Investigations of Isolated Sand Shoals and Associated Deposits Virginia Inner Shelf

Final Contract Report
Primarily in the Form of a Data Report

for

U. S. Department of the Interior
Minerals Management Service
Cooperative Agreement 14-35-0001-130643

via

Bureau of Economic Geology
University of Texas at Austin

and

Virginia Division of Mineral Resources

by

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FORWARD

This report is the final project report for the work performed under U. S. Department of the Interior, Minerals Management Service (MMS), Cooperative Agreement 14-35-0001-130643, performed by the Virginia Institute of Marine Science (VIMS), College of William and Mary under contract with the Virginia Division of Mineral Resources, the Bureau of Economic Geology at the University of Texas acting as agent for MMS.

The work described herein reflects the efforts of many people. S. M. Kimball, C. R. Berquist, Jr., and C. H. Hobbs, III variously served as Principal Investigator. Several individuals, especially C. S. Hardaway and D. A. Milligan, provided significant assistance in both interpretation and actual work. C. R. Berquist, Jr. has provided continued assistnace and encouragement. The high resolution seismic profiling was performed with the valuable aid of the captain and crew of the *R/V Bay Eagle* and R. A. Gammisch. C. H. Hobbs, III prepared this document and is responsible for any errors therein.

As was stated in an earlier report (Hardaway et al., 1995), our work in southern Virginia's inner continental shelf has benefitted from the commingling of several discrete projects. In addition to the primary funding source for this report, work performed under MMS Cooperative Agreements 14-35-0001-30731 (similarly managed through the Bureau of Economic Geology and the Division of Mineral Resources) and 14-35-0001-30740 directly with VIMS has contributed substantially to our understanding of the sedimentology and Quaternary geology of the area. Often it is impossible to separate the individual contributions.

Some of the text of this report repeats, in many cases word for word, the text of Hardaway *et al.* (1995). The repetition is necessary is providing background both as to the objectives and the geologically setting of the project.

It is our intention to continue work on Virginia's continental shelf. We will continue to acknowledge the participation of MMS and to advise MMS of our progress and of the products of the research

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INTRODUCTION

This report primarily serves to present minimally interpreted data from a tight spaced set of high-resolution, seismic-reflection, sub-bottom profiles obtained during the summer of 1992. The profiles were run in the inner continental shelf adjacent to Virginia Beach, Virginia as part of an investigation of offshore sounds potentially usable in beach nourishment and hurricane protection projects along Virginia's Atlantic shore south of the mouth of Chesapeake Bay. Figure 1 depicts the general study area.

Berquist and Gomillion (1993) presented an interpretation of a small portion of the work. A larger, interpretive report (Hardaway *et al.*, 1995) also utilizes information from this set of sub-bottom profiles.

The full set of most recent studies builds upon, amplifies, and modifies the interpretations of a set of earlier works especially, Shideler *et al.* (1972), Swift *et al.* (1977), Williams (1987), Dame (1990), Kimball and Dame (1989), Kimball *et al.* (1991), Chen (1992), and Chen *et al.* (1995).

The Problem

The primary drive behind this and the related series of projects is the need to locate substantial quantities of sand suitable for use on along the shoreline of the city of Virginia Beach, Virginia. In its Beach Management Plan (City Manager's Beach Management Task Force, 1993), city officials stated " ... from both an economic and community identity point of view the essence of Virginia Beach is 'the beach'" and "... the beaches of the City contribute to the overall quality of life of all citizens of Virginia Beach. The beaches give identity to the City as a coastal resort area, as such have a marked influence on the City's level of prosperity and the well-being of its citizens." As with many coastal areas, natural forces, in some areas accelerated by man's activities, attack the beach and decrease its size and thus lessen its effectiveness as both a "draw" and a line of protection from the effects of storms. The city and the U. S. Army Corps of Engineers have developed plans for replenishing the beach and for constructing works to absorb the impacts of hurricanes. Both sets of projects require significant quantities of sand.

Quoting from Hardaway *et al.* (1995)

> The City of Virginia Beach is faced with an ongoing problem of erosion along its ocean beaches. The "Resort Strip," the backbone of beach-going tourism in the Commonwealth, must be renourished annually. Steel bulkheads or sea walls have been constructed along most of the 7 km (4.5 mile) ocean shoreline of Sandbridge, a semi-private, ocean-side community. The City is

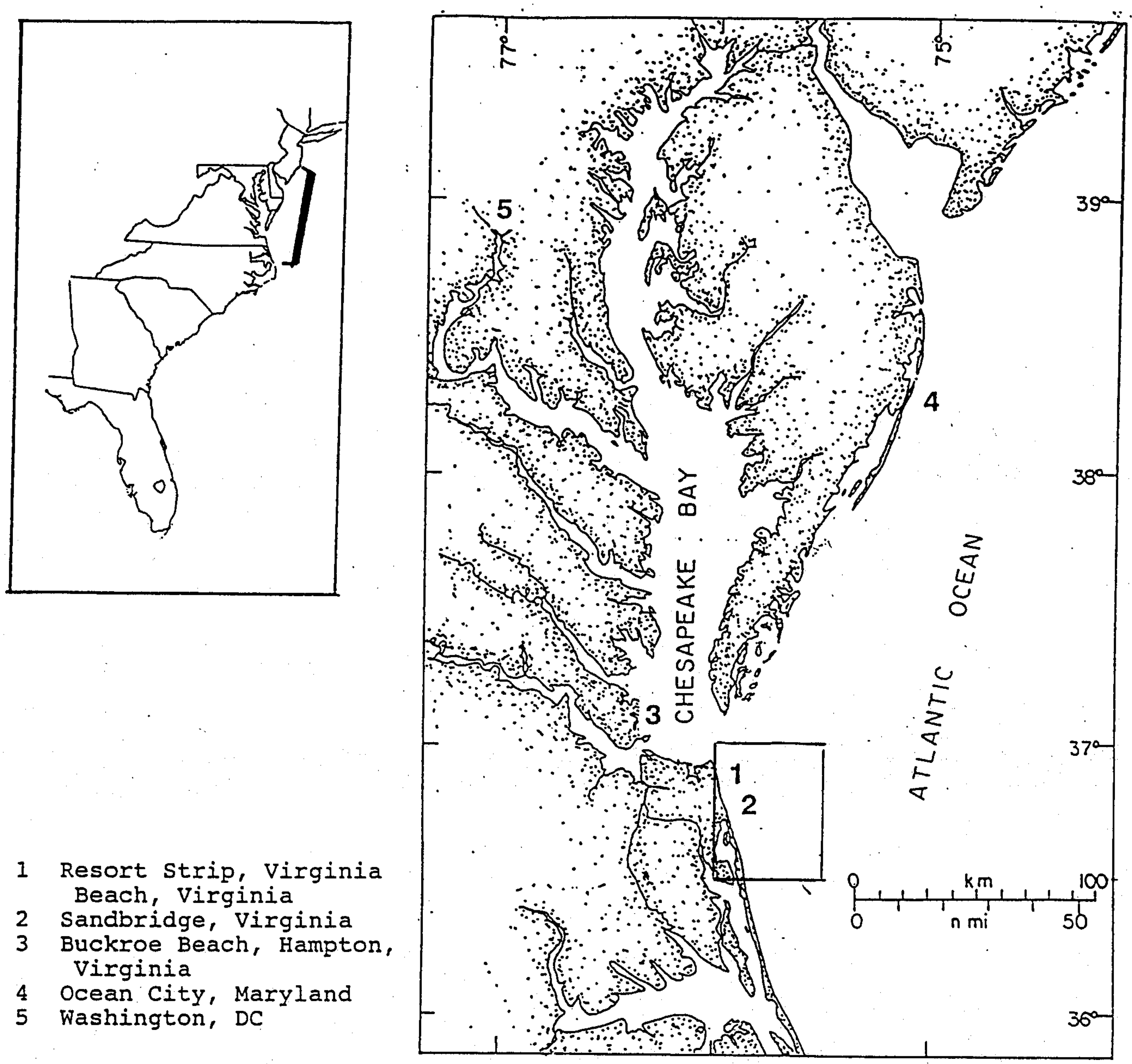

Figure 1: Map depicting the location of the study area and other sites mentioned in the study. the box in the bottom center represents the area shown in Figure 2 and in the track line maps in Appendix 1.

looking for beach material to reestablish its sandy coast. Maintaining a protective and recreational beach is the primary goal in both locales.

Previous sources of sand for the "Resort Strip" have been upland borrow pits that either have closed or are located too far from the shore for economically feasible truck-haul. Most recent nourishment efforts have relied on a large dredge material stockpile at Lynnhaven Inlet. Although, this stockpile is adequate at present for beach nourishment, it must be transported by truck and its future as a sand resource is not certain.

Nearshore borrow areas have been utilized with success at several locations around the U.S. including the nearby sites of Ocean City, MD and Hampton, VA. Two projects were constructed at Ocean City, MD, in 1988 and 1990-91 with of 1.8×10^6 m^3 (2.4×10^6 cy (cubic yards)) and 2×10^6 m^3 (2.7×10^6 cy) of suitable beach fill being mined and placed respectively. Hampton's Buckroe Beach was supplied with 210×10^3 m^3 (275×10^3 cy) of offshore borrow material from Thimble Shoals, Chesapeake Bay in August 1990 (Hobbs and Kimball, 1990; Hobbs, 1993).

Since the installation of steel bulkheads in 1987, Sandbridge essentially has lost its subaerial beach. The site never has been nourished; however recent overtures by the City and the U.S. Army Corps of Engineers indicate a potential partnership. Truck hauling sand is feasible with very good upland source about 22 road km (14 miles) away in the Pungo Ridge. However, offshore sand reserves occur at "Sandbridge Shoal" less than 3 n mi offshore and likely are a viable, less expensive sand source for beach nourishment.

In the summer of 1995 the U. S. Navy began the paperwork process intended to lead to the eventual mining of 5.35×10^5 m^3 (7×10^5 cy) for nourishment of 2,829 m (9,280 ft) of beach in front of the facility at Dam Neck, an area immediately north of Sandbridge. The discussion of potential reserves of sand for Sandbridge applies equally the Navy's to Dam Neck facility. Indeed the Navy proposes to use one of the sources, "Sandbridge Shoal" addressed in this and previous reports.

The work reported upon in this and earlier reports was undertaken to assist in the search for sand suitable for use on the shores of Virginia Beach.

GEOLOGICAL SETTING

A basic understanding of the regional geology is essential as a starting point for the interpretation of the sub-bottom profiles reported upon in this report. Therefore it is advantageous to reproduce another portion of Hardaway *et al.* (1995)

The inner continental shelf of the Commonwealth of Virginia is the subaqueous extension of the Coastal Plain Province. Several stratigraphic units that have been identified in outer coastal plain (Peebles *et al.*, 1984). These units range from Pliocene to Late Pleistocene in age and are overlain by a veneer of modern Holocene sediments that have been transported into the area from shoreline sources and the Chesapeake Bay and have been reworked from the older, underlying strata.

Williams's (1987) analysis and interpretation of seismic data, which is based upon Shideler *et al.* (1972), indicates that the stratigraphy of the Virginia inner continental shelf to depth of about 45 m (150 ft) (MSL) consists of four primary and distinct sedimentary units separated by unconformities, indicated as sharp reflectors, of regional extent. Reflector 1, the top of the deepest and oldest unit, Unit A (Shideler *et al.*, 1972), is about -36 m (-120 ft) MSL. The depth and acoustic character suggest this surface to be the top of the Yorktown Formation (Unit A), a major erosional surface throughout the Virginia Coastal Plain. The Yorktown Formation was deposited during the Pliocene.

The next, younger sedimentary sequence, Unit B, is characterized by planar stratification and prominent channels showing considerable relief with thalweg depths to -30 m (-100 ft) MSL. According to Williams (1987), their structural nature and stratigraphic position suggest the channels were eroded during the late Pleistocene ocean-level lowstands when rivers, such as the ancestral Susquehanna and James, flowed eastward across the then subaerially exposed continental shelf. Vibracores from this unit contain yellowish-brown coarse sand and gravel that suggest a fluvial origin. These channel deposits were determined to offer the greatest potential for sand and gravel resources in the area (Williams, 1987).

Unit C, the next younger sedimentary unit, is characterized by a gray moist clay with high plasticity. The surface of Unit C is at depth of approximately -18 m (-60 ft) MSL with some cores recovering 6 m (20 ft) of clay. The fine grained size and uniform character of Unit C suggest a low-energy depositional environment such as an estuary or back-barrier lagoon (Williams, 1987). Shideler *et al.* (1972) obtained two radiocarbon dates from Unit C that put the stratum at 20.5 to 26.0 Ka that suggest deposition during the middle to late Wisconsinian highstand.

The youngest and shallowest sedimentary stratum is Unit D, which comprises much of the surficial sediments except in areas where Unit B and C outcrop on the seabed. Unit D is characterized by a gray to tan fine to medium sand or muddy sand with modern shell fauna. Unit D is the modern sand sheet that originated during the Holocene transgression.

The four major stratigraphic units are separated from one another by regional reflectors thought to be regional unconformities (Shideler *et al.*, 1972). For the interested reader Toscano and York (1992) attempt to put units A through D into the context of the middle Atlantic Coastal plain and shelf.

More recently Chen (199) and Chen *et al.* (1995) discuss filled channel systems in the inner continental shelf south of the Chesapeake Bay entrance. Foyle (1994) and Oertel and Foyle (1995) discuss the seismic stratigraphy of the inner shelf offshore from the Delmarva Peninsula.

Hardaway *et al.* (1995) itself adds to the understanding of the regional geology with its conclusions emphasizing the complexity of the geology and the potential importance of filled Pleistocene (?) channels to the sand reserve.

METHODS

The data-set reported upon in this document is a set of (very-) high-resolution, seismic-reflection profiles (Hobbs and Dame, 1992) obtained in the summer of 1992. The lines were run aboard VIMS's *R/V Bay Eagle*. Although the ship usually was steered following loran-c navigation, actual positions were documented and recorded from a freestanding (no differential correction) GPS system.

The seismic data were developed with a system consisting of a Datasonics SBT-220 transceiver, TTV-120 towed transduce vehicle, and tow cable and either or both an EPC 3202 or EPC 4800 graphics recorder. The SBT-220 allows easy switching among 3.5, 5 and 7 kHz transmitted signals and provides simple filtering and amplification capabilities. Virtually all of the work was performed at 3.5 kHz as that frequency empirically produced the best results. The usual sweep rate of the graphic recorders was 63 ms (1/16 s) variously with a repetition or firing rate of 0.125 or 0.25 s (1/8 or 1/4 s). The sweep rate yields a full scale approximately equivalent to 47.5 m of penetration using an acoustic velocity of 1,500 m s^{-1}. This slightly underestimates depth in the sediment column as actual acoustic velocities in the sediment likely are somewhat greater. The seismic data exist on paper only; they were not recorded on electronic media.

After returning to the lab the data were processed in the following ways. Navigation information was reviewed and the data were edited or "cleaned up" by removing obviously erroneous points. Next a set of files containing times of individual fixes noted on the graphic records and corresponding latitudes and longitudes for each "line" was assembled and x-y plots depicting each line were prepared. These plots are presented, with additional information, in the appendix.

Initial interpretation of the graphic records involved tracing of prominent reflectors on a clear overlay. The tracings and the original records then were physically reduced with an office copy machine. Further reduced copies of both sets of images also are in the appendix. Finally, after studying the "raw" and traced data, each line was drawn in an interpretive sketch at a constant scale. The sketches, also in the appendix, began with the construction of a horizontally corrected baseline with a horizontal scale of 1 cm to 500 m (the original graphic records are time, not distance, based). Also the sketches all were constructed with west or north to the left to facilitate correlation of features from line to line. The lines representing the sea-floor reflection and prominent sub-bottom reflectors then were drawn to a vertical scale of 1 cm to 10 m (or 1 cm to 13.3 ms two-way-travel-time at 1,500 m s^{-1})(3 cm to 30 m or 40 ms).

Significant features from each line, usually filled channels, were marked in proper place on an overlay to the line map, the same overlay being used for all lines. Finally once again the lines themselves were reviewed individually and collectively to assist in the development of an overall sense of the geology.

RESULTS AND CONCLUSIONS

Virtually all of shoals that appear in the seismic lines that were obtained during this study exist as discrete bodies atop a reflector that appears to be the continuation of the adjacent sea floor. The shoals, which might be characterized as discontinuous surficial sand bodies, are analogous to Unit D as described by earlier authors, e.g. Shideler *et al* (1972). However the stratigraphic section itself is more complex than the relatively simple A, B, C, D layer-cake model.

Although the field methods employed in this study do not allow reflector by reflector correlation across more than two or three lines, it is apparent that there are more significant reflectors than accounted for in the simple model. But given more knowledge of the details of the regional Pleistocene history, this is not surprising. In their analysis of the regional stratigraphy, Toscano and York (1992) portray Units A and B and Reflector 1, of Shideler *et al.* (1972) and more recent authors as being of Pliocene age and Reflector B as being the Pliocene-Pleistocene boundary. Thus leaving Unit C as a single unit spanning the entir Pleistocene and the discontinuous Unit D as the (usually) active, surficial, Holocene sedimentary unit.

Given three major low-stands of sea level during the span of Unit C, regionally indicated by the Exmore, Belle Haven, and Eastville paleochannels and the post-Unit C, Pleistocene ending Cape Charles paleochannel (Colman and Hobbs, 1987, 1988; Colman and Mixon, 1988; Colman *et al.*, 1990; Foyle, 1994; Oertel and Foyle, 1995) in Chesapeake Bay, one would expect to see profound evidence of the series of transgression and regressions in the stratigraphy record within Unit C. Additionally, Toscano (1992) a set of sea-level oscillations during oxygen isotope level 5, the last Plesistocene high-stnd of sea level that would have affected what is today the inner continental shelf. Thus it is valid to assume that the Pleistocene stratigraphy record is more complex than has previously been described and that the complexity is manifest in the seismic records.

The present work also modifies Chen's (Chen, 1992; Chen *et al.*, 1995) description of the network of filled paleochannels imbedded in the sediments of the shelf. The major channel system identified in the data-set reported upon herein is substantially broader than was indicated in the earlier studies. The present data also tend to confirm the complexity of the other channe networks. Figure 2 is a sketch map of the major channel systems evident in the present data.

Viewed in the context of prospecting for sand, the data define two modes or models of deposit. One model is the discrete, surficial shoal; the other channel fill. Although both types of deposit are easily discernable in the seismic record, both require determination of actual material and confirmation of size by actual physical sampling. And that physical sampling must be in the three dimensional. An appropriate network of cores is essential to define the horizontal and vertical variability of sediment characteristics so as to enable precise calculations of the quantity of material available and the careful delineation of the areas proposed for mining.

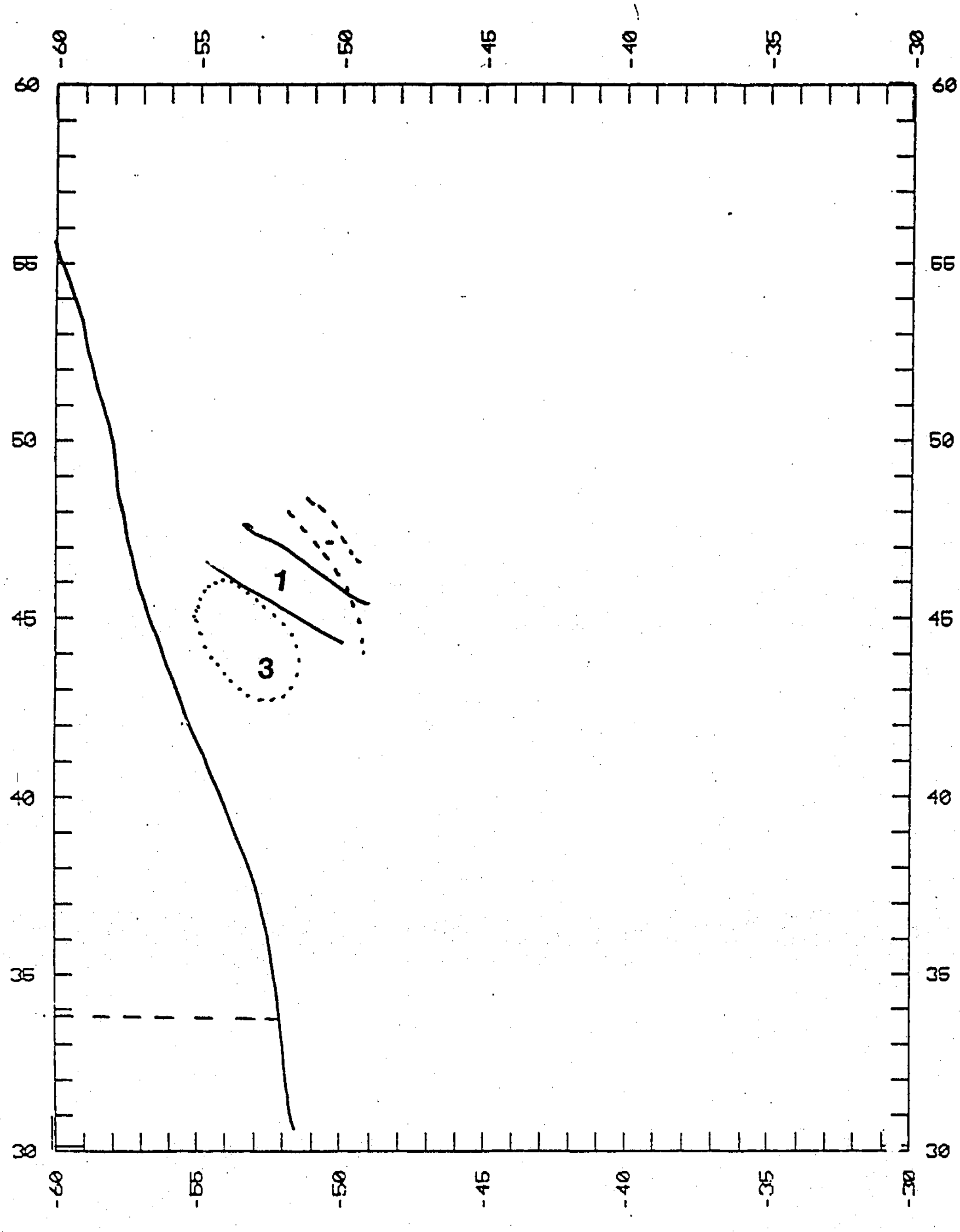

Figure 2: A sketch map depicting the major channel systems evident in the 1992 seismic reflection profiles. #1 is a major channel for which there is excellent control in terms of channel width. #2 shows the trend of a lesser but also distinct channel (system?) at the eastern limit of the 1992 data. #3 is an area within which there are numerous small channels.

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APPENDIX

Each page in this Appendix represents one of the sub-bottom profiles reported upon in the preceeding text. At the top of each page is a scaled sketch of the profile. As part of the drawing process the profiles were oriented with either north or west to the left in order to facilitate comparisons of adjacent lines even though the original data may have had opposite orientatons. A simple regional map depicting the shoreline and the location of the line occupies the bottom left of each page. The bottom right contains reduced copies of the original graphic recording and a tracing taken from the original.

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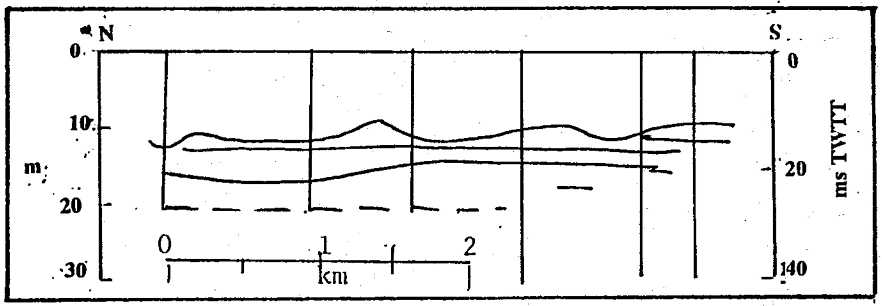

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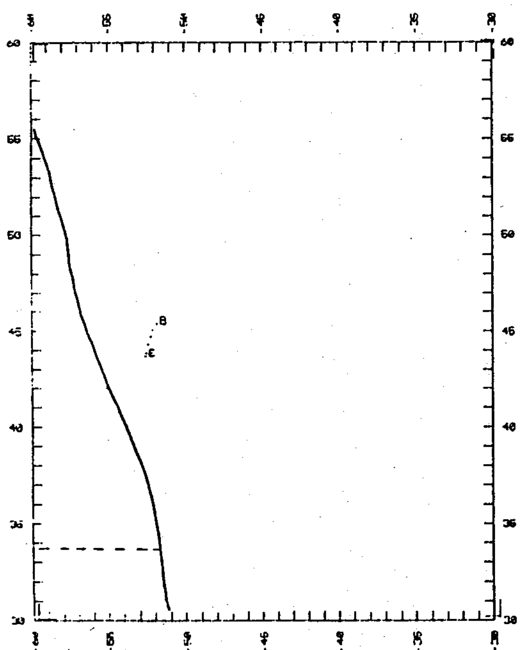

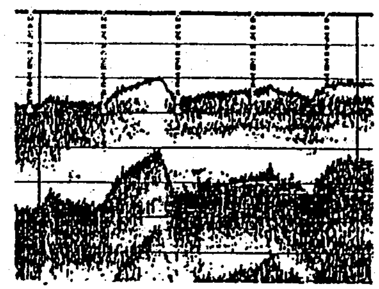

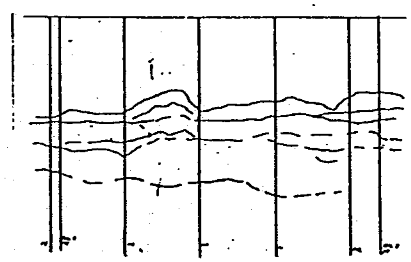

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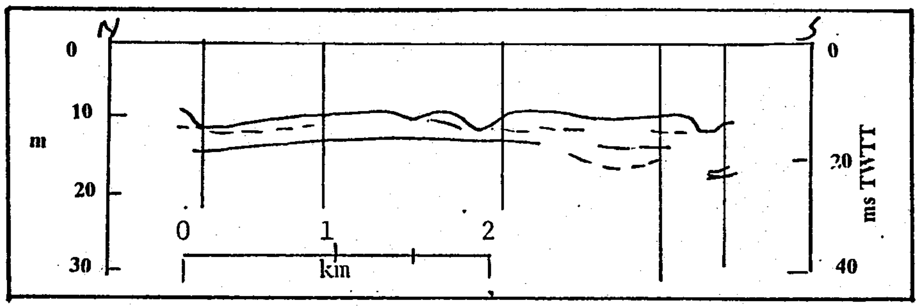

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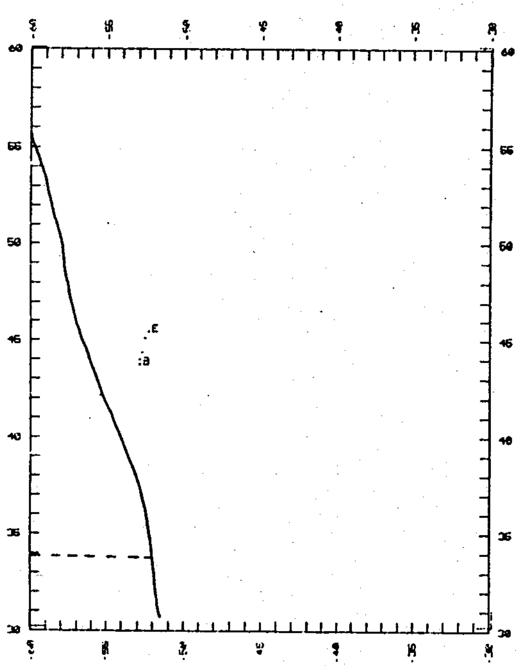

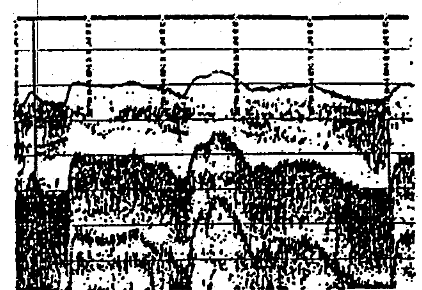

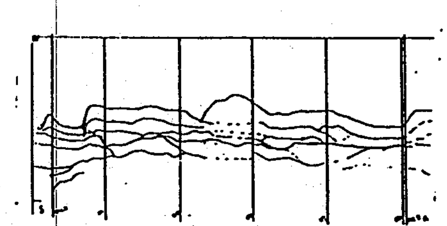

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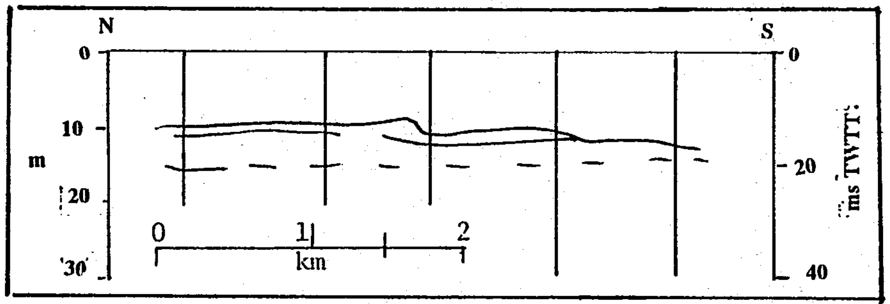

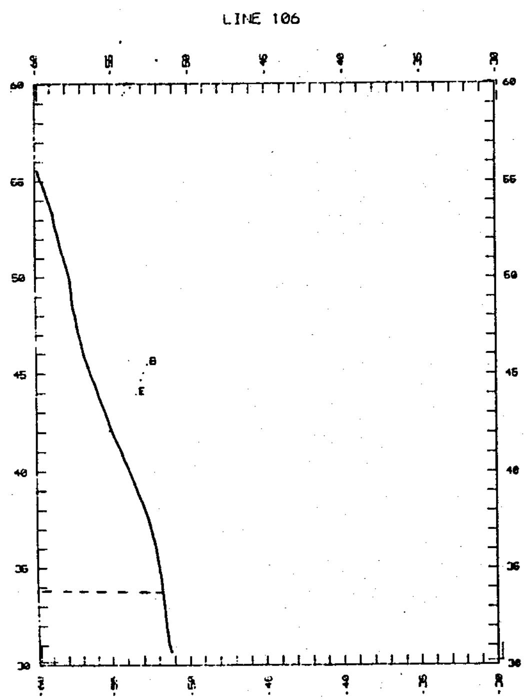

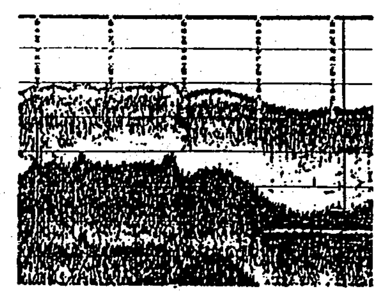

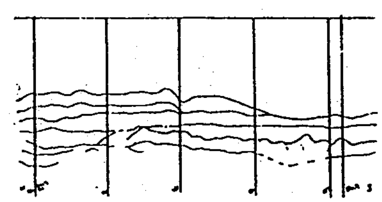

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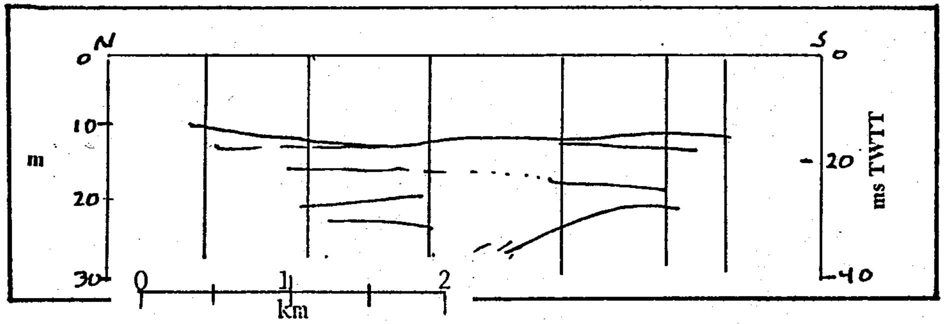

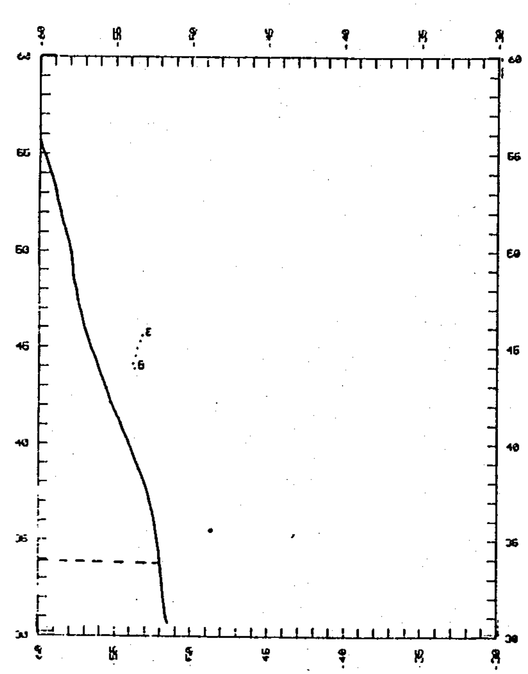

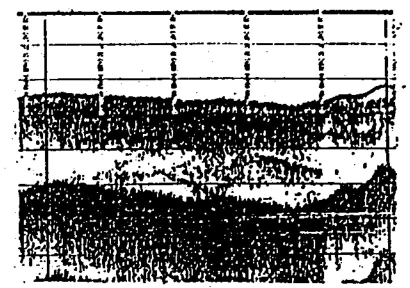

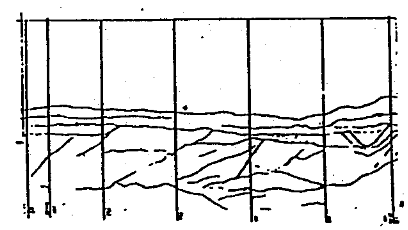

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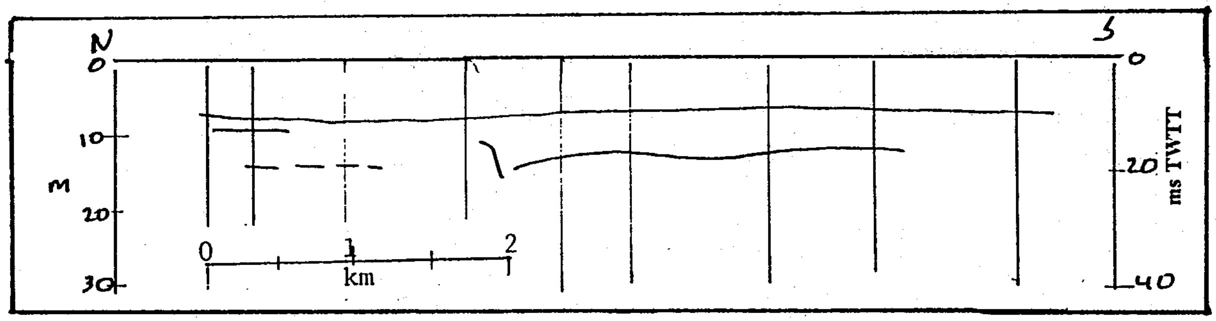

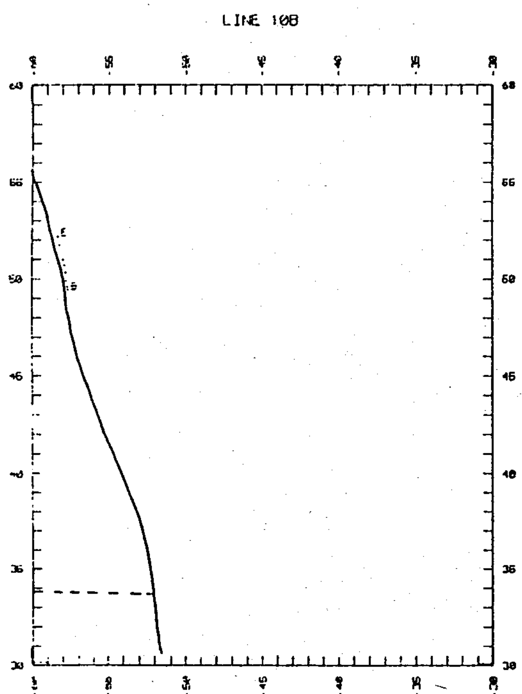

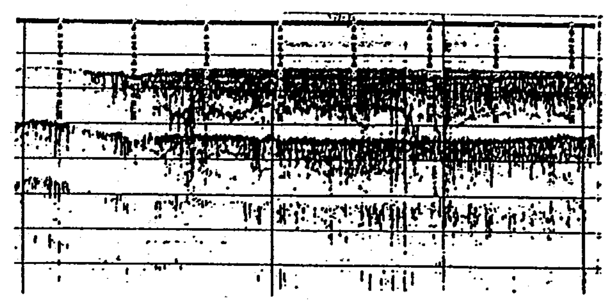

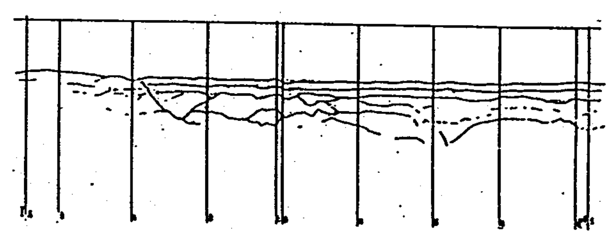

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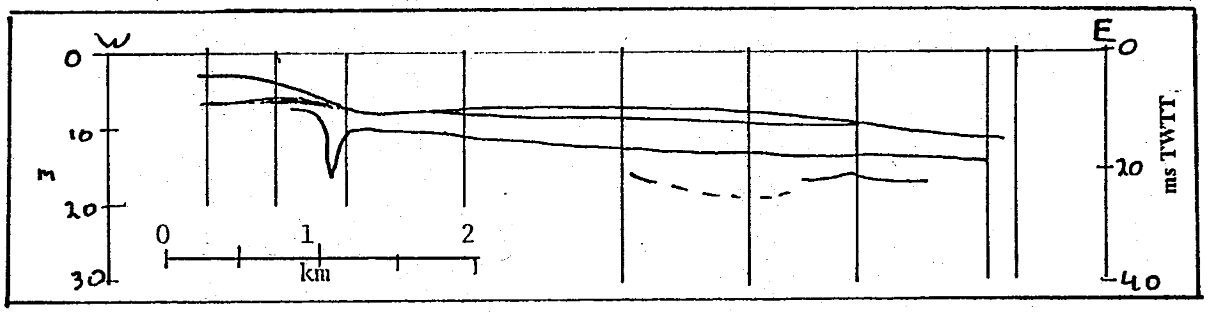

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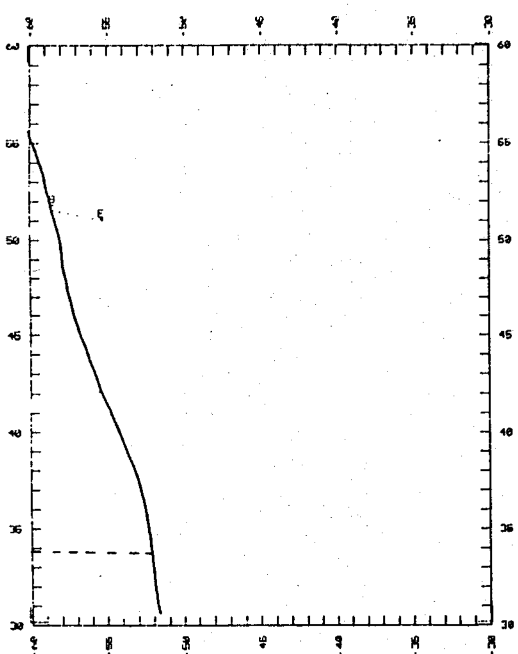
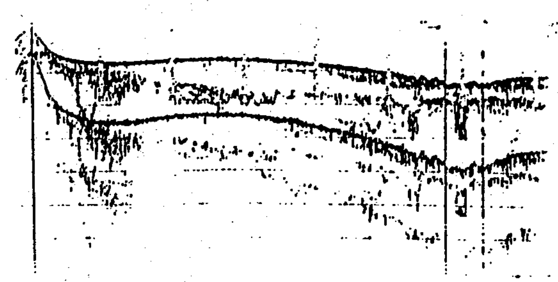
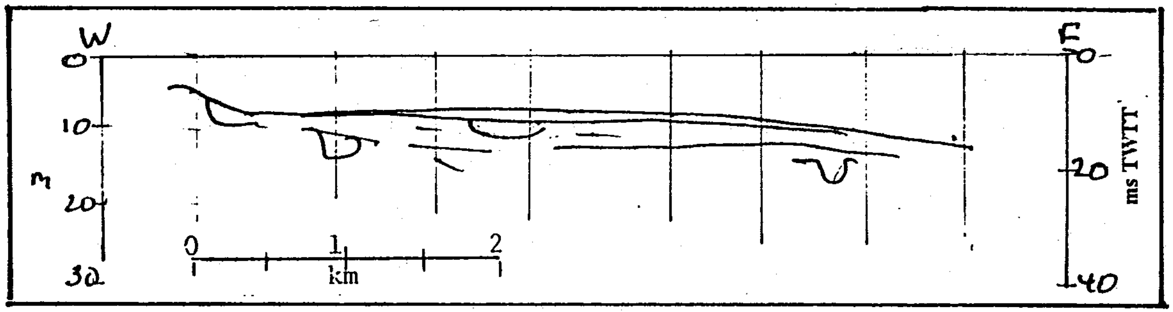
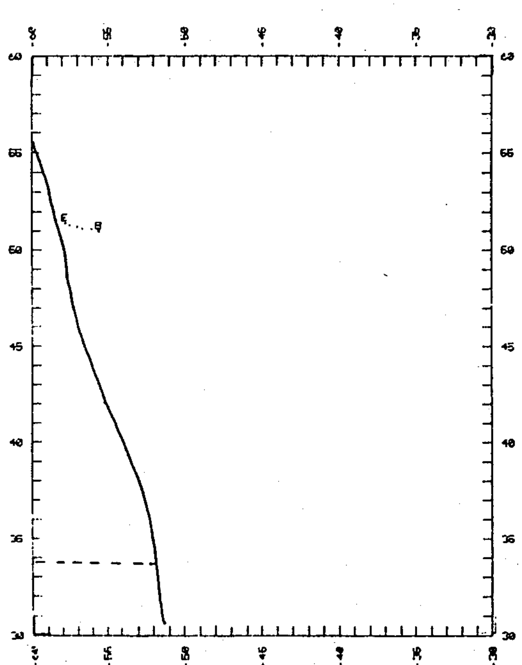
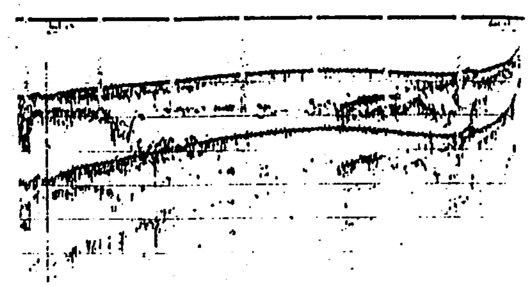




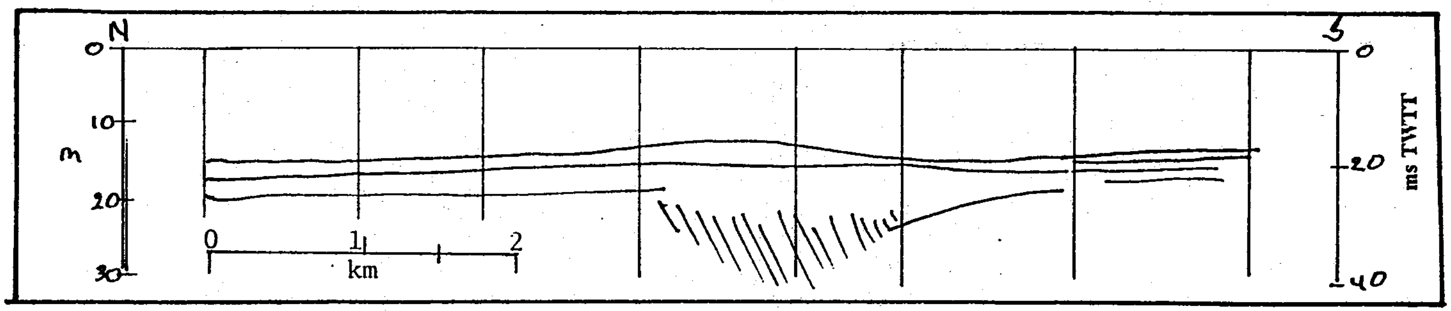
Line #110, July 92-13

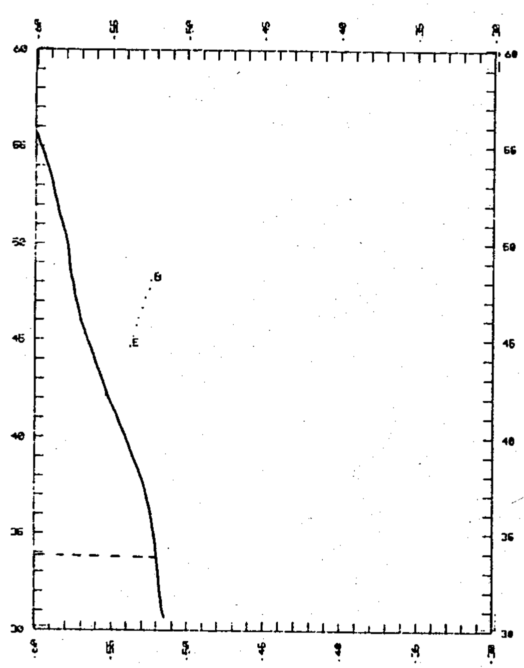


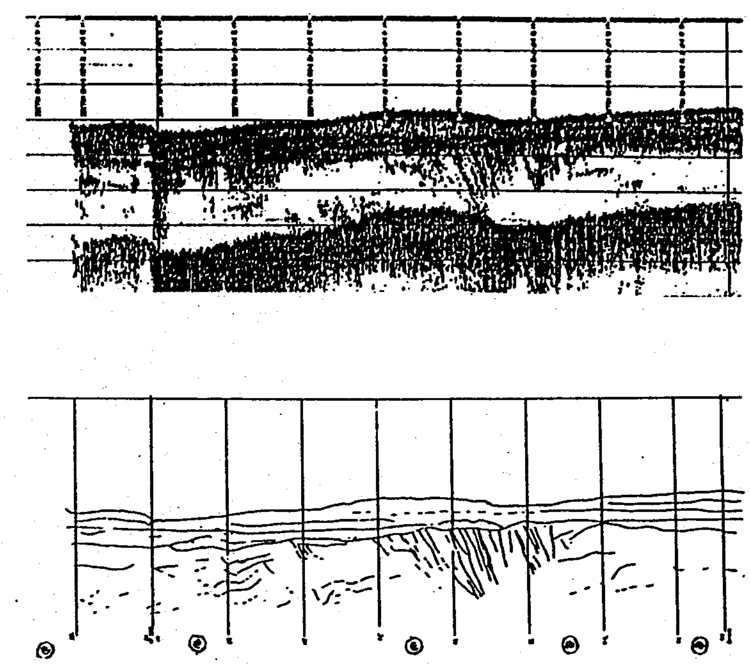




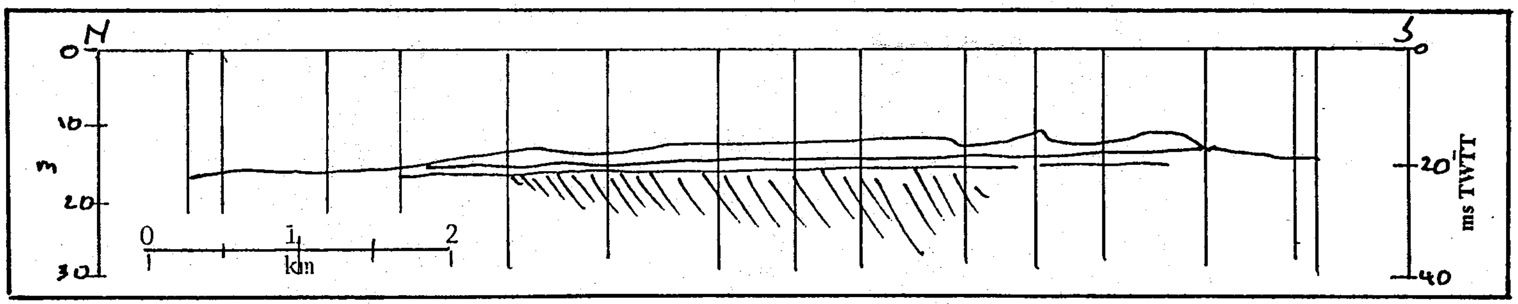
Line #111, July 92-14

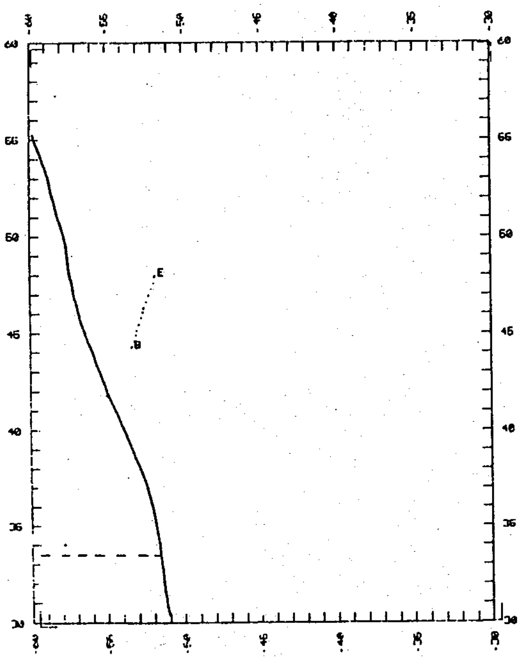


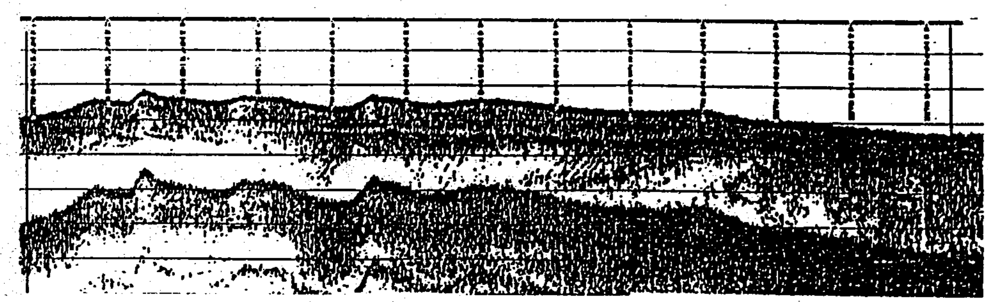


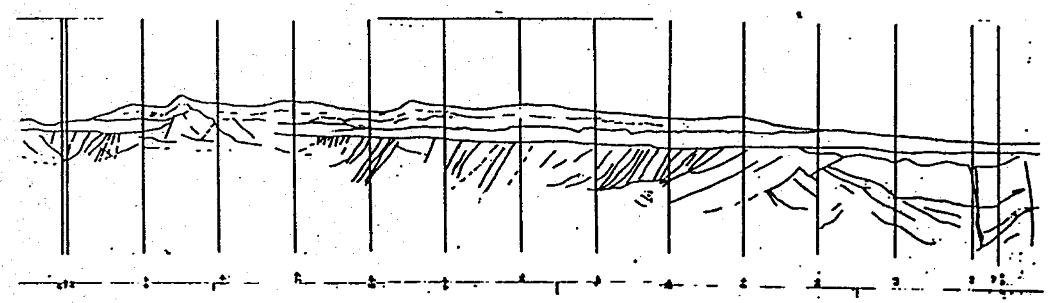


Line #112, July 92-15

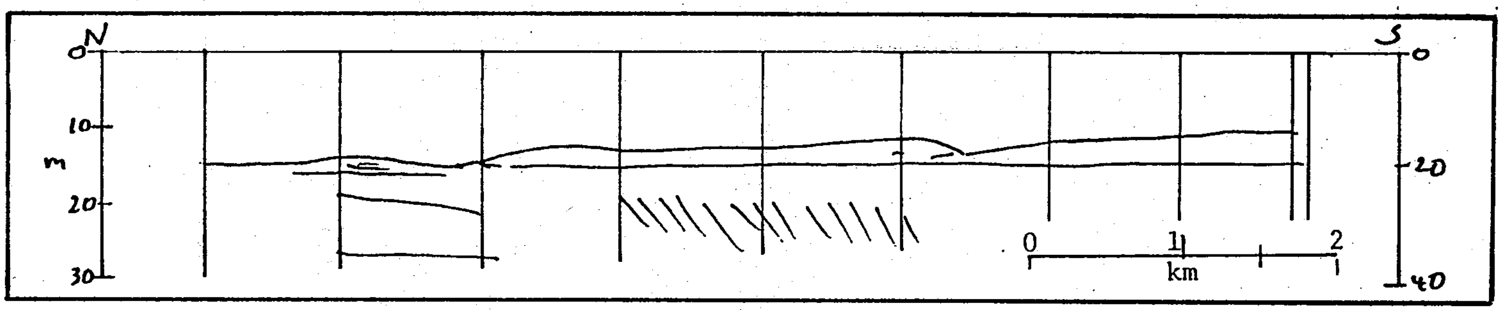


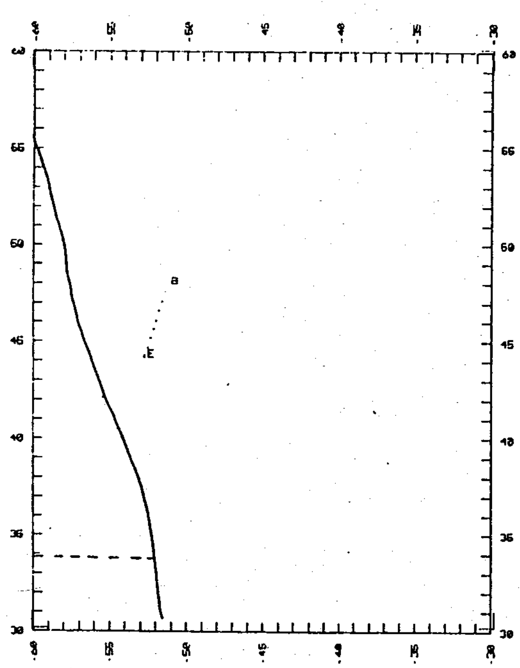


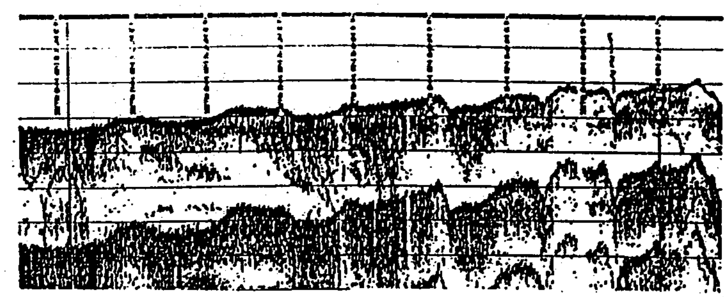


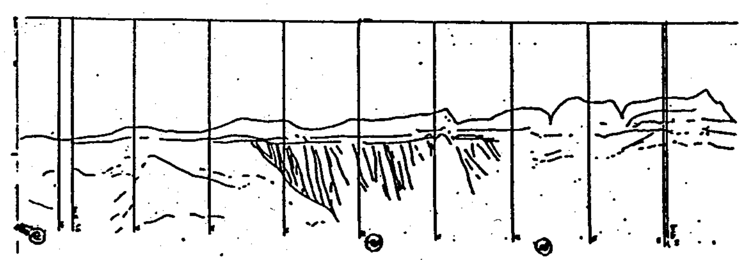


Line #113, July 92-16

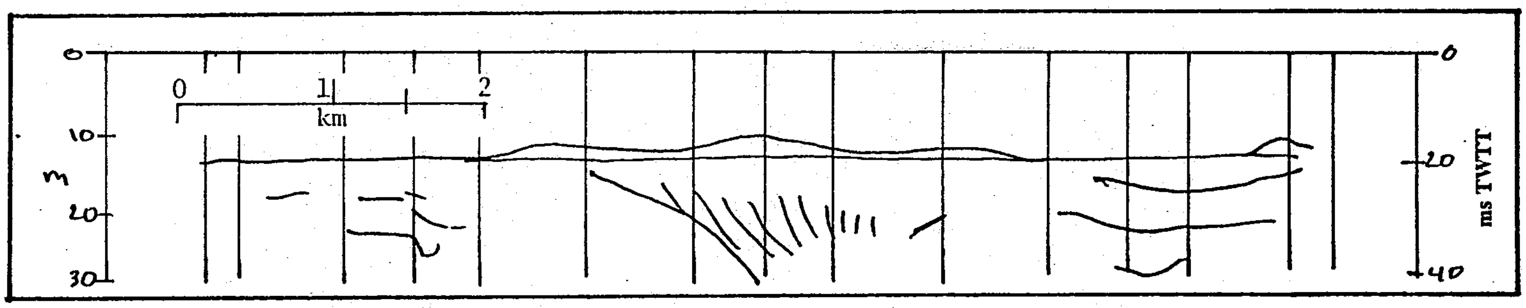


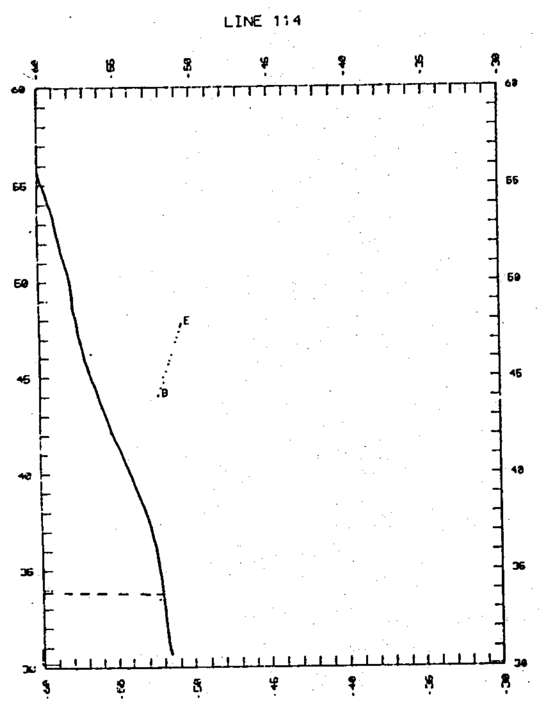


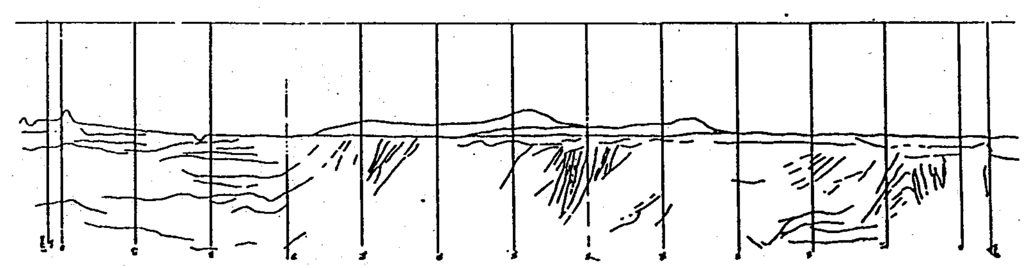




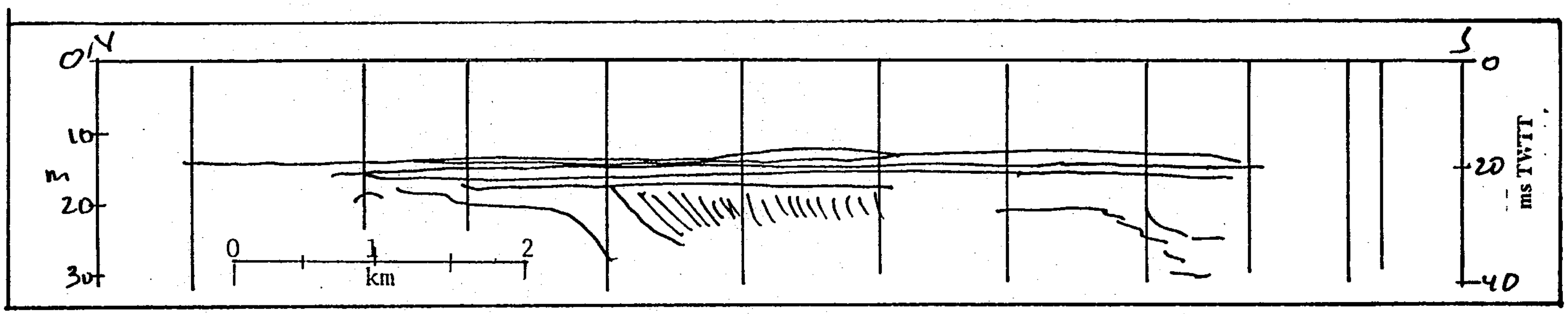
Line #114, July 92-17

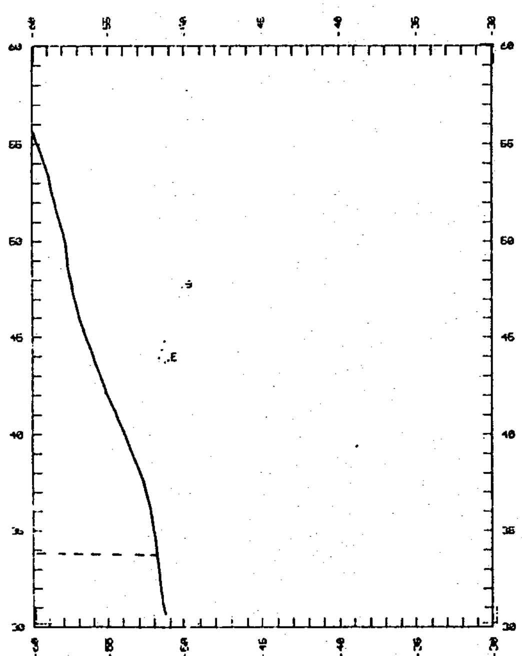


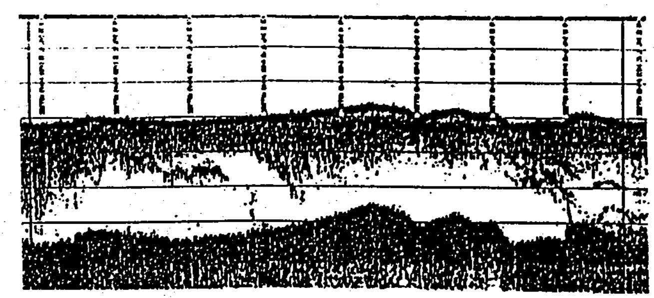


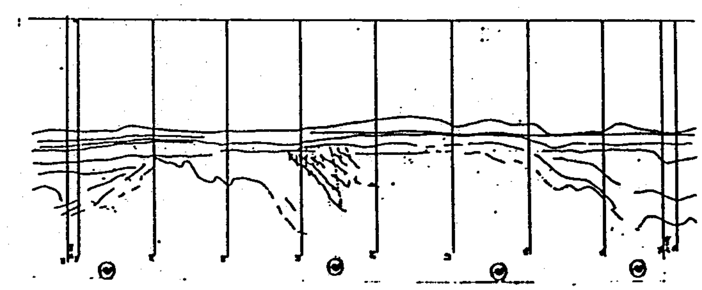


Line #115, July 92-18

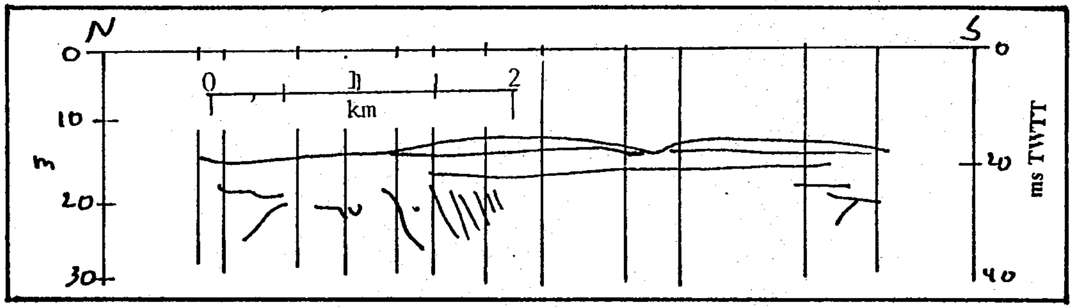


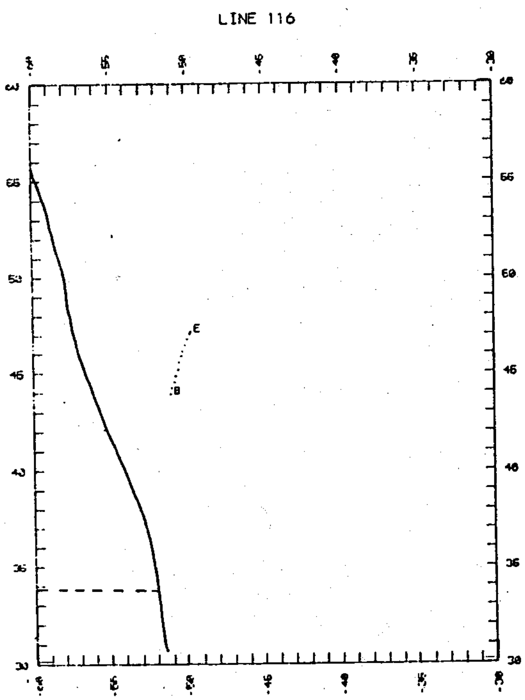


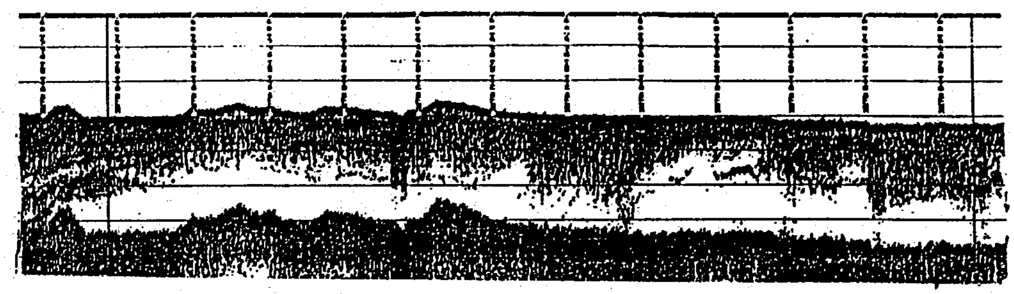


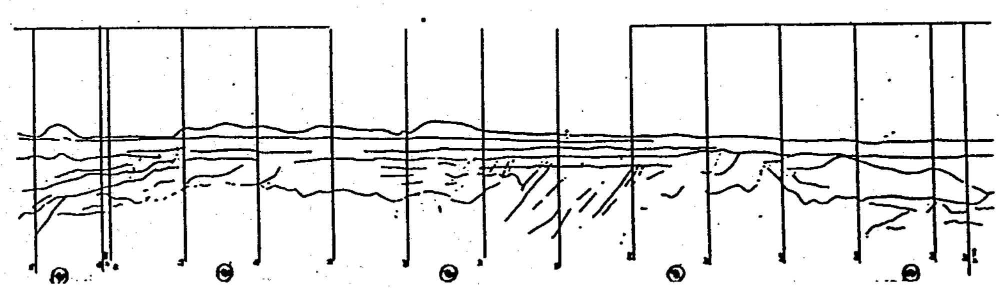


Line #116, July 92-19

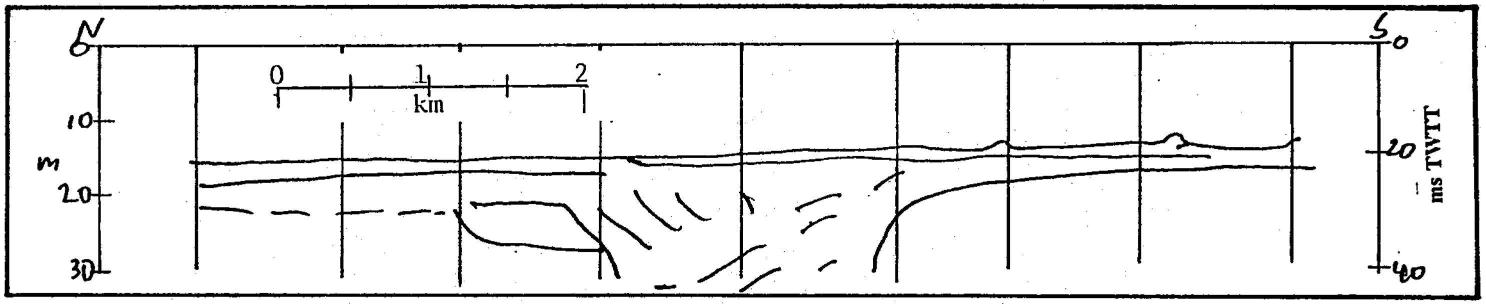


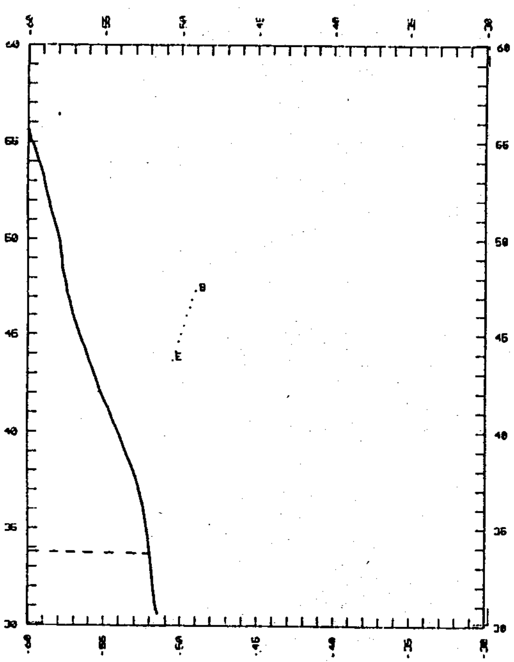


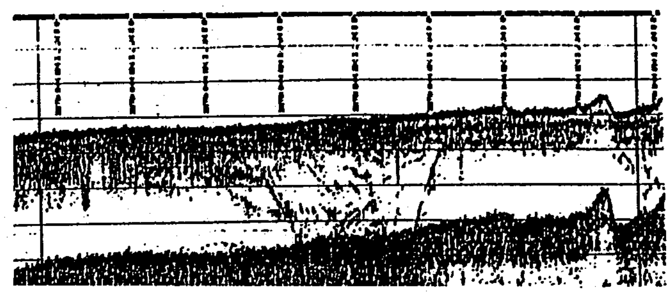


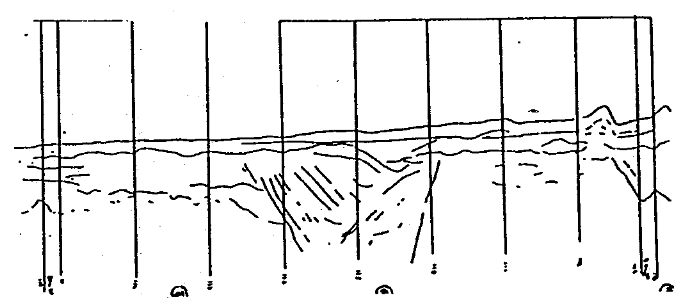


Line #117, July 92-20

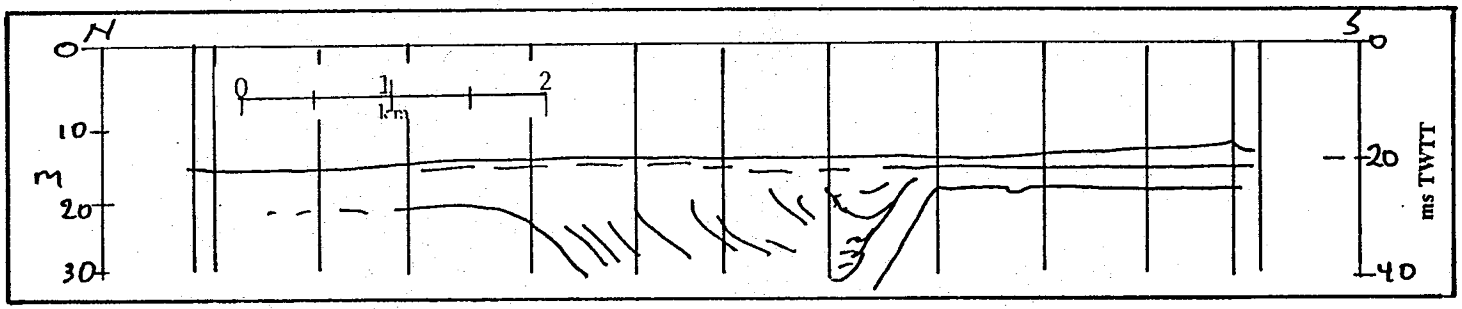


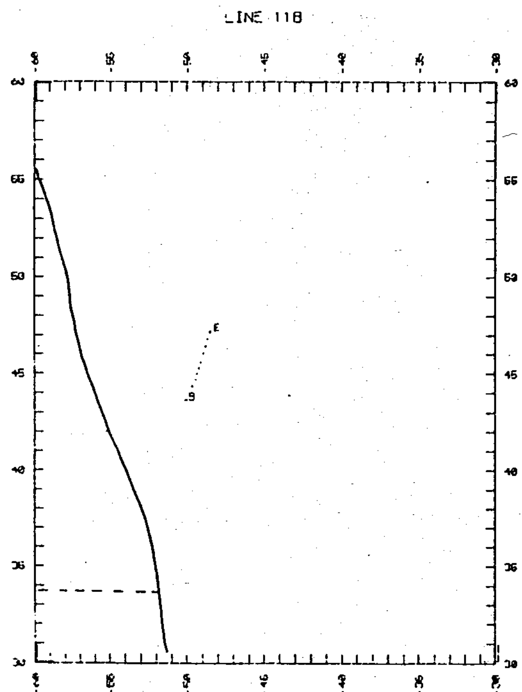


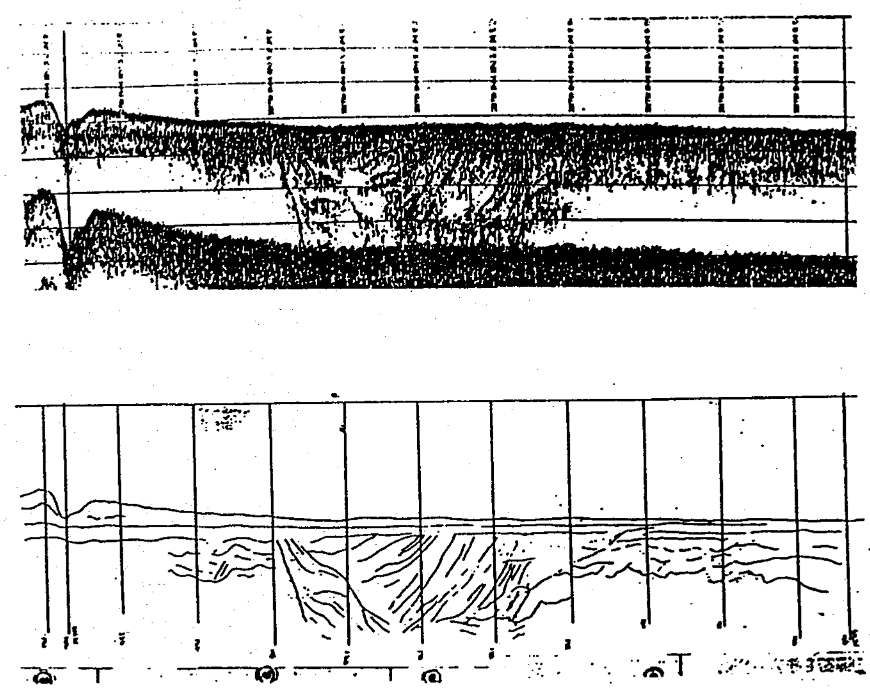




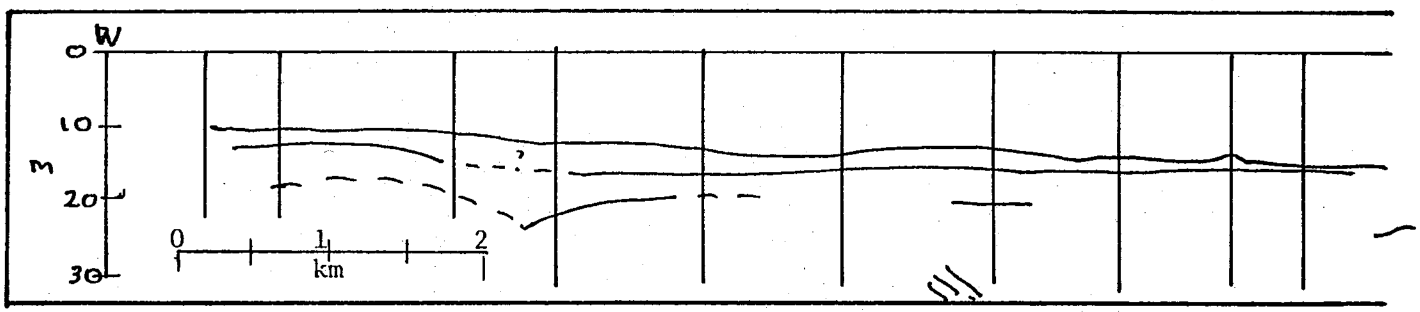
Lne #118, July 92-21

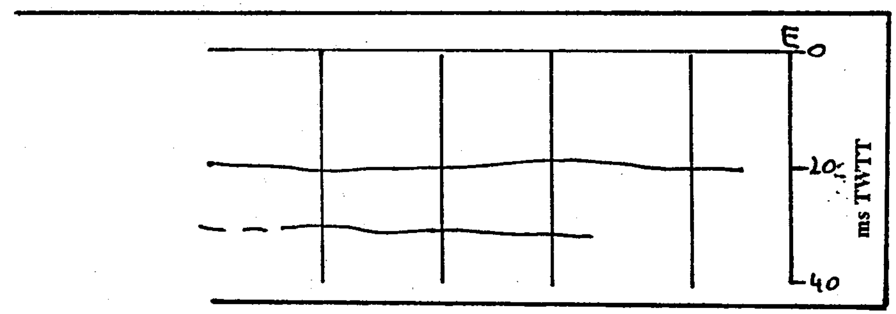


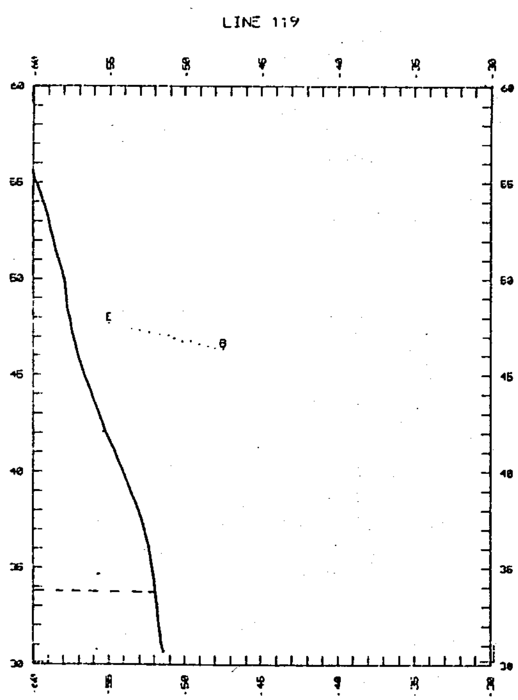


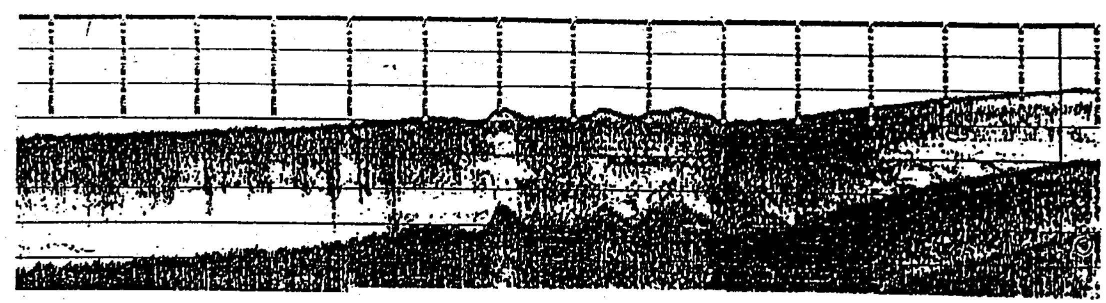


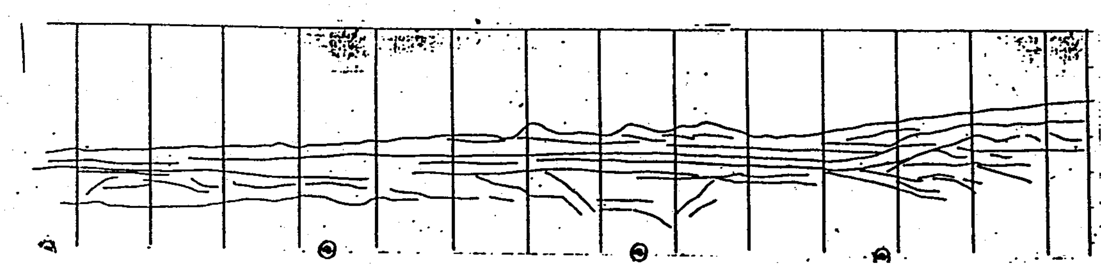
Line #119, July 92-22



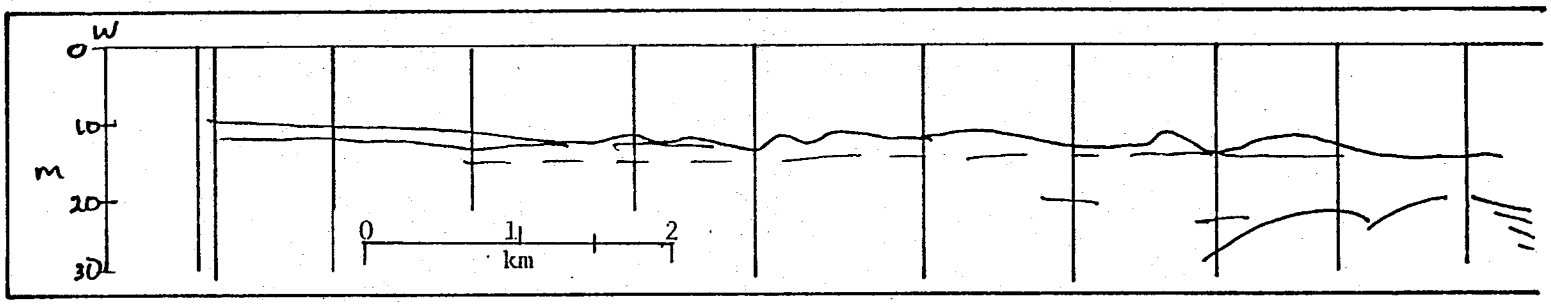


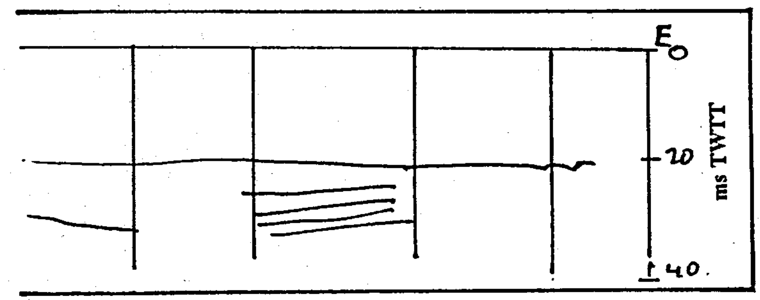


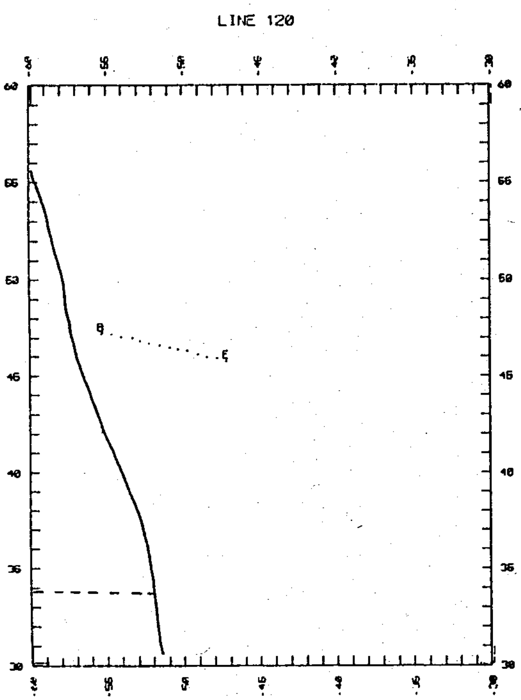


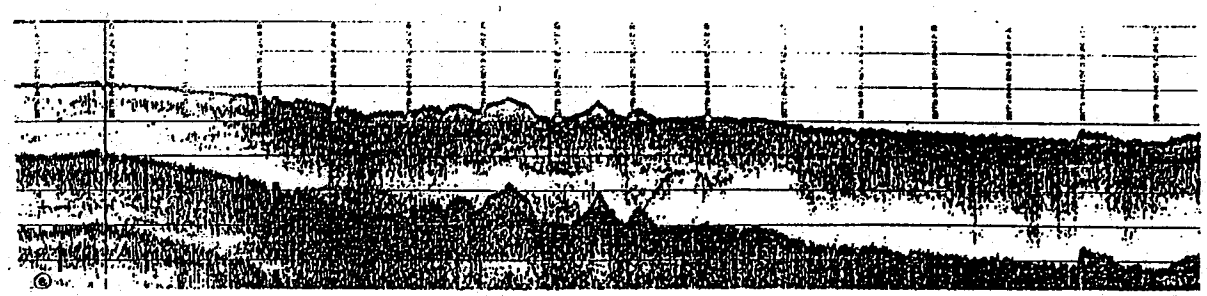


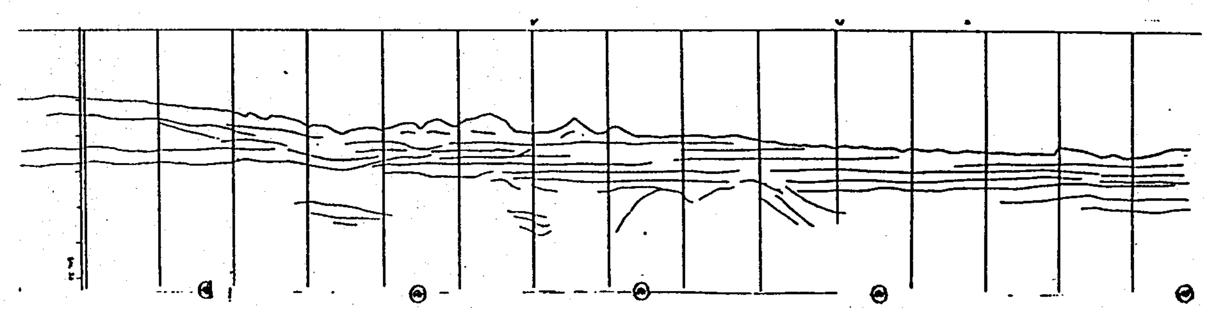
Line #120, July 92-23



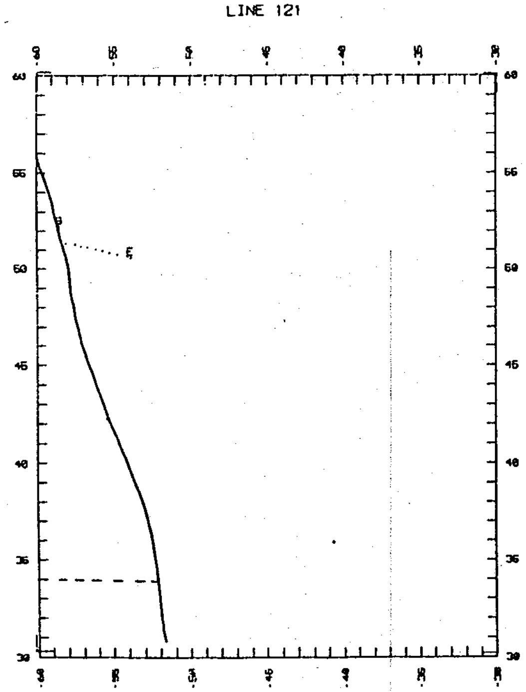


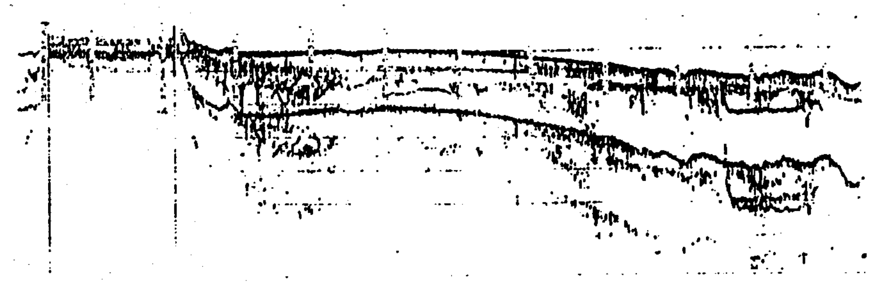




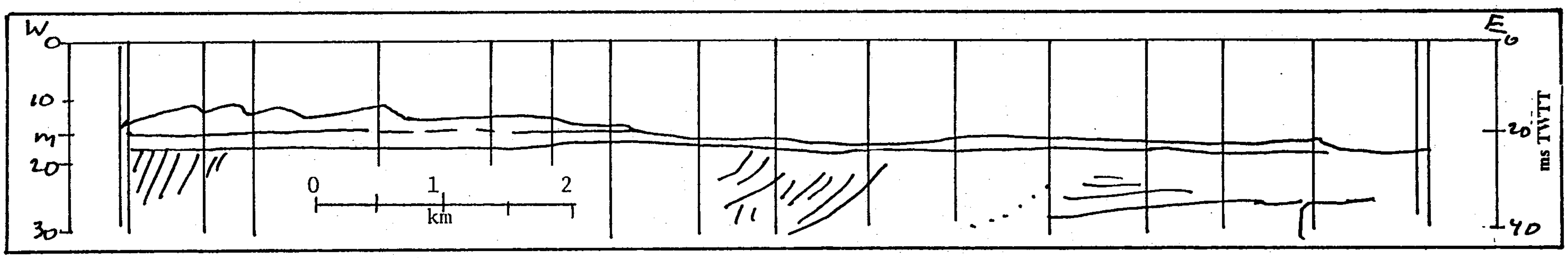


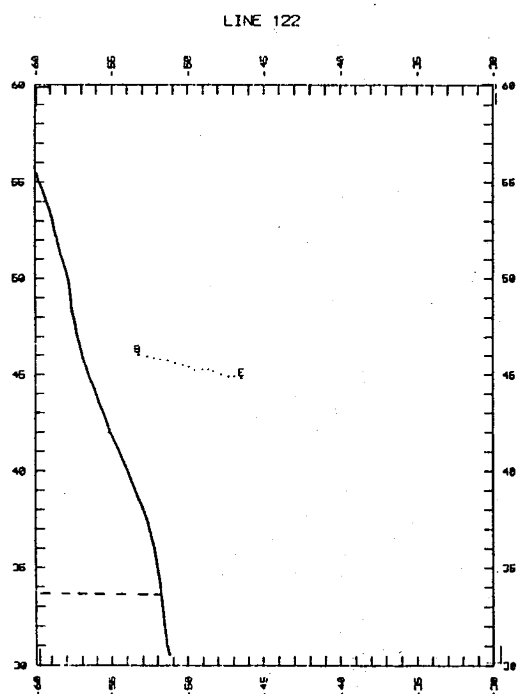
Line #121, July 92-25

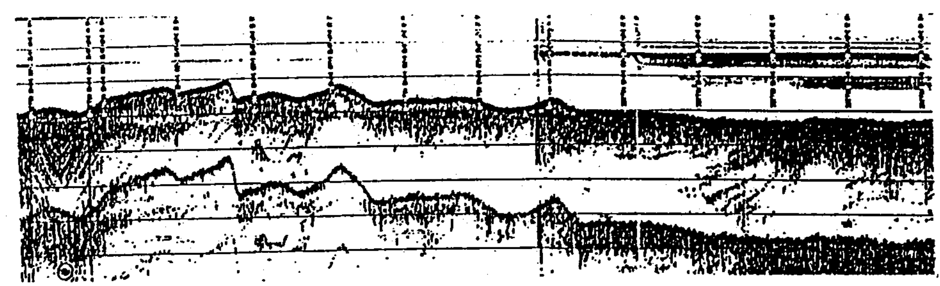


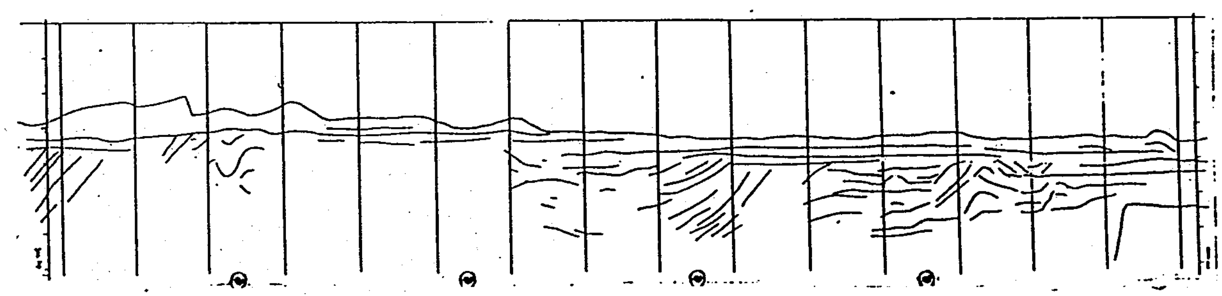


Line #122, July 92-26

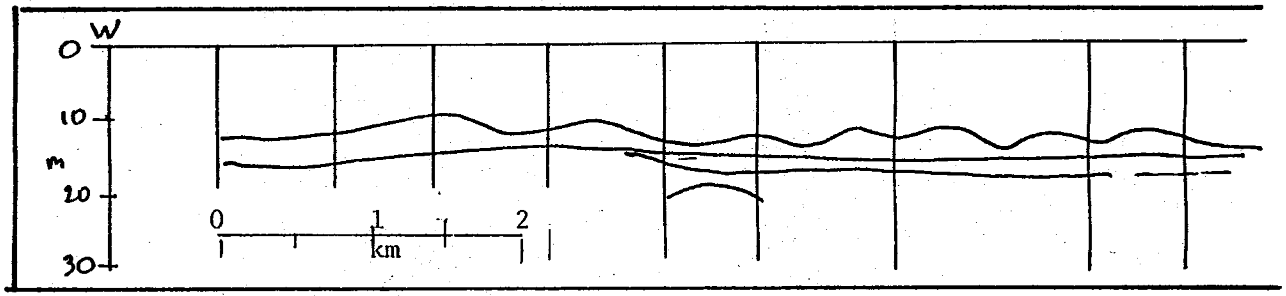


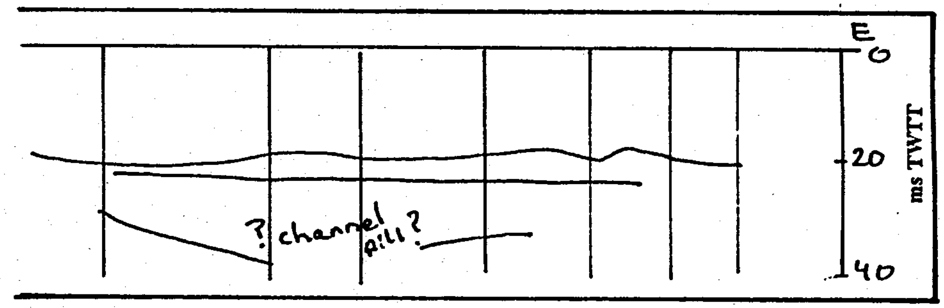


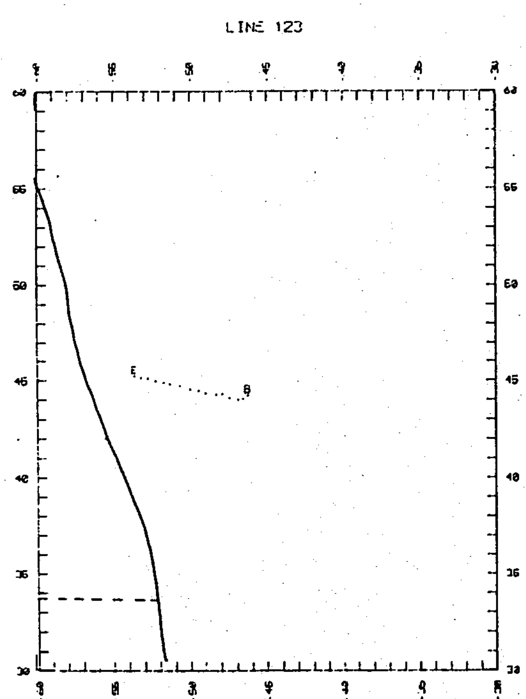


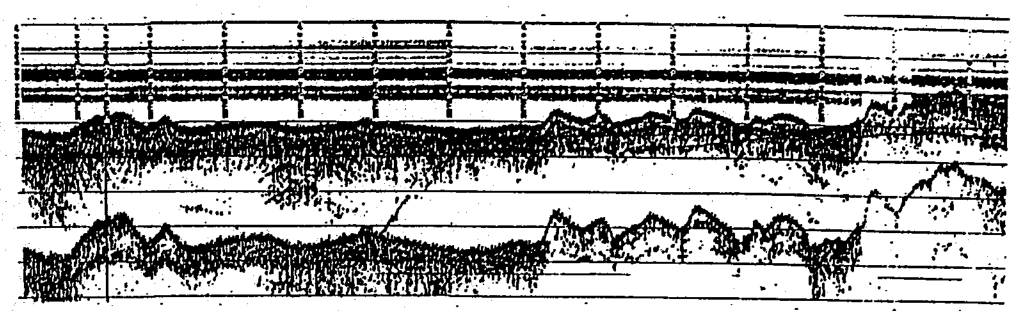


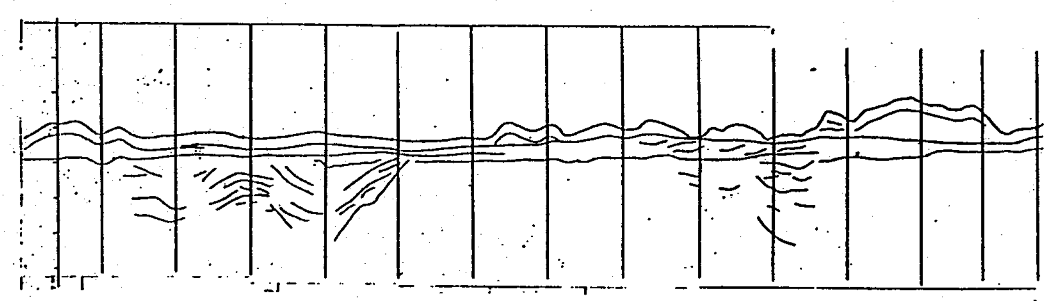
Line #123, July 92-27



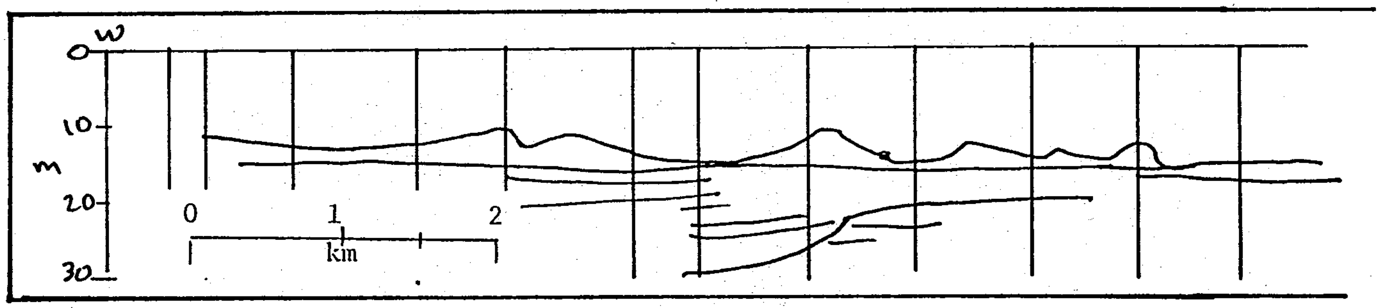


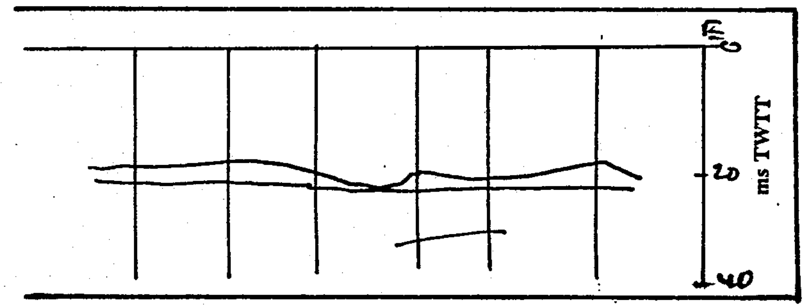


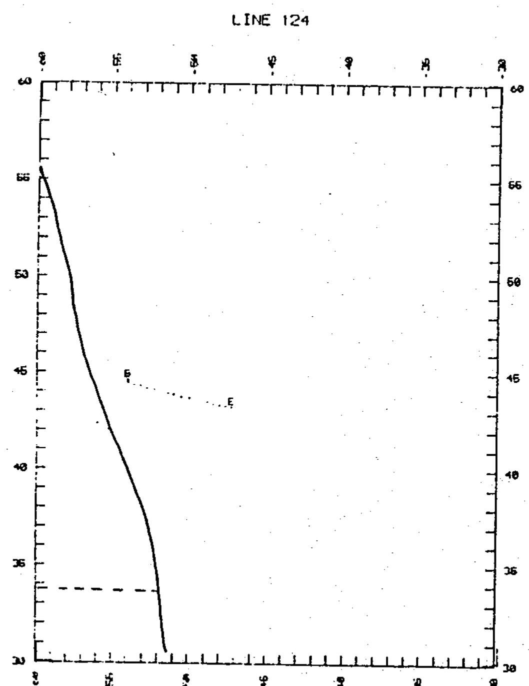


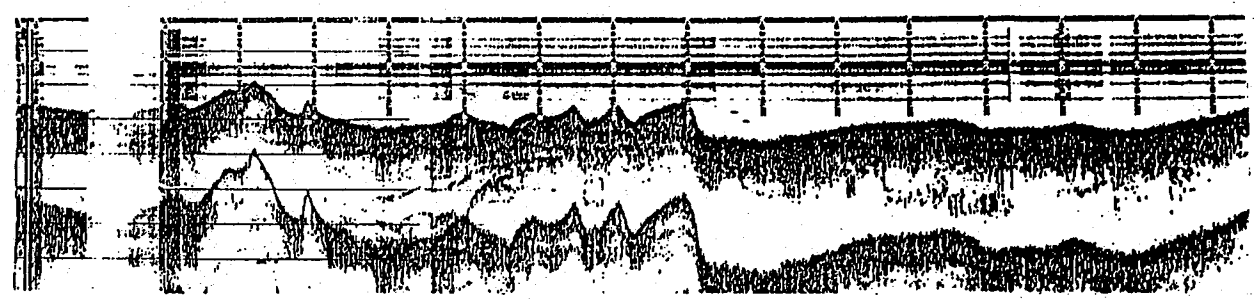


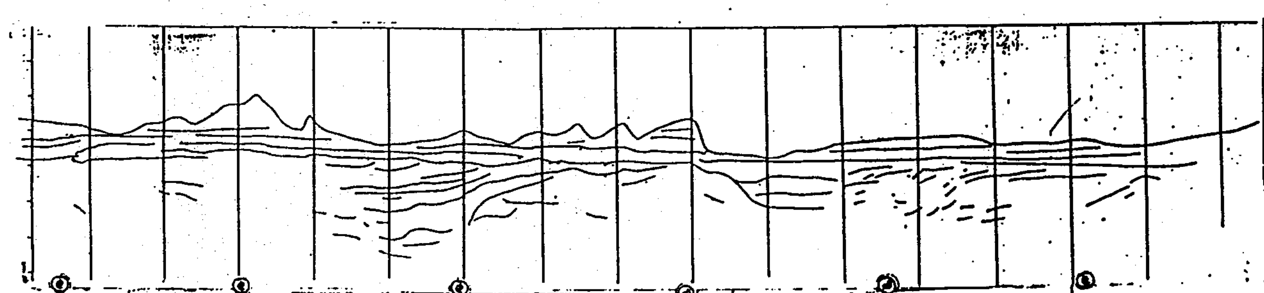
Line #124, July 92-28



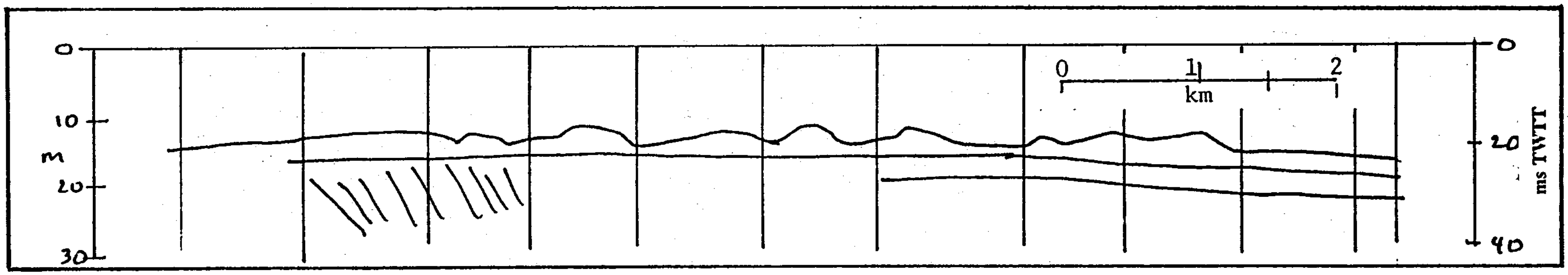


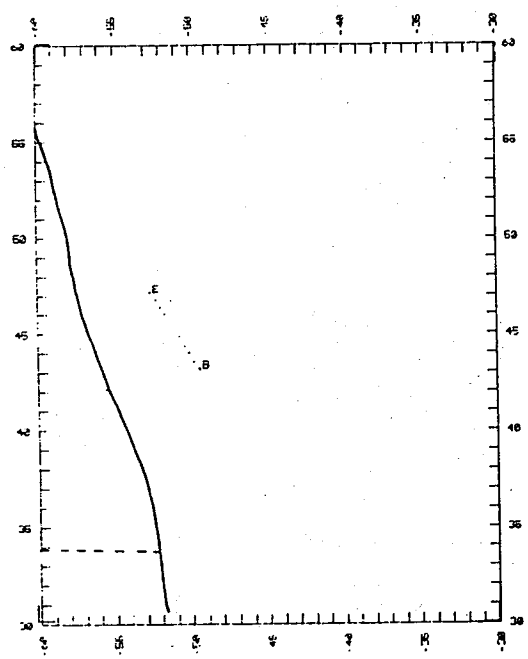


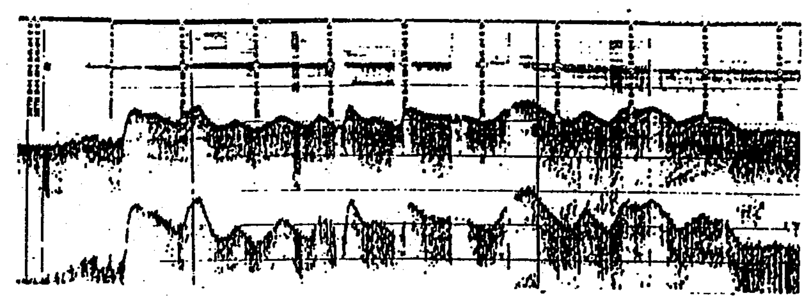


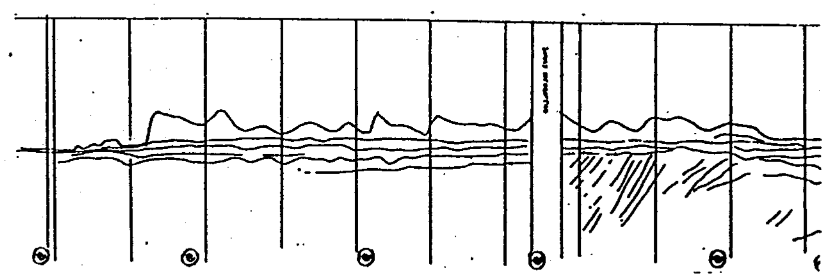


Line #125, July 92-29

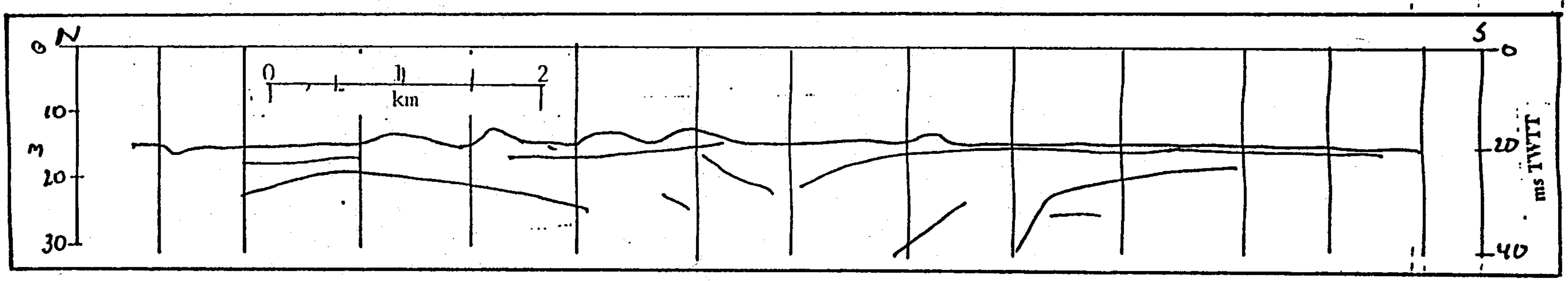


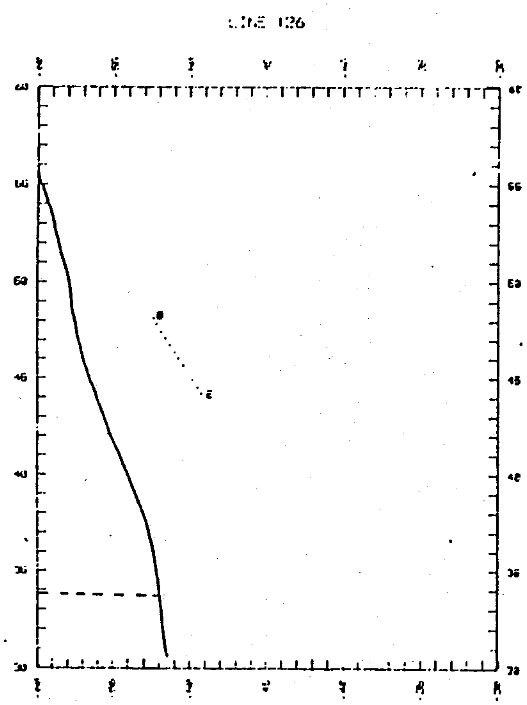


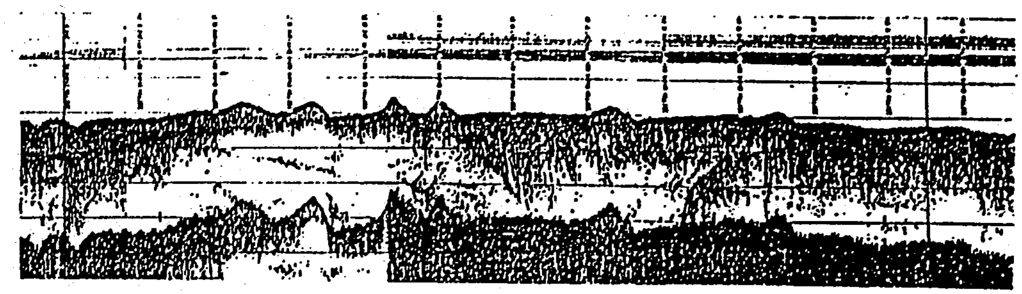


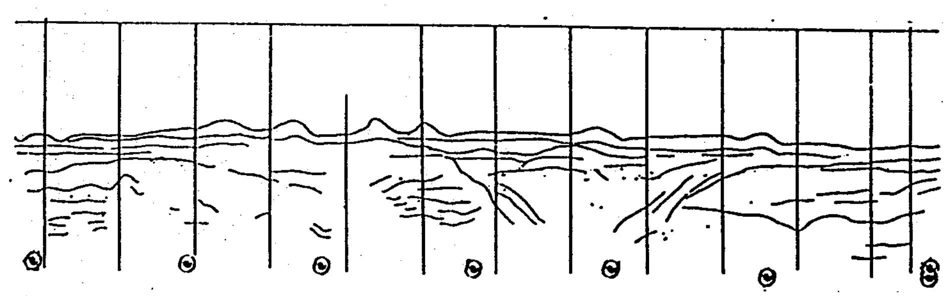


Line #126, July 92-30

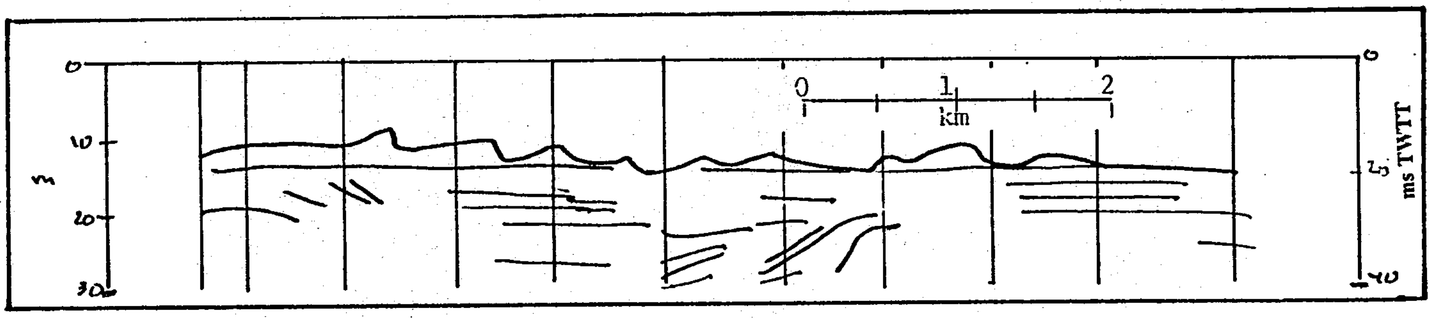


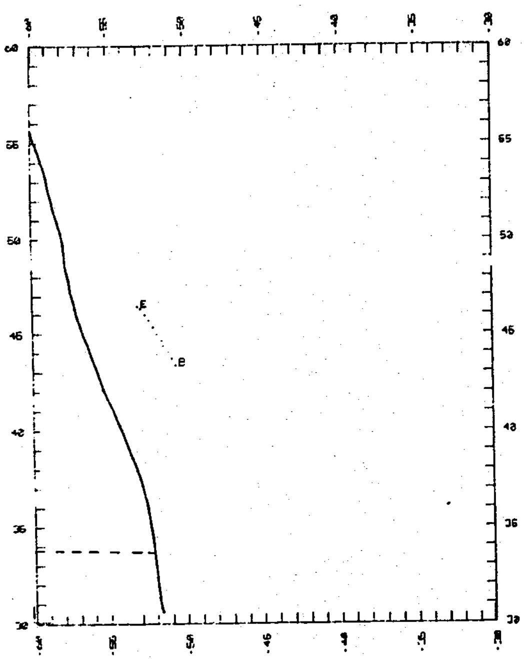


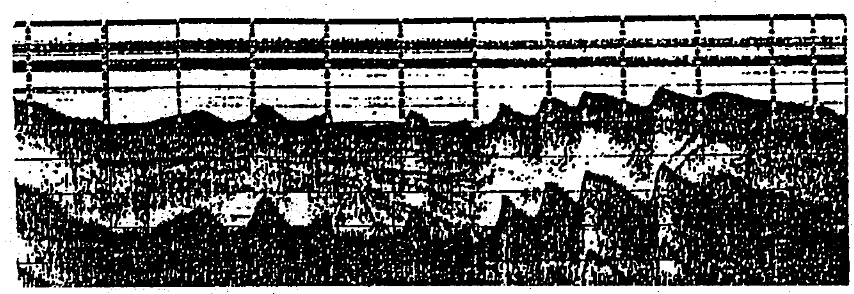


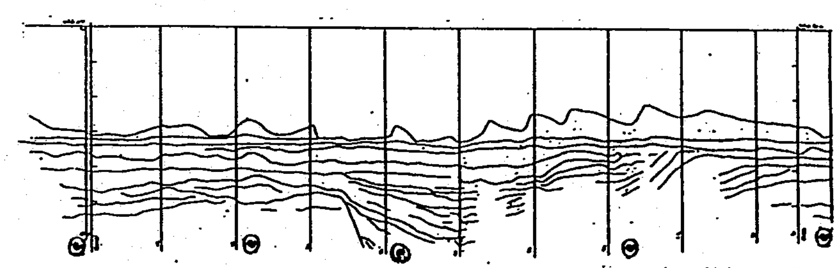


Line #127, July 92-31

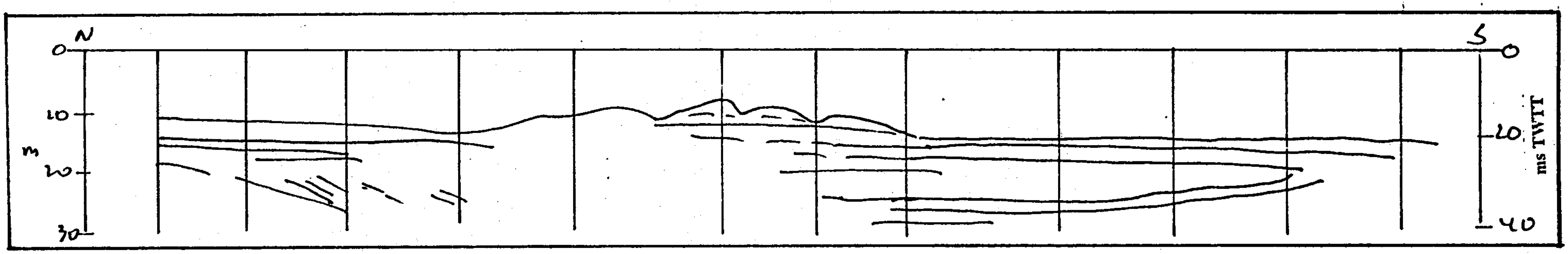


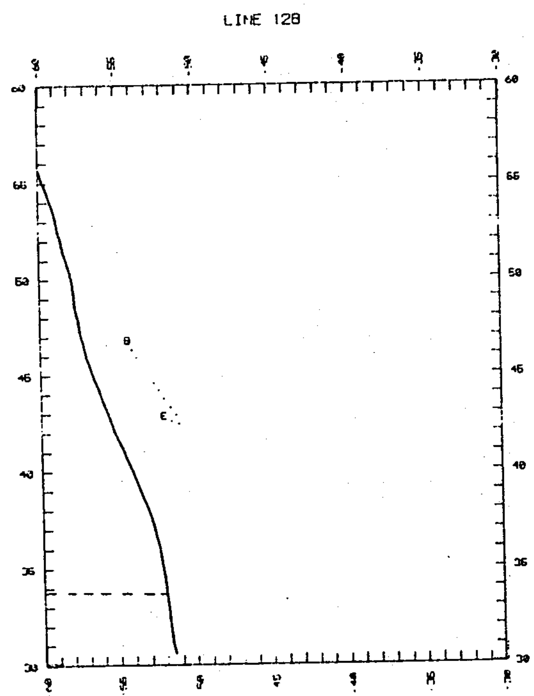


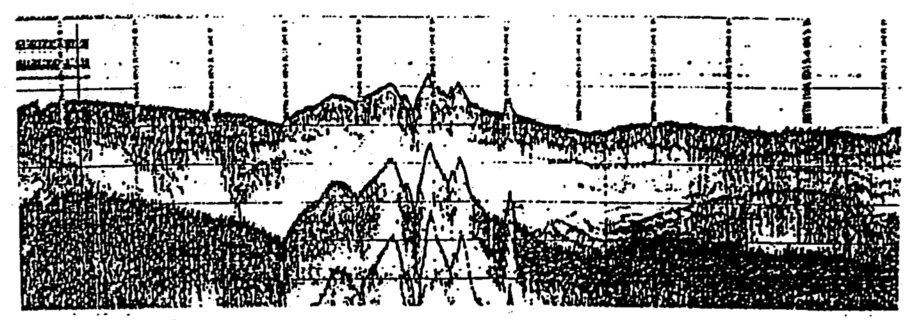


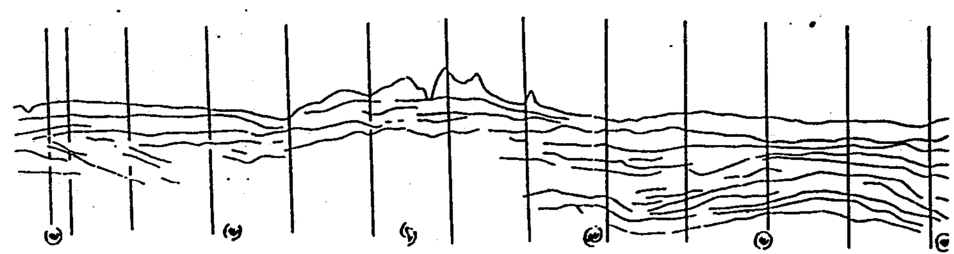


Line #128, July 92-32

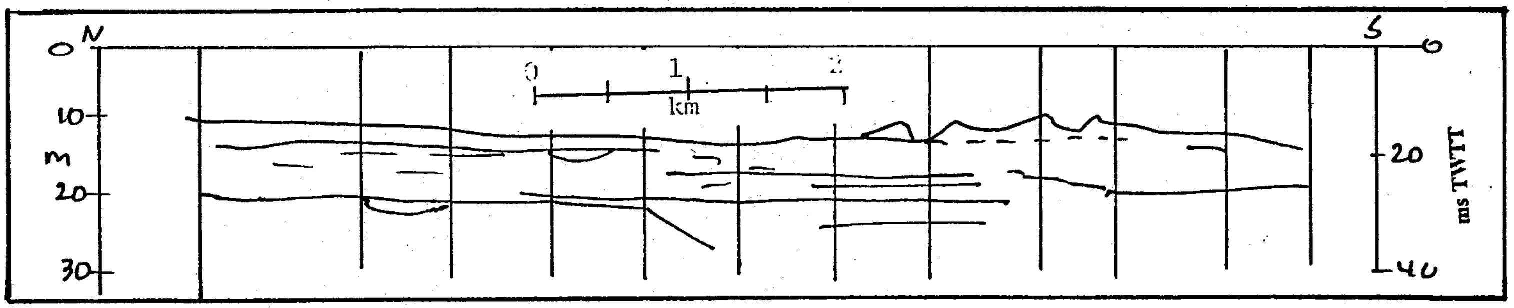


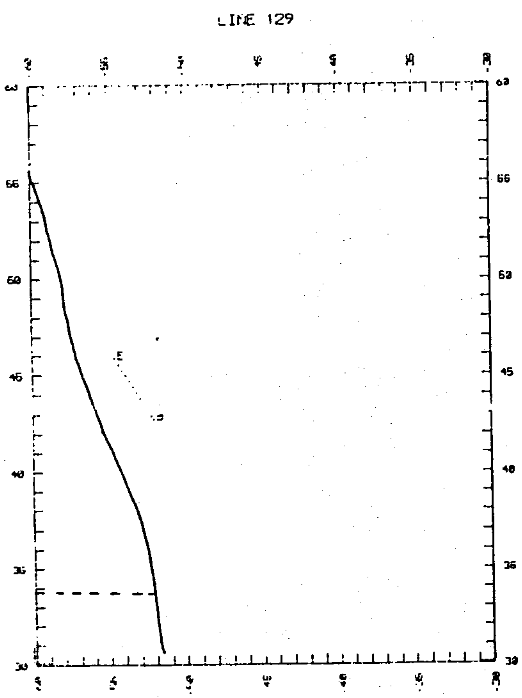


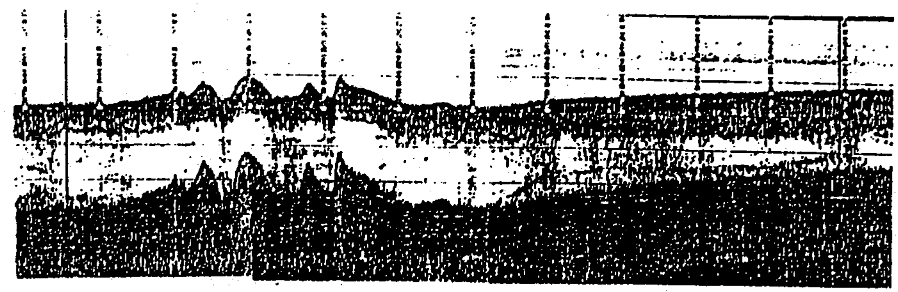


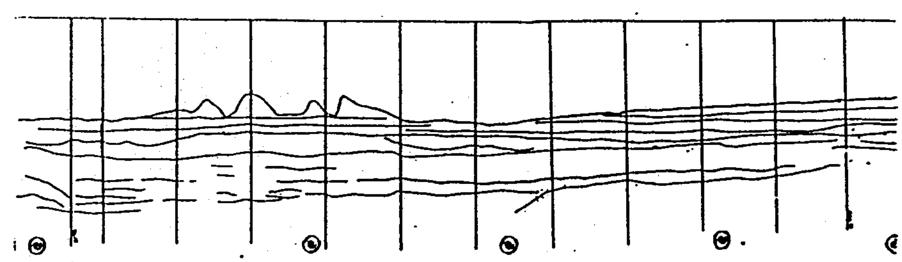


Line #129, July 92-33

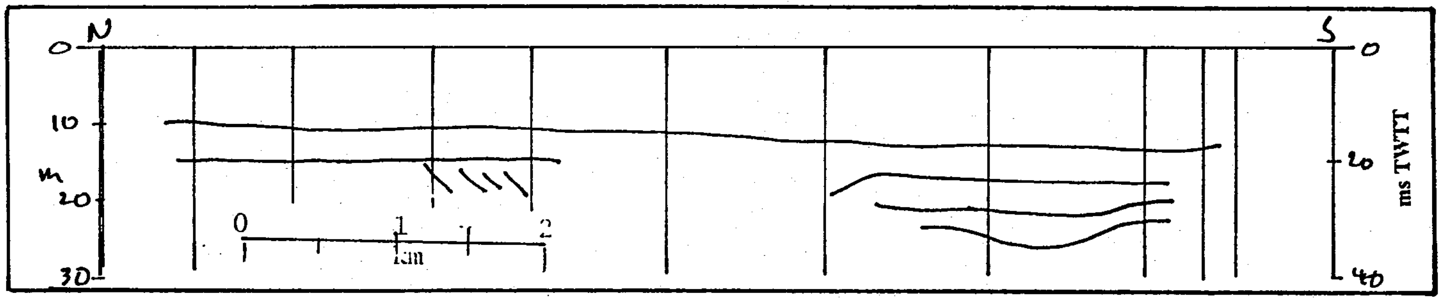


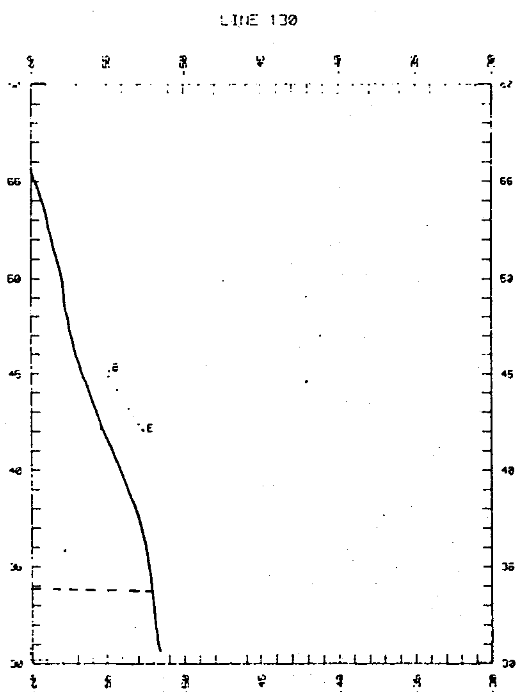


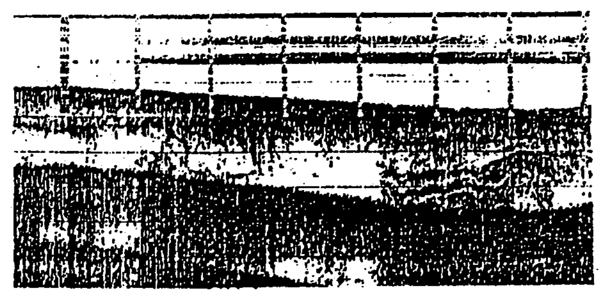


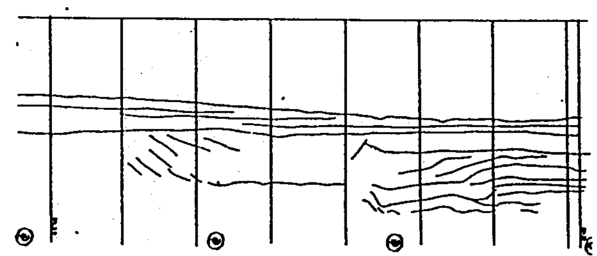


Line #130, July 92-34

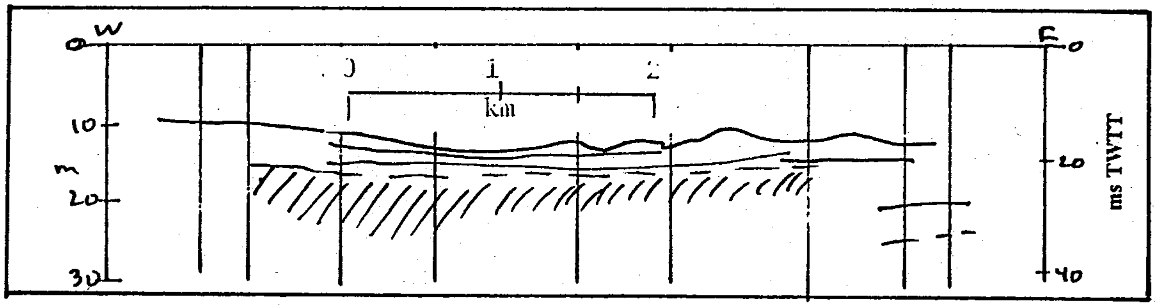


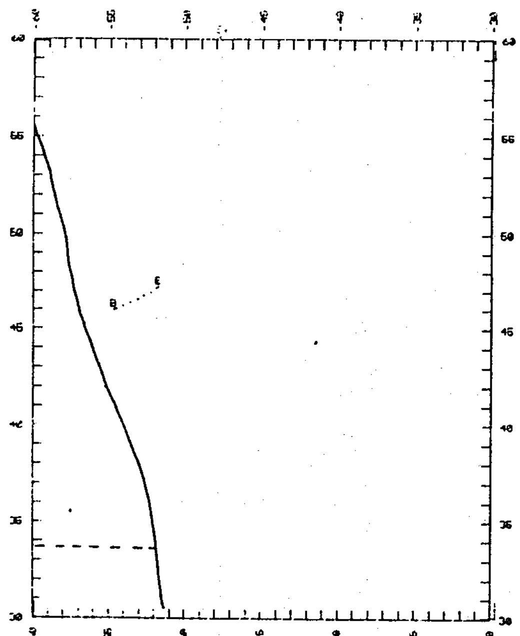


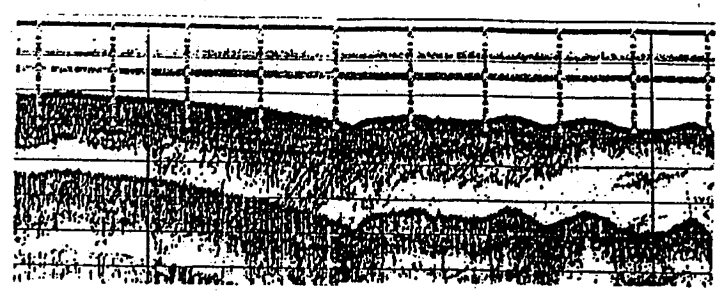


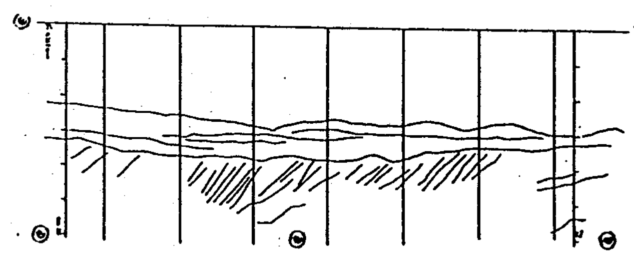


Line #131, July 92-36

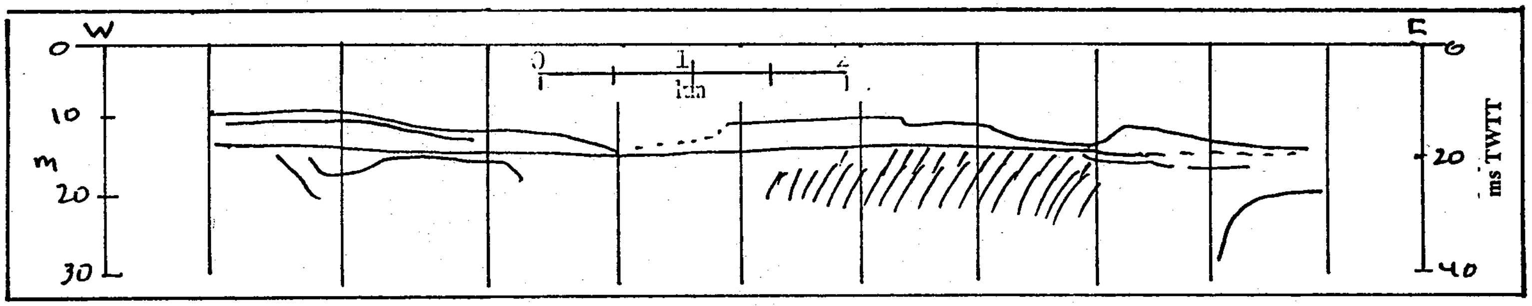


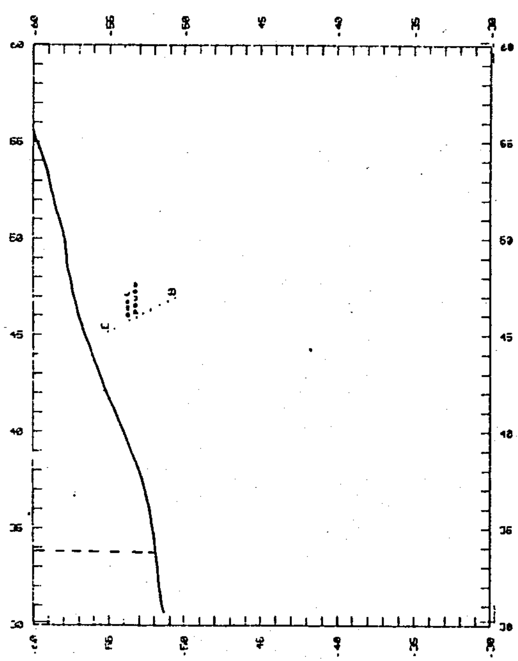


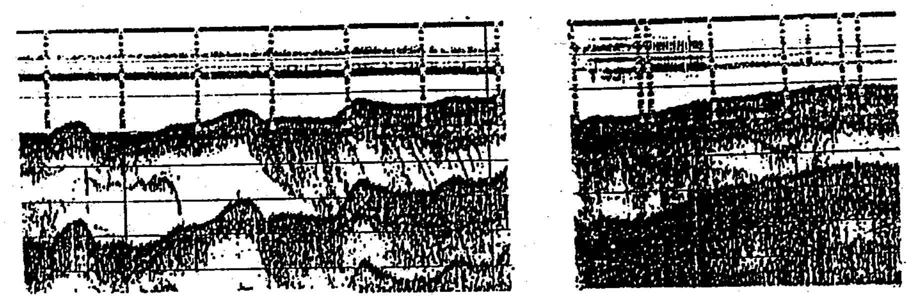


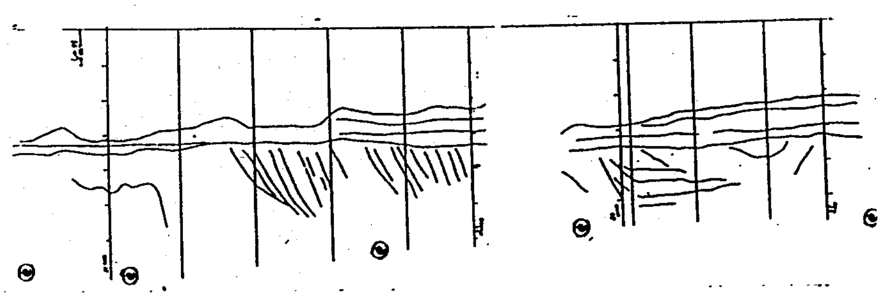


Line #132, July 92-37

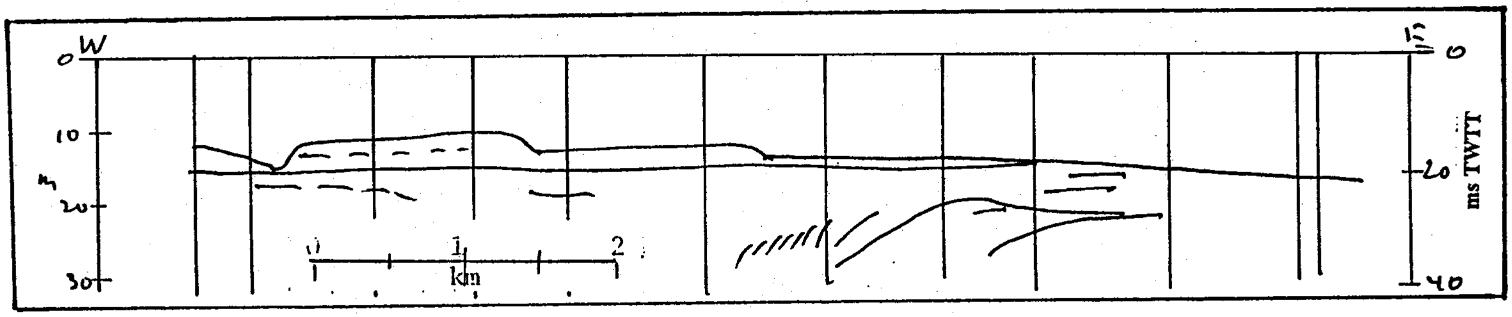


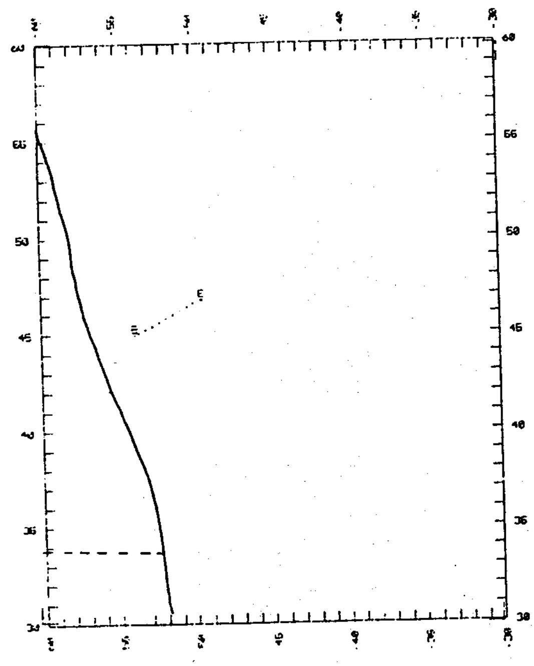


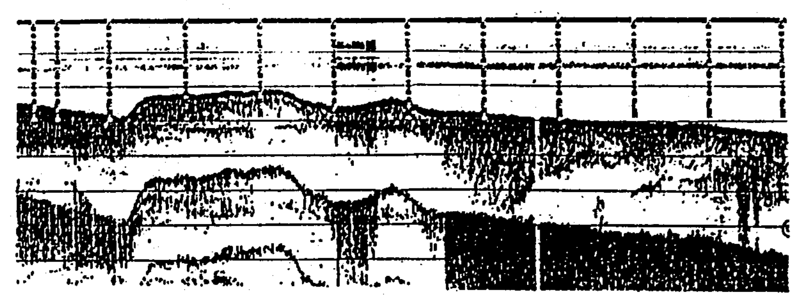


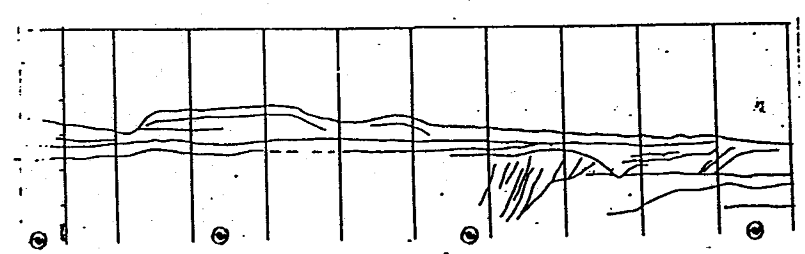


Line #133, July 92-38

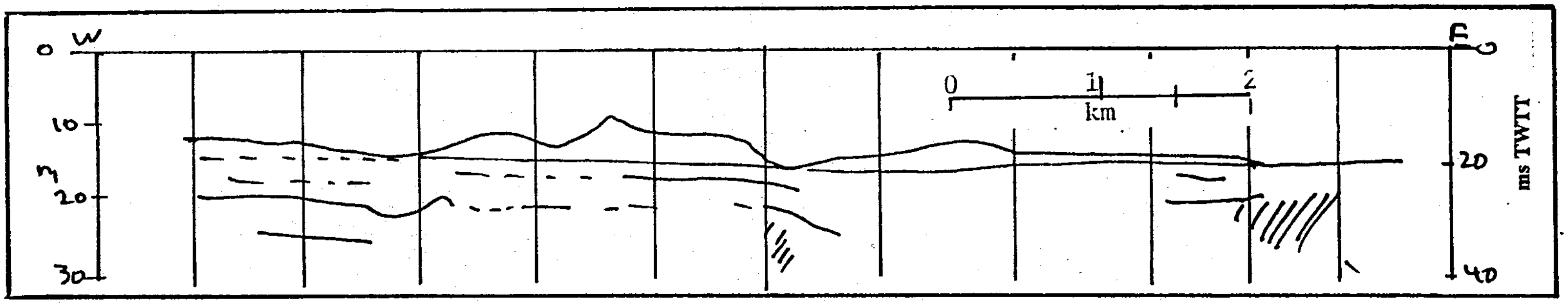


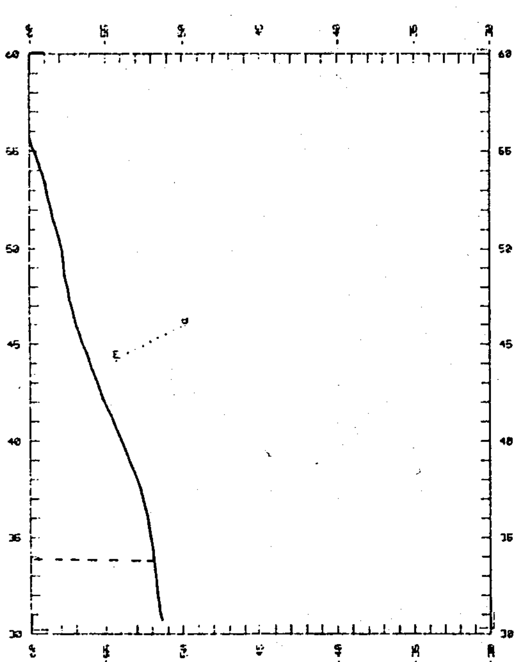


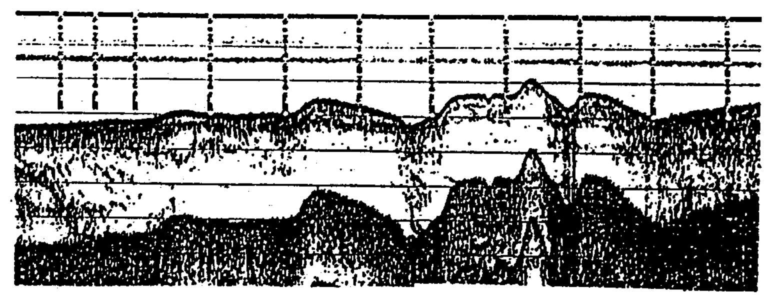


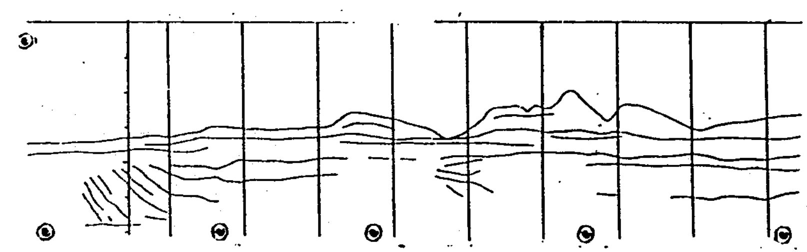


Line #134, July 92-39

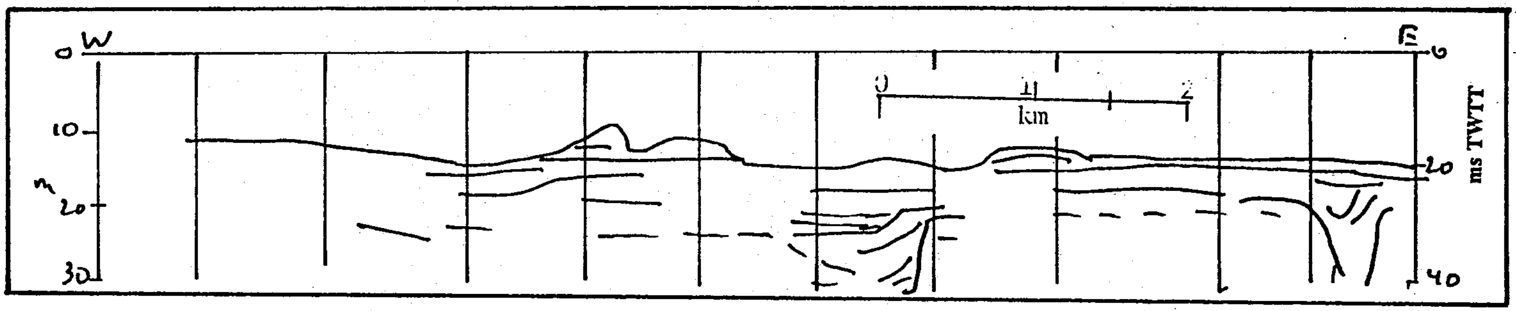


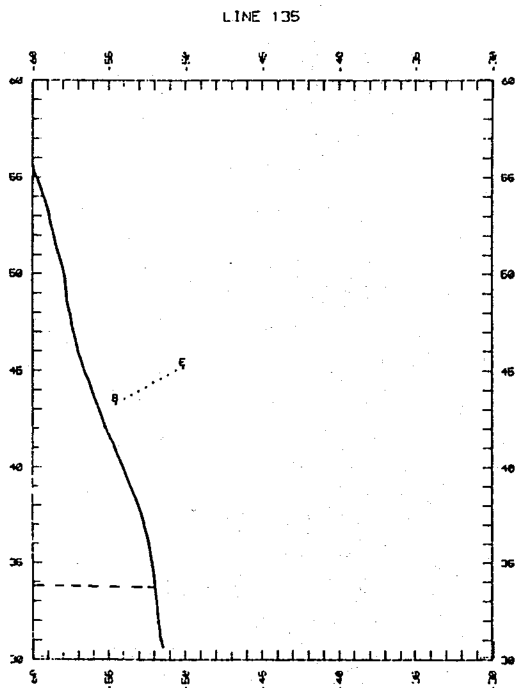


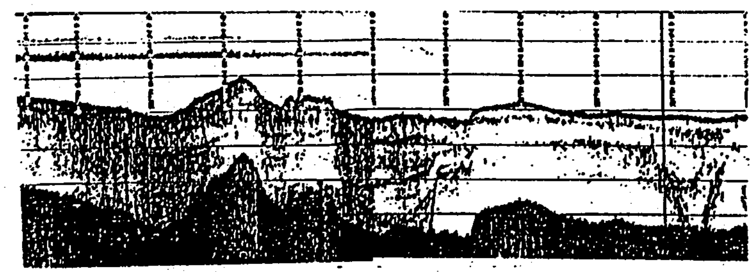


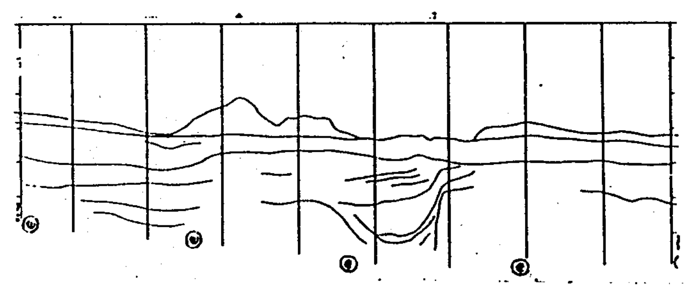


Line #135, July 92-40

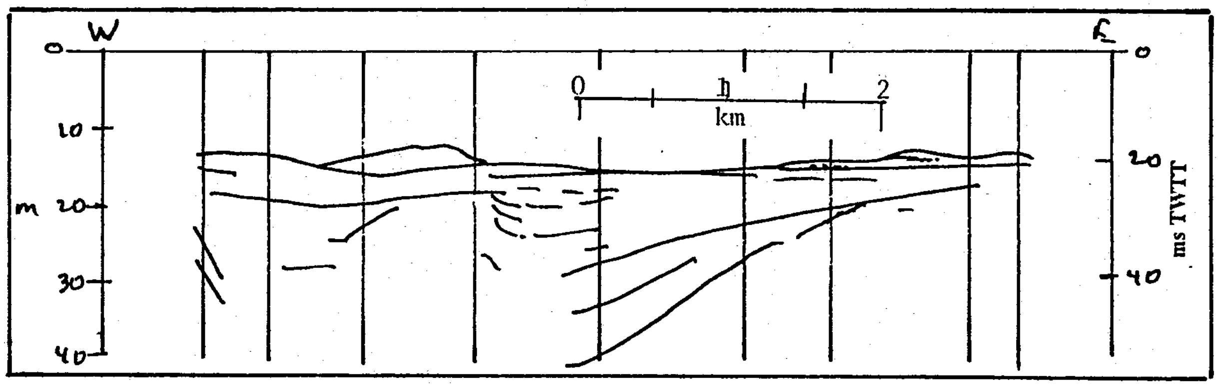


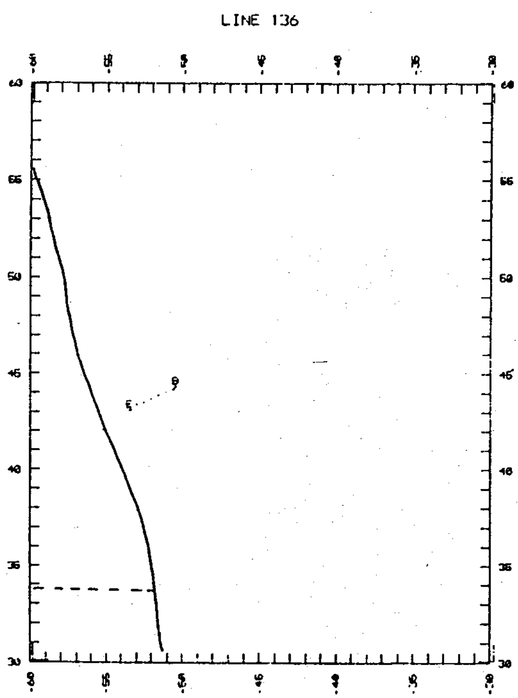


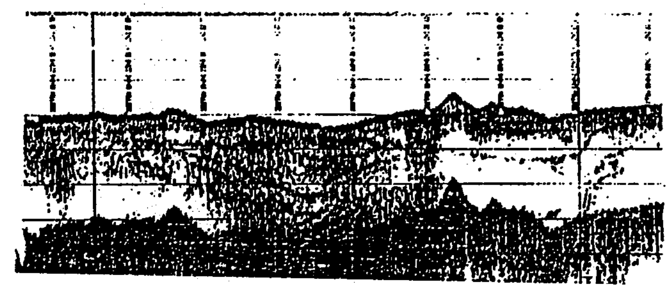


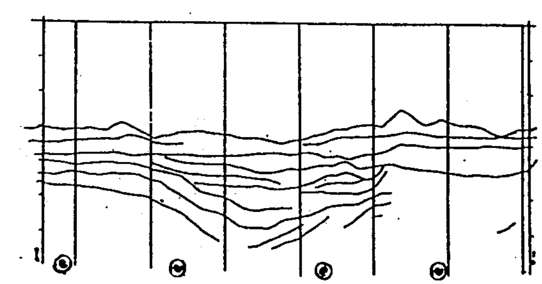


Line #136, July 92-41

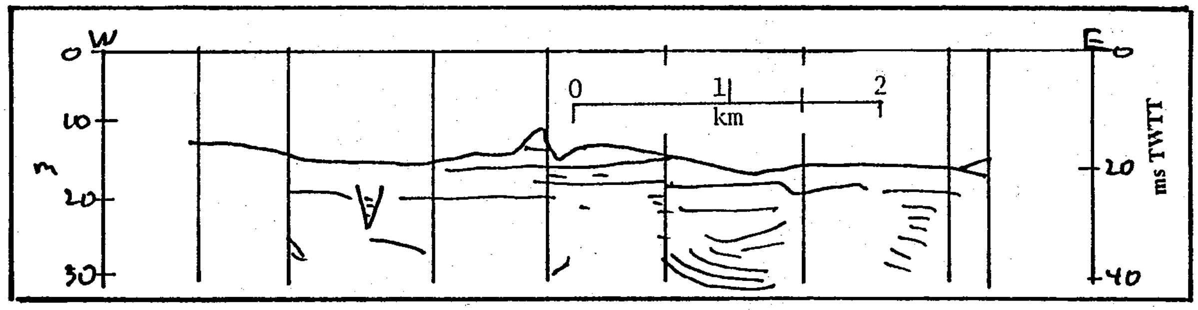


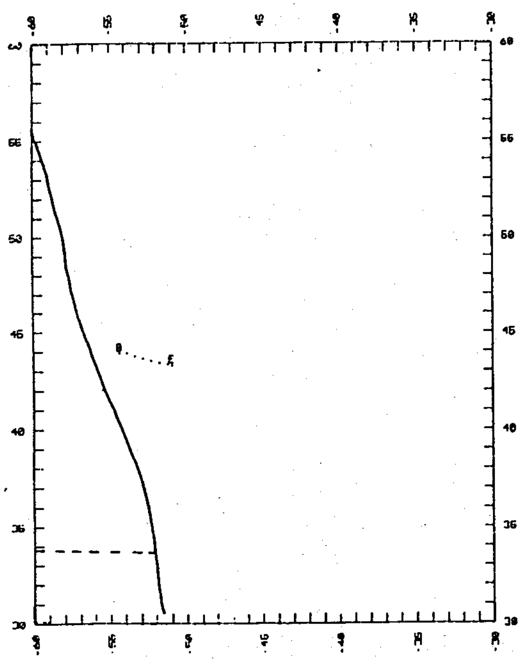


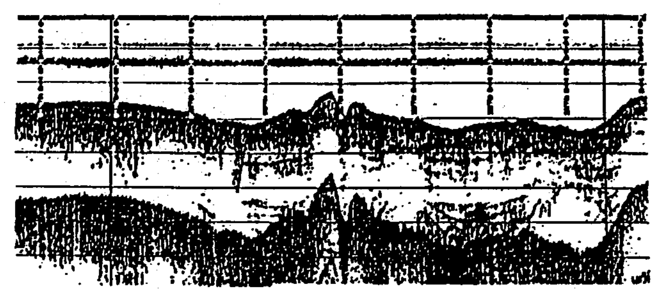


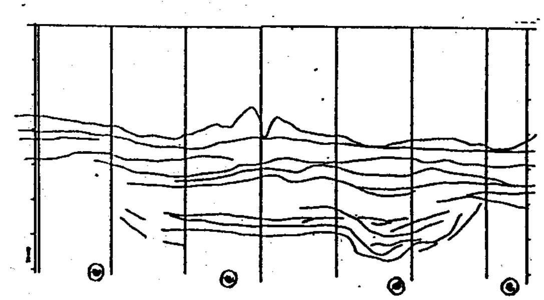


Line #137, July 92-42

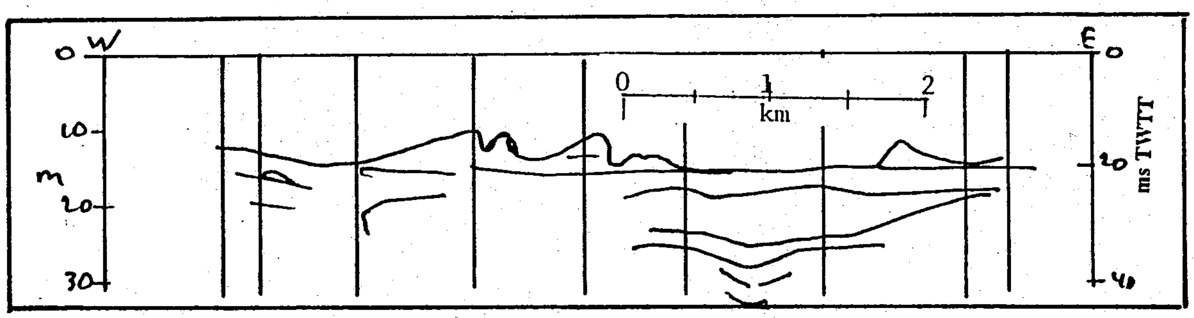


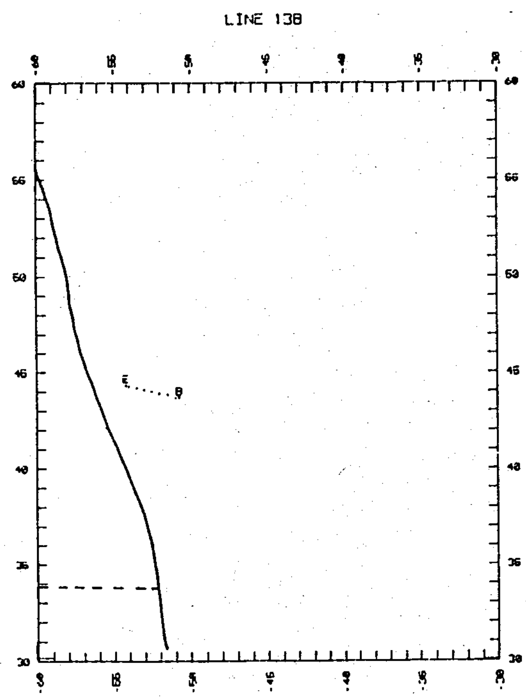


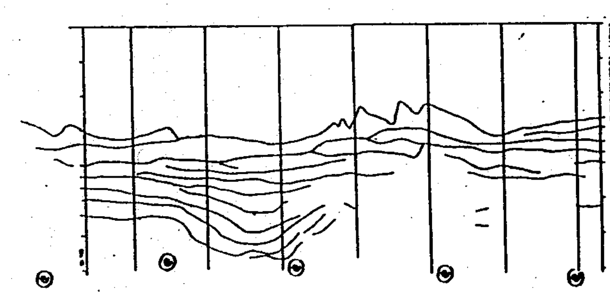




Line #138, July 92-43







Line #139, July 92-44