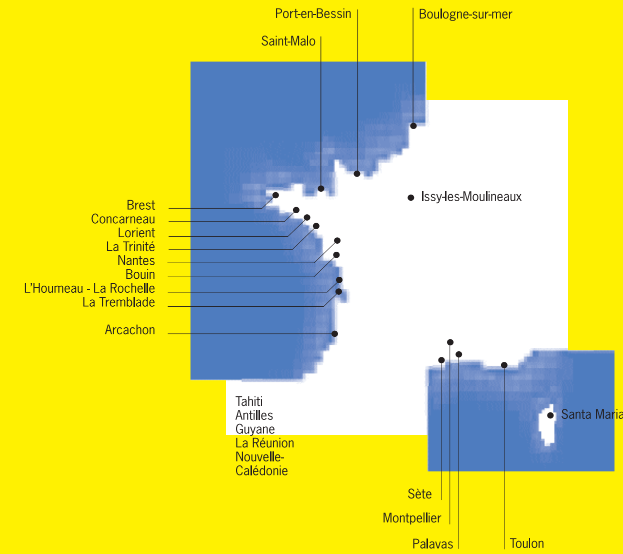

- Modélisation des écosystèmes côtiers
- Comportements des polluants
- Observation et surveillance de la mer côtière
- Gestion durable des ressources halieutiques
- Optimisation et développement des productions aquacoles
- Transformation, valorisation et qualité des produits de la mer
- Mise en valeur de la mer côtière et économie des ressources marines
- Compréhension de la circulation océanique
- Connaissance et exploration des fonds océaniques
- Grands équipements pour l'océanographie
- Génie océanique

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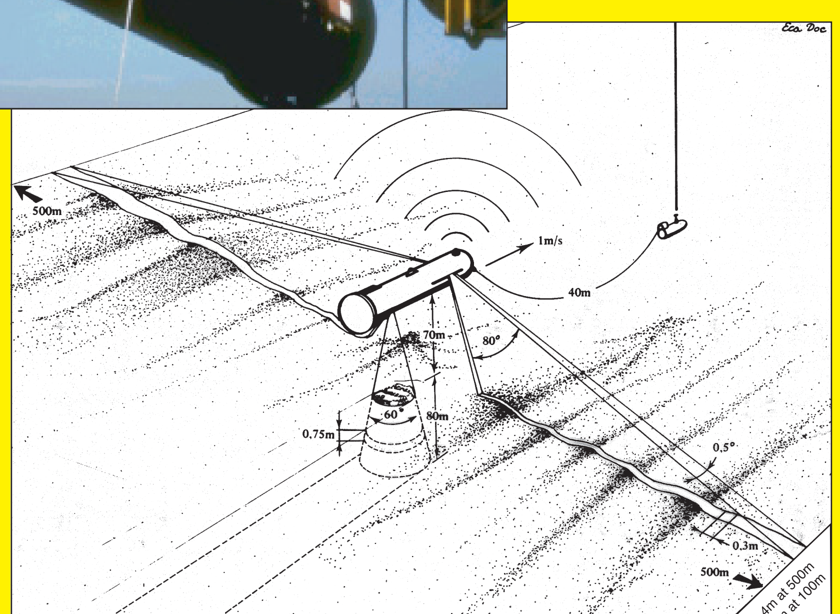

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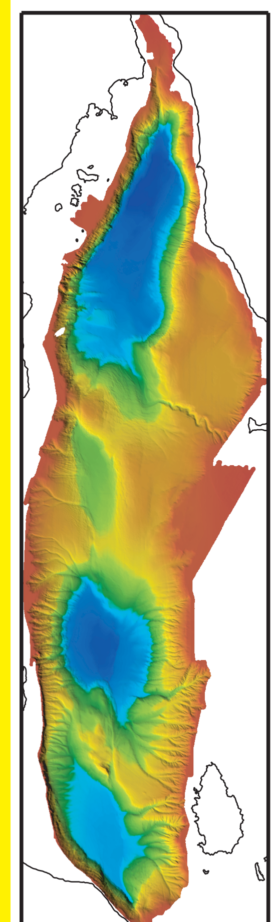
Marine Atlas of the Sea of Marmara

— Turkey —

Marmara Cruise
Le Suroît

September 2000



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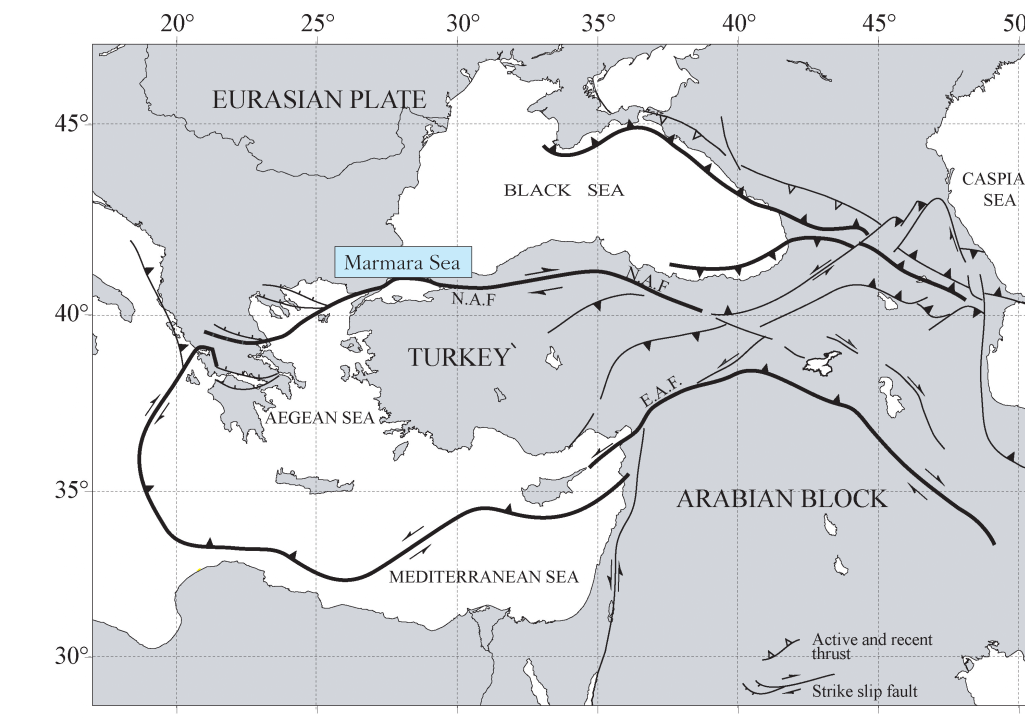

Chief scientists : X. Le Pichon, C. Şengör and E. Demirbağ

Atlas prepared by :

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Claude Rangin (CNRS-ENS), Emin Demirbağ
and Caner İmren (İTÜ)

Technical team :
Alban Crusson, Alain Normand
and Eliane Le Drezen (IFREMER),
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Data collected on board R.V. Le Suroît, September 2000

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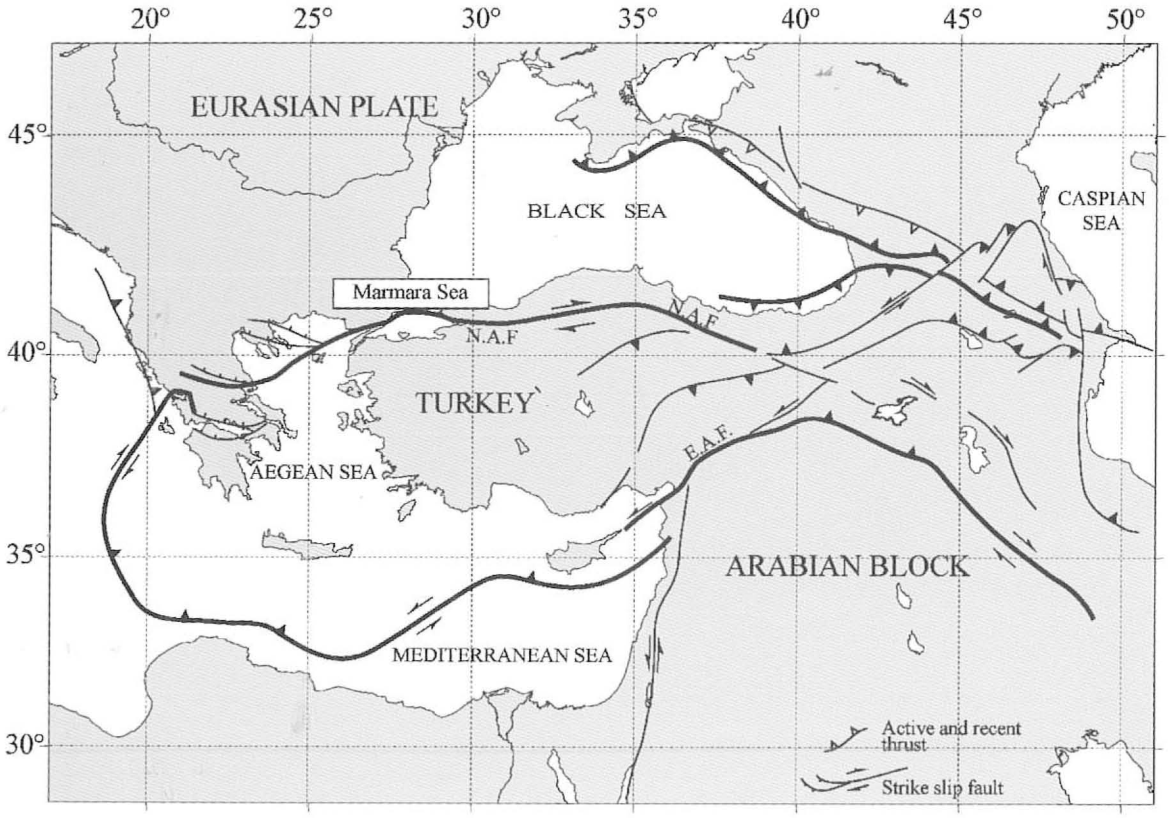

Data collected on board *R.V. Le Suroît*, September 2000

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INTRODUCTION

On the basis of seismic surveys made by the Mineral Research and Exploration Directorate of Turkey (MTA) and multibeam surveys made by the Department of Navigation, Hydrography and Oceanography (SHOD) of the Turkish Navy partly revealing the presence of active structures in the Sea of Marmara, a group of French and Turkish scientists planned a detailed and complete study of the northern Sea of Marmara where most of the sea floor exceeds 100 m depth with the following objectives:

Study the link between the İzmit Gulf active faults to the east and the Ganos fault to the west, both responsible for some of the most devastating earthquakes of west of Turkey in the last century.

To reach this goal we performed a detailed bathymetric mapping which allows us a 4 m contouring interval with a scale of 1/50000 equivalent to a precise topographic map made onland. For this we have used swath bathymetry tool EM 300 installed on board *R.V. Le Suroît.*

We present in this Atlas colored and contoured maps at two different scales, 1/250000 on plate 1 and 1/100000 on plates 2, 3 and 4. Selected three dimensional views of the bathymetry are also presented in plate 5. EM 300 generates also sea bottom reflectivity maps at the same scale that the bathymetry (plates 1 then 6, 7 and 8). This reveals scarps as well as hardness or softness of the sea floor on the basis of backscattering information. More precise imagery of some of the structures identified on the sea bottom were surveyed by a deep towed side scan sonar (SAR). Plate 9 provides an 1/20000 scale image of the Central Basin as an example.

We have also collected during the cruise various types of shallow penetration of about 400 m (500 ms twt), single channel seismic reflection data including:

- Sparker tool with source and receiver on the sea surface. Selected profiles are shown on plate 10.
- PASISAR deep towed receiver pulled by SAR vehicle providing finer image of the subsurface are presented on plate 11.

This booklet presents the technical aspects of the tools used on board and is also a guide to help some of the readers to understand the information presented here.

RV Le SUROIT
Basic characteristics

Lenght overall : 59.34 m
Overall breadth : 11 m
Max draught : 4.1 m
Max speed : 10 knots
Year of throwing : 1975
Year of mean overhaul : 1999
Ship's crew : 16 up 23 according to cruises necessities
Scientific team : 14 to 17

Scientific Navigation tools
2 DGPS receiver
Racal Marine Star device
Integrated navigation system : CINNA (Ifremer tool)

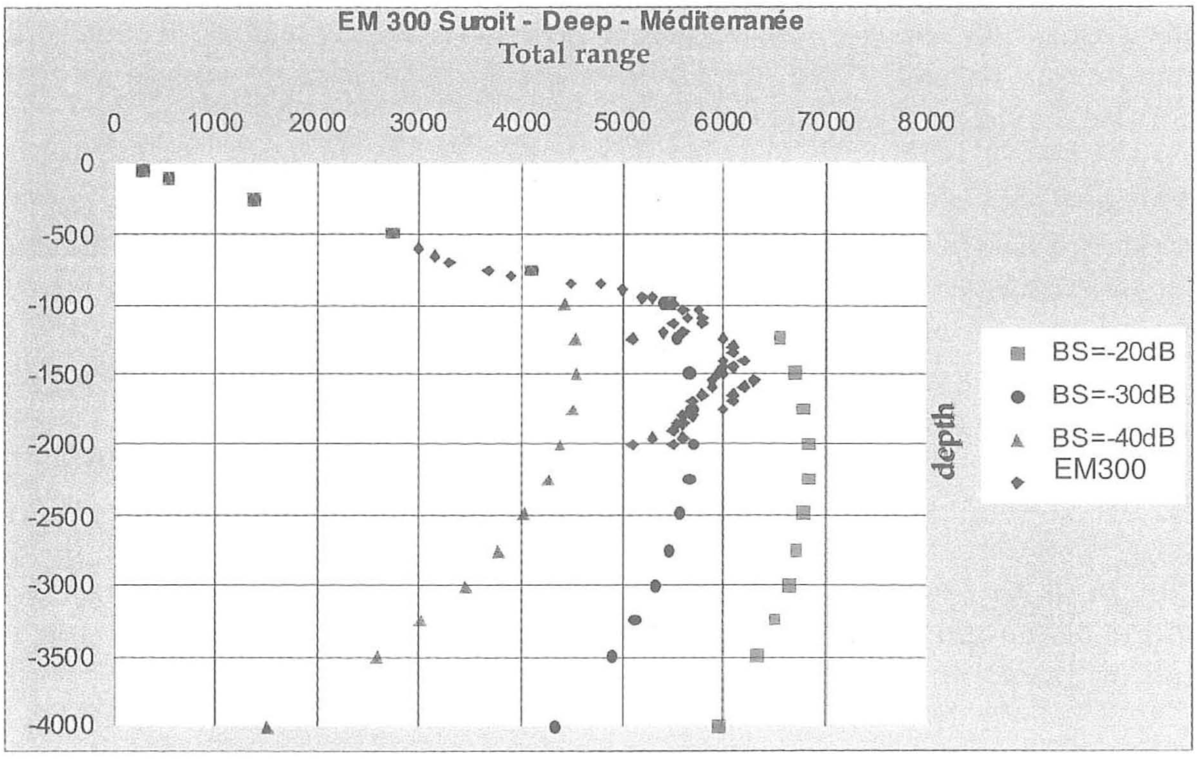
Scientific equipments
Mud penetrator (shirp)
ADCP RDI 150kHz
Thermosalinograph Seabird
Bathythermograph Sippican
Motion sensor and heading TSS-HDMS
Ultra short base : Posidonia TMS

Basic specifications of the EM300 :
Frequency : 30 kHz
Peak power : 4.5 or 9 kW
Pulse lengh : 0.7 or 2 ms (Marmara cruise), 5 or 10ms
Number of beam : 137
Beam width : 1°x 2°
Coverage sector : up to 150°
Depth range : 10 m to 6000 m

SIMRAD EM300

Multibeam echo sounder (Mbes) aboard RV/ Le Suroit. It is a medium Mbes designed for seabed mapping from the shoreline (10m depth) to beyond the continental slope. This capability has extended now to 6000m with a very narrow swath. This equipment get the last new development in signal processing. The nominal sonar frequency is 30kHz with an angular coverage of up to 150°, 137 simultaneous beams 1°x 2° (option on le Suroit). The angular coverage and beam pointing angles are variable with depth according to achievable coverage to always maximise the number of usuable beams. The transmit acoustic fan is split according to vessel roll, pitch and yaw to get a best fit to a line perpendicular to the survey line and thus a uniform sampling of the bottom.

Mode	Very Shallow	Shallow	Medium	Deep	Very Deep
Range	10 - 50m	30 - 300m	100 - 1000m	500 - 3000m	1000 - 5000m
Pulse lenght	0.7 ms	0.7 ms	2 ms	5 ms	5 ms
Longitudinale aperture	4°	2°	1°	1°	1°
Nb of transmit sector	3	3	3	9	9
Lateral aperture	150°	150°	150°	150°	100°



SAR (Système Acoustique Remorqué ; Towed Acoustic System)

The SAR is a high-resolution geophysical multisensor tool. The towed system is composed of a heavy depressor and a positive buoyancy vehicle. The operating depth is 150m to 6000m. The link between the RV is a armor coaxcial cable, the vehicle is linked to the depressor by an umbilical. (see plate 11).

SIDE SCAN SONAR : Range up to 750m each side (depend of the physical caracteristic of sea water and sea bottom), for the Marmara sea the limitation of the swath is 2x500m. Vertical beam 80° ; horizontal beam 0.5°, range resolution 0.3m.

Sub Bottom Profiler : frequency 3-4 kHz ; vertical resolution 0 .7m. maximum penetration range 80m.

3 axis magnetometer.

Navigation, Ultra Short Base : **Posidonia**

PASISAR (see plate 11 for more information)

In 1993, IFREMER, adapted a single channel seismic streamer to the deep tow side scan sonar SAR. The streamer is towed behind the SAR vehicle.
This tool called : Pasisar. This new seismic acquisition system combines a conventionnal source near the sea surface and a deep towed single trace streamer. This unconventional geometry reduces the width of the first Fresnel zone which increases the lateral resolution. The streamer, 20 m long, consist of a lead-in cable, two hydrophone arrays composed of 7 or 10 groups of 3 hydrophones (high and low frequency acquisition modes) and a tail rope attached to the far end.

The analogue seismic data are amplified inside the SAR vehicle and transmitted to the ship through the coaxial cable. The analogue signal are dizitized and recorded using a commercial seismic acquisition system (Savoye et al., 1995).

A specific processing sequence must be applies to the data to obtain a readable seismic section.

CARAIBES Submarine Mapping System

Since 1977, Ifremer develops submarine mapping software to process the data from the multibeam echosounders and the sidescan sonars. Their specifications are prepared in close collaboration with researchers and specialists in the signal processing and submarine acoustic fields. The development process benefits from a good technical environment : software engineering tools, simulation platforms, experienced subcontractors (CAP GEMINI), testing facilities at sea (research vessel L'Atalante, EM12 and EM950 multibeam echosounders, Le SUROIT EM300 multibeam echosounders, SAR sidescan sonar, Edgetech DF1000...).

CARAIBES is the Ifremer submarine mapping system. It is composed of two software : **CARAIBES_TD** for data post-processing and CARAIBES_TR for real time data processing. The software are object-oriented and developped in C++. They are based on ILOG Views and Vision class libraries for the user interface, 2D and 3D visualizations, data structure manipulation, NetCDF (UCAR/Unidata) library for file format specification and manipulation and Ifremer CARTOLIB++ library for the cartographic computations and visualizations.
CARAIBES_TR is a real time software installed on board the survey vessel.
For more information, we suggest to browse through our internet server **http://www.ifremer.fr/caraibes/**

CARAIBES_TR main functionalities

- real time acquisition and archiving of the bathymetry and sonar image data from the multibeam echosounders,
- velocity profile production for use by the multibeam echosounders,
- multibeam echosounder calibration by computation of the heading, yaw and pitch biasses on test profiles,
- real time cartographic visualization of the bathymetric data displayed as colored isobaths along the ship navigation.
- real time cartographic visualization of the sonar data from the multibeam echosounders and sidescan sonars, displayed as an image mosaic.

CARAIBES_TD main functionalities

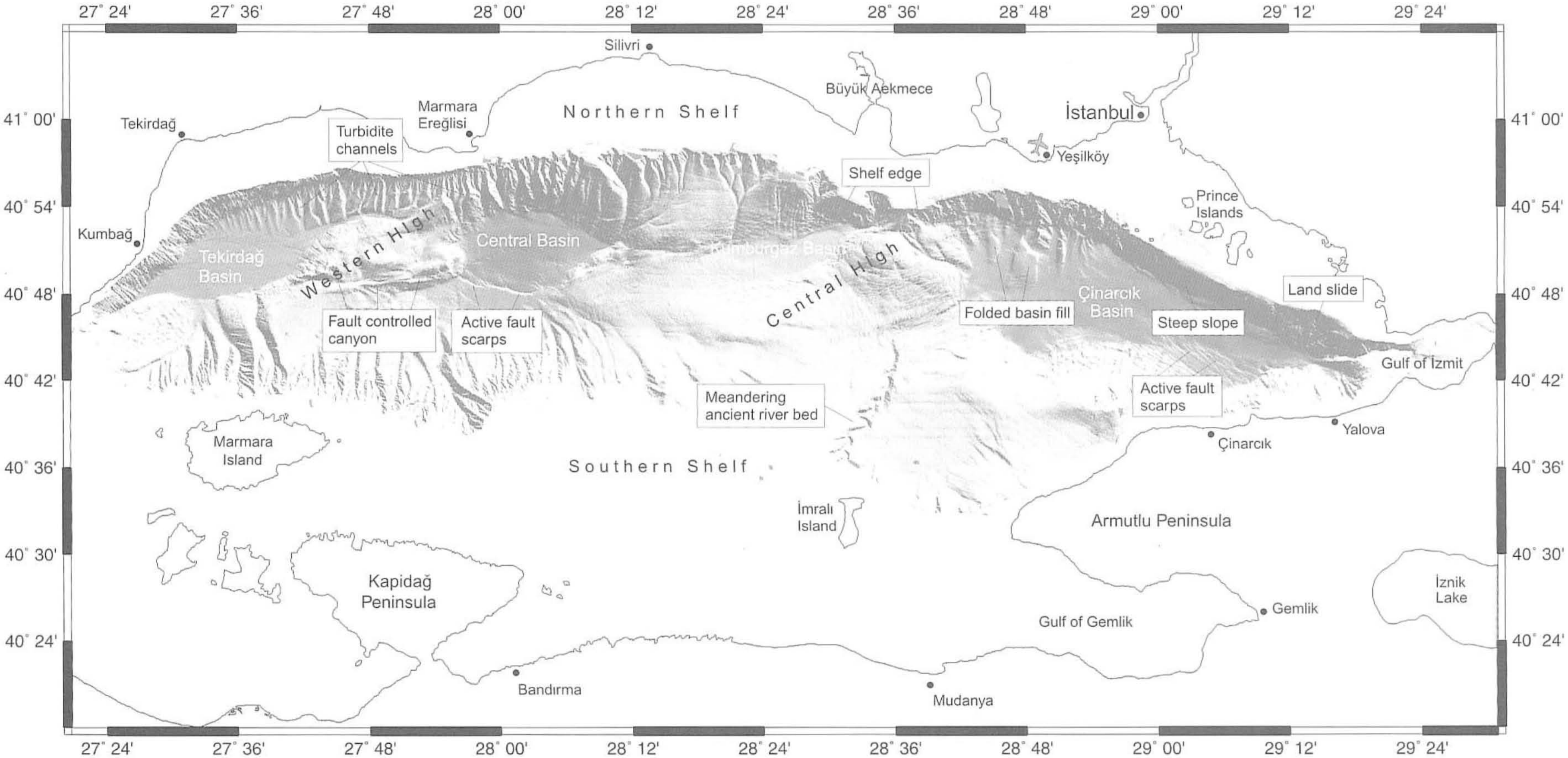
CARAIBES_TD is a post-processing software used by cartographic laboratories ashore or offshore. It offers a large panel of sidescan sonar and multibeam echosounder bathymetry and image processing modules. These modules can be integrated in a processing flow using a processing flow editor, the outputs of a module being used as inputs to the next module in the flow. Once saved, these flows allow to perform serially several operations on a dataset.

The **BATHYMETRY** processing modules offer the following functionalities :

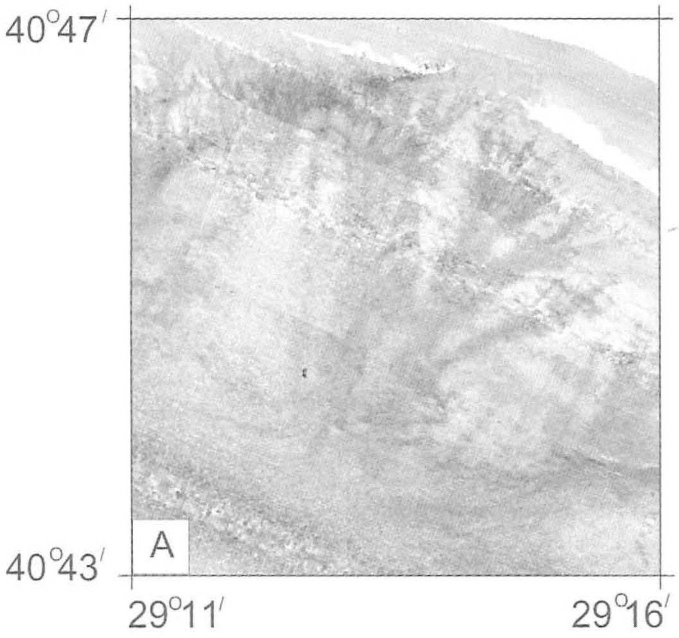
- on the raw bathymetric data
- on the projected bathymetric data
- on the digital terrain model (DTM)

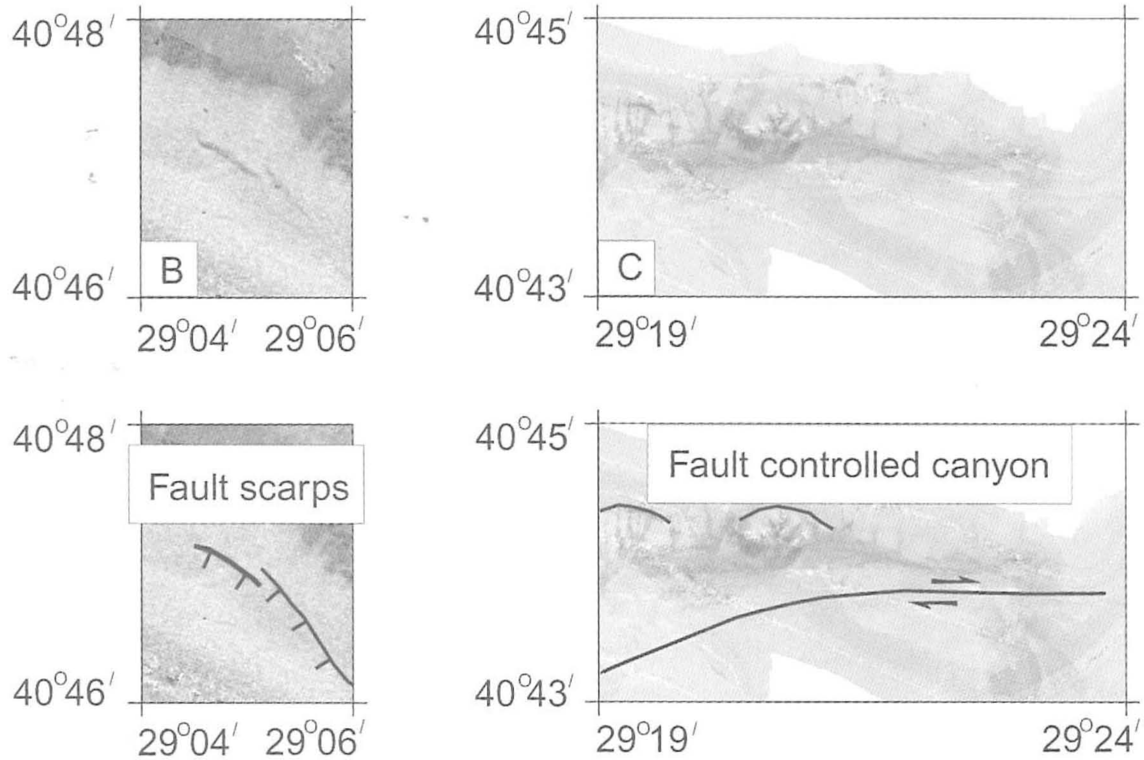
The SONAR IMAGE PROCESSING modules offer the following functionalities :

- on the multibeam echosounder and side scan raw data
- on the projected sonar image data.



This gray scale bathymetric image of the Sea of Marmara was formed with an illumination source from the northeast. The northern looking slopes appear brighter than the southern looking ones, and the distinct basins are darker than the highs. This image reveals significant details in the submarine morphology that appears to be controlled both by erosional processes, gravitational collapses or active faults. (i) Erosional processes : within this category we observed first, numerous canyons that dissect the steepest slopes and some of the highs. Some of these canyons are flowing directly downslope as observed on both flanks of the westernmost part of the Marmara Sea (Tekirdağ and central basins) or are slightly deflected westwards by the prominent central high. These generally N-S elongated canyons are using a direct pathway towards the deepest part of the basin, and are evidently not controlled by active structures. These canyons are the main feeders for the turbiditic infill of the deep basins. Another type of these underwater flowing system is the large meandering canyon flowing northward from İmralı Island. This canyon that dissects an old erosional surface could be the trace of an ancient river bed, now submerged. (ii) Collapse stuctures: a large curvilinear feature affects the SE end of the straight wall bounding the Çinarcık basin towards the north. This feature is probably the scar of a large landslide that has recently affected this area located immediately west of the Gulf of İzmit This type of landslide could be a response to the slope instabilities generated by the active seismicity present along the North Anatolian Fault. (iii) Active tectonic processes : E-W trending canyons dissect the western and central highs and do not follow the slope gradient. This type of linear scar is the trace of a major fault that extends continuously from 28° 36'E to 27° 24'E along most of the western part of the Marmara Sea. This is the most spectacular evidence of the active Marmara strike slip fault zone evidenced on the sea bottom (labeled as "Fault controlled canyon" on the figure). Other scarps in the central deep basin and Çinarcık basin are also indications of active faults due to the sharpness of the scarps (labeled as "Active fault scarps" on the figure).





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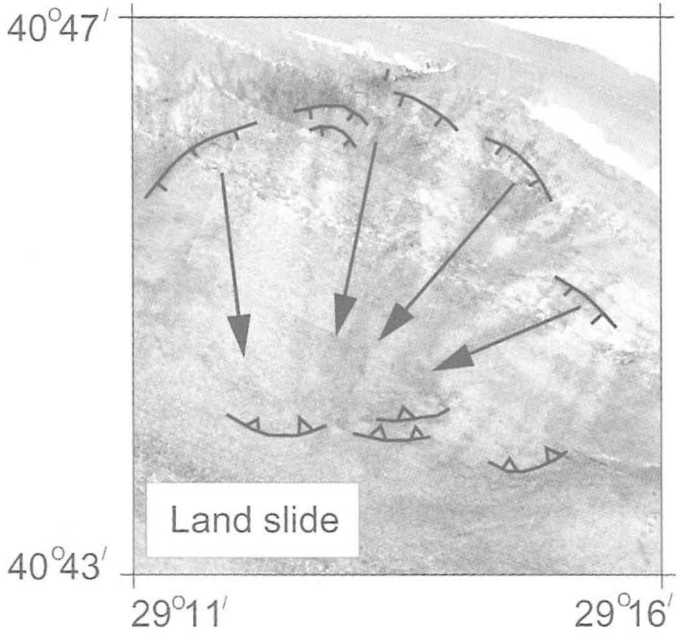
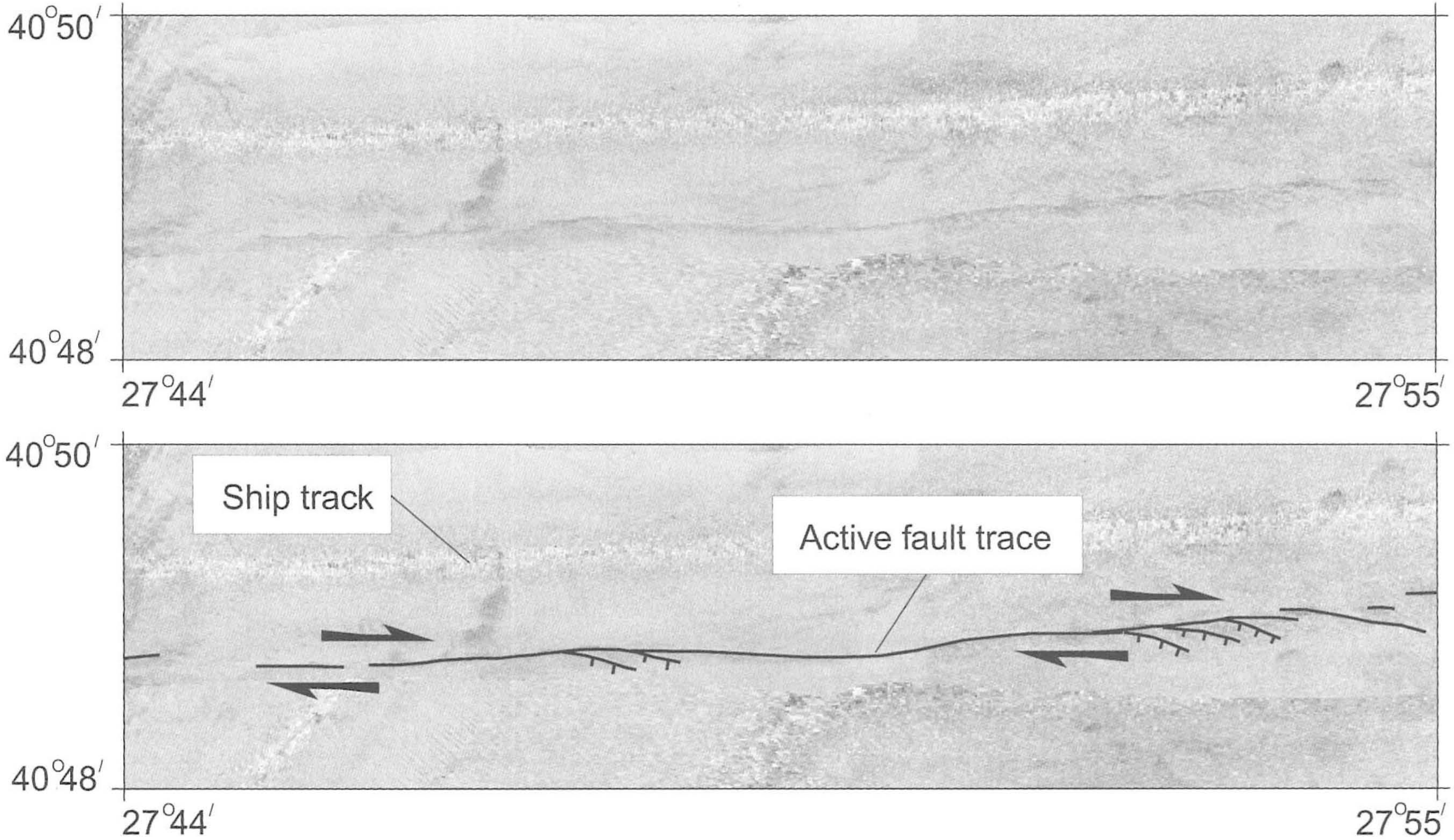
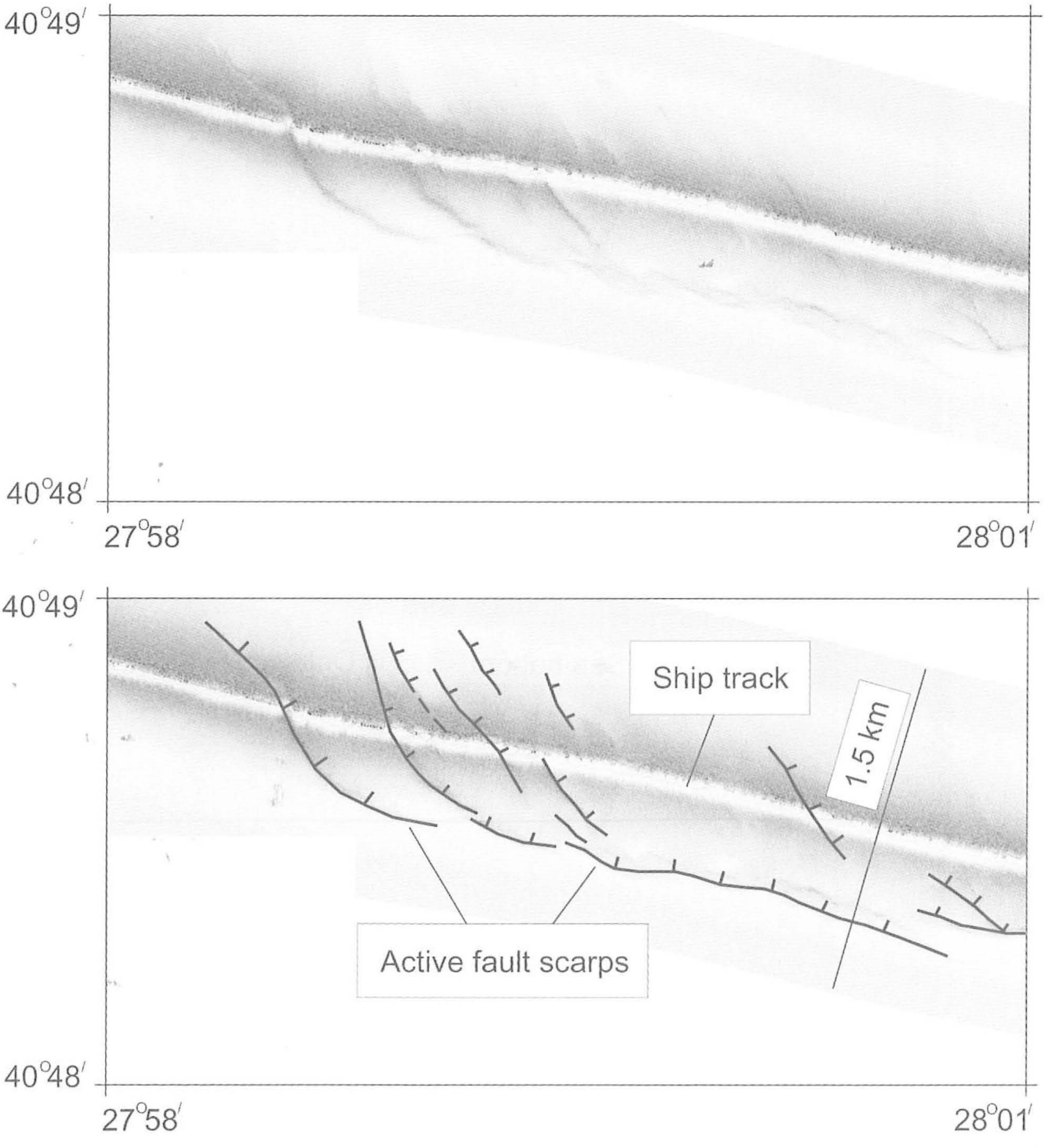


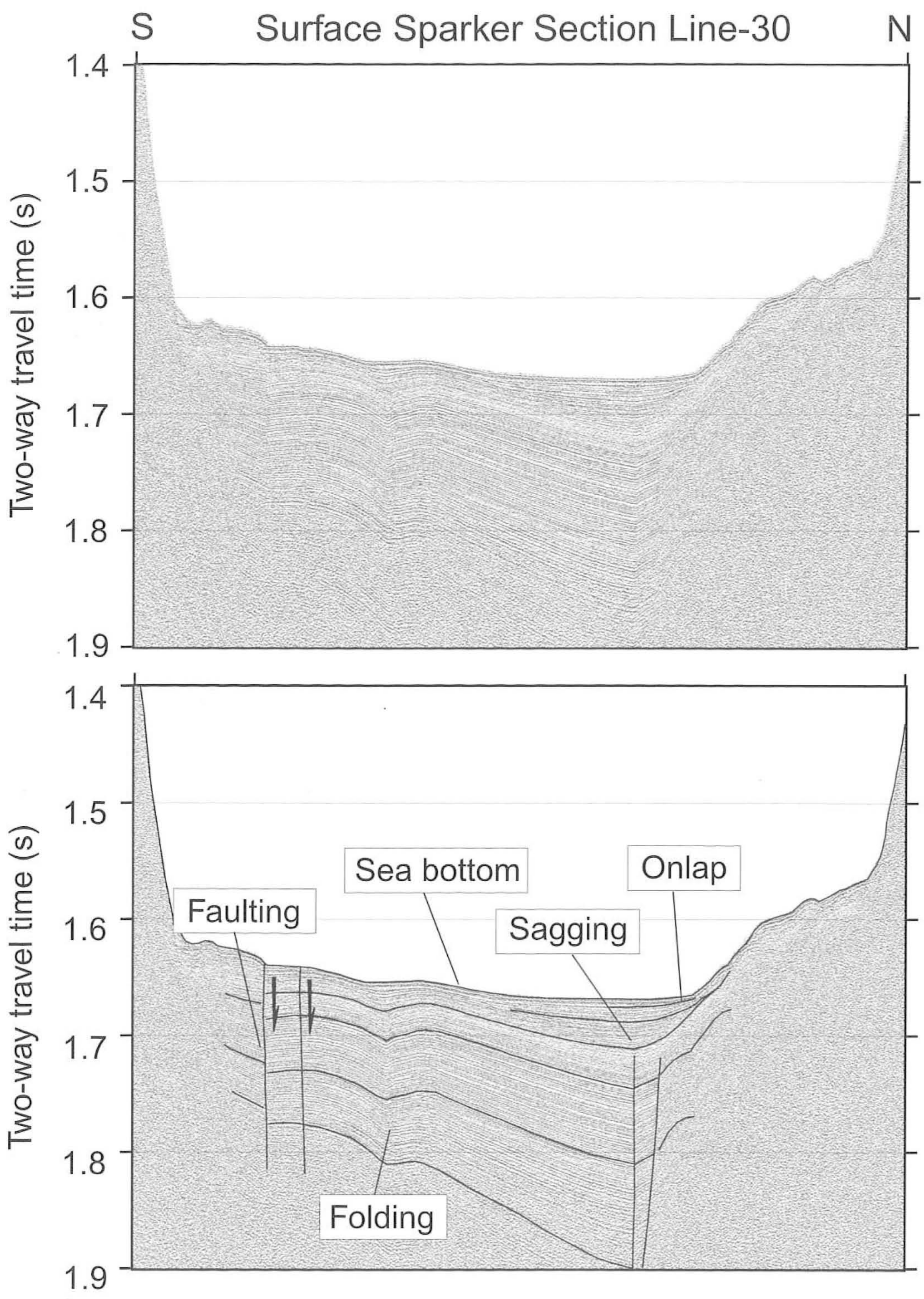
Details of the processes described in page 8 but imaged here on the reflectivity. The top figures display the features and the bottom ones show how the images are interpreted from geological and geomorphological point of view. In A, the landslide is located on the steep northern slope of the Çinarcık basin. A huge mass of chaotic sediments was detached from the upper part of the slope along curvilinear normal faults (indicated by ticks). Transport of sediment mass is indicated by arrows. The sliding sediment package is inducing moderate thrusting (indicated by diamonds) at the toe of the slope. In B, sharp scarps are the traces of recent small normal faults. These en echelon faults are found along the foot wall of the steep slope bounding the Çinarcık basin towards the north, testifying for its tectonic activity. In C, the fault controlled E-W elongated canyon observed at the entrance of the Gulf of İzmit is the offshore western extension of the İzmit fault observed on land, responsible for the August 2000 devastating earthquake. The fault is located along the southern flank of the canyon. It induced small landslides along the northern slope (arrows indicate the sense of motion along this fault).



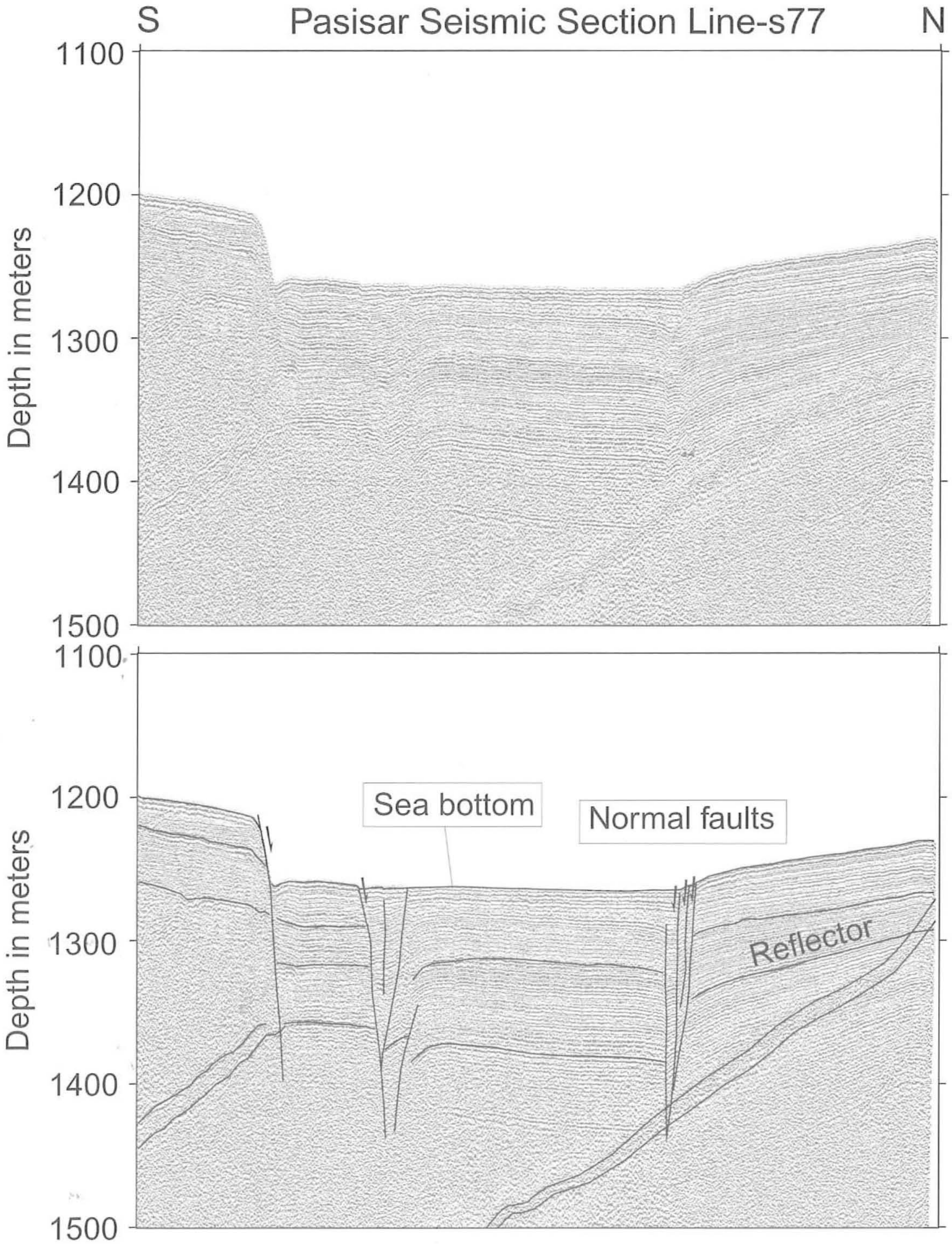
Bottom reflectivity image of the active E-W trending dextral vertical fault cross cutting the western high. The top figure shows the image and the lower one is its tectonic interpretation. The linear trace of the fault that transects the whole western high is actually composed of short en echelon segments branching on horse tailed normal faults that do not alter the global continuity of the structure. Arrows indicate the sense of motion along this vertical fault. The central beam of the EM300 is labeled "ship track". Black spots are either debris flows or pock marks ventilating methane gasses along the major fault.



Example of a SAR image from the central basin. The swath width is about 1.5 km. The figure above shows the active fault scarps along the southern part of the central basin. The lower figure shows the tectonic interpretation of the image.



An example of a single channel seismic reflection sections from Çinarcık basin. This N-S section crosses the Çinarcık basin and displays the major active structural elements. The uppermost reflection level represents the sea bottom while lower reflection levels represent sedimentary layering in the basin. To the south of the section, the continuity of the reflectors are cut by normal faults so that the reflection packages are displaced vertically, whereas to the north the presence of a flexure (sagging) in the sedimentary layers indicate a deep seated vertical (strike slip) fault at the toe of the steep northern slopes of the Çinarcık basin.



An example of a single channel Pasisar seismic reflection section from the Central basin. Pasisar seismic data were processed by unconventional means and displayed as depth sections. This N-S section crosses the Central basin and shows the major active structural elements. The uppermost reflection level represents the sea bottom while lower reflection levels represent sedimentary layering in the basin (labelled as "Reflector"). On the section, the continuity of the reflections are abruptly cut by a series of normal faults so that the reflection packages are displaced in vertical downfaulted compartment as indicated by an arrow. Interfering multibeam signal is confined by a lane of oblique lines.

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