCESSING OF GEOPHYSICAL TIME SERIES DATA

BY
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INTRODUCTION

Marine geophysical data are routinely processed aboard Woods Hole Oceanographic Institution's vessels. Data profiles and charts are ready within 24 hours for serious interpretation by scientists aboard ship. Sources, listings and write-ups of the programs mentioned below can be obtained from the National Geophysical and Solar-Terrestrial Data Center, Code D62, NOAA, Environmental Data Service, Washington, D. C. 20235. The sources are stored on magnetic cassettes and were written by a Hewlett-Packard computer in ASCII coding. The programs described below were developed over the years by Woods Hole Oceanographic Institution personnel with funds provided by the Office of Naval Research (Contract N00014-66-C-0241). Recent modifications of these programs were made possible by funds provided by the International Decade of Ocean Exploration.

The general purpose hardware computer used aboard ship is a Hewlett-Packard model 2116A or 2116B computer with a 16384 - 16 bit word memory. Tied to this computer are several input/output devices. A cathode ray tube display device serves as the operator communications terminal and high speed lister for data scanning and editing. A cassette magnetic tape system capable of handling three cassettes simultaneously is used for program loading and data storage, while two nine-track magnetic tape units are used as the mass storage devices as well as the system tape input device. A teletype serves as the hard copy listing device and a high speed paper tape reader and punch are also part of this system. For plotting purposes, 30-inch and 10-inch digital incremental plotters are available.

PROCESSING SCHEME

General

The software system is designed for producing error free geophysical data versus position for raw geophysical time series data. Three basic steps are involved: 1) data acquisition in time series formats, 2) editing of these series, and 3) merging of these series with geographical position. The software package has provisions for alternate routes of data processing. This built-in flexibility is needed in the event of computer hardware malfunction since data acquisition goes on 24 hours a day. Figure 1 is a block diagram for both the automatic and manual (dashed line) methods that can be employed to process the raw data. For example, in the first column, magnetic and gravity data will normally be automatically digitized by the HP 2114A computer, which is part of the gravity system, but if this method fails the data can be hand-digitized from strip chart recordings. Because of additional steps necessary for manual acquisition and processing, Figure 1 appears quite complicated. A simpler view is shown in Figure 2, which includes only the automatic acquisition and data processing scheme.

Navigation

The basis for the navigation used in the data processing is the satellite positions acquired periodically by a Magnavox Satellite Receiver System located on the bridge. To these fixes the ship's officers add Omega, Loran, celestial, radar and dead-reckoned fixes when they are available. These fixes are then keypunched onto paper tape in a time versus position format (called FIXSE Format). Navigational data also are obtained from a measurement of the ship's (instantaneous) velocity through the water (see below). These data are automatically digitized and processed with the gravity data.

An analysis program (Program FCHK) calculates the speed, heading, and time difference between each fix pair and flags those fixes which do not meet certain criteria. For example, if the ship's speed is calculated as over 13 knots between two fixes, the fix is flagged as an error. The ship's officers and the chief scientist are presented with a Mercator chart of the navigation for study and evaluation. Any errors in navigation are edited out of the data tape. If, however, the computer plot compares well with the ship's track as plotted by the ship's officers (corrected by them for apparent current in standard manner), then the basic navigation time series is considered final. If any doubt arises between the validity of two different fixes and one is a satellite fix, usually the satellite fix is considered the correct one. Also, satellite fixes are never changed in the editing process. If they are thought in error due to low elevation for instance, they are omitted.

Magnetics and Gravity

A portable laboratory usually mounted on the ship's deck contains instruments to measure and record the earth's magnetic and gravitational field (Bowin and Wing, 1968). A small computer in the gravity laboratory aboard ship digitizes 5-minute averages of the earth's gravitational field and ship's velocity; the earth's magnetic field is sampled every five minutes. The data in AQU1 format (data versus time) can be output either to paper tape or cassette magnetic tape. The computer prints a real-time list of the data output with hourly annotations and comments. These annotations and any processing comments also go onto the data tape.

Figure 2 shows the steps followed to process these gravity-magnetic tapes (Bowin, et al., 1972). At this stage, preliminary plotting and editing can be done. After editing, program ESORT separates the data from the various comments included on the original tape. (A hard copy listing of all the comments also is made at this time.) To merge the navigation series with the AQU1 data a three-step process is followed:

Step 1: The ship's velocity information, acquired by the gravity system, is used to dead reckon the ship's position between two consecutive navigation fixes (usually only satellite fixes). This is accomplished through program ATS1. Any differences between the calculated ship's position and the second navigation point is attributed to drift caused by ocean currents and winds. The position pair and ocean drift is output as a single record in NAVC7 format for later use.

Step 2: Program ATS2 is an analysis program which studies the NAVC7 records for systematic errors in ship's velocity and heading. These systematic errors can be removed from the data.

Step 3: Program ATS3 merges the NAVC7 records with the gravity and magnetics data to produce a navigation versus data format (called SEAG1 Format). The Eötvos correction and Free Air Anomaly are calculated by this program. Any systematic errors in ship's speed or heading (as calculated by Program ATS2) can be removed during this step of the processing. The Bouguer Anomaly is calculated using the infinite slab model with an assumed density of 2.67 gm/cm^3 by merging the bathymetry time series data with the gravity format through Program MRGDS. The gravity data may be edited further to remove instrument bias and drift.

The navigation, time, and total magnetic field strength is extracted from the final gravity tape and a separate magnetic tape (in CALCM Format) is made by Program MAN1. The International Geomagnetic Field (IAGA Commission 2 Working Group 4, 1969) is calculated and subtracted from the total field to yield the local magnetic anomaly.

Bathymetry

The 3.5 kHz or 12 kHz echo-sounding records, in fathoms assuming 800 fms/sec, are read at 1 to 10 minute intervals, depending on the topography and recorded in a log book. These log book data are then keypunched onto paper tape in a simple time versus depth format (called EASYD). Program EZTD is used to correct for velocity of sound variations according to Matthews' Tables (1939). The Matthews' Table is selected according to the geographic location of the soundings and is input by the program operator. The bathymetry data are plotted in profile to check for reading or keypunch errors. Any errors are corrected with an editing program.

Program DTOB is used to merge the ship's position with the bathymetry. As is explained above, the navigation that is used here is not just the satellite and bridge fixes, but an integrated navigation stream which makes use of the ship's velocity information taken by the gravity acquisition system. The merged bathymetry data (in MBATR Format) can be plotted as a profile versus cumulative distance or time; as values written along the ship's track on a Mercator chart projection; or as a profile plotted along the ship's track on a Mercator chart.

It is important to realize that the MBATR format and the SEAGL format with merged depths (after step B in gravity processing, Fig. 2) contain different information. MBATR format is the depth series taken at time intervals necessary to represent the true topography trace in the most accurate manner. On the other hand, the depths merged into SEAG1 format are "filtered" because a depth is determined only for each 5-minute gravity value. This is because the depths are used only to determine the Bouguer anomaly in the SEAG1 format.

REFERENCES

Bowin, C. O. and C. G. Wing, 1968, Experience with the MIT vibrating string gravimeter: Trans. Amer. Geophys. Un., v. 49, No. 1, p. 121.

Bowin, C. O., T. C. Aldrich, and R. A. Folinsbee, 1972, VSA gravity meter system: Tests and recent developments: Jour. Geophys. Res., p. 2018-2033.

IAGA Commission 2 Working Group 4, 1969, International geomagnetic field 1965. O: Jour. Geophys. Res., v. 74, p. 4407-4408.

Matthews, D. J., 1939, Tables of the velocity of sound in pure water and salt water: Publication N.D. 282 of the Hydrographic Department, Admiralty, London (2nd edition), 52 p.

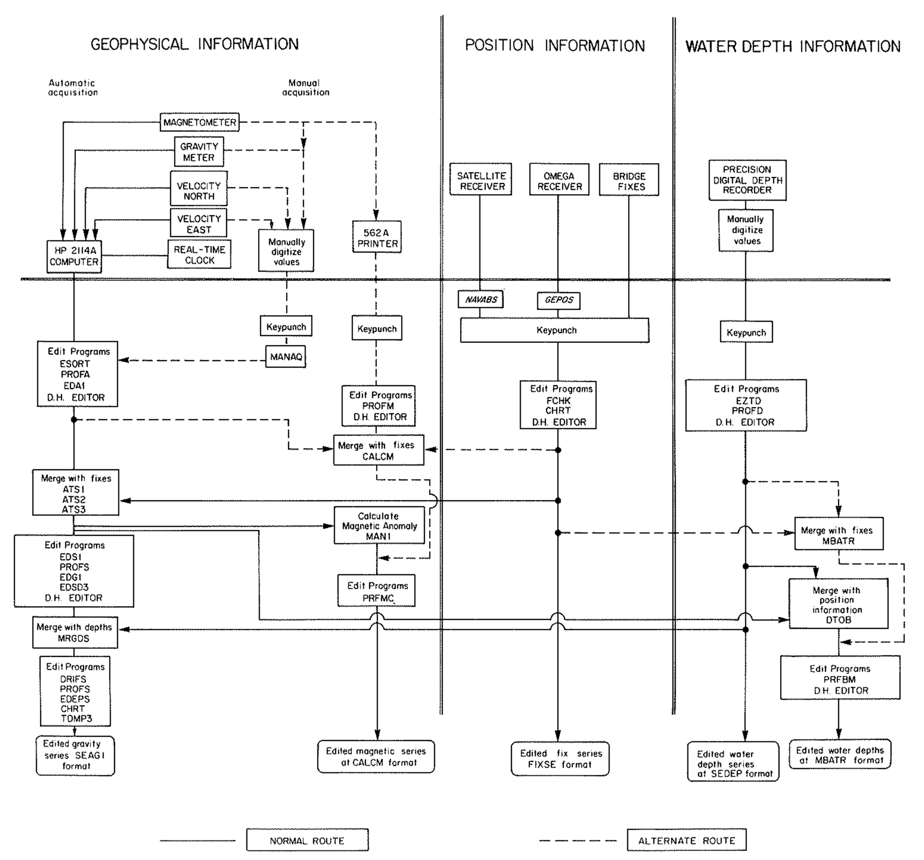


Figure 1

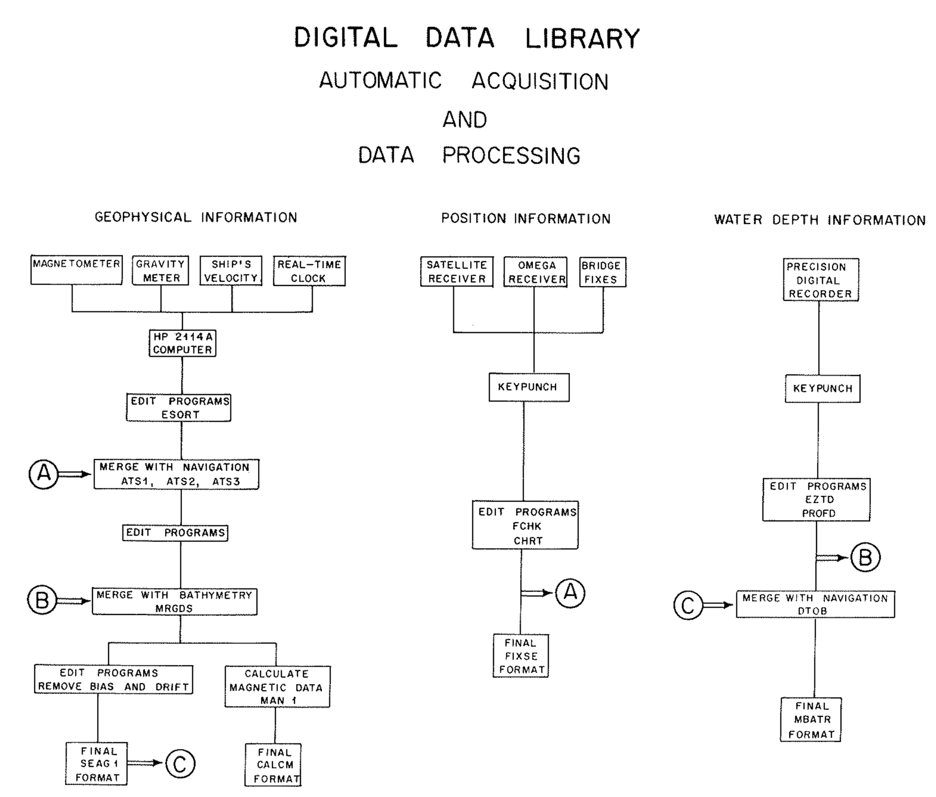
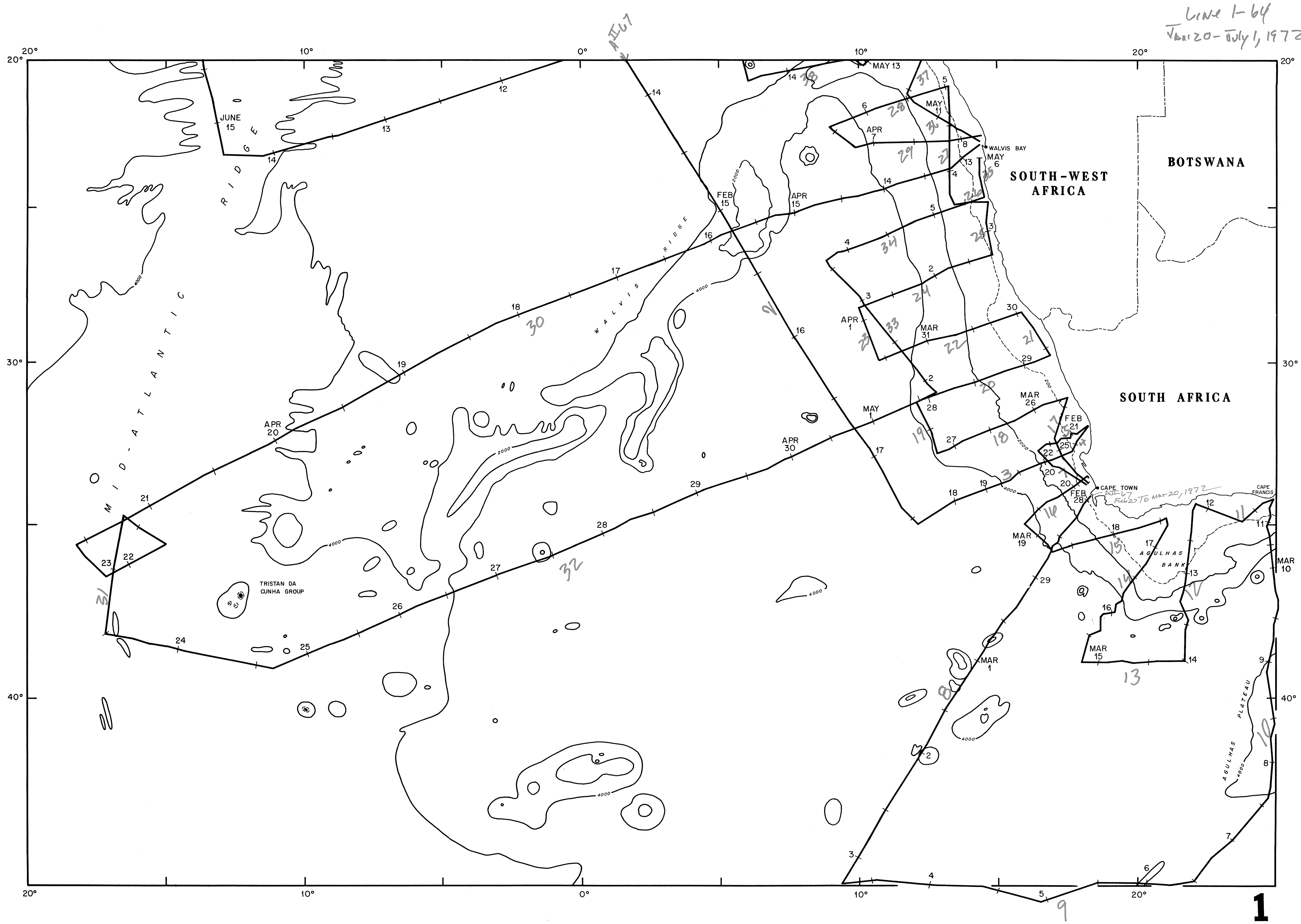


Figure 2

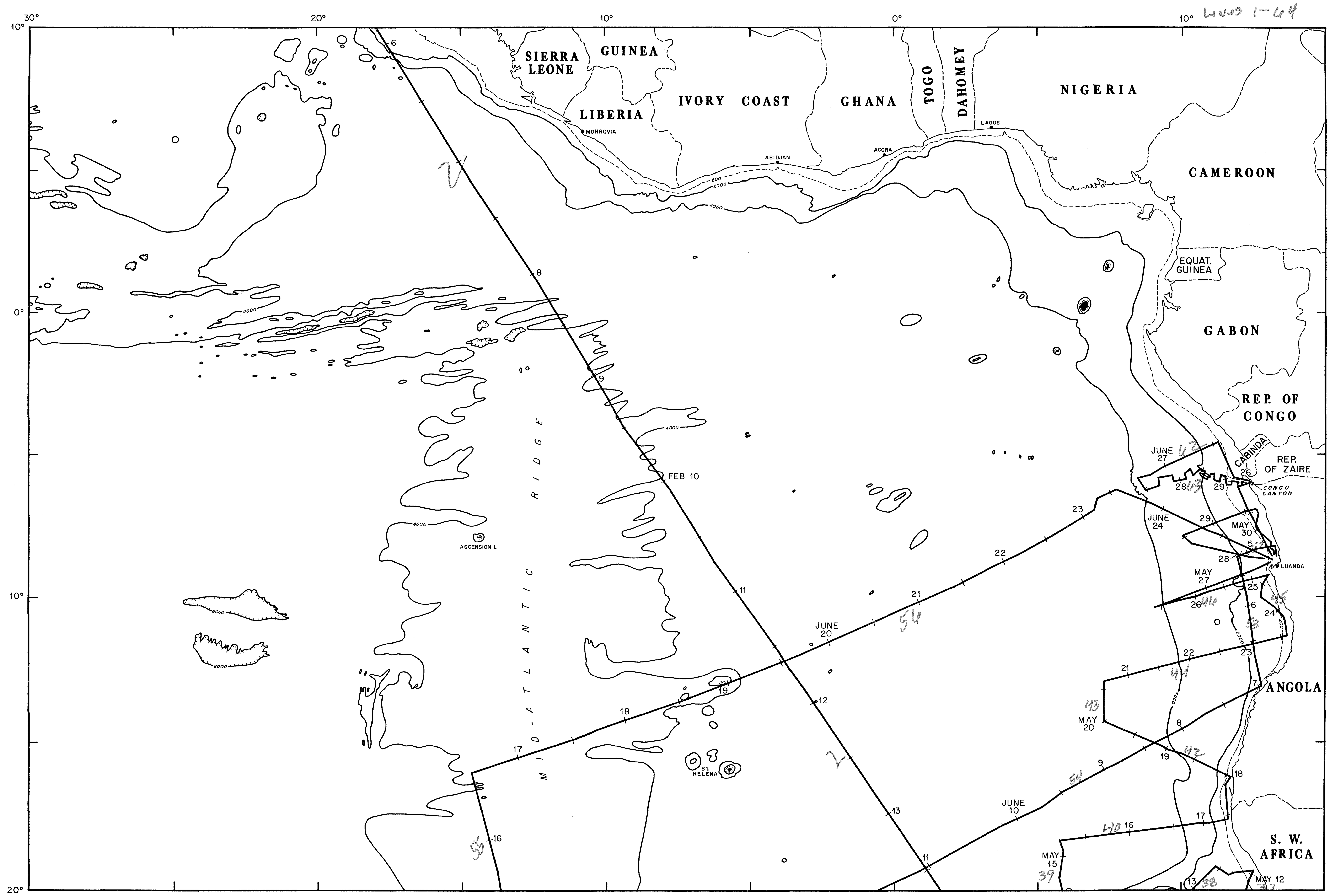
A II 67
Line 1-64
Jan 20 - July 1, 1972



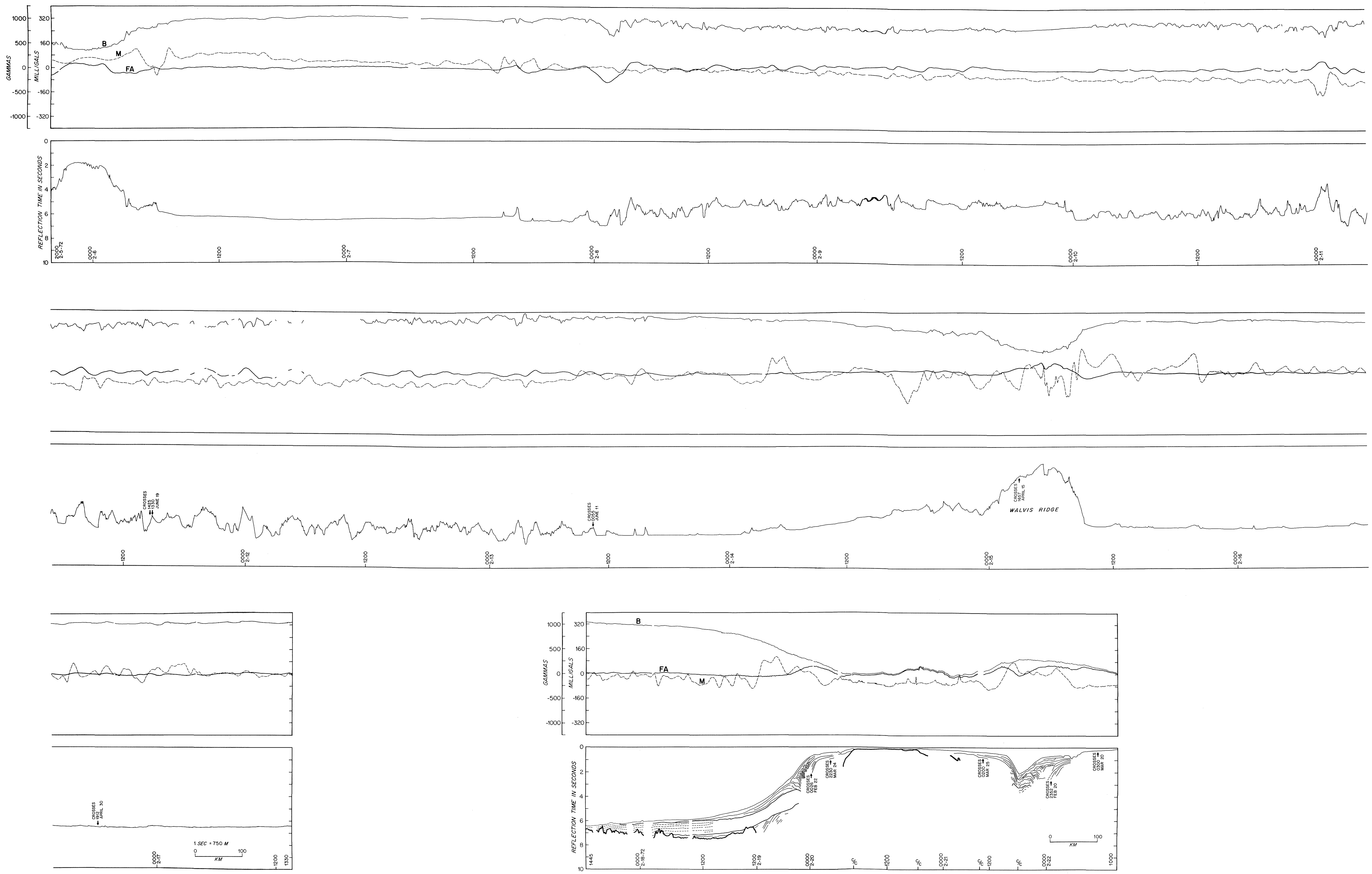
JAN 20 - July 1, 1972

A II 67

Lines 1-64

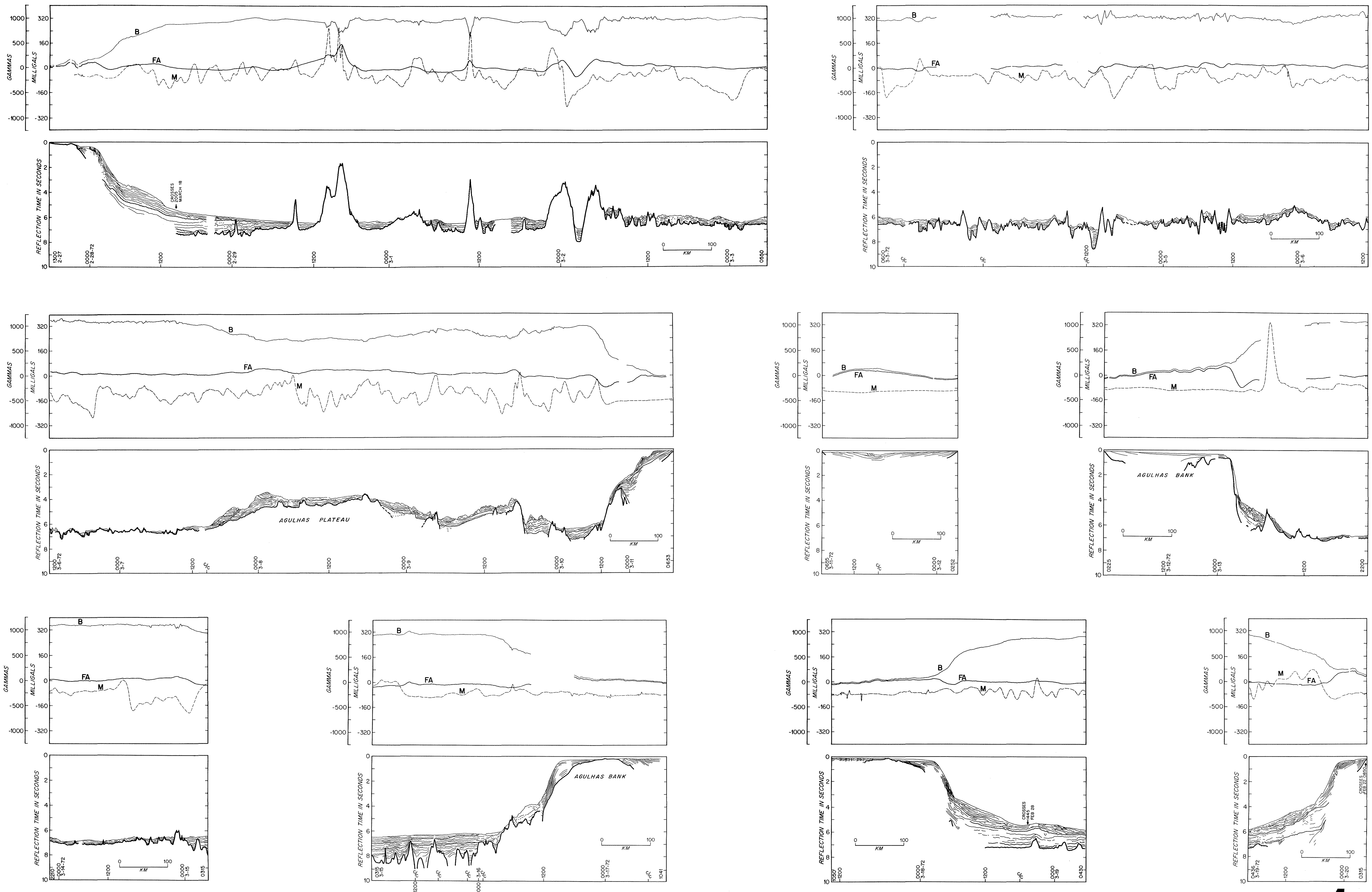


2

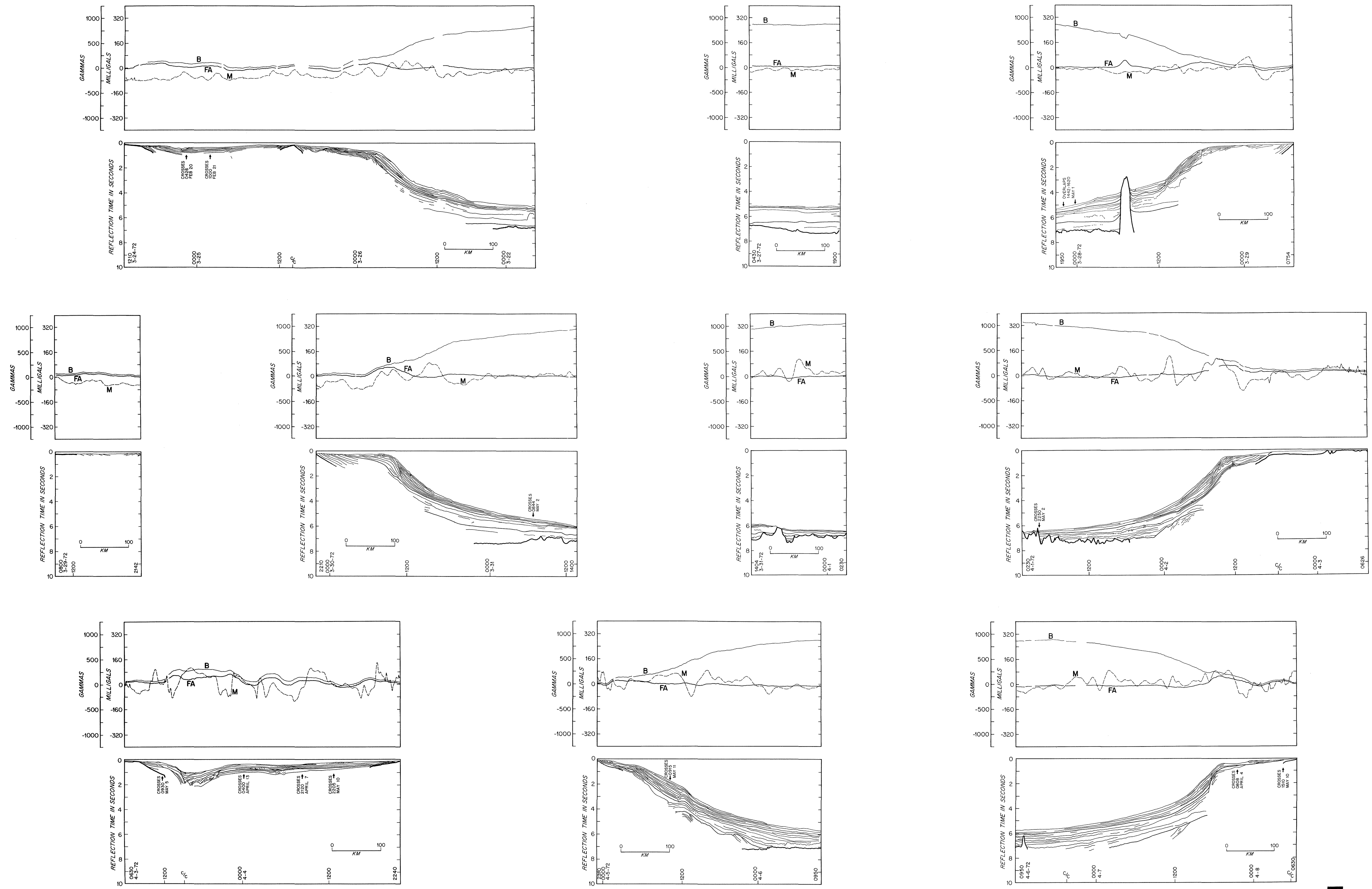


GAMMAS
MILLIGALS
1000
500
0
-500
-1000
320
160
0
-160
-320
B
M
FA
REFLECTION TIME IN SECONDS
0
2
4
6
8
10
WALVIS RIDGE
1 SEC = 750 M
0
100
KM

3


GAMMAS
MILLIGALS
B
FA
M
REFLECTION TIME IN SECONDS
KM
AGULHAS PLATEAU
AGULHAS BANK
CROSSES
MARCH 18
FEB 28

4



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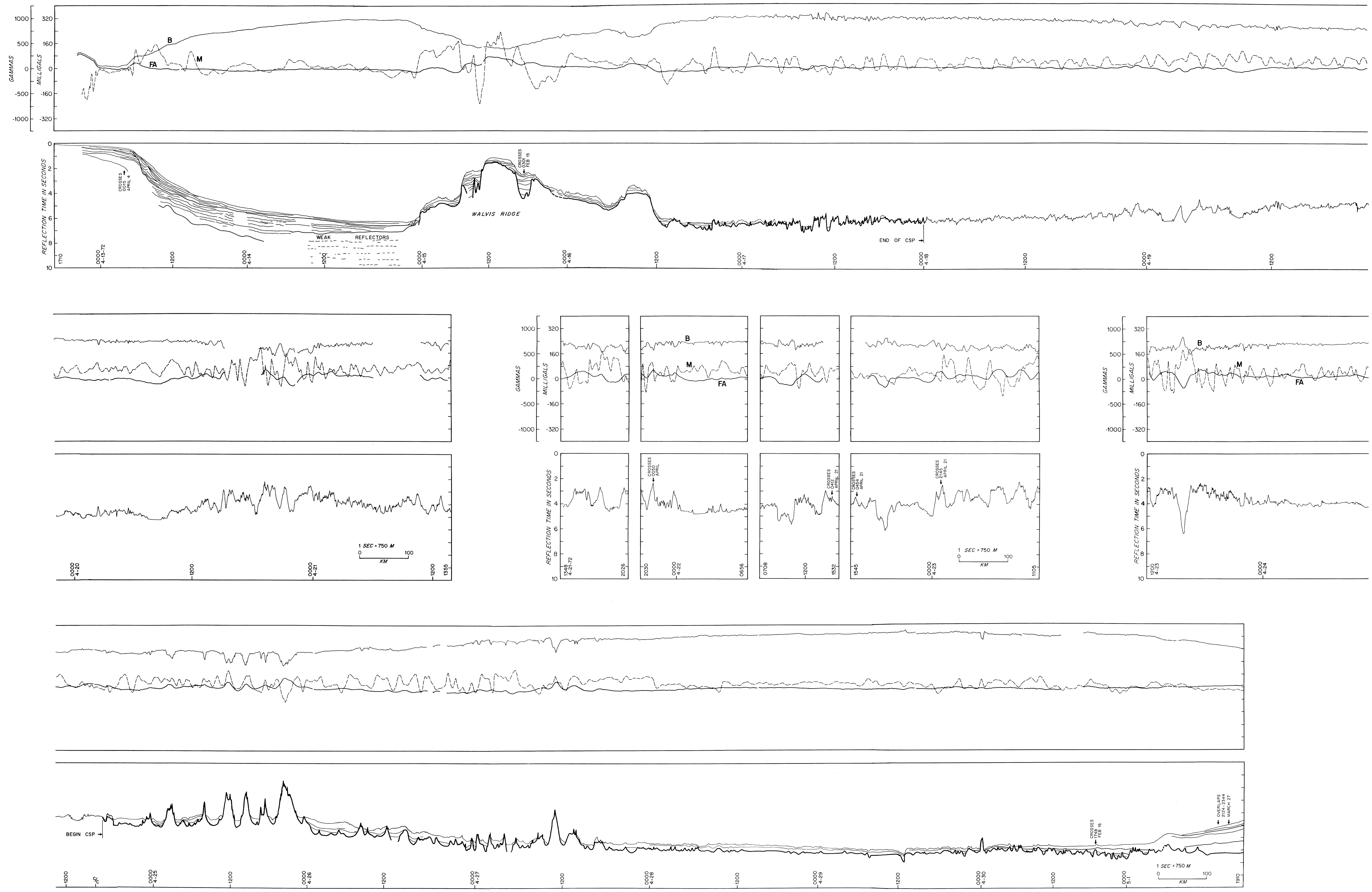
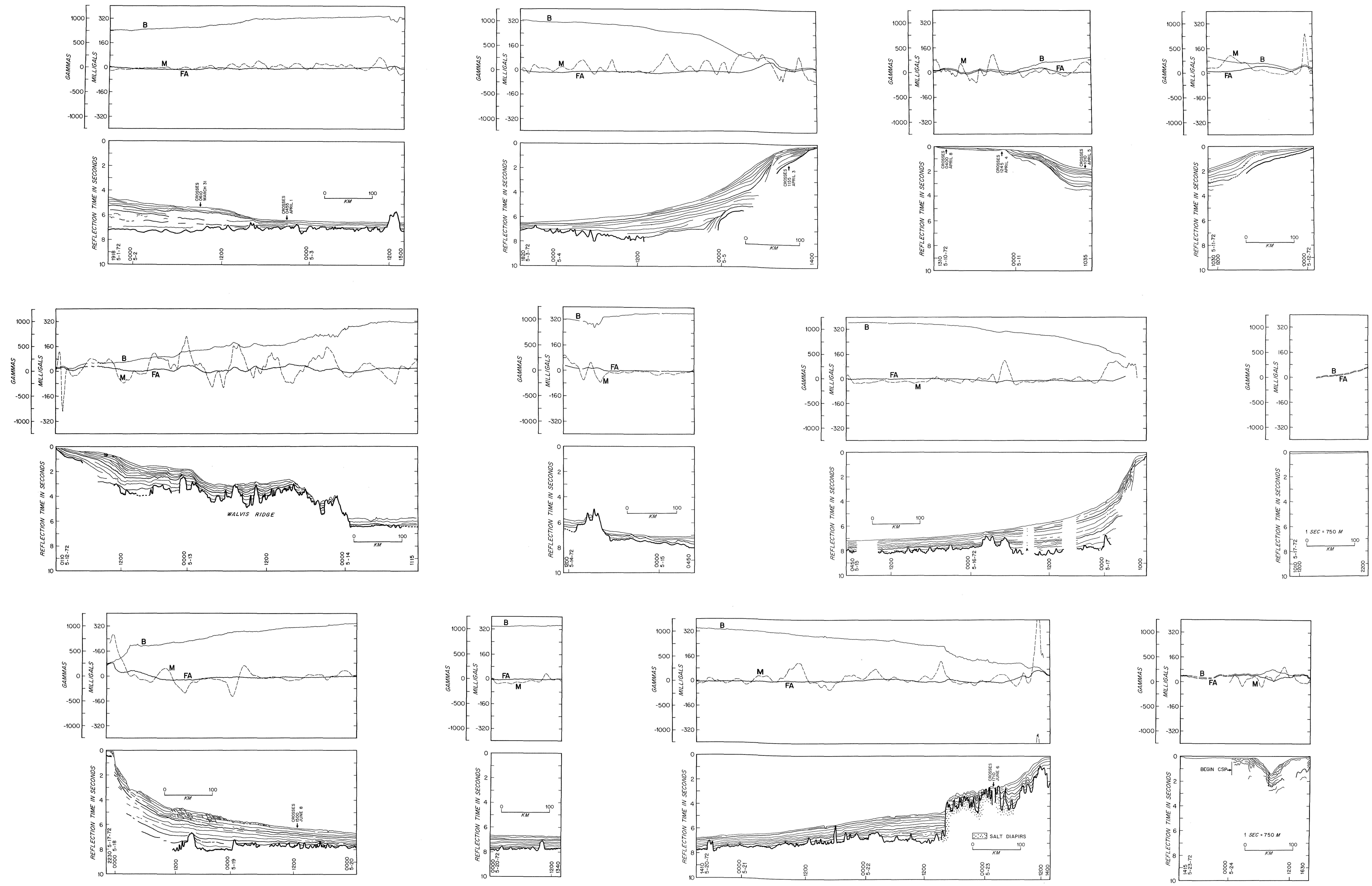
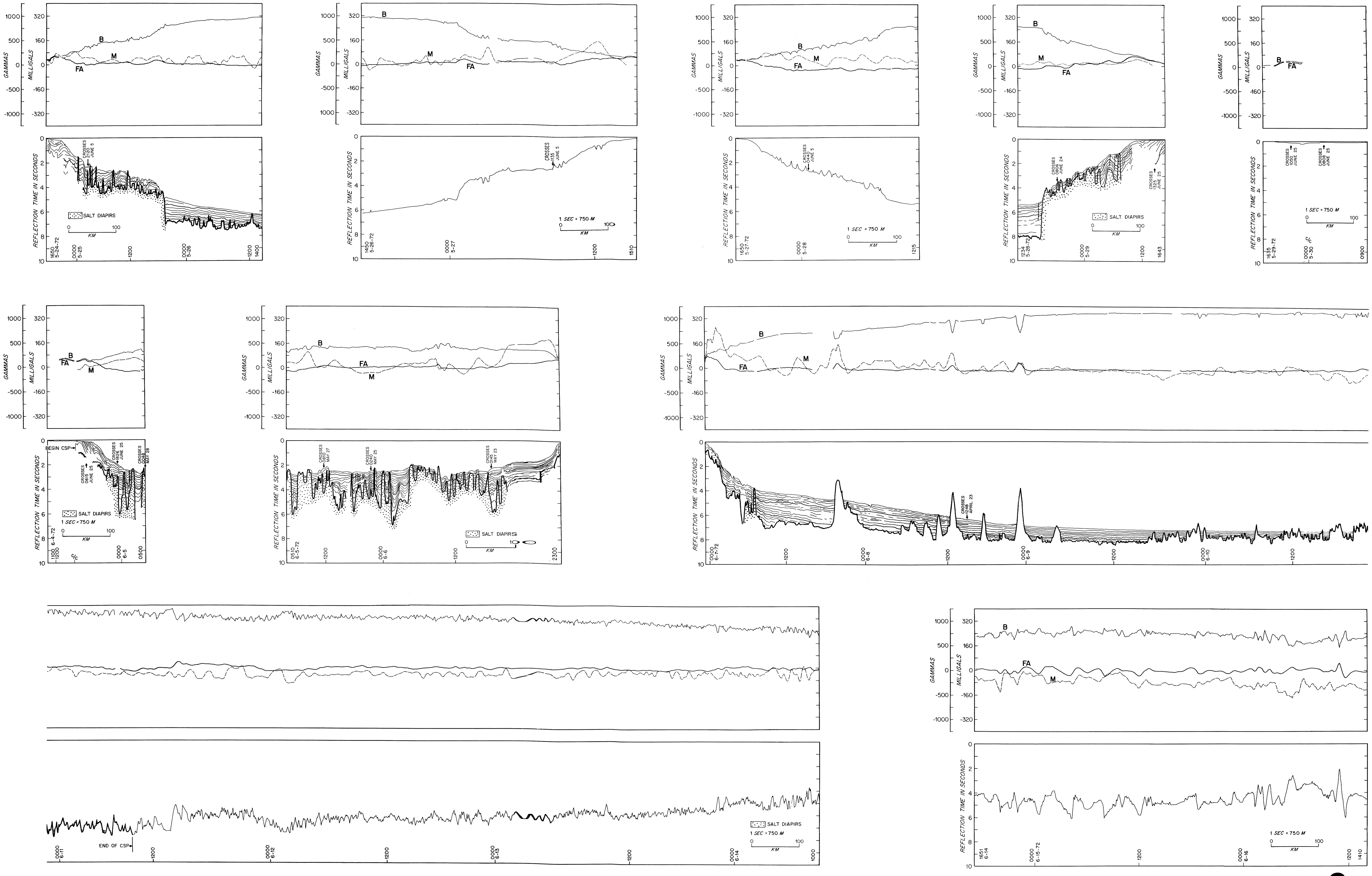

GAMMAS
MILLIGALS
B
M
FA
REFLECTION TIME IN SECONDS
WALVIS RIDGE
WEAK REFLECTORS
END OF CSP
BEGIN CSP
1 SEC = 750 M
KM

6


GAMMAS
MILLIGALS
B
M
FA
REFLECTION TIME IN SECONDS
KM
WALVIS RIDGE
SALT DIAPIRS
BEGIN CSP
1 SEC = 750 M

7



GAMMAS
MILLIGALS
B
M
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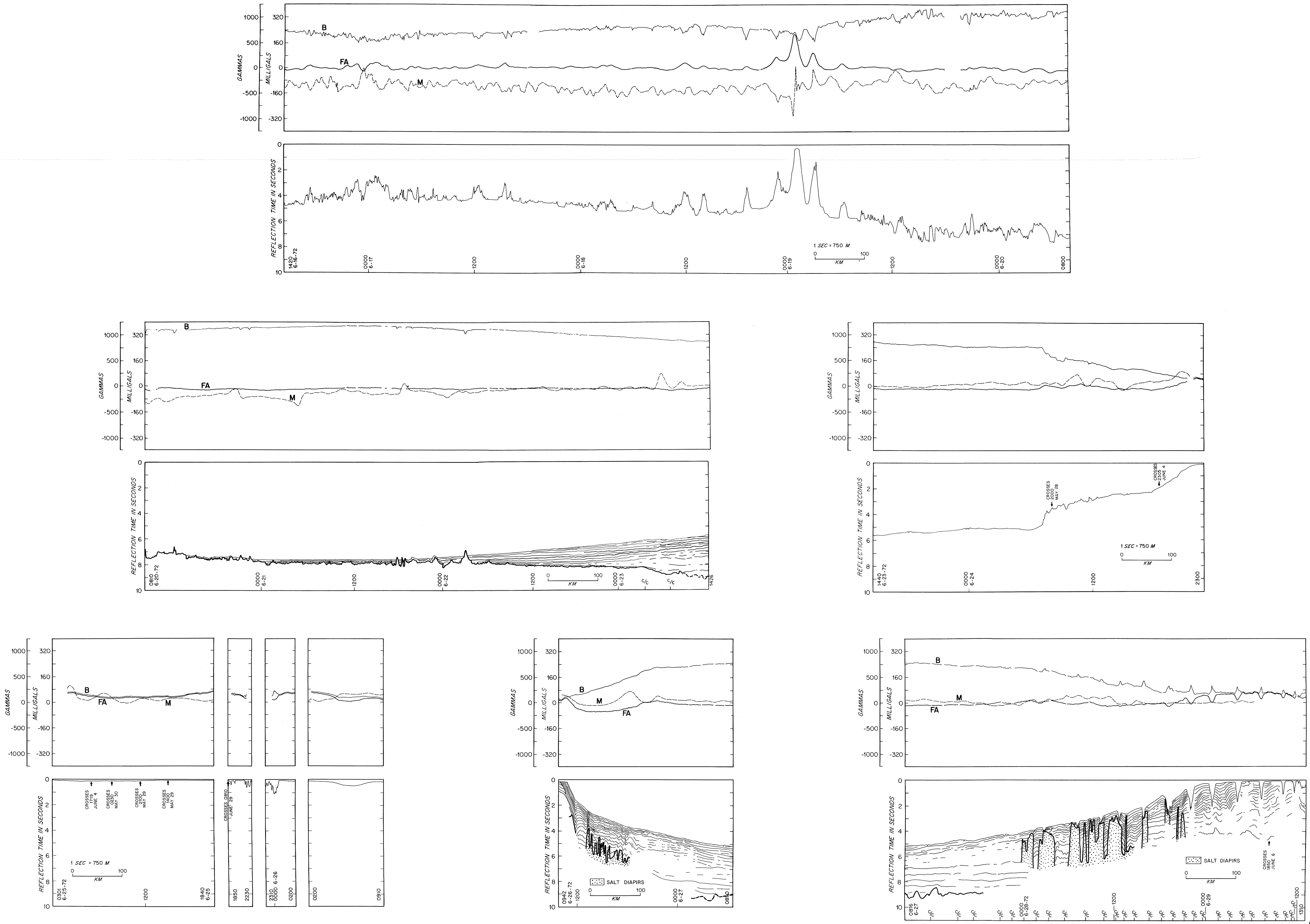
REFLECTION TIME IN SECONDS
SALT DIAPIRS
1 SEC = 750 M
KM
BEGIN CSP
END OF CSP

8


GAMMAS
MILLIGALS
B
FA
M
REFLECTION TIME IN SECONDS
1 SEC = 750 M
KM
SALT DIAPIRS

9