Appendix A
Surveying

As in previous Duck experiments, surveying was a critical part of DELILAH. The CRAB was used to locate the instrument pipes and to survey the minigrid area. An additional survey was conducted of the bathymetry surrounding the FRF, out to a water depth of 13 m, using a combination of the CRAB and a survey sled. In this survey, referred to from here on as the “13-m-deep” survey, the sled was towed behind the FRF's amphibious Lighter Amphibious Resupply Cargo (LARC). Presentation of the data and descriptions of this survey and the minigrid surveys, as well as details about the survey equipment and sources of error follow.

Coordinate System

All survey data were collected relative to the FRF coordinate system, which has its origin located behind the duneline near the southern boundary of the FRF property. The baseline of this system (cross-shore distance = 0) is perpendicular to the FRF pier and is aligned 20 deg west of true north. Elevations were measured relative to the National Geodetic Vertical Datum (NGVD) of 1929. This datum is 0.42 m above Mean Low Water.

Survey Equipment

All DELILAH surveying was conducted with either a Zeiss Elta 2s® total station or a Geotronics Geodimeter 140-T® auto-tracking total station. Problems developed with each of these instruments, and it is important to understand what the problems were and their impact before using the DELILAH survey data.

Zeiss Elta-2s

The Zeiss system incorporates in one compact unit a first-order electronic theodolite, distance meter, microprocessor, rechargeable power supply, and an interchangeable solid state memory module. The instrument is manually aimed at a reflecting prism and a collimated infrared beam measures the distance and the electronic theodolite measures both horizontal and vertical angles. The microprocessor then uses these measurements plus the coordinates of the instrument to compute X, Y, and Z Cartesian coordinates of the prism (corrected for earth curvature).

The ELTA-2s was primarily used for positioning the instrumented sled, the instrument pipes, and for beach surveying. It is classed as a first-order survey instrument with 0.6-sec horizontal and vertical angle reading accuracy. Unfortunately, it began malfunctioning during the latter half of the experiment with some impact on the positioning of the instrumented sled. The errors resulted from a problem in the horizontal rotation of the instrument and were easily identified as inconsistent changes in horizontal position.

Geotronics Geodimeter 140-T

The Geodimeter 140-T (Figure A1) consists of an electronic theodolite, distance meter, tracker, joystick, and cables. The system is designed to track the position of a moving object with the aid of a servo unit, which permits automatic motorized rotation of the instrument in the horizontal and vertical directions. The angle and distance measuring unit is both mechanically and electronically connected to a top-mounted tracker unit. The initial aiming of the instrument is controlled by a joystick. Once locked onto the prism array mounted on the CRAB, the Geodimeter 140-T continues to follow it.

Figure A1. Geodimeter 140-T

With the auto-tracking ability of the Geodimeter 140-T, the CRAB was able to move continuously, obtaining position information every 2-3 m along the survey transect. Data were collected by a shore-based personal computer, and steering information was radioed to the driver. The Geodimeter was put into use at the FRF early in 1990 and the DELILAH surveys were the first real production surveys with the instrument.

A combination of unfamiliarity with the instrument and several unique quirks resulted in problems processing and interpreting some of the Geodimeter survey data, particularly the 13-m deep data. The problems affect elevation measurement. There were three types of problems.

One of the instrument errors of the Geodimeter results from the separation of the tracking unit and the angle measurement unit. For accurate vertical measurements, the two units must be parallel. Instead of attempting to fine adjust the parallelism, the angular error was computed based on targeting a fixed prism of known elevation. This *vertical angle correction* was then applied to the measured vertical angle in the collection software. It wasn't learned until later that the correction angle changes during the day, especially on hot days. Although checks of the vertical angle correction were made, they were not made frequently enough to fully remove the error. This vertical error increases with distance from the instrument. Over a distance of 1,000 m, a 20-s angle error, if uncorrected for, would result in a vertical error of 10 cm (elevation checks were also made with the ELTA-2S, but there were no vertical problems with the Zeiss data) .

Another error associated with the vertical angle correction occurred when there was slight shifting of the instrument out of level (probably due to differential heating) during full days of surveying. Some of this movement is automatically compensated for by the Geodimeter, and it is designed to stop acquiring data if the instrument tilts outside the range of the internal compensator. However, it was determined well after DELILAH that this applies only for the horizontal compensation, not for the vertical. Consequently, even when tilted, the instrument continued to collect slightly erroneous vertical data with the only indication being an off-centering of the bubble level. Because the operator watches a computer screen, and not the bubble level, a tilted instrument could go undetected. From the beginning, this error was minimized by sheltering the Geodimeter with an umbrella or by setting it up in a "dome shelter" located on the roof of the FRF building. Unfortunately, during the first year of use, some of the out-of-level errors were wrongly corrected for by recomputing the vertical angle correction, thus compounding the error. This type of error manifests itself as an offset of the survey data that increases with distance from the instrument. In several cases, the survey data for one or more profile lines collected in sequence shifted during one survey and then unnaturally shifted back for the next and later surveys. When this shift was significant, the data were adjusted accordingly.

A further source of error was vertical oscillations of the Geodimeter which occurred because of an improperly adjusted tracker amplitude. This resulted in jagged data with an oscillatory amplitude of a few centimeters. Although the data follow the true profile shape, it is difficult to remove the oscillations since they are <u>not centered</u> on the true profile. At its worst, the tracker would drift completely away from the prism and temporarily lock onto a horizontal plane above the actual position of the moving prism for a short distance before reacquiring the prism center, resulting in a “step function” appearance to the data. These problems affect the nearshore data of some of the profile lines from the September 1990 CRAB survey that is part of the 13-m-deep survey data and affected several of the minigrid surveys. These errors were not a problem in most of the minigrid data and are not to be confused with the megaripples, which were reliably surveyed on many of the profile lines. Data affected by these oscillations are characterized by small oscillations along the entire profile line with no smooth regions. Major changes caused by the tracker drift were identified by overlaying all surveys of each profile line and deleting points that fell outside the overall envelope or had a “step” shape to them when compared to subsequent surveys of the same line.

While these Geodimeter errors are unfortunate, their impact on the minigrid survey data is seldom >±15 cm in the vertical and is typically <±10 cm.

Because of the height of the prism, data affected by the tilt of the CRAB on steep parts of the profile (particularly the foreshore and the bar slopes) were adjusted using an iterative technique in the analysis. The measured slope was used as a first guess to adjust the data points both horizontally and vertically. A new slope was then determined and a second pass, if required, was made. On a 10E slope typical of the beachface, the tilt can result in a +20-cm vertical adjustment to the data.

13-m-Deep Survey

The first 13-m-deep survey was conducted on 1 May 1990, followed by subsequent surveys on 2, 8, and 27 August 1990. All of the surveys were conducted with the Geodimeter 140-T, which was located on the end of the FRF pier and which tracked the sled as it was towed behind the LARC.

The final 13-m deep bathymetry data were acquired on six different dates and include sled data from the three dates given above and CRAB survey data from the September FRF 26-line bathymetry survey and a preliminary minigrid survey on 19 September 1990. Unfortunately, the CRAB and sled data do not overlap well, resulting in discontinuities where the data sets meet. The difference is usually less than 20 cm, but the effect is quite pronounced on the bathymetric chart and on specific cross sections (an explanation for the discontinuities is given below). The most serious discontinuity, and the largest data gap, is around the 8-m pressure gauge array location. Neither the CRAB nor the sled were normally driven through the 8-m array. A special deepwater parallel pass was made alongside the array with the CRAB, but not until January 1991. In order to fill the data gaps in a reasonable way, a very large "search" area had to be defined in the gridding routine which was used to plot the data. This has the adverse effect of overly smoothing all of the data, particularly the irregular bottom found in the 10-to 13-m depth south of the pier.

Problems with the sled were also encountered. These resulted primarily from the sled tilting sideways while on a turn, or backward when under tow. During the surveys on 2 and 8 August, strong currents caused the sled to tilt sideways when it was under tow. Consequently, these surveys were not used in the final data set unless they provided the only coverage of an area. Sled tilt results in a vertical error, which can show up as either a bump or a hole. If the tilt occurred gradually, it was difficult to identify and correct.

Because of these problems, the data processing included rechecking and recomputing the data points based on a reanalysis of the vertical angle correction data for each day (any out-of-level errors were not corrected for). Data with nearby coverage from the same or different days were overlaid and compared. The plan view and the cross-section view of each profile line were examined and suspect points, indicated by wide variations in depth between adjacent points, were removed. Where data from two surveys overlapped and didn't match well, data that best fit the rest of the data were retained. Confidence in a particular survey was determined by the overall smoothness of the data (no Geodimeter oscillation) and from the frequency and quality of the vertical angle error checks. Most of the data from the 1 May 1990 and the 27 August 1990 surveys were kept. Data were deleted if there was evidence of sled tilt. Finally, the large gap in the data at 1,280 m longshore and 900 m cross-shore was filled with data from 1,100 m in the longshore. To reduce the total number of points only the median depth value of every three data points along a line was kept (limited by a maximum allowable distance and vertical change). Still, the raw data file includes over 10,000 points. It should be noted that all of the errors described in the 13-m-deep survey section result in less than 30 cm vertical error at the outer edge of the survey region.

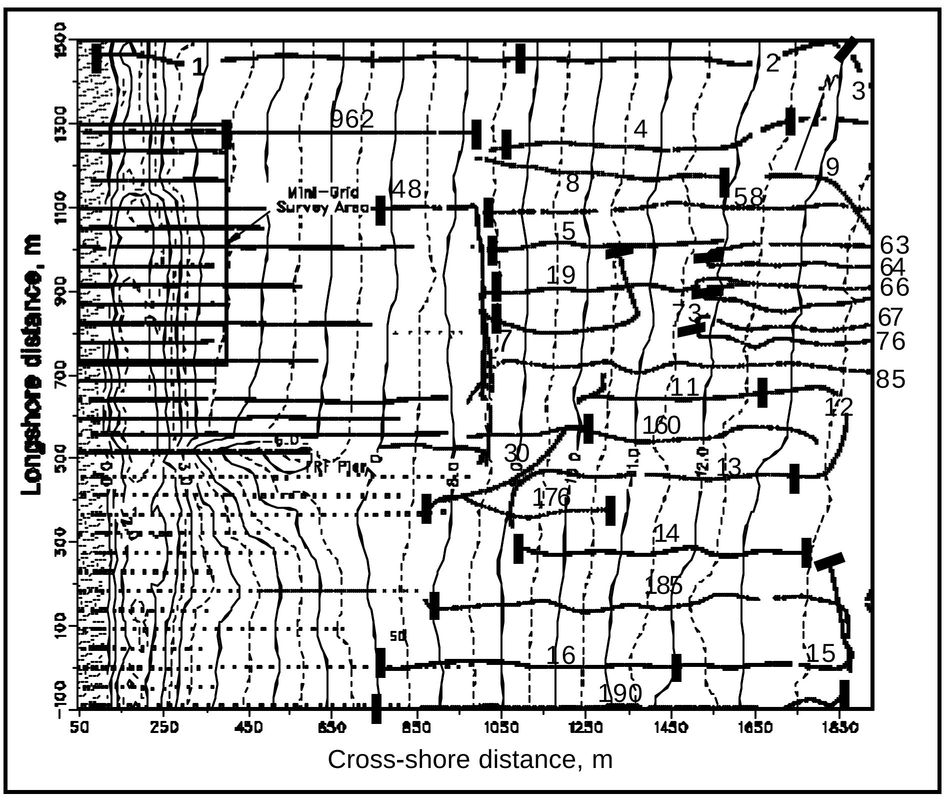

Figure A2. Sled tracklines from 13-m-deep survey. Numbers indicate profile lines surveyed; bold rectangles indicate end points

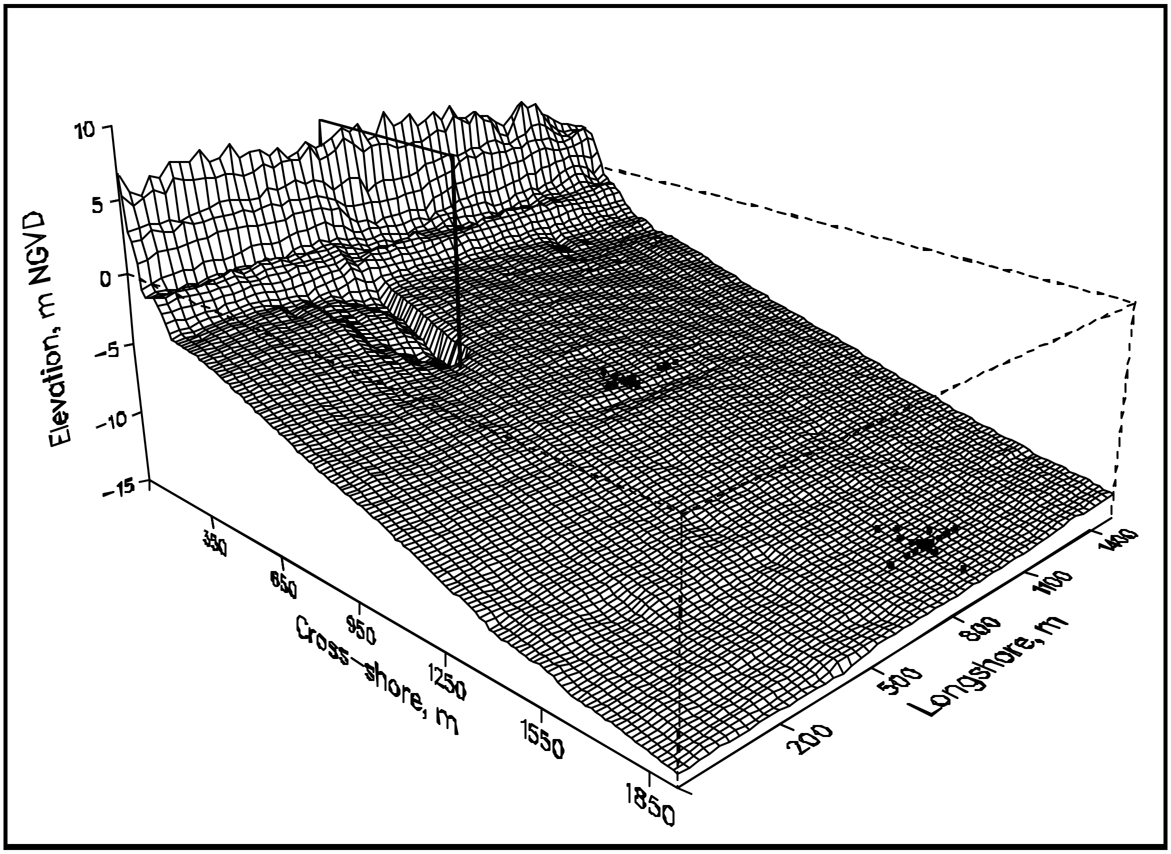

Figure A3. 13-m-deep survey showing the 13-m array, and the FRF's 8-m array

The 13-m deep survey data are shown in Figures A2 to A4. Figure A2 shows the tracklines of all the data points used with profile numbers marked.

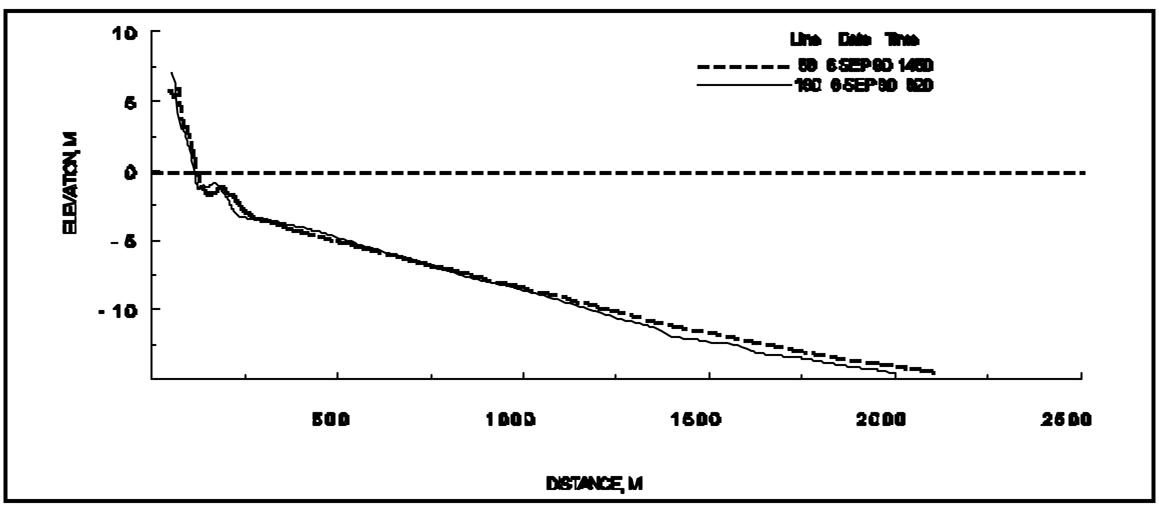

Figure A4. North (line 58) and south (line 190) transects from the 13-m-deep survey

The 1 May 1990 data used FRF profile numbers, but the later data used a sequential numbering system primarily dictated by software restrictions. As can be seen in Figure A3 and the transects shown in Figure A4, the bottom 580 m north of the pier (line 58), out to -13 m, is basically flat, while 516 m south of the pier (line 190), there are some interesting irregularities with cross-shore lengths of approximately 150 m, and vertical relief on the order of 1 m.

Minigrid Surveys

A series of 20 profile lines were surveyed every day during DELILAH beginning 1 October and continuing throughout the experiment. The lines were spaced approximately 25 m apart near the instruments and 50 m apart elsewhere. Profile lines, along with the locations of the nearshore instruments, are shown in Figure A5. All lines extended from the base of the dune to approximately 375 m offshore, except during the high wave period on 13 October 1990. The dune section of each profile line was only surveyed at the beginning of the experiment. To provide continuity between surveys, the dune data points were automatically added to each survey. The surveys were sequentially numbered. Unlike the 13-m-deep survey, a median smooth was not used to reduce the number of data points.

Most of the changes which occurred resulted from the offshore movement of the inner bar. This can be seen in Figure A6, which overplots all the surveys for profile line 230, located just north of the cross-shore instrument line. The largest vertical changes occurred at approximately 160 m

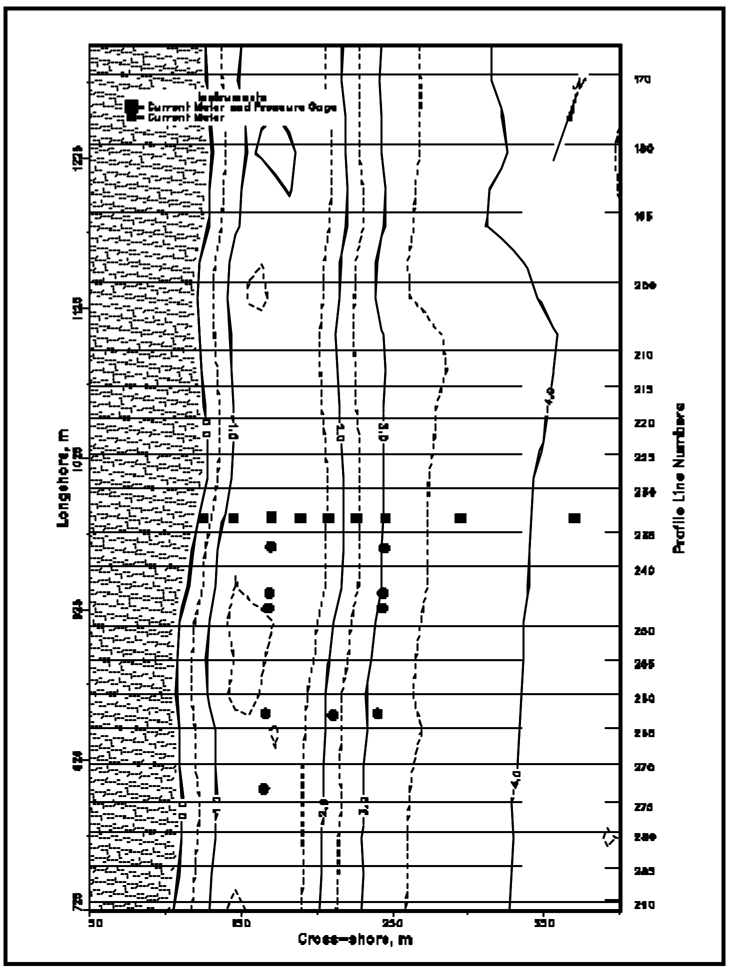

Figure A5. DELILAH minigrid profile lines

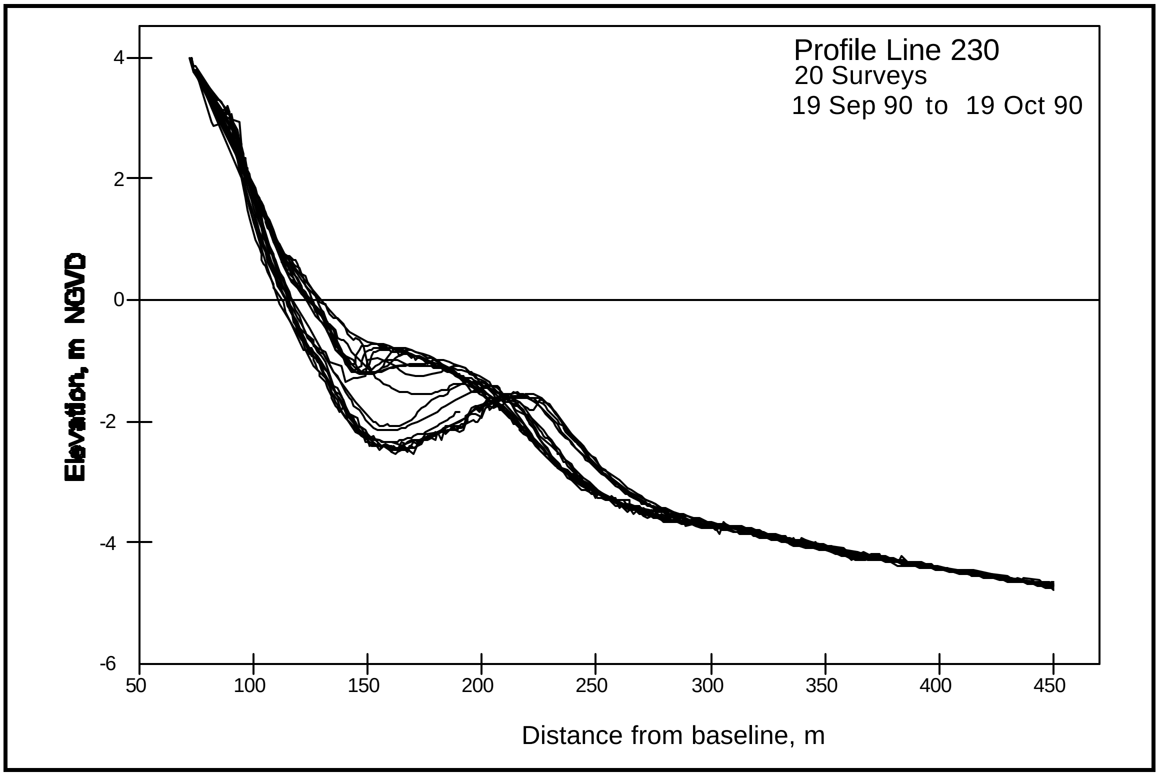

Figure A6. Envelope of all surveys of profile line 230

offshore and were caused by the rapid development of the nearshore trough and the offshore movement of the bar. Seaward of 300 m, the bottom was stable and the influence of the errors previously discussed is more significant.

One interesting feature that was measured for the first time at the FRF was large bed forms, or megaripples, which developed along some of the profile lines in the nearshore trough and seaward of the bar (Figure A7). These features are large enough to be felt by the wheels of the CRAB and are reflected in the data (the CRAB surveys the average elevation between the two back wheels). Because they appeared repeatedly from day to day, and were observed by the CRAB operators, there is convincing evidence that these features are not the result of the Geodimeter oscillations described previously.

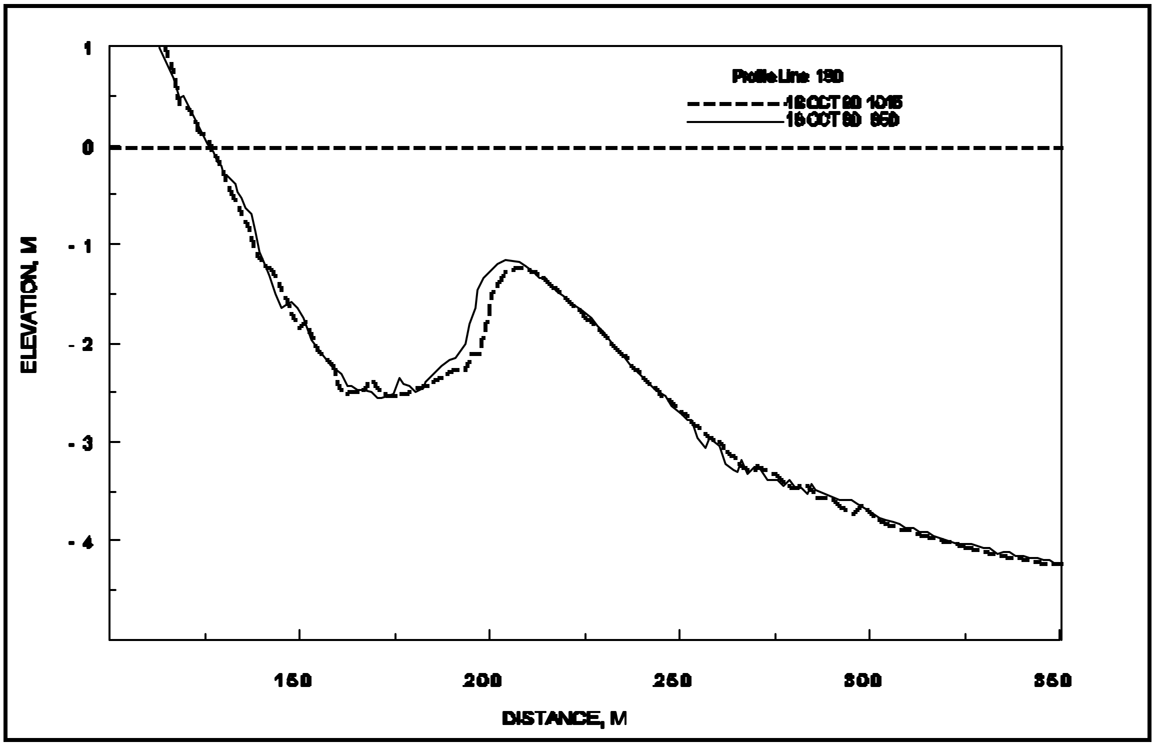

Figure A7. Megaripple features in the trough and offshore of the nearshore bar

Collection of the minigrid survey data under the changing DELILAH conditions was arduous. Some of the profile lines were perilously close to the instruments. Many individuals contributed to the survey data collection, most notably Messrs. Kimble Milliken, Doug Alden, and Brian Scarborough who drove the CRAB and Mr. Steve Blanchard who processed all of the data and assisted in its collection.

Table A1 provides a summary, by profile and survey number, of the data collected. Numbers in the table are of computed cross-section volume changes (m^3/m) between successive surveys. Surveys were conducted daily, but conditions limited the operation of the CRAB during 12-14 October 1990, when only the inshore portion of the lines could be surveyed and some of the lines had to be skipped completely. Following Table A1 are plots of the minigrid survey data, which are presented in two ways. First, the original cross-section data are displayed as comparison plots between successive surveys of all of the lines surveyed (Figures A8-A25). Then, contour and perspective plots are shown for each survey (Figures A26-A44).

Table A1
Summary of Profile Lines Surveyed and Net Volumetric Change Between Surveys

Profile Line Number	170	180	195	200	210	215	220	225	230	235	240	250	255	260	265	270	275	280	285	290	Averag eTotal Volume Change m^3/m**
Longshore Distance, m	1280	1234	1189	1143	1097	1074	1052	1029	1006	977	954	914	892	869	846	823	797	777	754	732	
Survey Date	Net Volume Change, m^3/m																				
19 Sep 90	0	0	0	0	0	0	0	0	0	--	0	0	0	0	0	0	0	--	--	--	0
1 Oct 90	6	19	31	-5	-17	11	-10	26	18	--	10	-6	14	-19	3	-18	8	0	0	0	5
2 Oct 90	15	-2	8	12	-4	-8	-4	-8	-8	0	-5	6	2	-2	-7	-3	-6	-3	1	2	0
3 Oct 90	-35	-25	-24	-20	-13	-13	-17	-13	-8	-7	-8	4	-10	-1	-10	-1	-11	1	-12	-2	-13
4 Oct 90	-4	-9	0	-2	8	-15	7	-14	10	-15	8	-10	1	-10	-1	-9	3	-6	6	-6	-3
5 Oct 90	9	-4	18	18	9	0	1	1	-2	3	5	-1	0	2	1	2	2	3	3	2	4
6 Oct 90	-18	2	--	2	1	9	9	5	2	6	8	1	11	*	4	-1	4	-6	-4	-6	2
7 Oct 90	15	6	0	-15	-19	10	-19	--	14	11	0	-5	-13	-8	-6	2	4	14	1	-6	-1
8 Oct 90	2	14	-2	-9	11	-10	9	-3	2	0	-6	-11	1	-4	7	-1	-1	-9	-5	-4	-1
9 Oct 90	13	-5	-16	3	8	9	20	11	4	-27	-23	10	*	12	-12	4	-21	-8	-30	2	-3
10 Oct 90	-5	-6	-14	-10	15	3	-10	-7	-25	-15	-7	-3	-6	-12	-2	-19	-10	-29	0	-6	-8
11 Oct 90	-21	-15	-7	24	*	-17	-25	*	-43	--	-32	--	-10	5	-1	0	-4	9	16	35	-5
12 Oct 90	-9	-20	-2	*	*	*	--	-24	-7	*	*	*	*	*	-8	-14	-8	-4	3	10	-5
13 Oct 90	*	*	*	*	*	--	*	--	*	--	*	*	--	*	--	*	--	*	--		0
14 Oct 90	19	0	*	*	-42	-19	*	*	-14	-70	*	*	-9	-17	-5	2	22	*	56	63	-3
15 Oct 90	-21	3	-26	-2	20	1	-35	-26	16	12	-33	-24	-14	*	-15	*	-8	41	-8	1	-6
16 Oct 90	14	-7	22	-7	-20	-11	17	-2	-18	1	1	-2	-2	0	-3	1	8	7	6	-5	0
17 Oct 90	2	-2	-2	-5	0	1	-5	2	22	7	-1	-7	10	-7	14	-3	9	-4	2	-16	1
18 Oct 90	-3	4	4	4	-15	5	-9	-11	-24	-11	4	-6	-4	0	-1	-3	2	2	-6	-5	-3
19 Oct 90	-6	6	-3	1	8	-19	-6	-2	-7	0	2	4	7	6	5	9	7	1	2	10	1
Cumulative Total***	-28	-42	-14	-10	-50	-62	-76	-65	-69	-106	-78	-50	-23	-54	-35	-52	1	10	31	69	-38

Net volume changes in m^3/m for the region between 70 m and 365-400 m offshore (actual surveys may extend further offshore than 400 m).
-- Profile line not surveyed.
* Profile line surveyed, but survey did not reach 365 m distance.
** Average volume change per meter alongshore, weighted by the distance between profile lines.
*** Cumulative change computed based only on surveys that reached 365-400 m offshore.

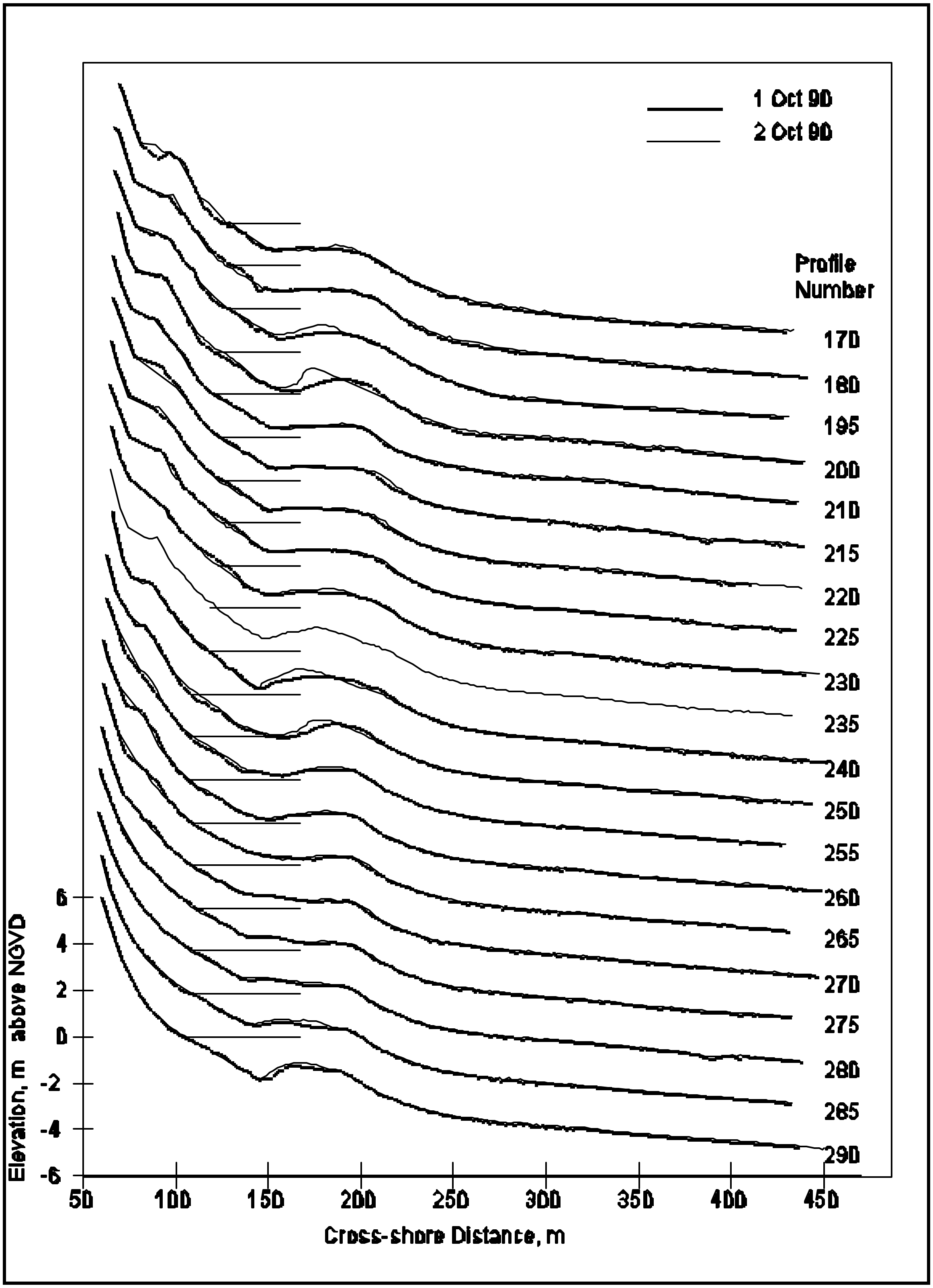

Figure A8. DELILAH profile line cross sections, 1-2 October 1990

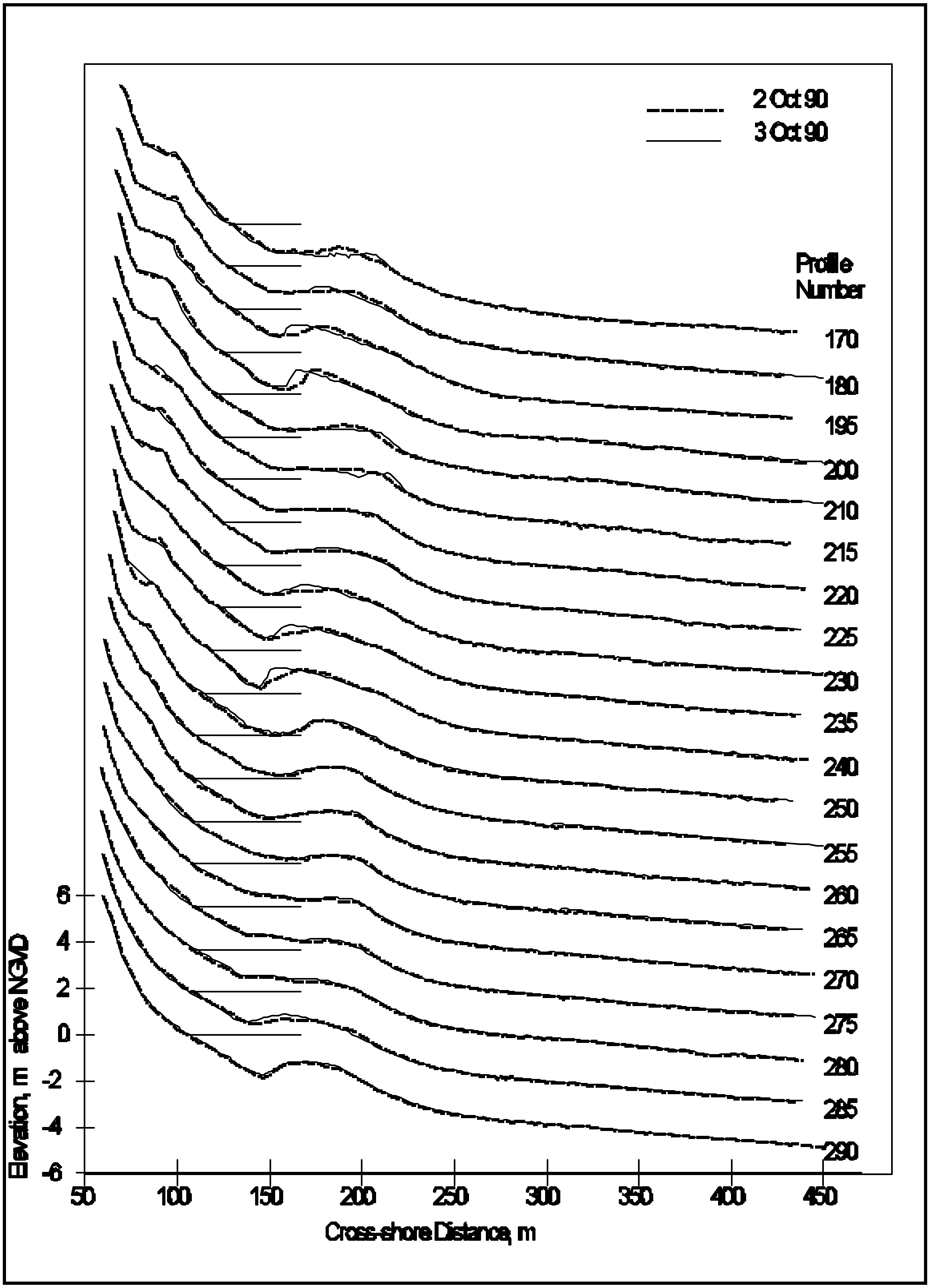

Figure A9. DELILAH profile line cross sections, 2-3 October 1990

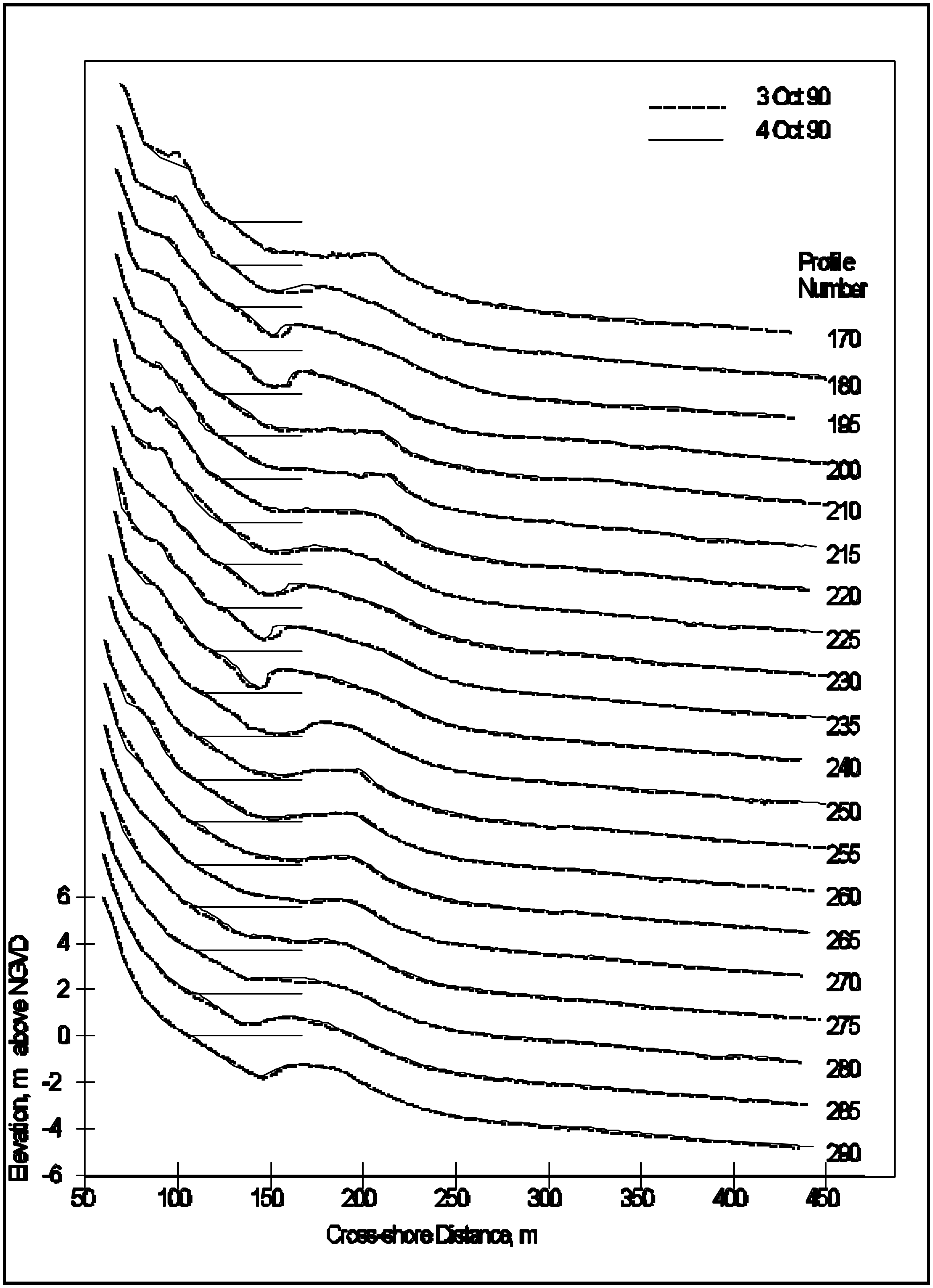

Figure A10. DELILAH profile line cross sections, 3-4 October 1990

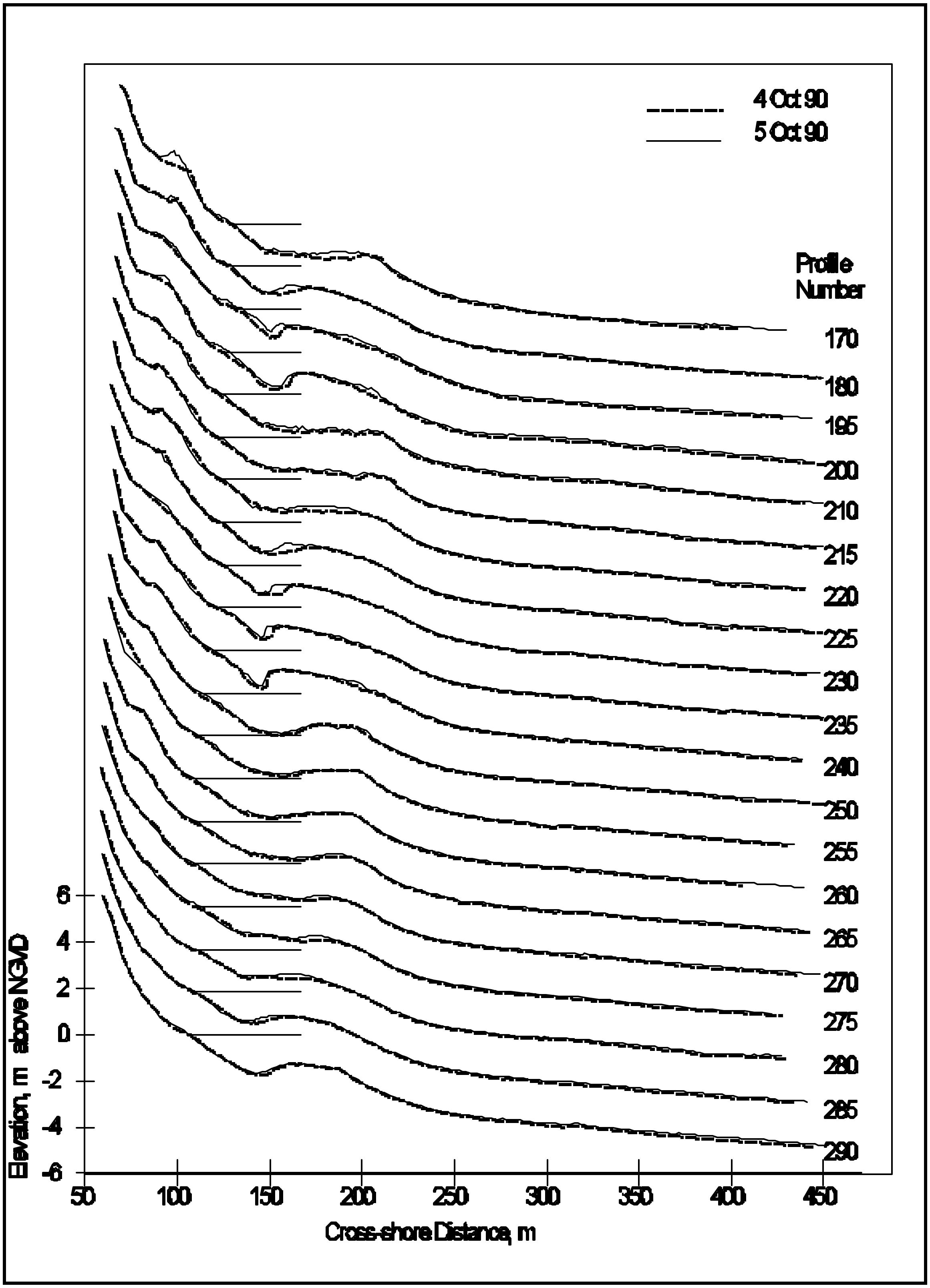

Figure A11. DELILAH profile line cross sections, 4-5 October 1990

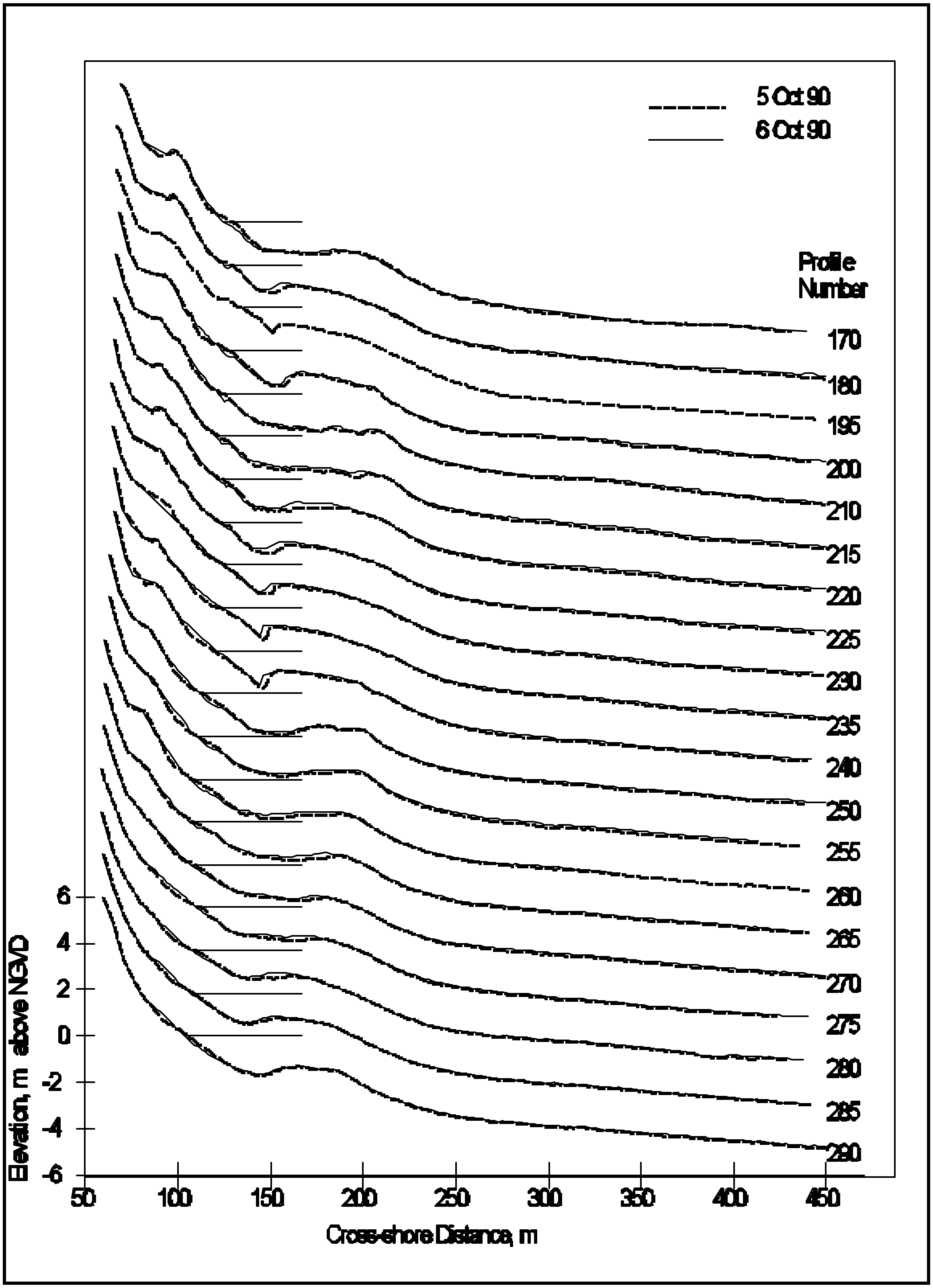

Figure A12. DELILAH profile line cross sections, 5-6 October 1990

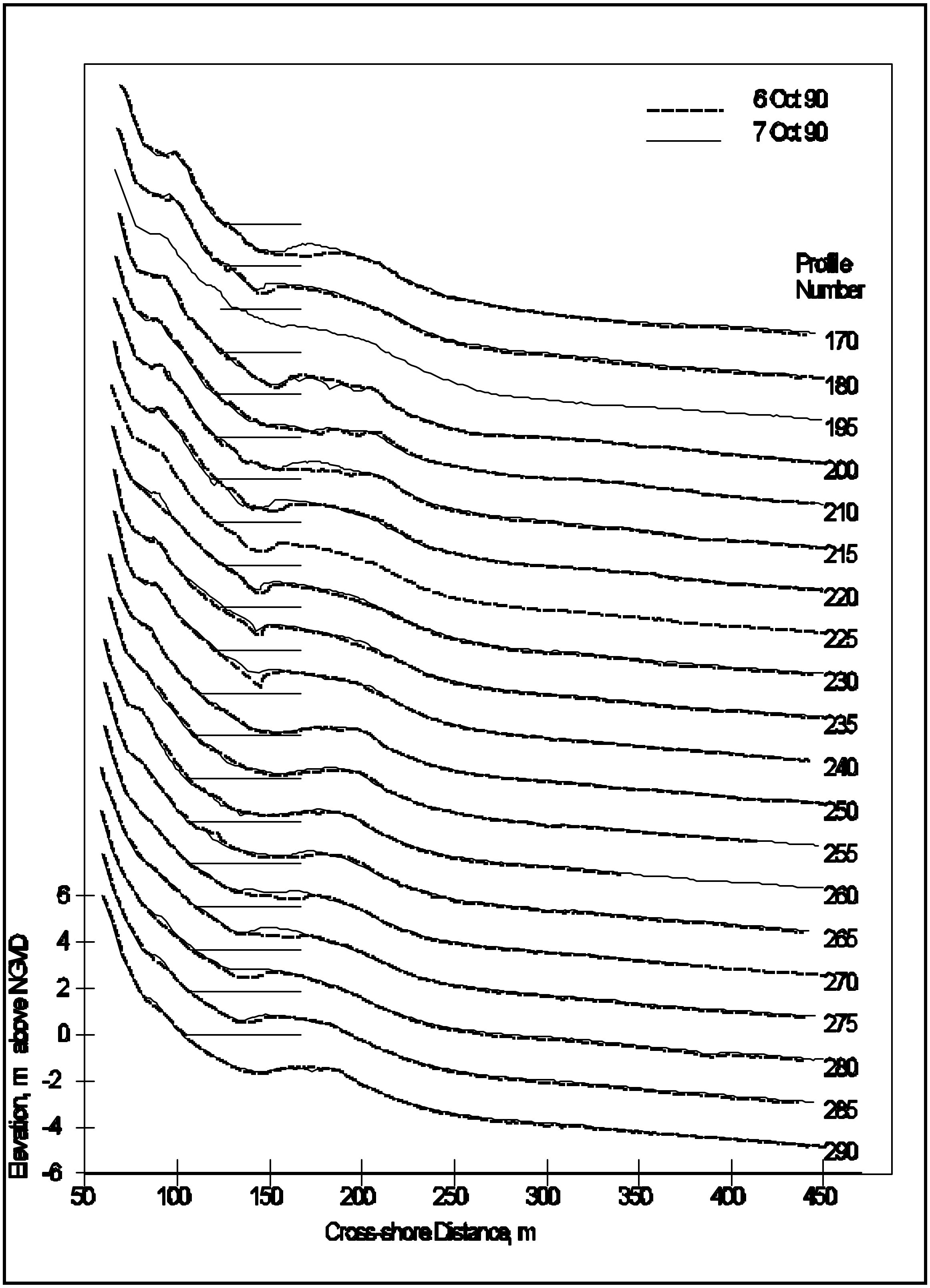

Figure A13. DELILAH profile line cross sections, 6-7 October 1990

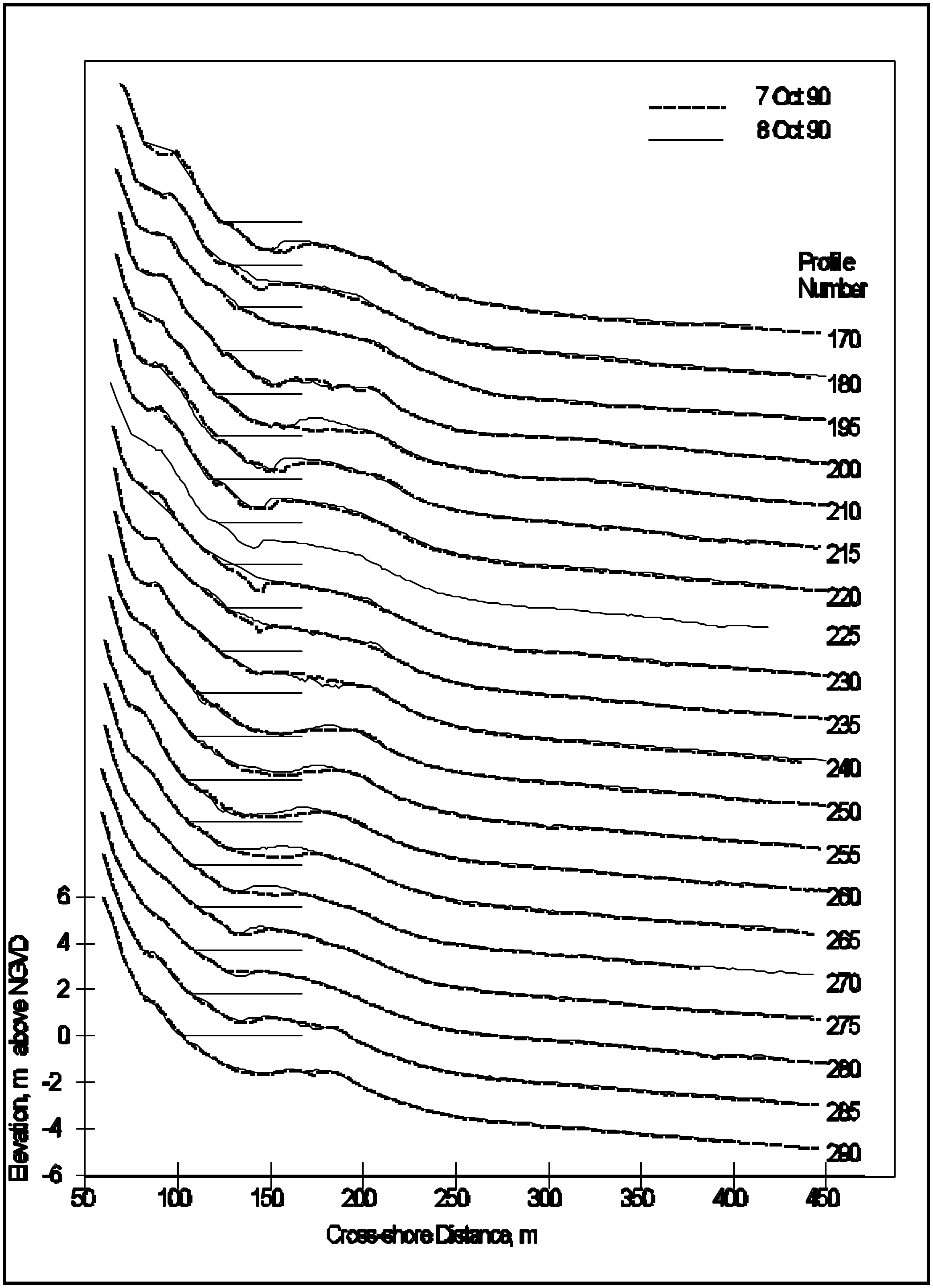

Figure A14. DELILAH profile line cross sections, 7-8 October 1990

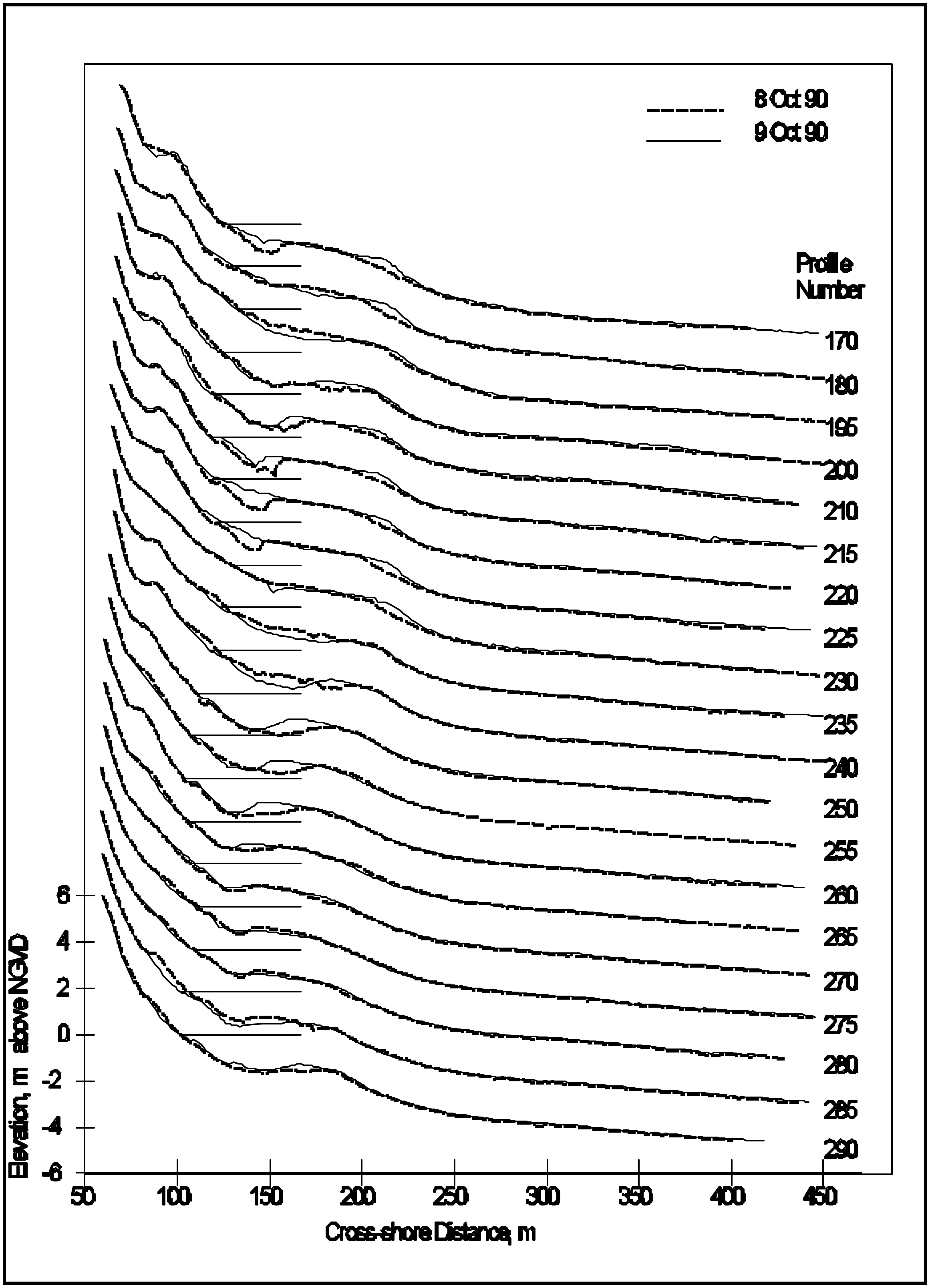

Figure A15. DELILAH profile line cross sections, 8-9 October 1990

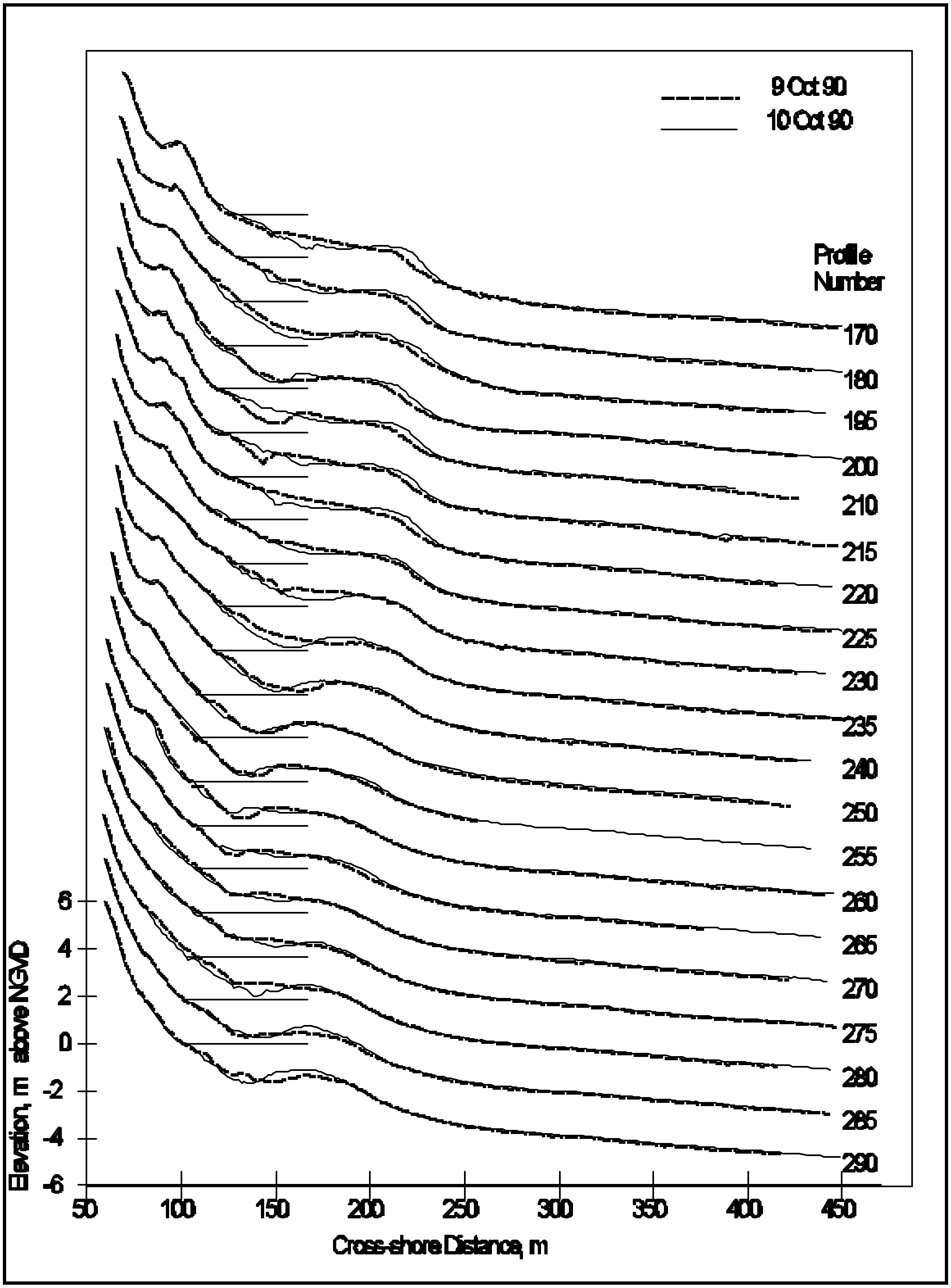

Figure A16. DELILAH profile line cross sections, 9-10 October 1990

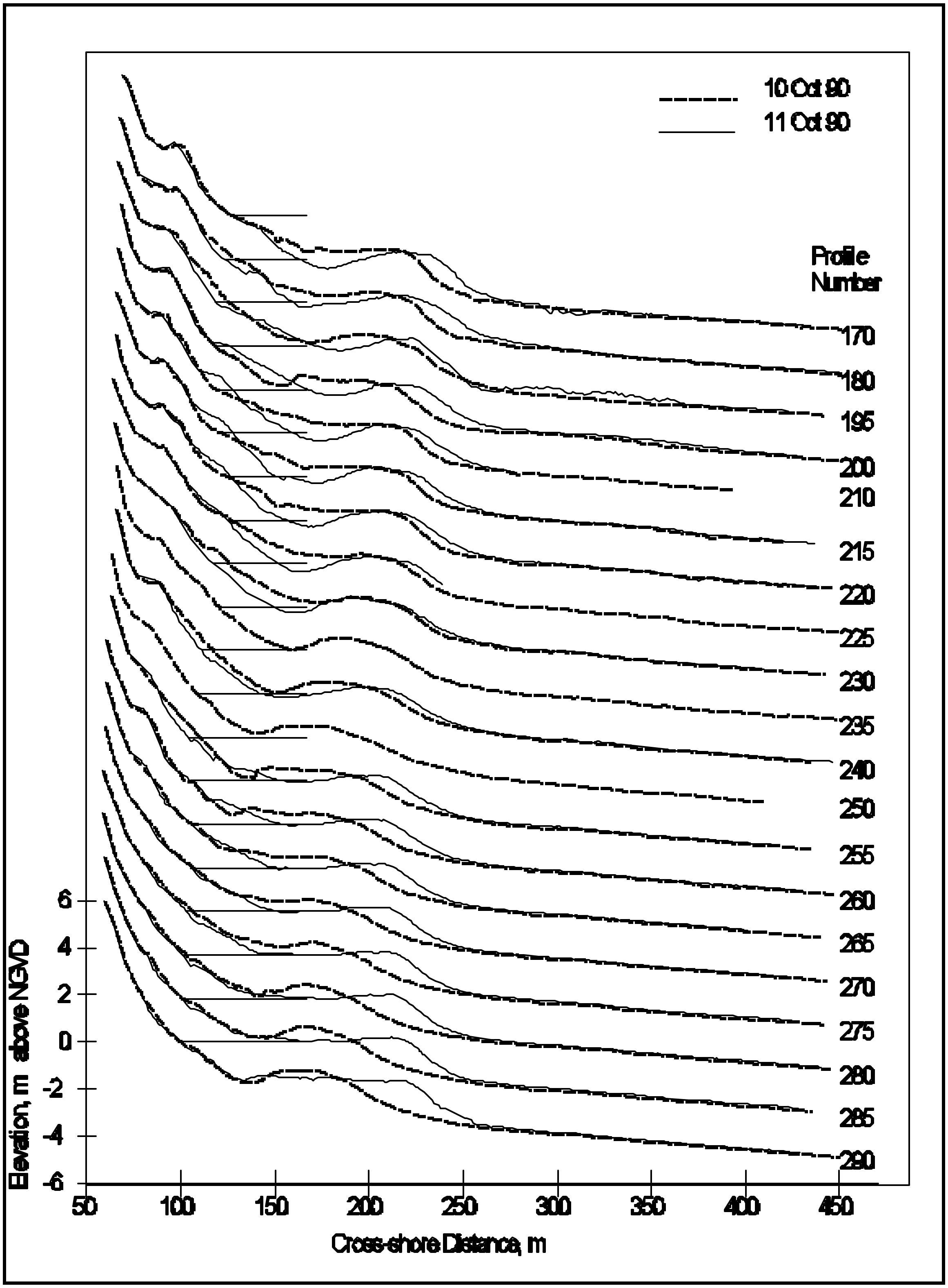

Figure A17. DELILAH profile line cross sections, 10-11 October 1990

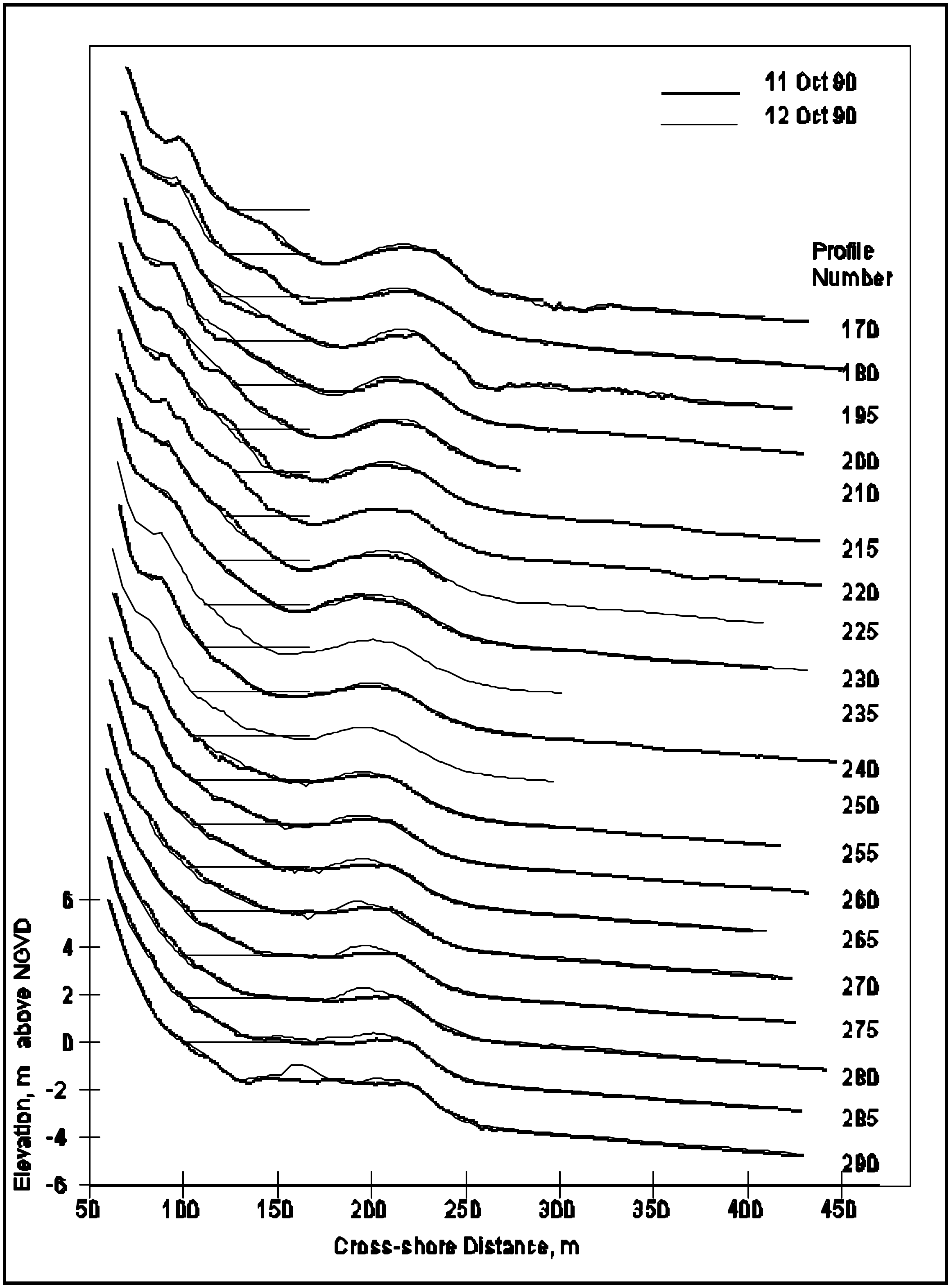

Figure A18. DELILAH profile line cross sections, 11-12 October 1990

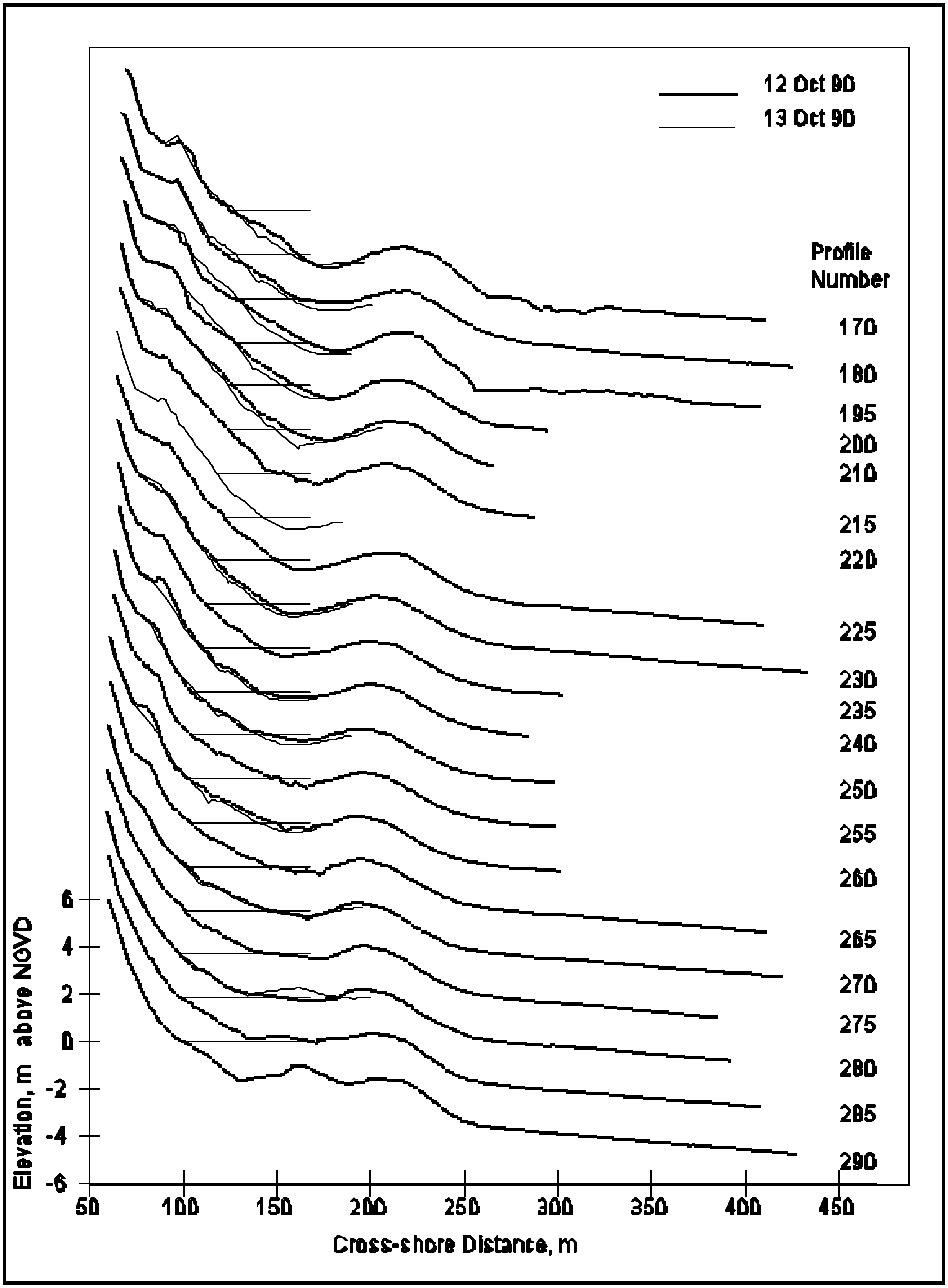

Figure A19. DELILAH profile line cross sections, 12-13 October 1990

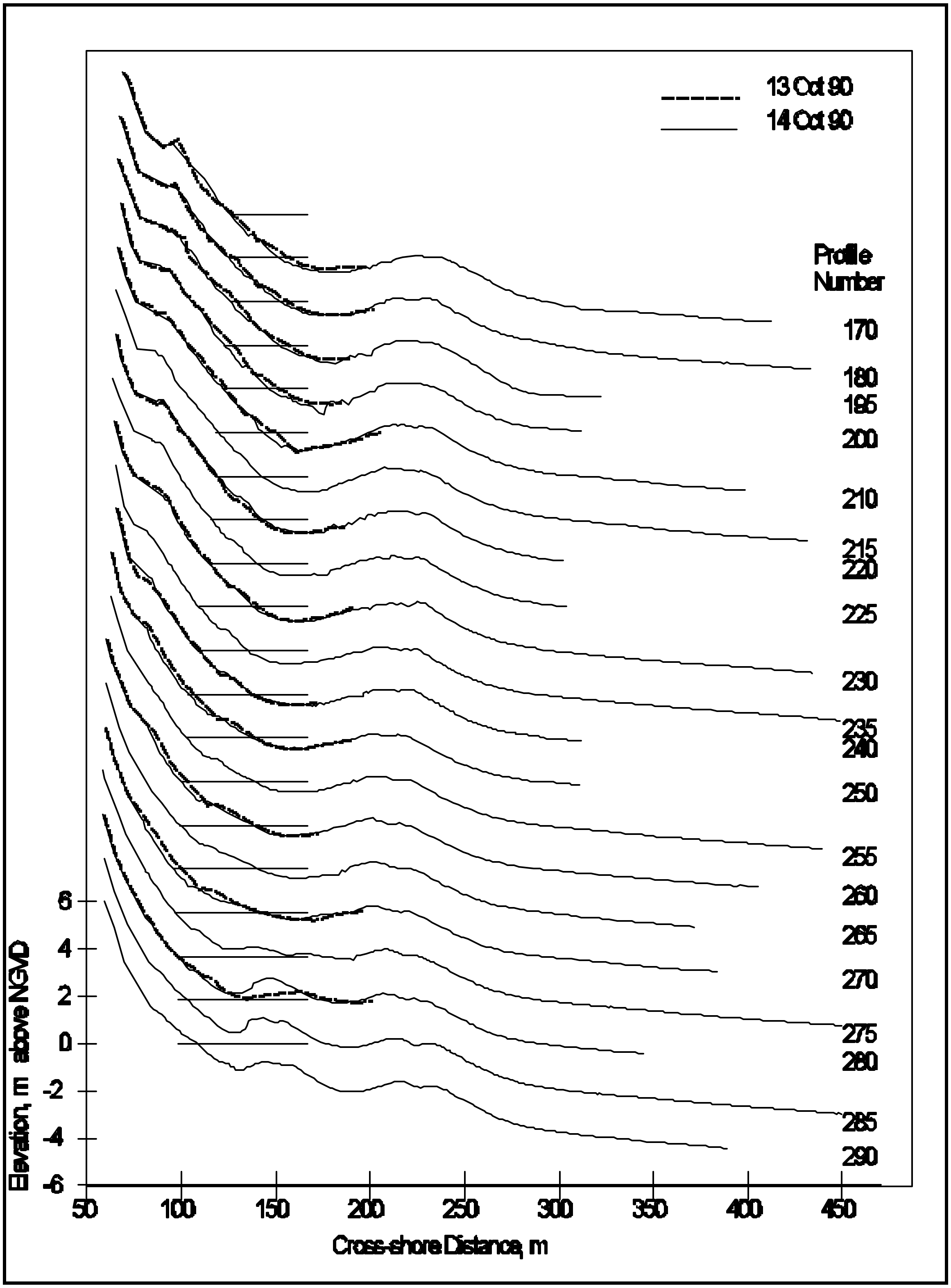

Figure A20. DELILAH profile line cross sections, 13-14 October 1990

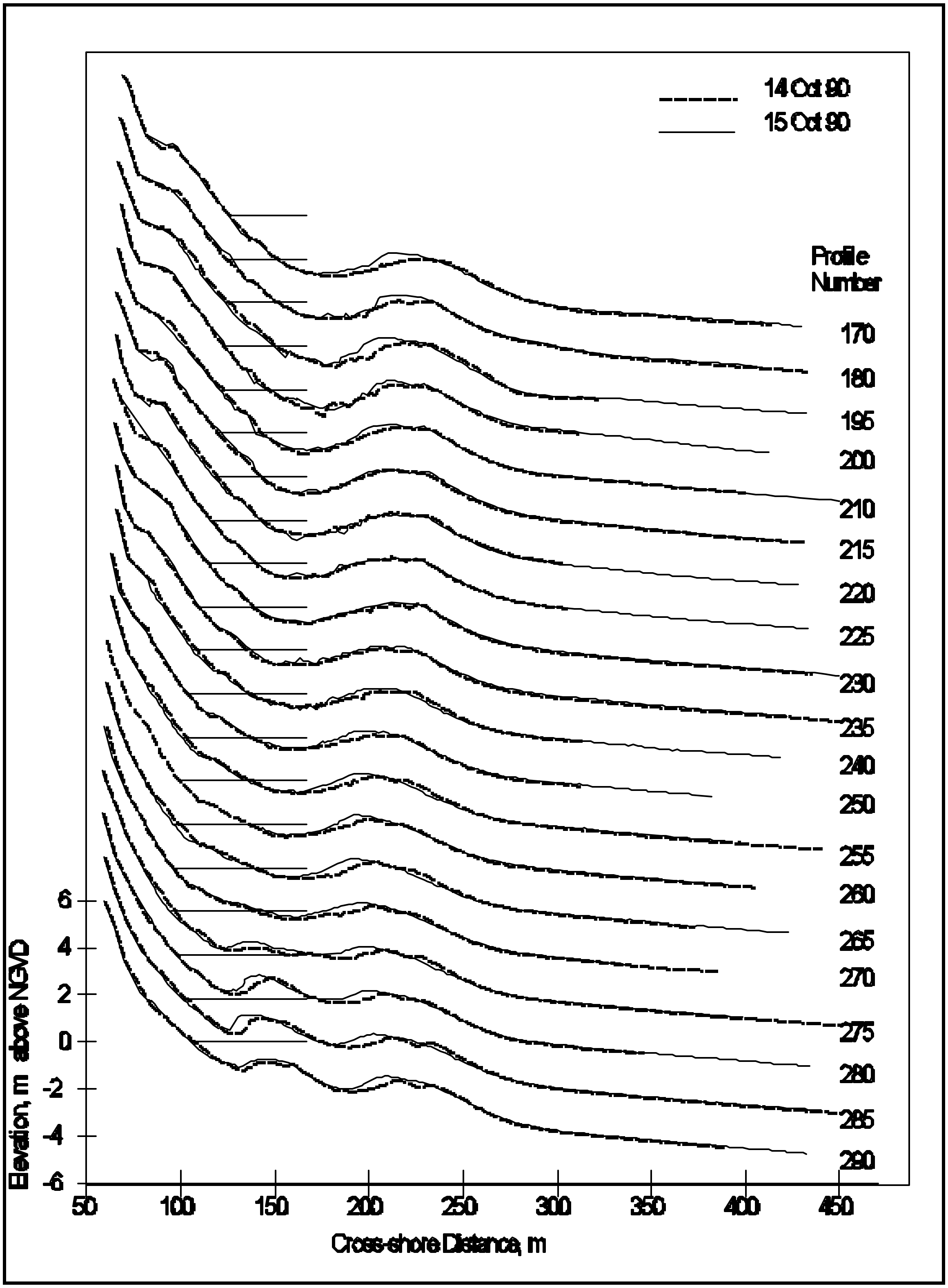

Figure A21. DELILAH profile line cross sections, 14-15 October 1990

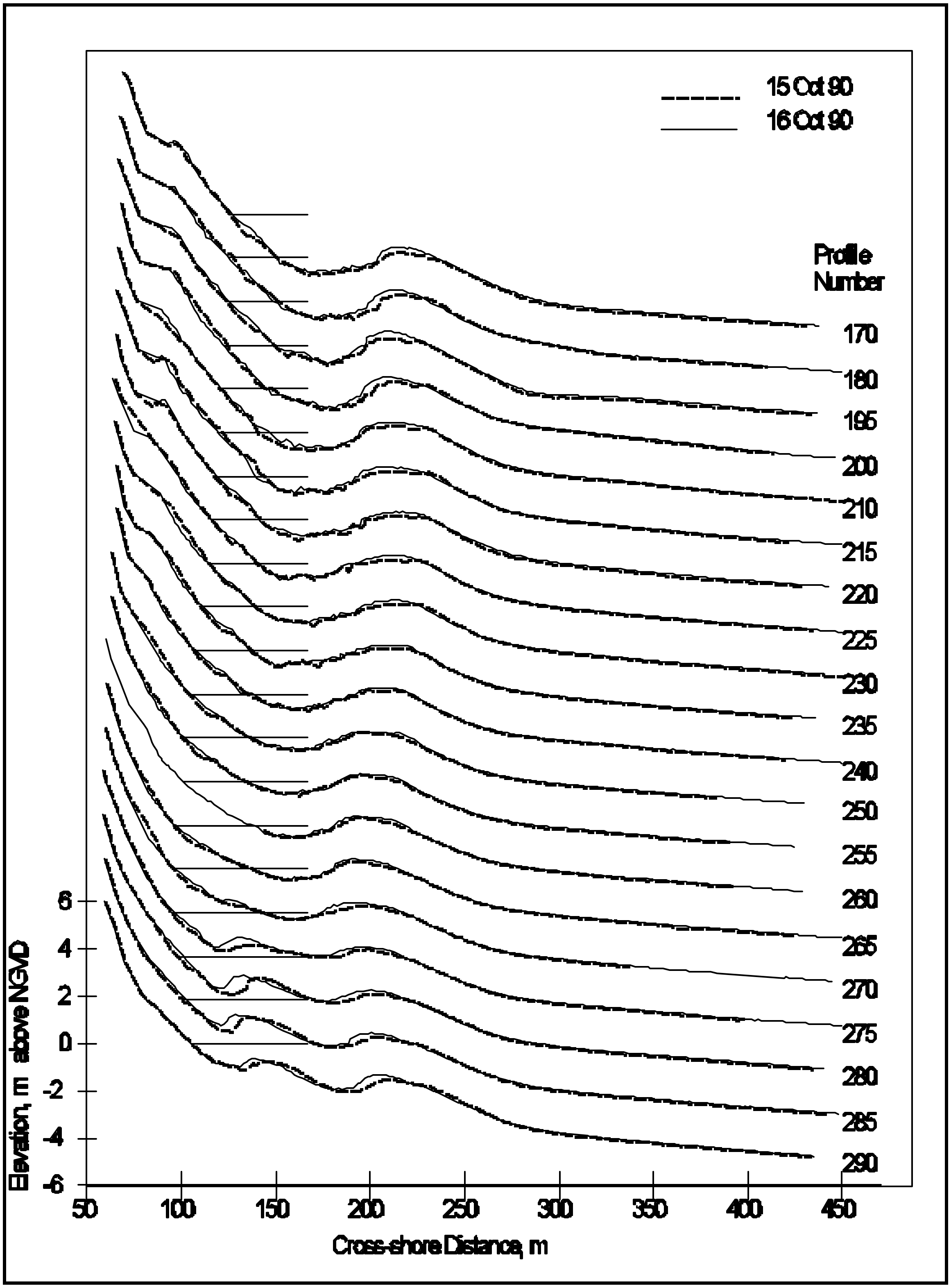

Figure A22. DELILAH profile line cross sections, 15-16 October 1990

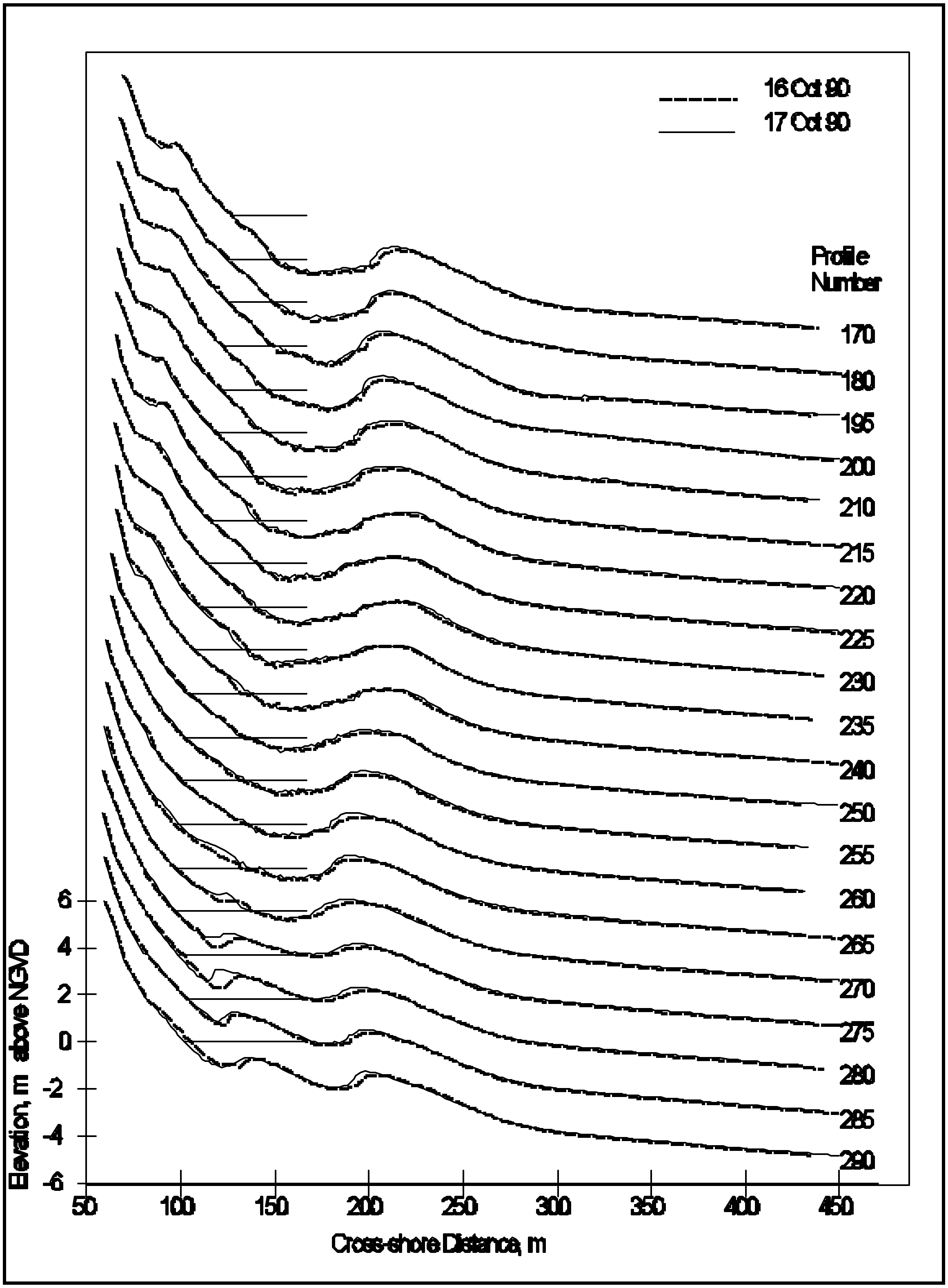

Figure A23. DELILAH profile line cross sections, 16-17 October 1990

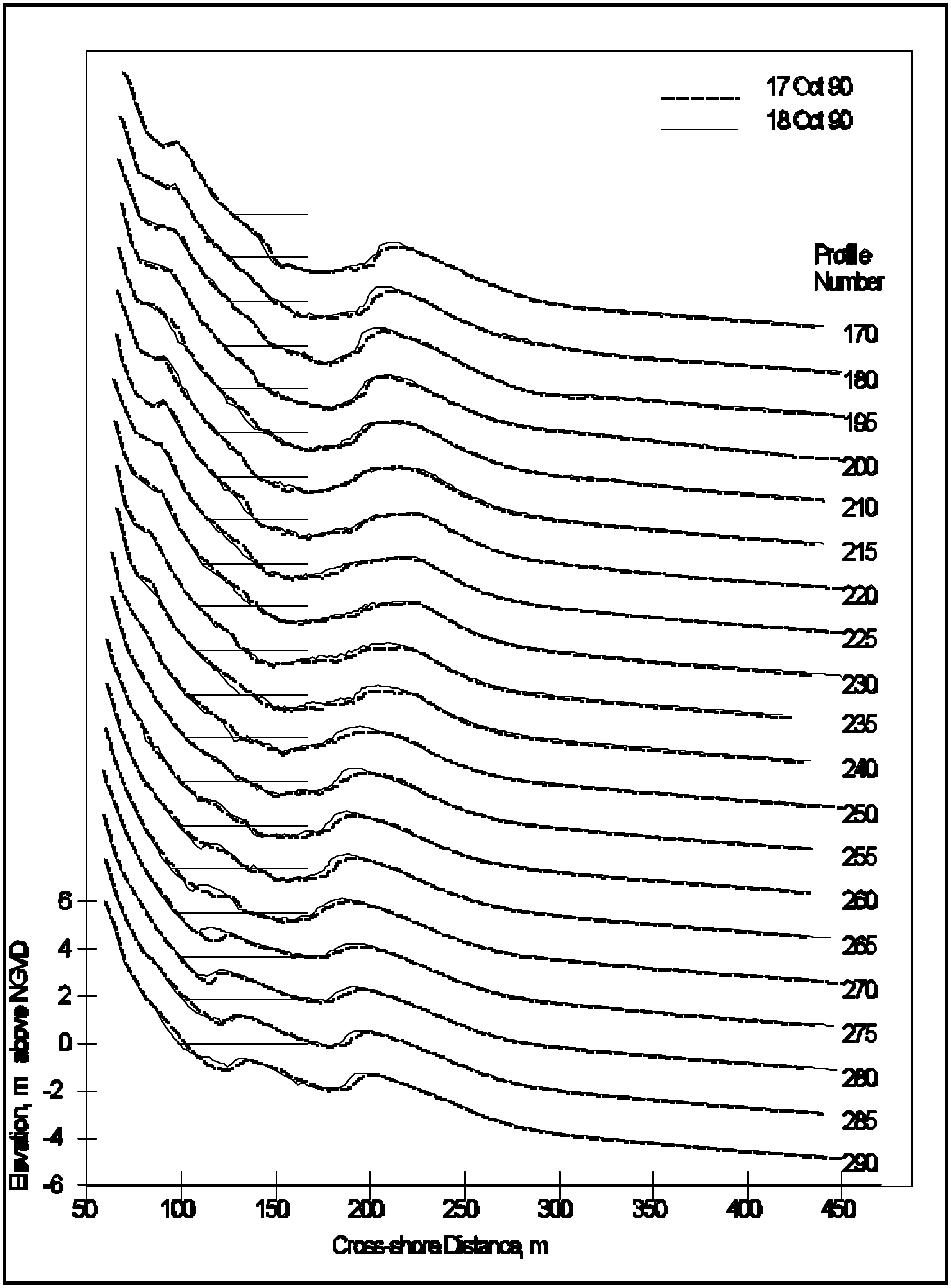

Figure A24. DELILAH profile line cross sections, 17-18 October 1990

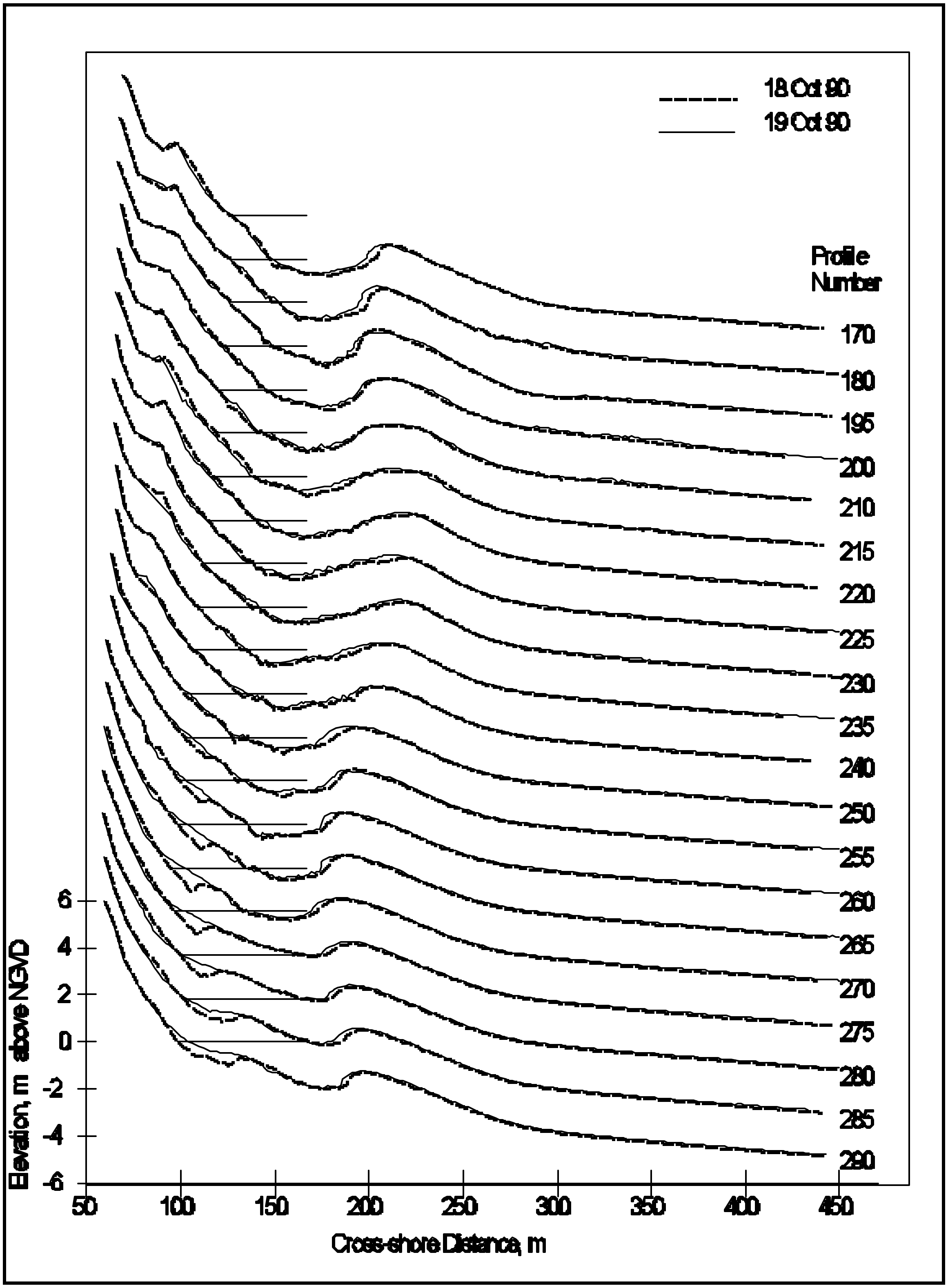

Figure A25. DELILAH profile line cross sections, 18-19 October 1990

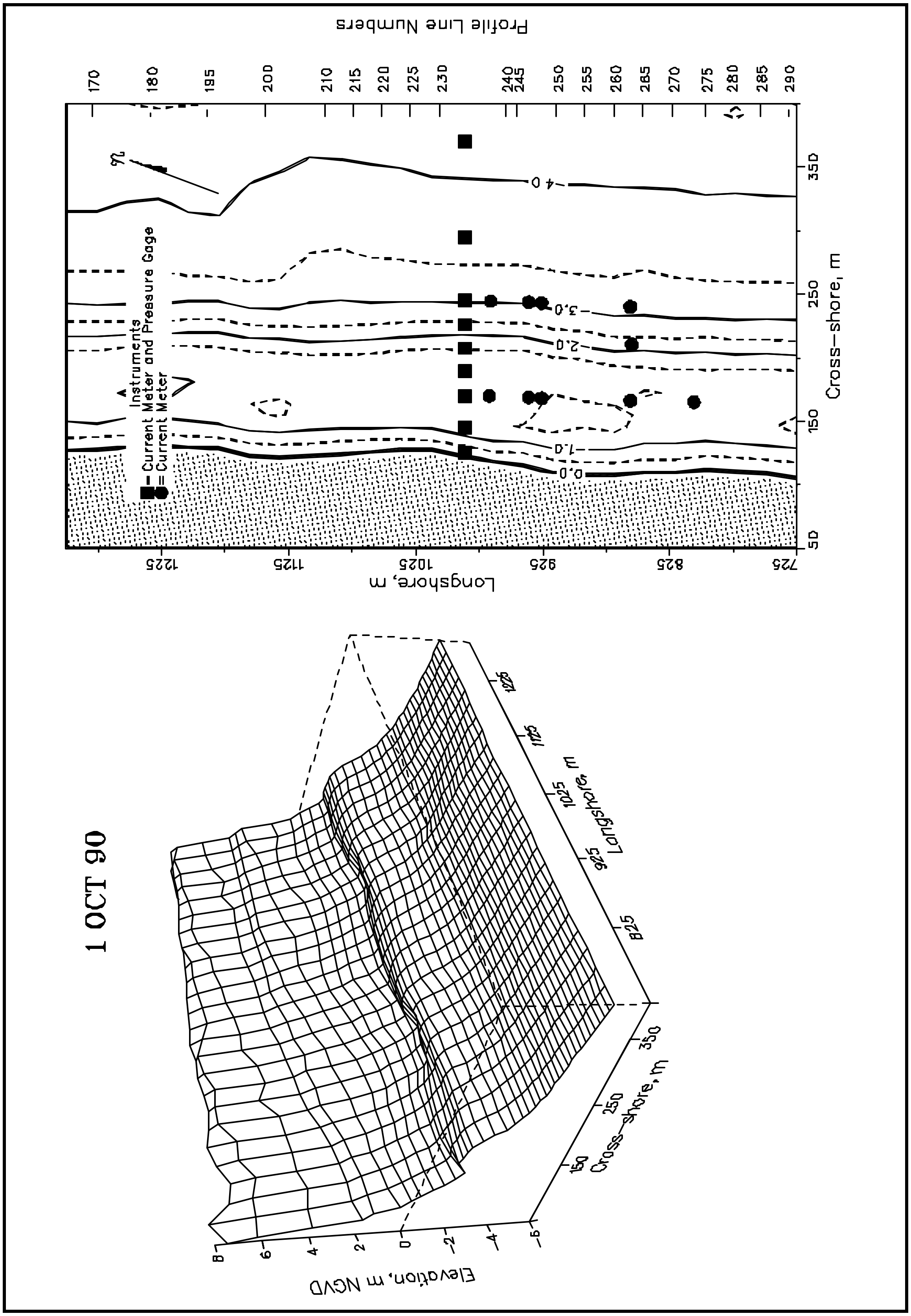

Figure A26. DELILAH Minigrid Survey, 1 October 1990

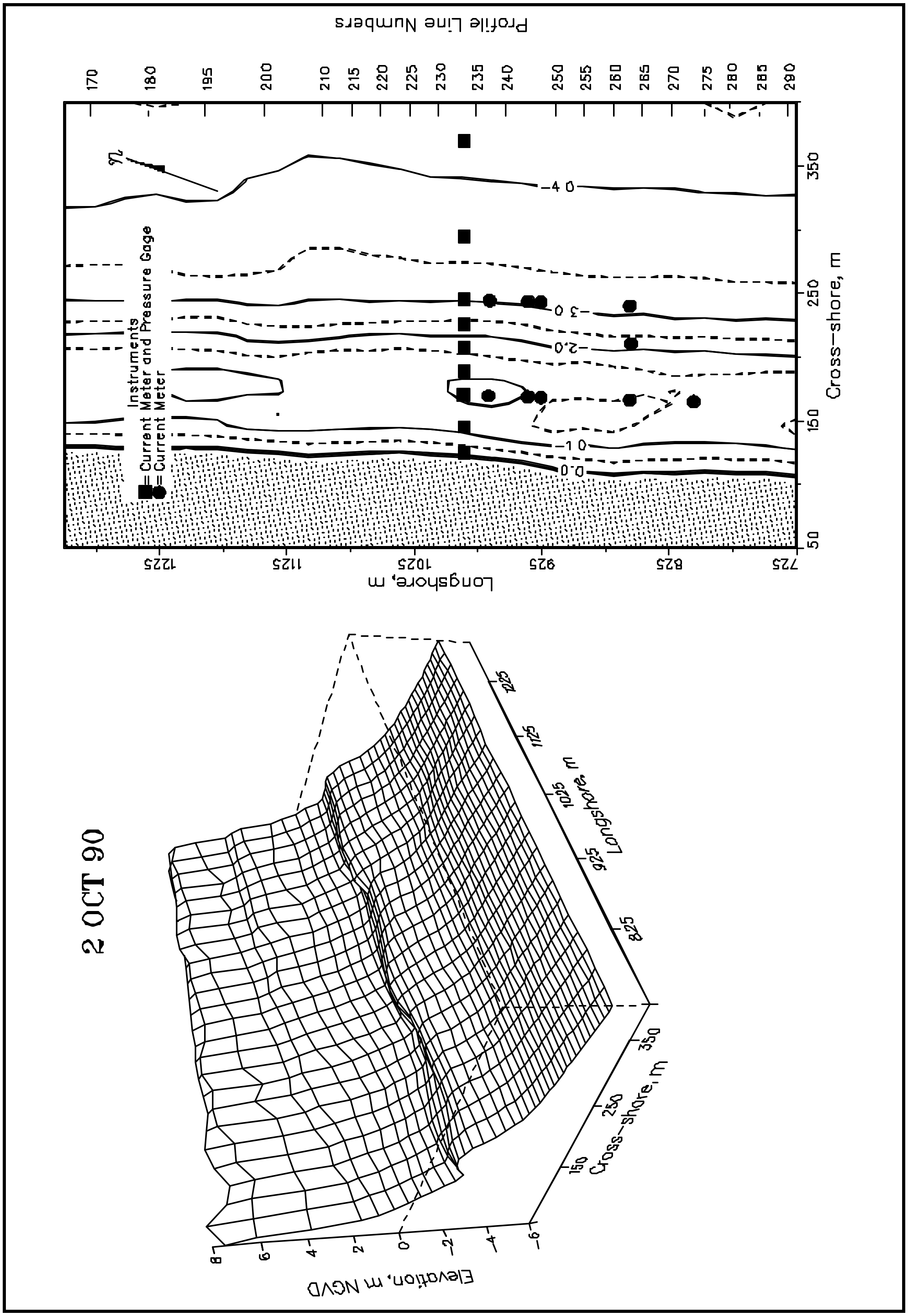

Figure A27. DELILAH Minigrid Survey, 2 October 1990

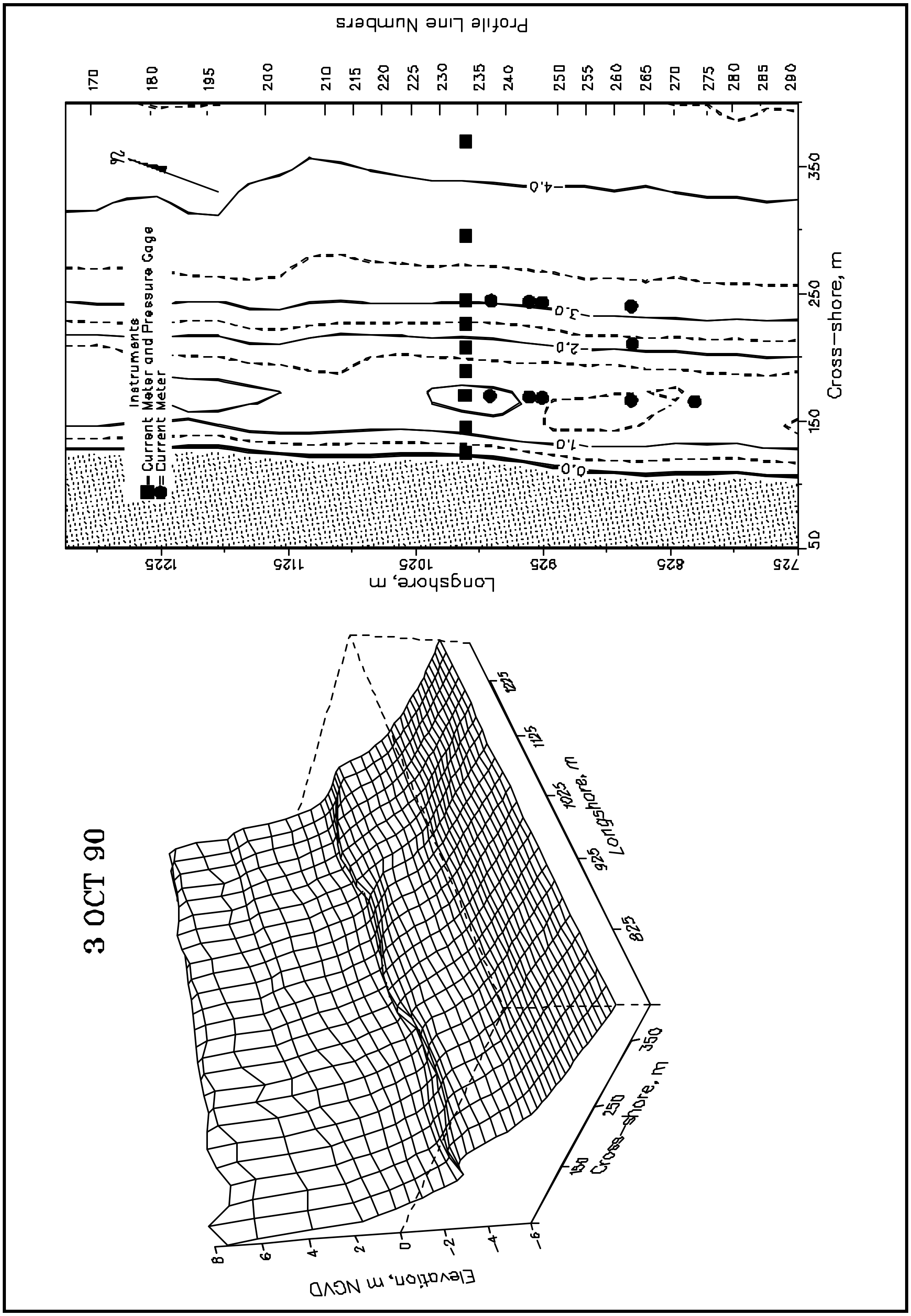

Figure A28. DELILAH Minigrid Survey, 3 October 1990

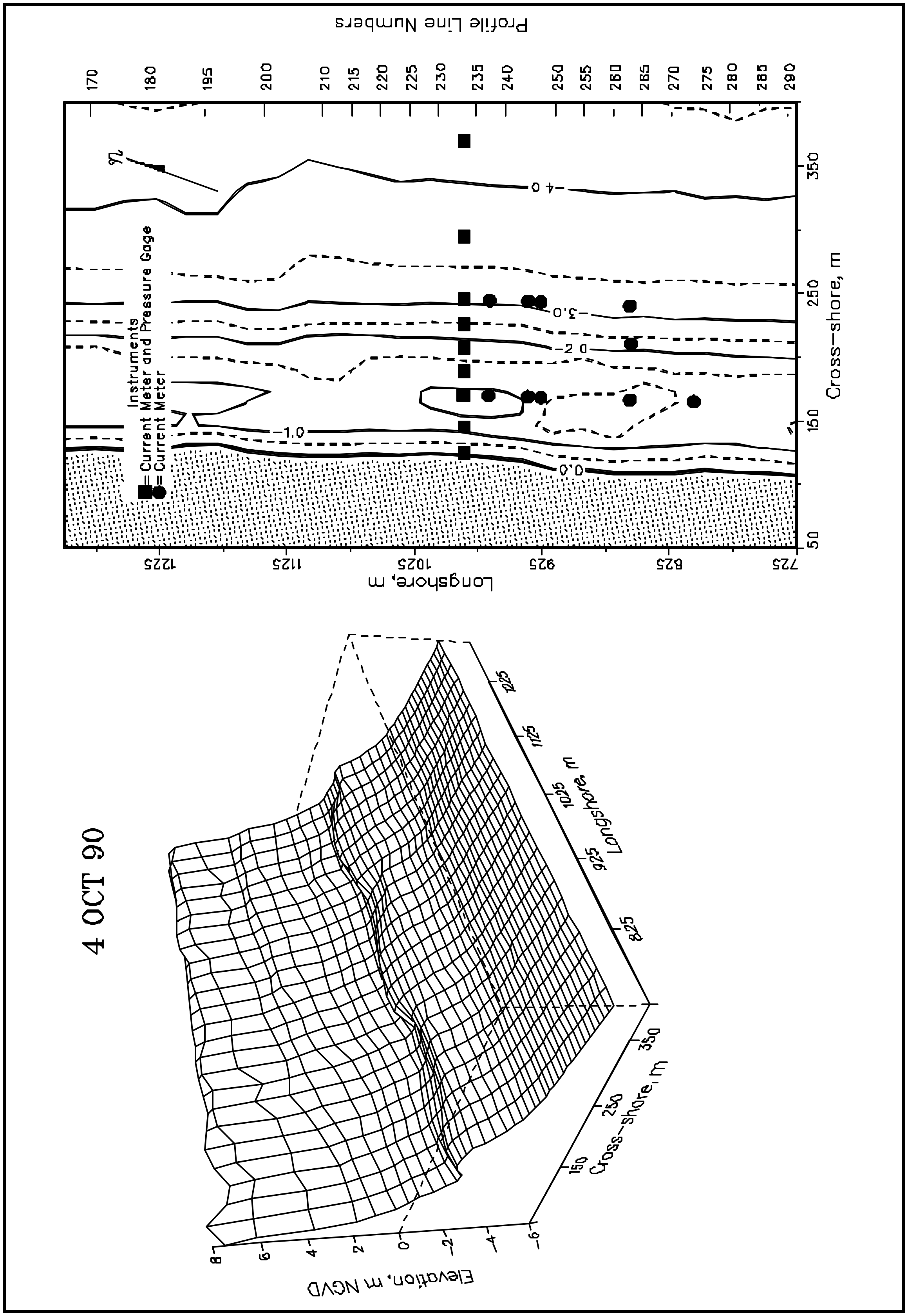

Figure A29. DELILAH Minigrid Survey, 4 October 1990

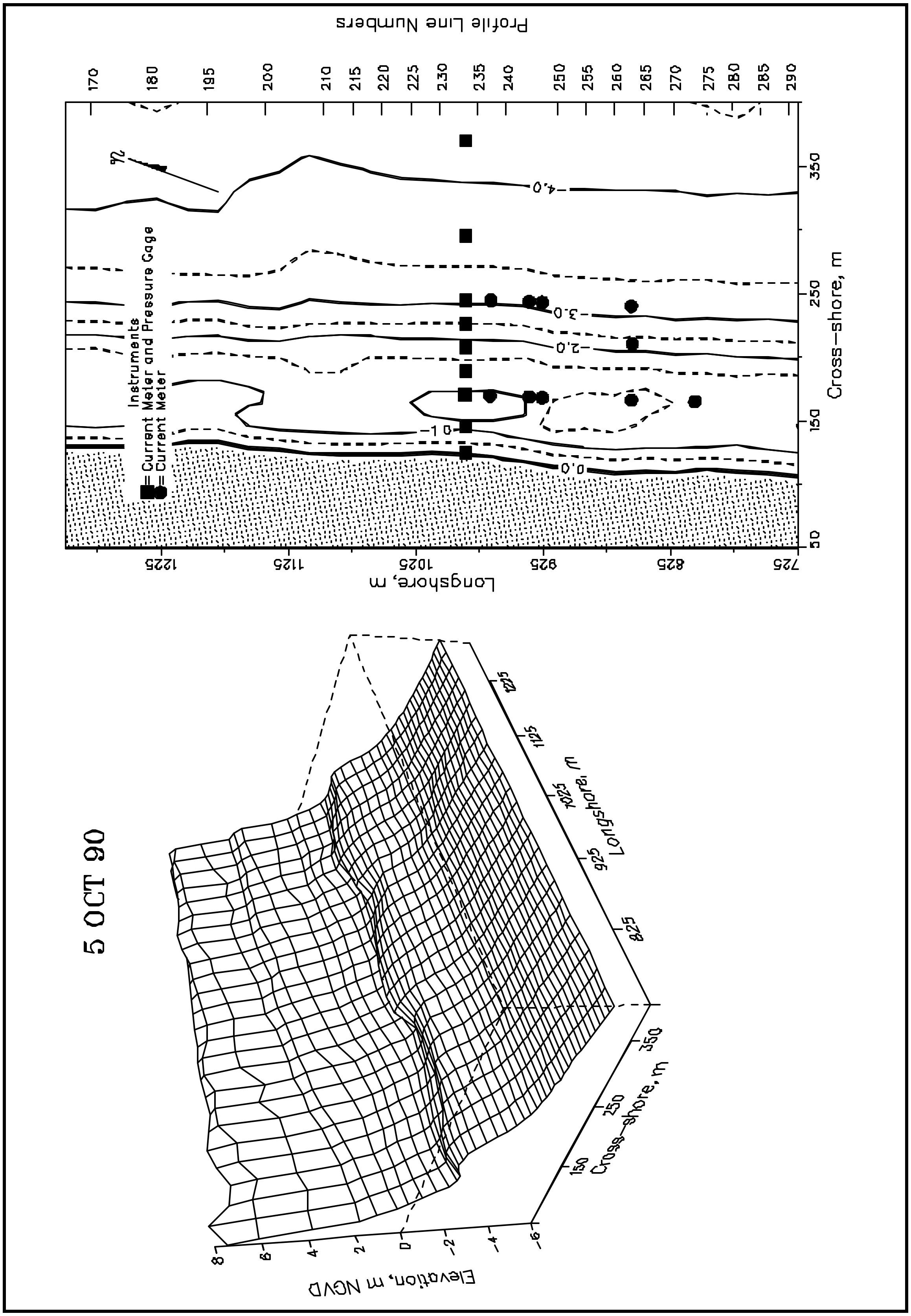

Figure A30. DELILAH Minigrid Survey, 5 October 1990

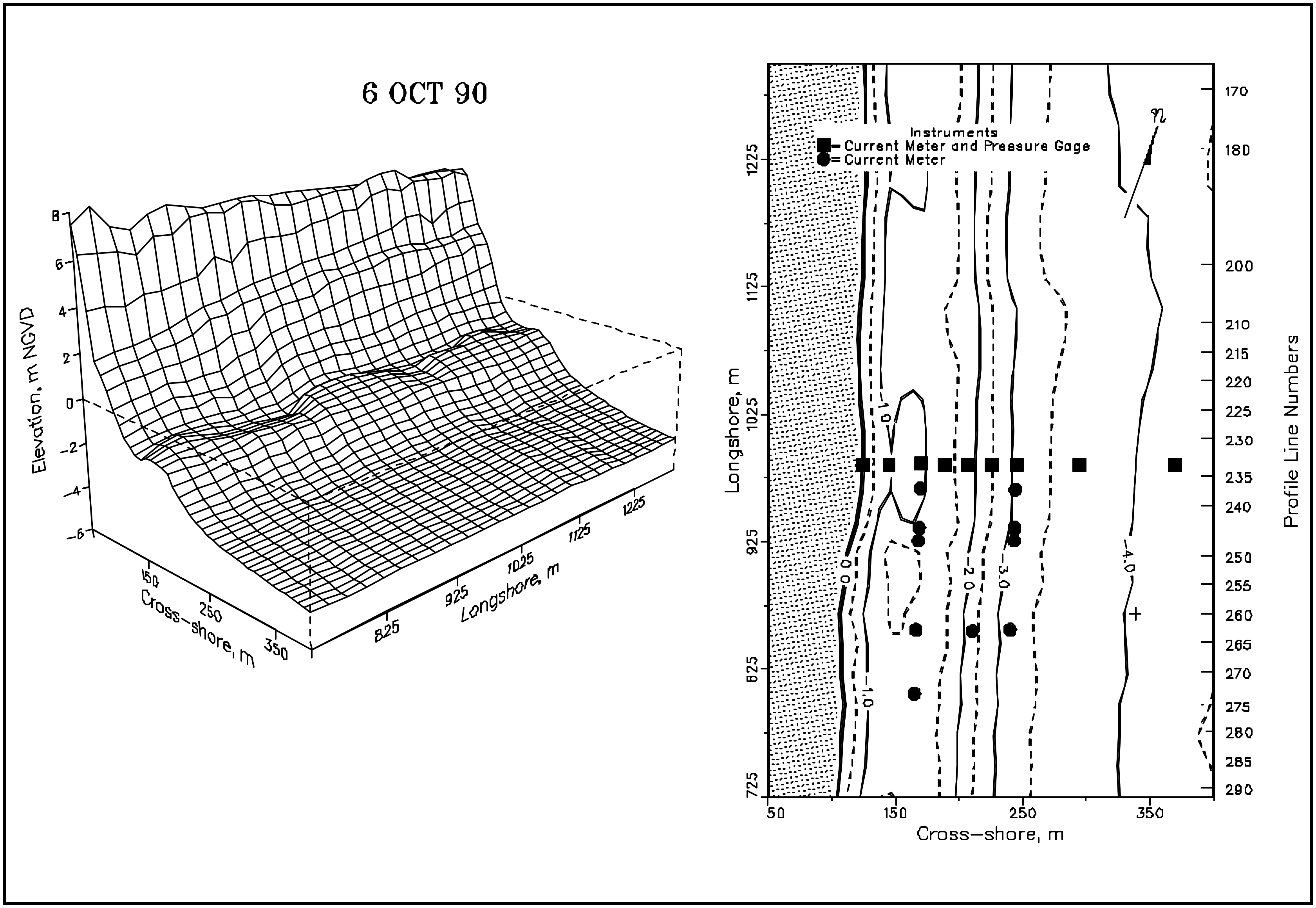

Figure A31. DELILAH Minigrid Survey, 6 October 1990 (crosses on right panel mark end of survey lines)

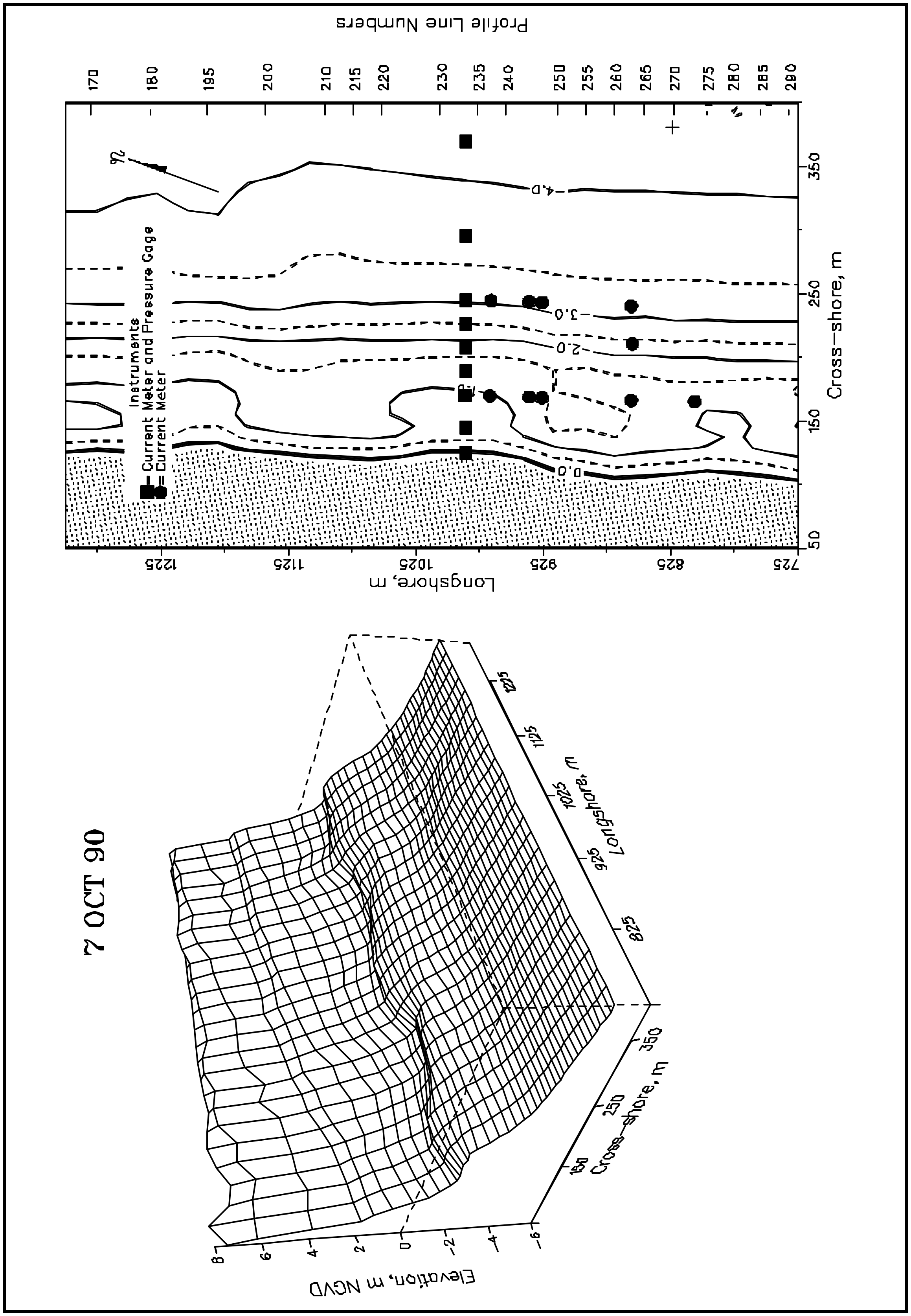

Figure A32. DELILAH Minigrid Survey, 7 October 1990 (crosses on right panel mark end of survey lines)

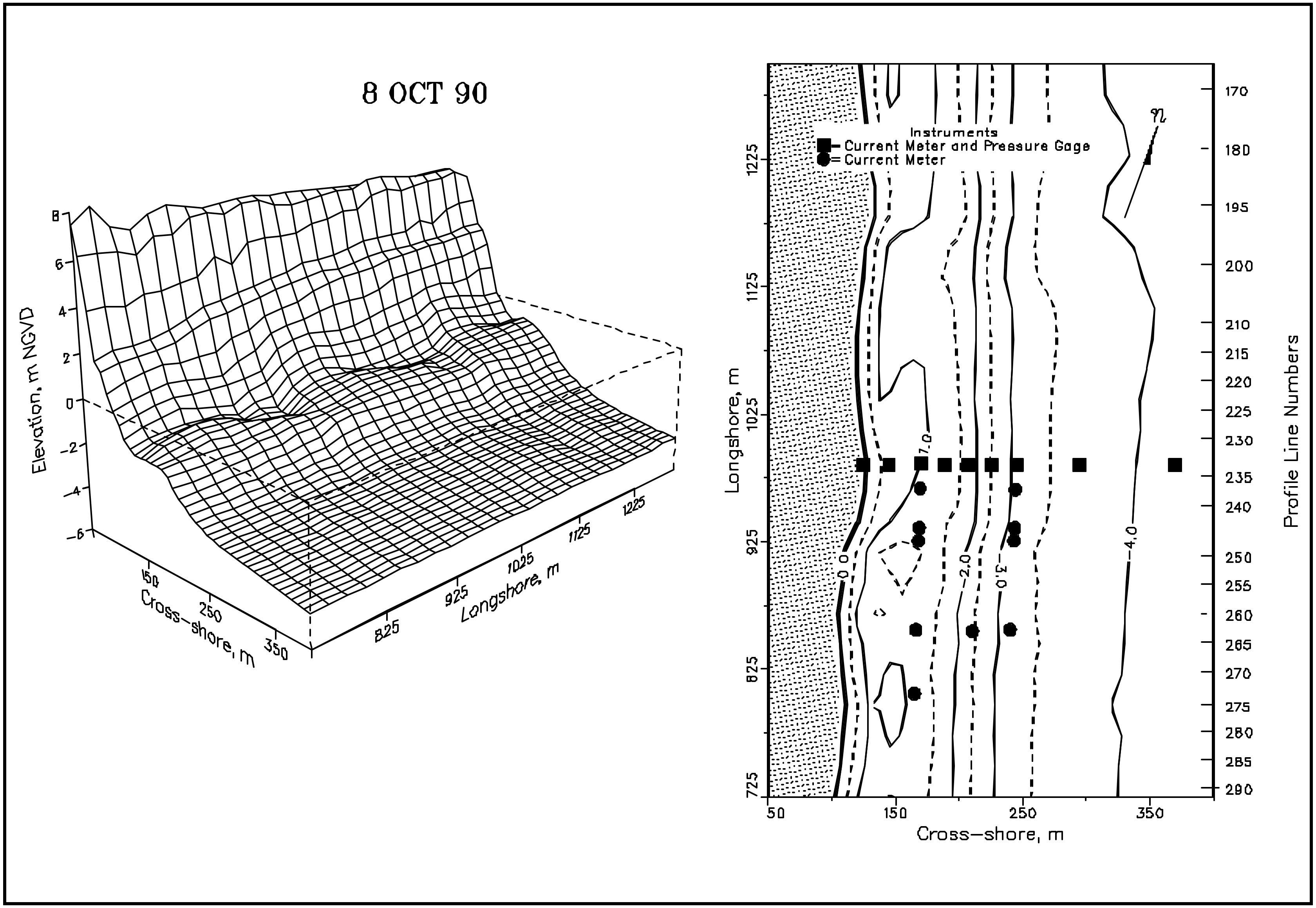

Figure A33. DELILAH Minigrid Survey, 8 October 1990

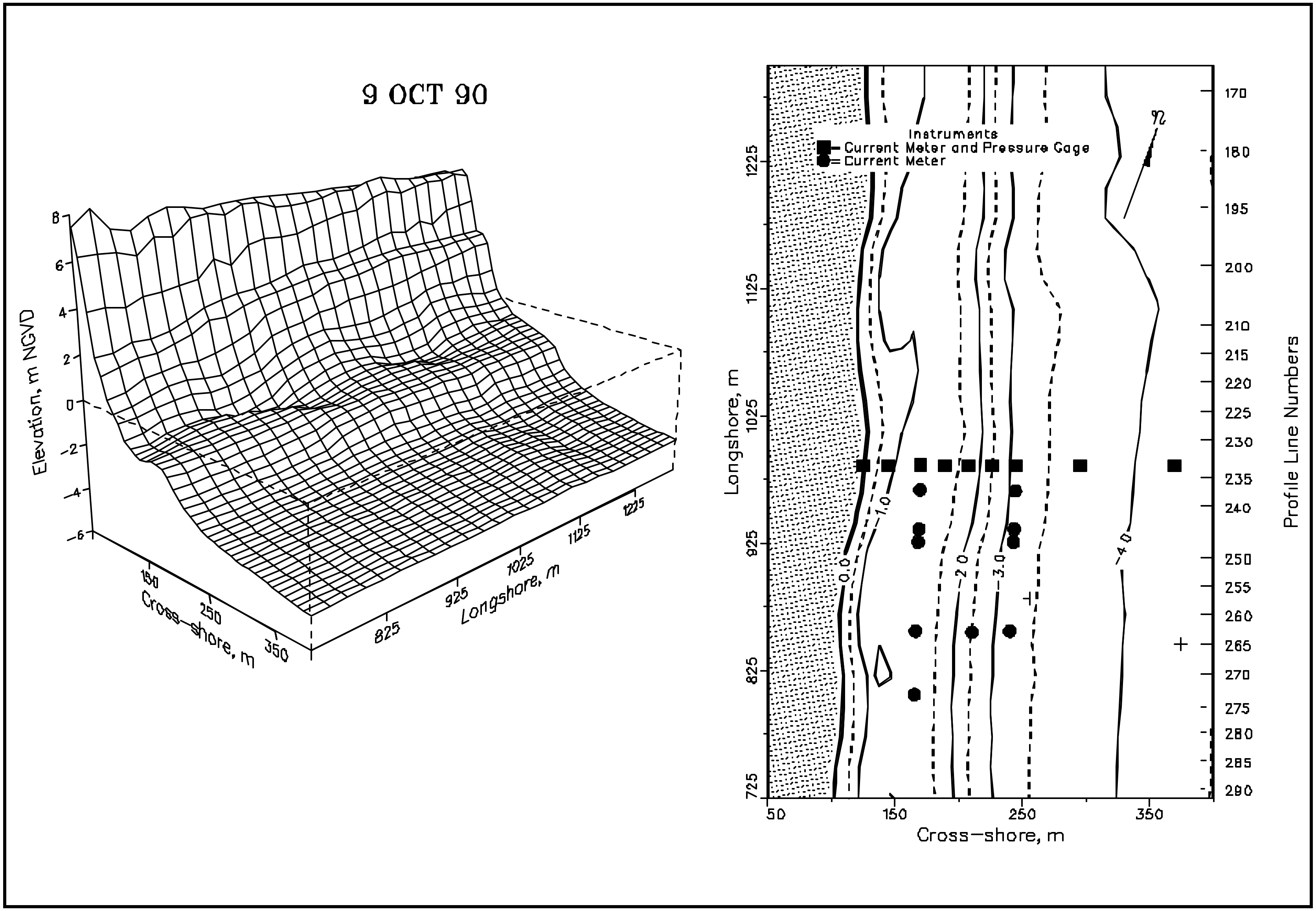

Figure A34. DELILAH Minigrid Survey, 9 October 1990 (crosses on right panel mark end of survey lines)

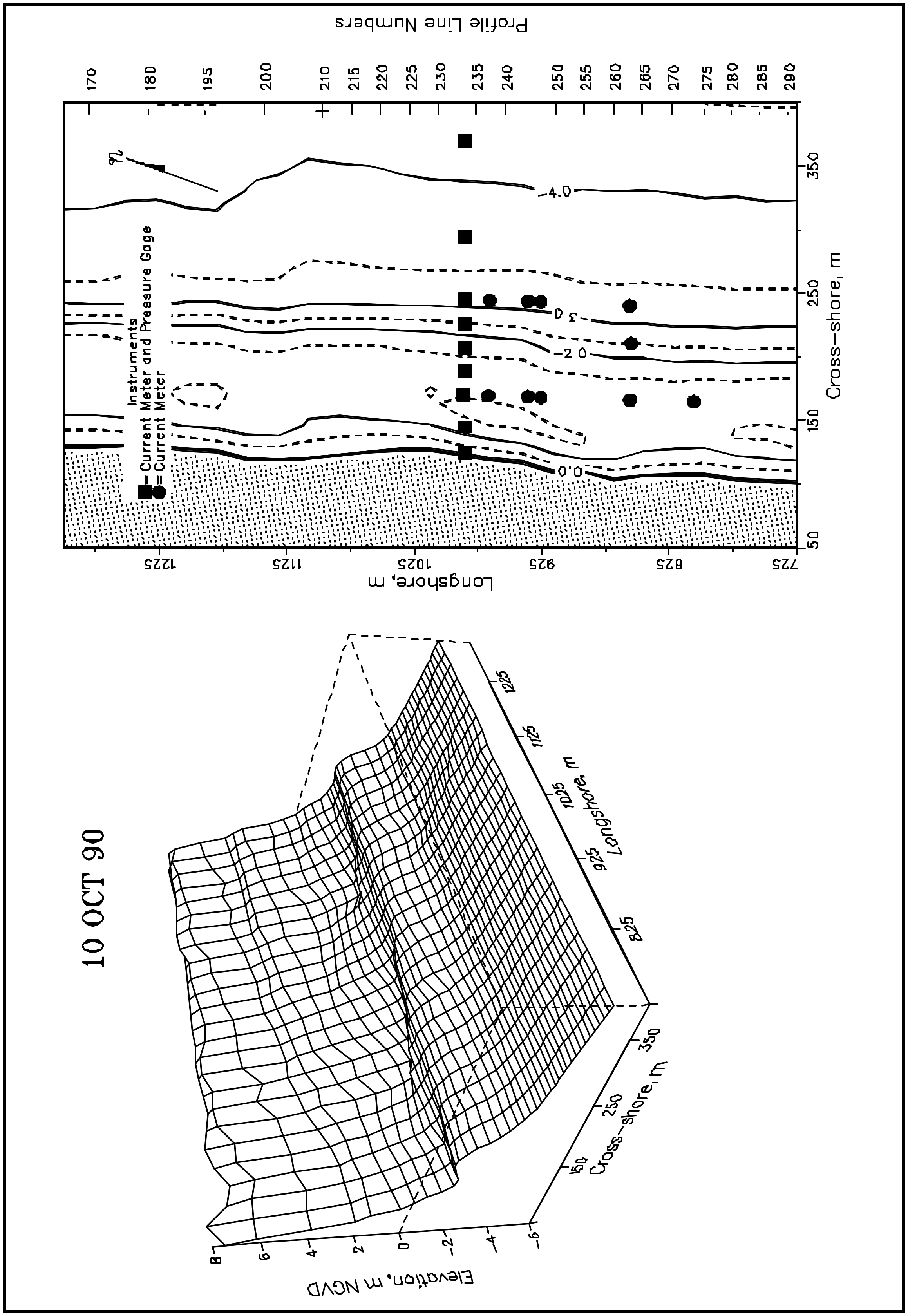

Figure A35. DELILAH Minigrid Survey, 10 October 1990

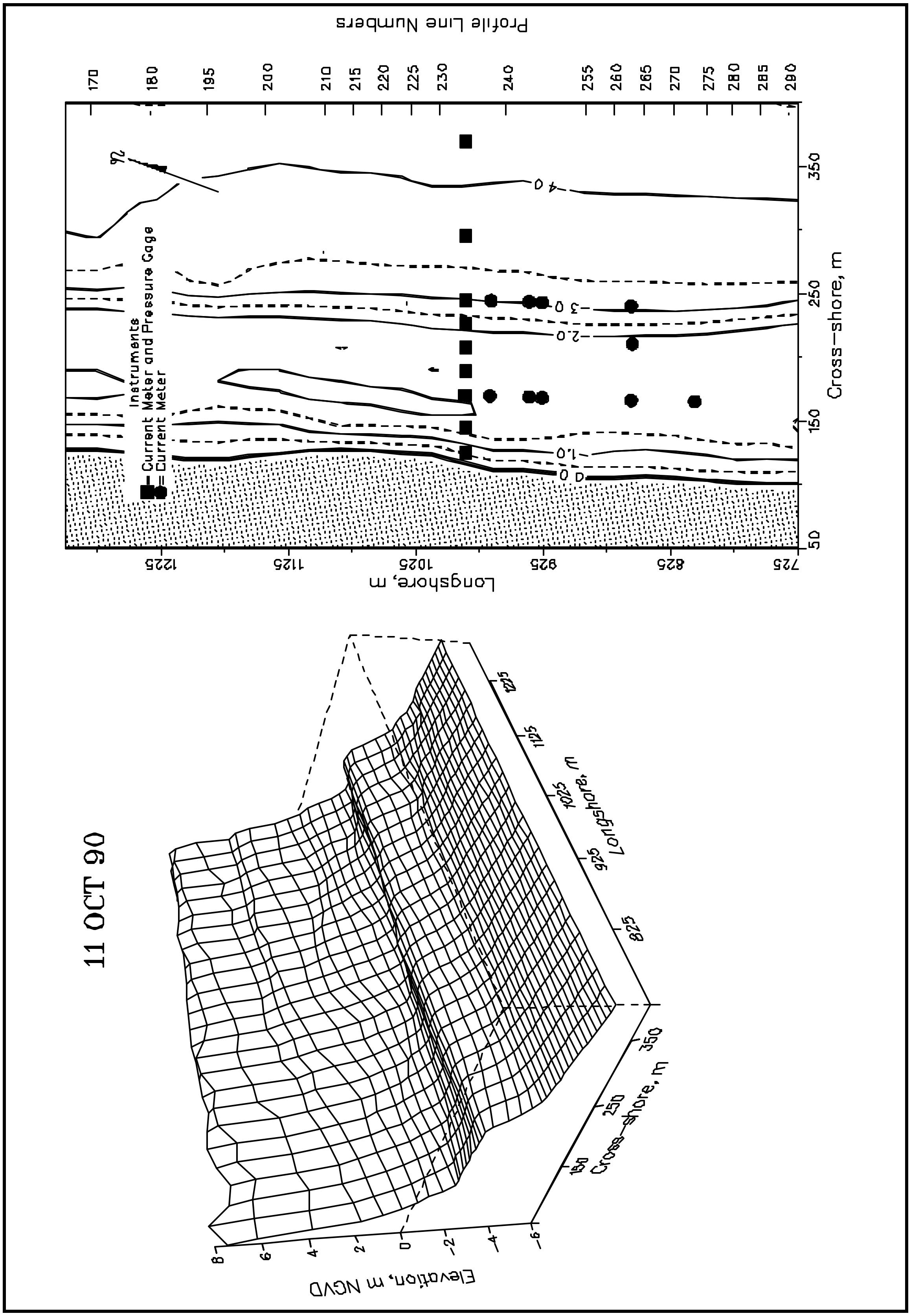

Figure A36. DELILAH Minigrid Survey, 11 October 1990

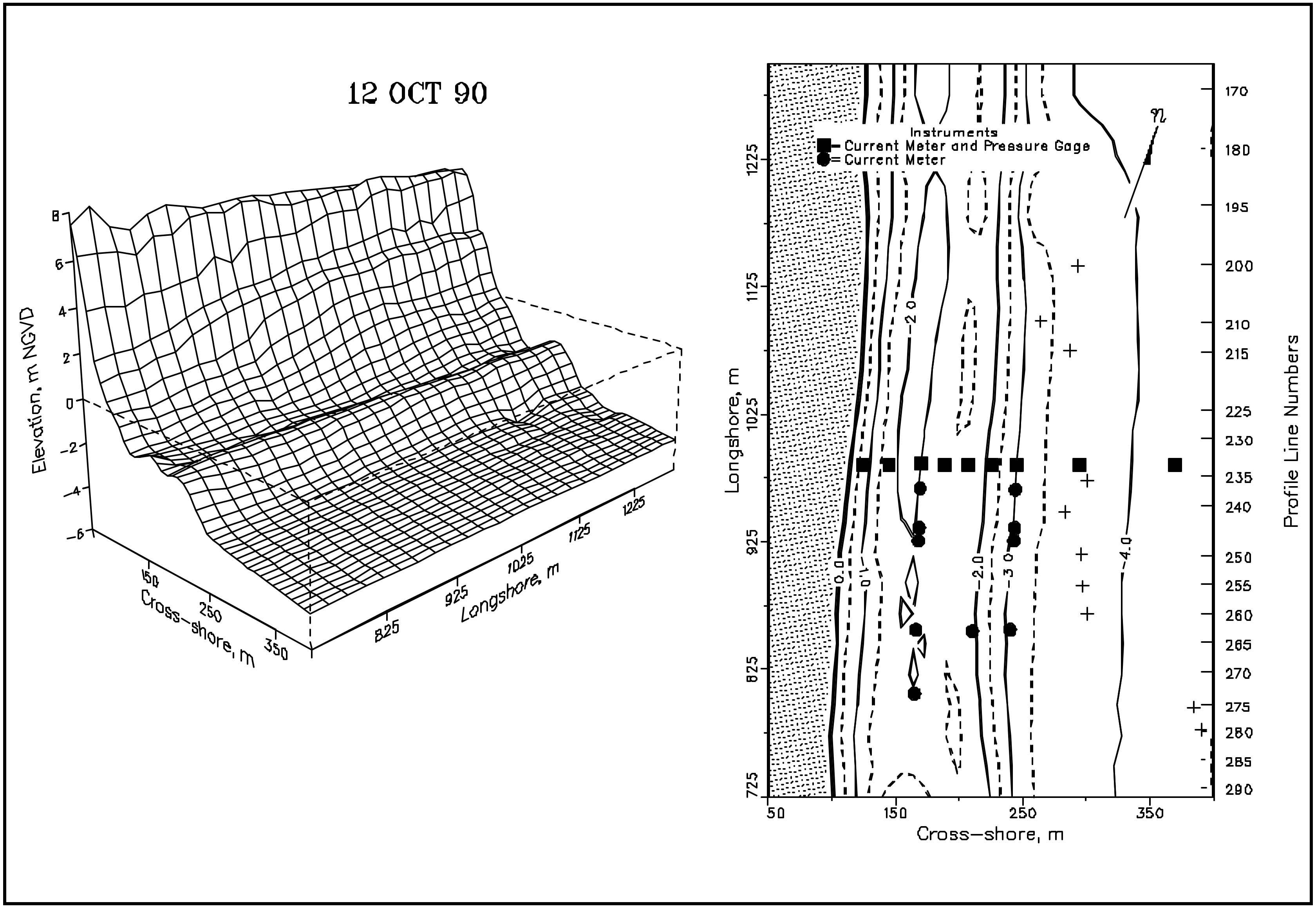

Figure A37. DELILAH Minigrid Survey, 12 October 1990 (crosses on right panel mark end of survey lines)

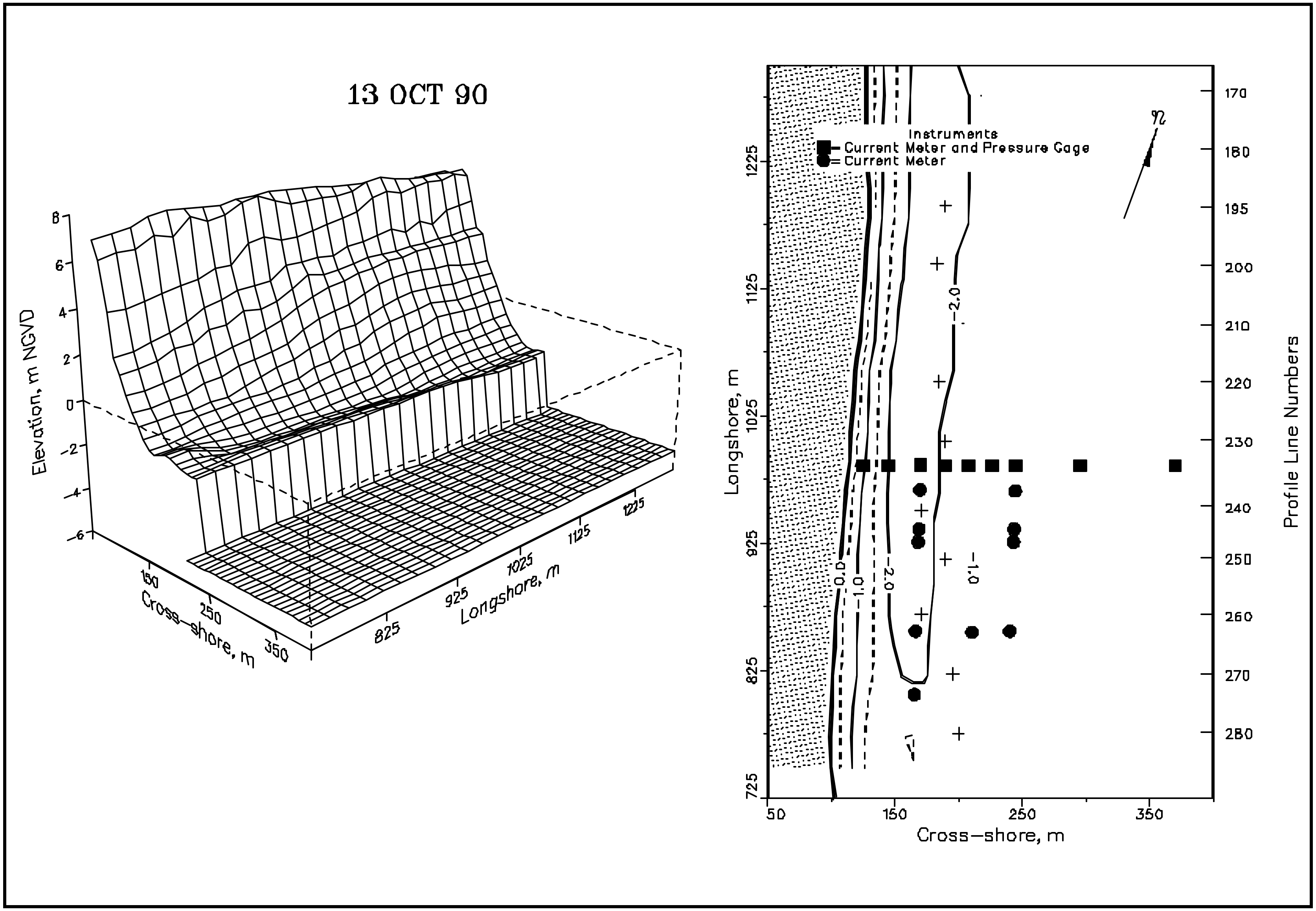

Figure A38. DELILAH Minigrid Survey, 13 October 1990 (crosses on right panel mark end of survey lines)

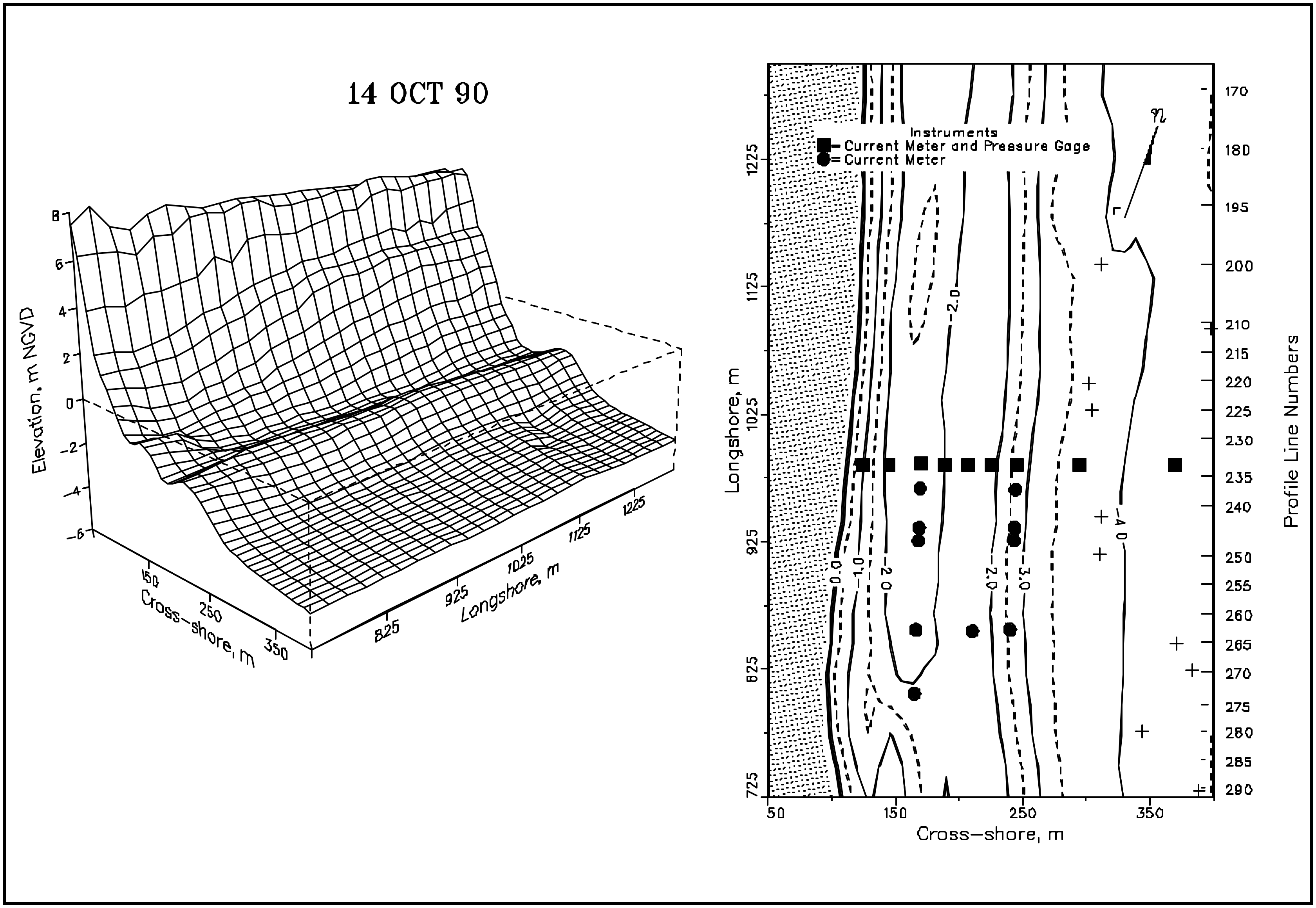

Figure A39. DELILAH Minigrid Survey, 14 October 1990 (crosses on right panel mark end of survey lines)

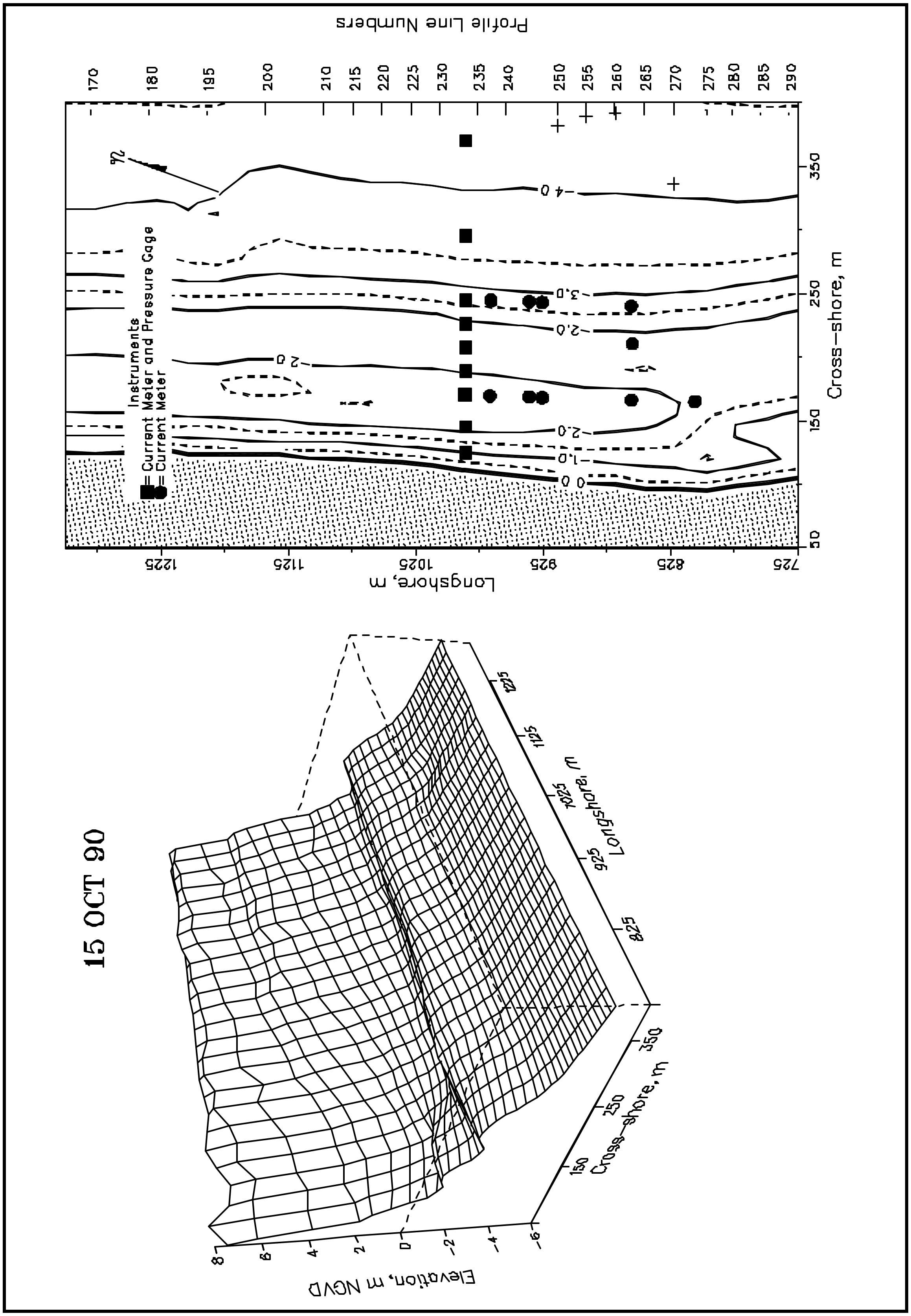

Figure A40. DELILAH Minigrid Survey, 15 October 1990 (crosses on right panel mark end of survey lines)

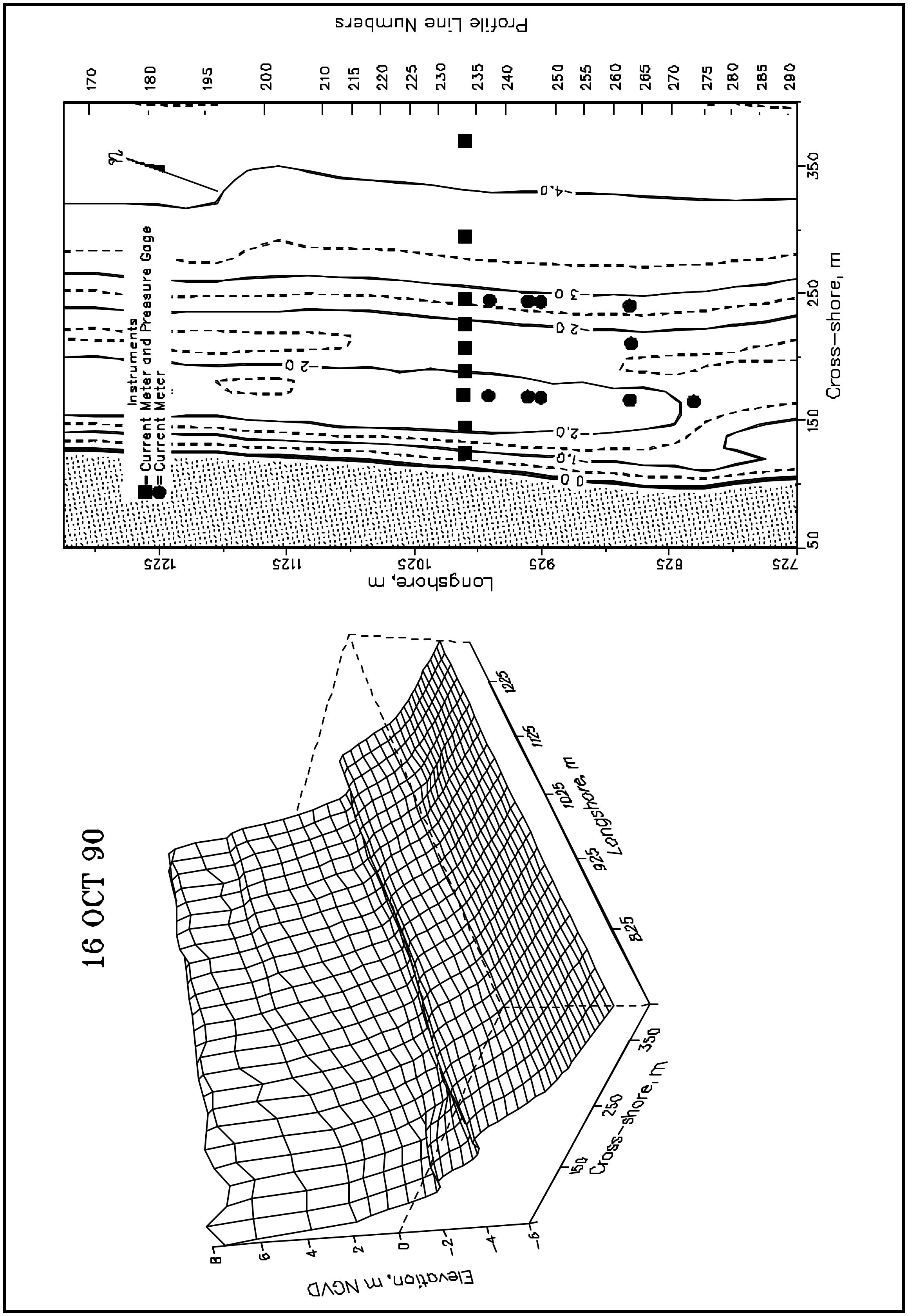

Figure A41. DELILAH Minigrid Survey, 16 October 1990

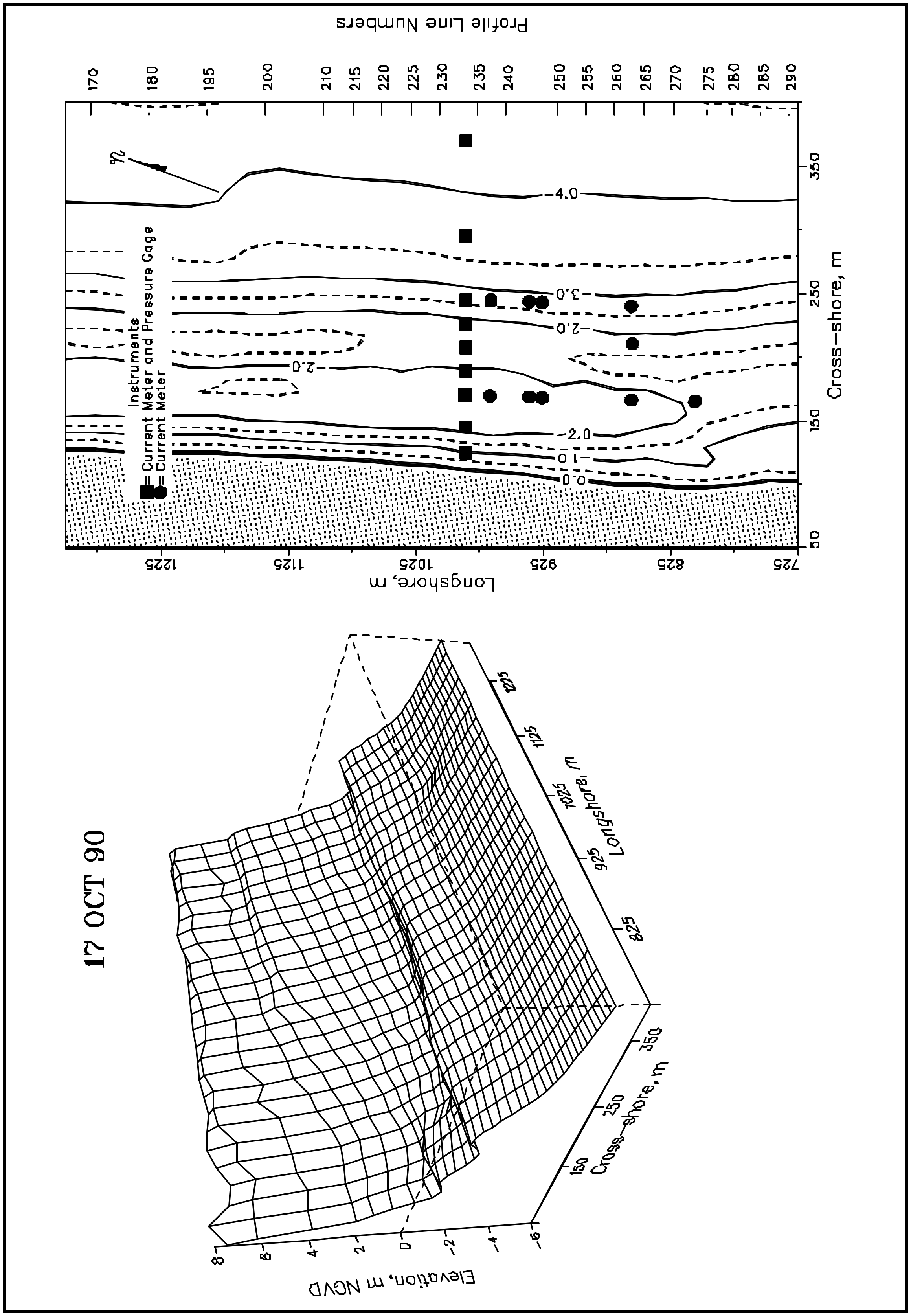

Figure A42. DELILAH Minigrid Survey, 17 October 1990

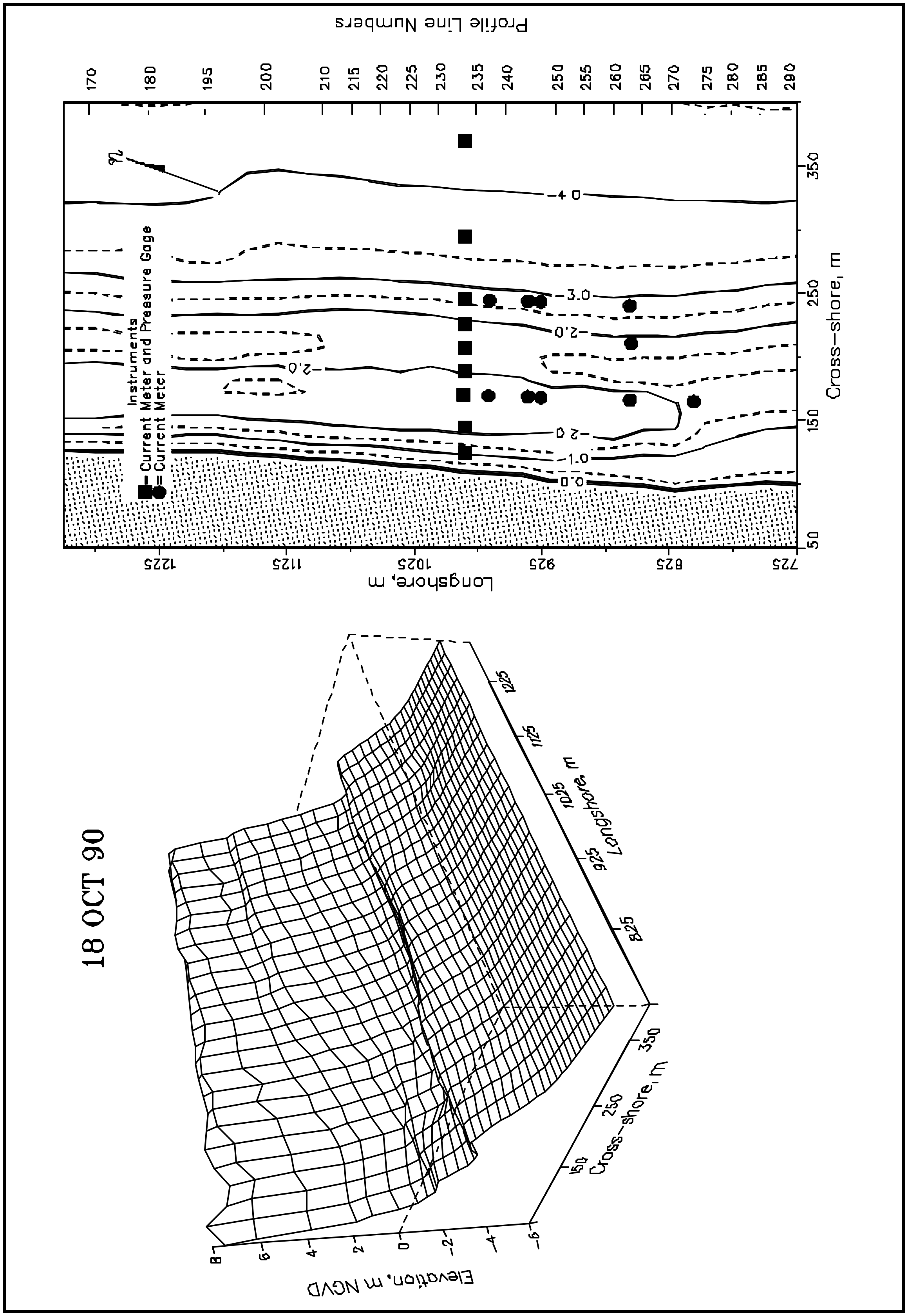

Figure A43. DELILAH Minigrid Survey, 18 October 1990

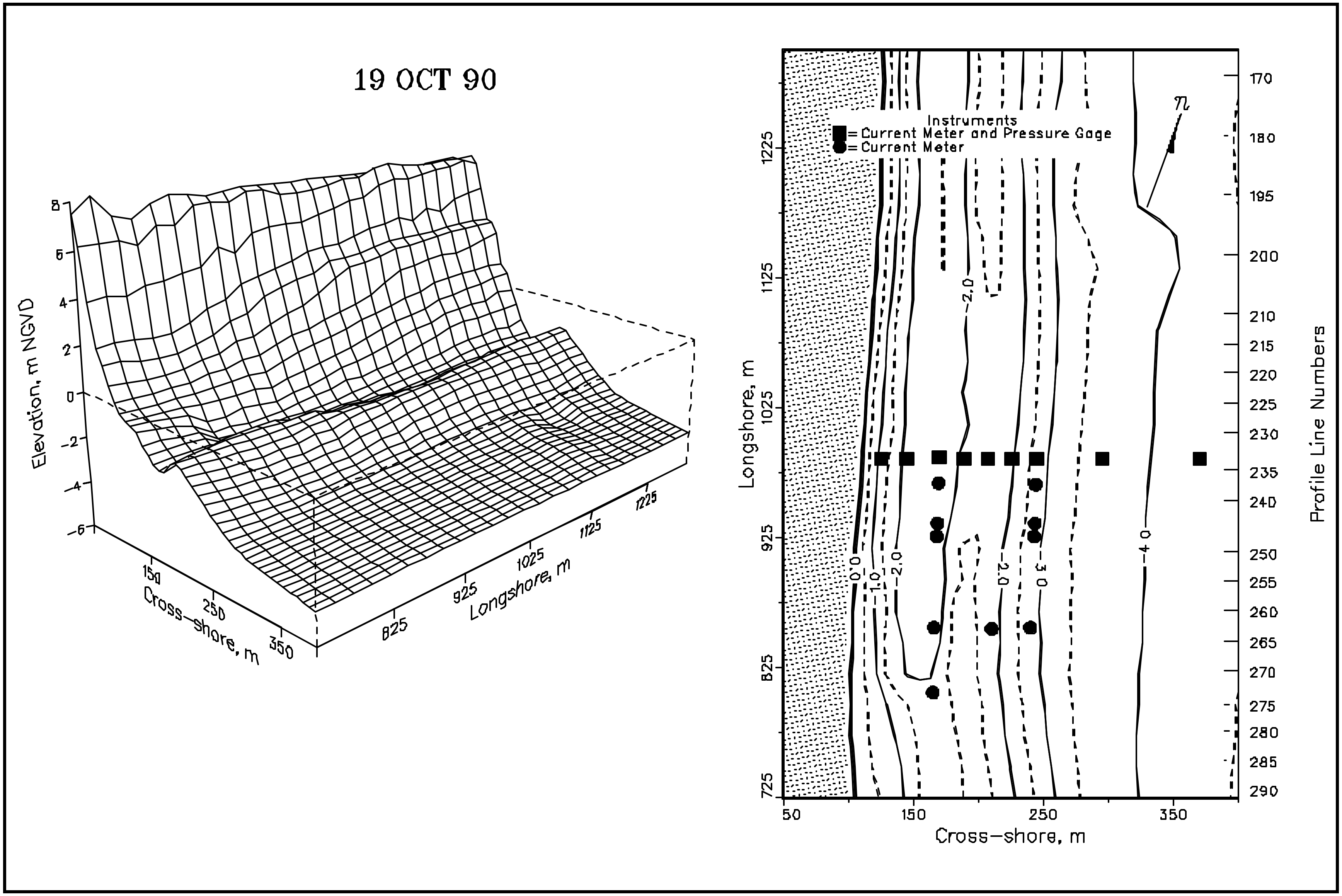

Figure A44. DELILAH Minigrid Survey, 19 October 1990