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Mosaic of the Alsek Sediment Instability Area, Northeastern Gulf of Alaska

by

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INTRODUCTION

As part of a detailed, multisystem investigation of the northeastern Gulf of Alaska continental margin, a 25-km^2 sea-floor area offshore of the Alsek River was surveyed in 1980. The area had been previously identified as containing pockmarks, slumps, and other types of sediment-failure features (Molnia and Rappeport, 1982; Carlson and others, 1980; Molnia, 1979; Molnia and others, 1978). The multisystem survey of this area, designated the Alsek Sediment Instability Area, was run at a 100-m line spacing utilizing a precision range-range system for navigation, 3.5- and 12-kHz echosounding systems, and 400- to 800-J minisparkers, 5-to 25-in^3 airgun acoustic systems. Additionally, a digitally recording and processing side-scan sonar system with slant-range correction was used to compile a 100-percent overlap mosaic of the sea floor. Sediment samples were collected by Van Veen grab sampler and small corers from within the study area. Uniboom seismic profiles were recorded between the study area and the coastline with a profiling system towed from a motorized launch.

CONSTRUCTION OF THE MOSAIC

A complete picture of the sea floor in a 10 x 2 km part of the mosaic area was made by using 21 speed-corrected, digitally processed, east-west, side-scan sonar lines; these lines were assembled using a best fit method of matching prominent features. A single mid-mosaic line was selected as the starting line and adjacent lines were then added to the north and south. Based on the unpublished computer-generated navigation trackline map of the mosaic area, all lines had previously been speed adjusted at five-minute intervals to componensate for currents, and ship speed changes. During mosaic assembly, many cuts had to be made in the chronoflex copies of each lines in order to compensate for irregularities in the tracklines.

The mosaic is internally consistent and possesses only minimal internal distortion. This distortion is due to two factors: 1) it is impossible to precisely mirror the ship's tracklines on either plastic or paper and still accurately depict individual features in the mosaic area and 2) even with precision navigation of the ship ($\pm$10m), the side-scan SONAR fish, which was towed up to 600 feet (approx. 180m) behind the ship, was free to drift with the currents and therefore did not precisely follow the ship's track. Both of these facts were considered in not only the construction of the mosaic but also in the generation of the latitude and longitude coordinates and the north arrow shown on the map.

DESCRIPTION OF THE AREA

Analysis of the mosaic and related bathymetric and seismic data has allowed us to delineated four sea-floor zones in the mosaicked area: (1) a northwest zone of minimal sediment disturbance characterized by isolated pockmarks, fields of ripple marks, or featureless mud; (2) a northcentral zone of medium-density slumping with small slumps and pockmarks,; (3) a southcentral zone of intensive and massive sediment disturbance characterized by blocky failures, pockmarks, areas of multiple scarps, large slumps, accumulation debris, and numerous flow lobes; and (4) an eastern area characterized by north-south sediment funnelling channels. Figure 2 is a schematic drawing of the area.

Zone 1 - The northwestern "undisturbed zone" is characterized by the presence of broad expenses of sand, often covered by ripples with wavelengths of 1-5 m, and large featureless areas of cohensive mud.

Figures 3-5 show typical characteristics of this zone. Isolated slumps and pockmarks are present (Figs 3 & 5) but cover less than 10 percent of the zone. Ripple orientation suggest onshore/offshore sediment movement.

Sediment instability is indicated by collapse features without evidence of translational motion. Isolated pockmarks and collapse depressions are generally less than 50 m in maximum dimension, with many smaller than 10 m.

Zone 2 - The northcentral zone of small-scale, medium density sediment instability characterized by many small slumps, slides, small collapse features, and a variety of types of flows (Figs 6 & 7). Most sediment failures have well-defined boundaries and are not layered or superimposed, one slide or slump on top of another. Many areas are characterized by an irregular, blocky surface, suggestive of differential in-situ sediment volume reduction.

The largest features present in this zone are closed collapse depressions, up to 300 m in maximum dimension, and elongate flows, also up to 300 m long. Most features, however, are much smaller, with maximum dimensions less than 50 m.

In the northwestern part of Zone 2 the relationship between sediment-failure features and the sand and mud blanket of Zone 1 is unclear. Whether failures of Zone 2 are expanding northward into Zone 1 or whether the mobile sediment blanket of zone 1 is burying older craters, pockmarks, and collapse features of northern zone 2 remains unknown.

Zone 3 - Zone 3 (the southcentral zone of intensive and massive sediment disturbance) is characterized by multiple generations of slides, slumps, flows and collapse features (Figs. 8-10). Features are extremely complex with multi-directional flow lobes. The size of flows appears to increase toward the southern limit of the area. Topography is complex, with many areas of flows bounded by channels which are floored by well-developed sand waves.

Zone 4 - The eastern area of channels and chutes occupies about 15 percent of the entire mosaic area. Here, generally north-south oriented, well-developed linear troughs, channels, and chutes 3-6 m deep, up to 300-400 m wide, and as much as 1.5-1.8 km long, occupy most of the area. The chutes serve as active channelways for the funnelling of currents and probably sediment. Many sets of fishing boat trawl marks were observed approaching the chutes, disappearing within the channel, and then continuing on the far side of the chutes.

Inter-channel areas are generally devoid of slides, slumps, and other types of sediment-failure features. They do, however, have much higher surface reflectivity than channels and chutes. Examples of Zone 4 features are shown in Figures 11 and 12.

GEOTECHNICAL STUDIES IN THE AREA

Laboratory and shipboard Geotechnical studies were conducted under the supervision of Homa J. Lee and William C. Schwab. A recent publication (Schwab and Lee, 1983) presents a normalized soil parameter approach to understanding the geotechnical characteristics of this mosaic area.

In-Situ Tests - In-situ cone penetration and vane shear tests were conducted with a Multi-purpose In-Situ Test System (MITS) leased from Woodward-Clyde Consultants. Two stations were occupied, one in undisturbed ripples sand (Zone 1), and the other in an area of disturbance (Zone 3).

At the Zone 1 site, tests indicate the presence of a layer of dense sand with a friction angle of about 38 degrees and a relative density of nearly 100 percent which extends from 1-3 m below the sea-floor. This is overlain by a 1-m-thick

layer of weaker material. Where examined in cores and grab samples, this material was either loose sand or clayey silt. Interbedded silts and sands exist from 3-5 m below the sea floor.

The sands have a relative density of about 80 percent and a friction angle of about 34 degrees. The silts are relatively dense and have a strength to overburden pressure ratio of about 1.0.

Vane and cone test in the disturbance area (Zone 3) indicate relatively weak material, probably silt, interbedded with sands. The sands comprise 30-40 percent of the total 6-m sub-bottom section that was tested and occur in beds ranging in thickness from 10-70 cm. The sand is loosely packed and its abundance decreases with depth. Silt in the lower 3 m appears normally-to slightly underconsolidated and has a strength to overburden pressure ratio of 0.5.

Index Property Tests - Twelve gravity cores from the area were tested for vane shear strength, water content, and Atterberg limits. The material tested was almost exclusively silt. Vane shear strength ranged from 3-19 kPA with a slight tendency toward lower strength in the eastern part of the mosaic area. Water contents ranged from 27-50 percent dry weight with the higher values occuring in the eastern part. Liquid limits ranged from 2-41 percent and were typically near the natural water content, a condition that is generally indicative of a very sensitive material.

Triaxial Testing - Four gravity cores from the area were subject to static and cyclic triaxial tests. The ratio of strength to overburden pressure for the material in a normally consolidated state was determined to be 0.7. This value can be used to determine the consolidation state of the silts tested in place. The cyclic tests showed strength degradation of 70 percent during 10 cycles of loading. This is significantly greater than the 30-40 percent strength degradation usually found with nearshore silts and clays, and indicates the material could easily lose most of its strength during earthquake or wave loading.

CAUSES OF SEDIMENT INSTABILITY

The upper few meters of sediment in the mosaic area may be failing as a result of liquefaction and degassing induced by the action of one or more of the following processes, (all of which are active in this area): cyclic wave loading, earthquake ground shaking, rapid sedimentation, or saturation of the sediment by biogenic methane gas. Additional factors that may contribute to the sediment instability include high water content and the possible presence of a slip surface between the present-day Alsek River sediment and an underlying dewatered, older silty-sand and clayey-silt layer. Schwab and Lee (1983) concluded that in water depths less than 35 m, major storms are the likely triggering mechanism for instability, while in deeper water, earthquakes are the likely causative factor.

The pockmarks, slumps and other sediment-failure features observed occur on slopes as gentle as 0.4 degrees and in water 35-80 m deep. Sedimentological evidence from the cores and grab samples suggest that the regional stratigraphy in the mosaic area consists of a veneer of sand less than 1 m thick, overlying a 2.4 m thickness of underconsolidated clayey silt with a high water content. The silt, which contains thin sand lenses, overlies a much thicker dewatered clayey silt. Minisparker and airgun seismic data indicate that the total thickness of Holocene sediment in the mosaic and surrounding areas ranges from 40-120 m and unconformably overlies a lithified unit. The boundary between the two units is characterized by rounded, presumably glacially-eroded morphology and by many small U-shaped channels.

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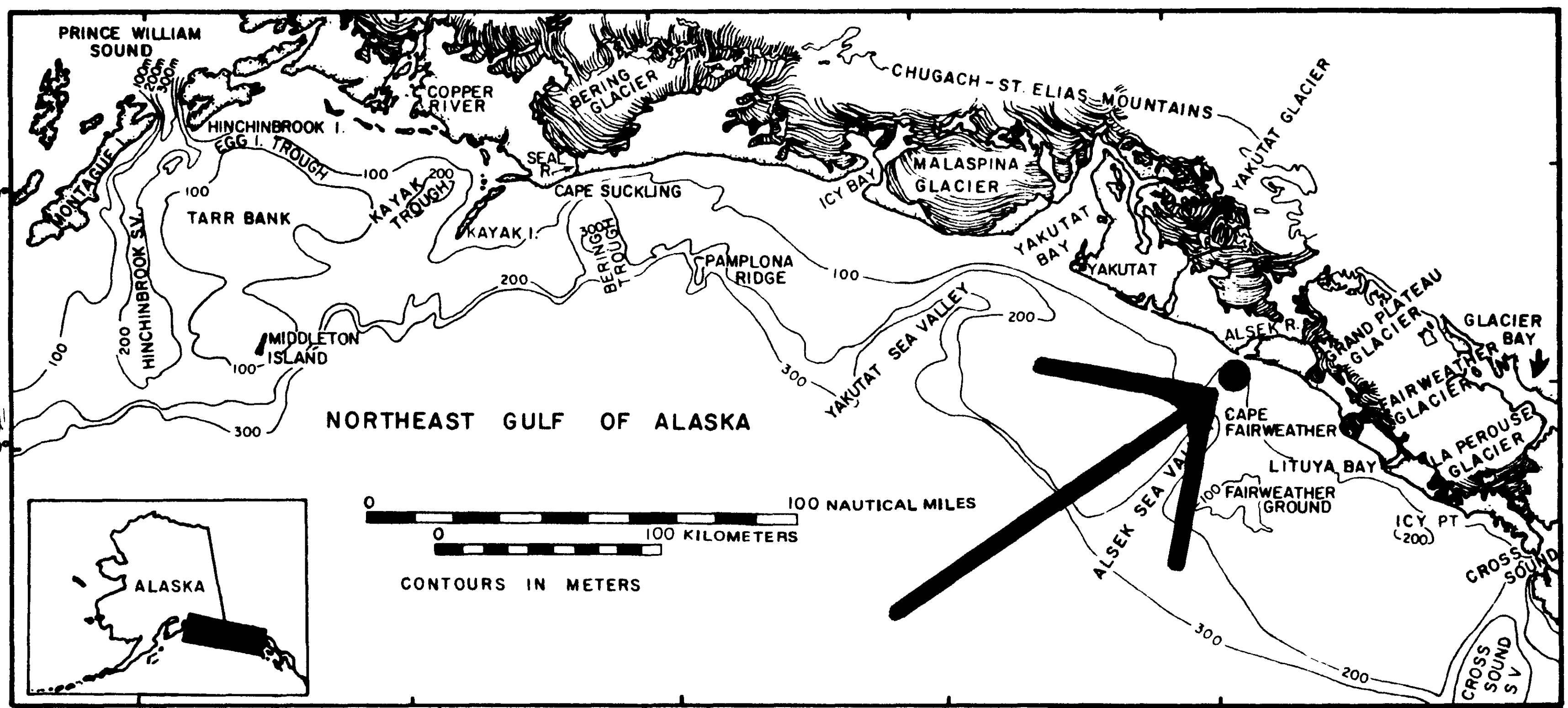

Figure 1.–The study area in the northeastern Gulf of Alaska and the location of the major geographical features

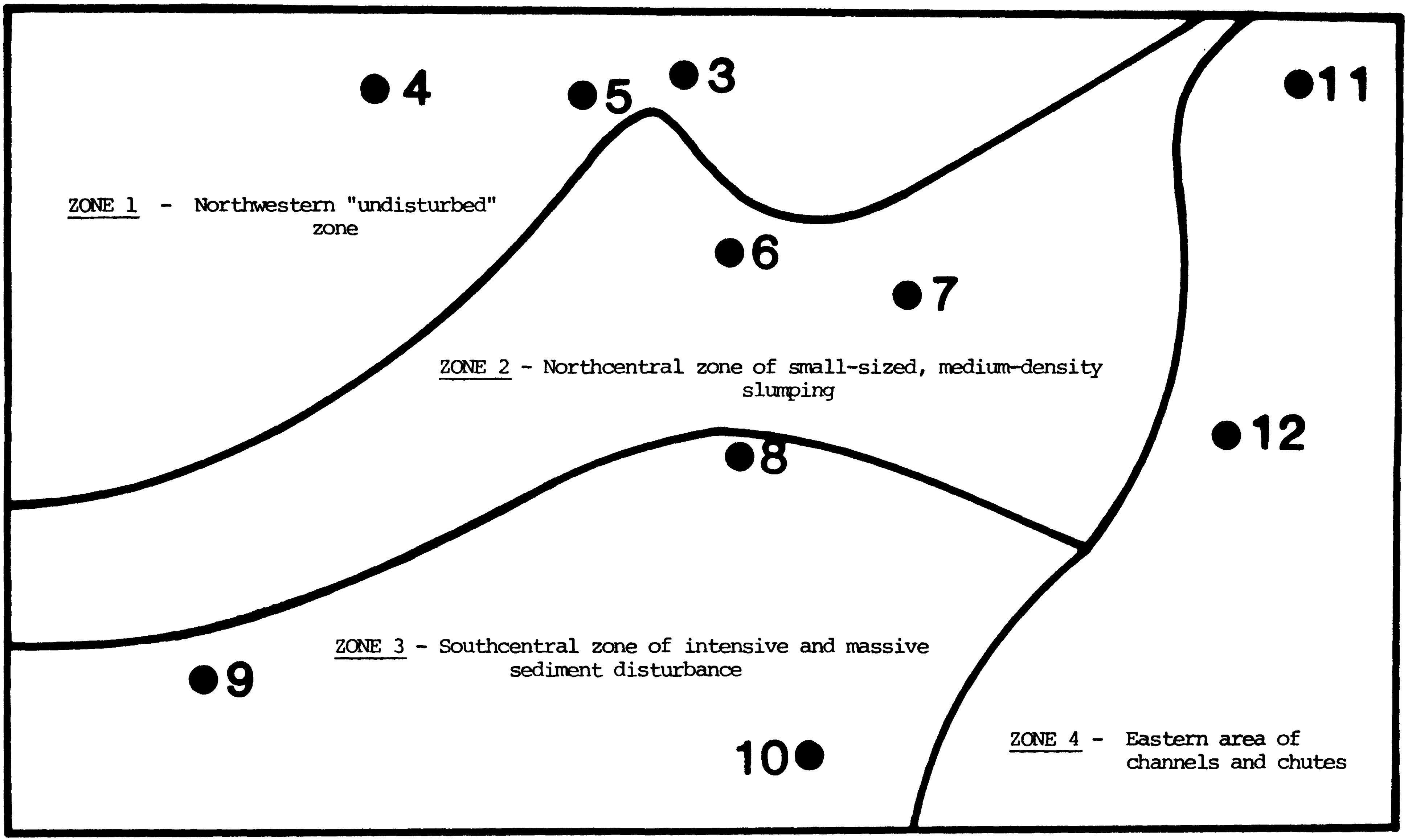

Figure 2. Schematic drawing of the Alsek Sediment Instability Study Area showing the four zones, each characterized by a different style of sediment instability. Numbers correspond to the locations of Figures in this section.

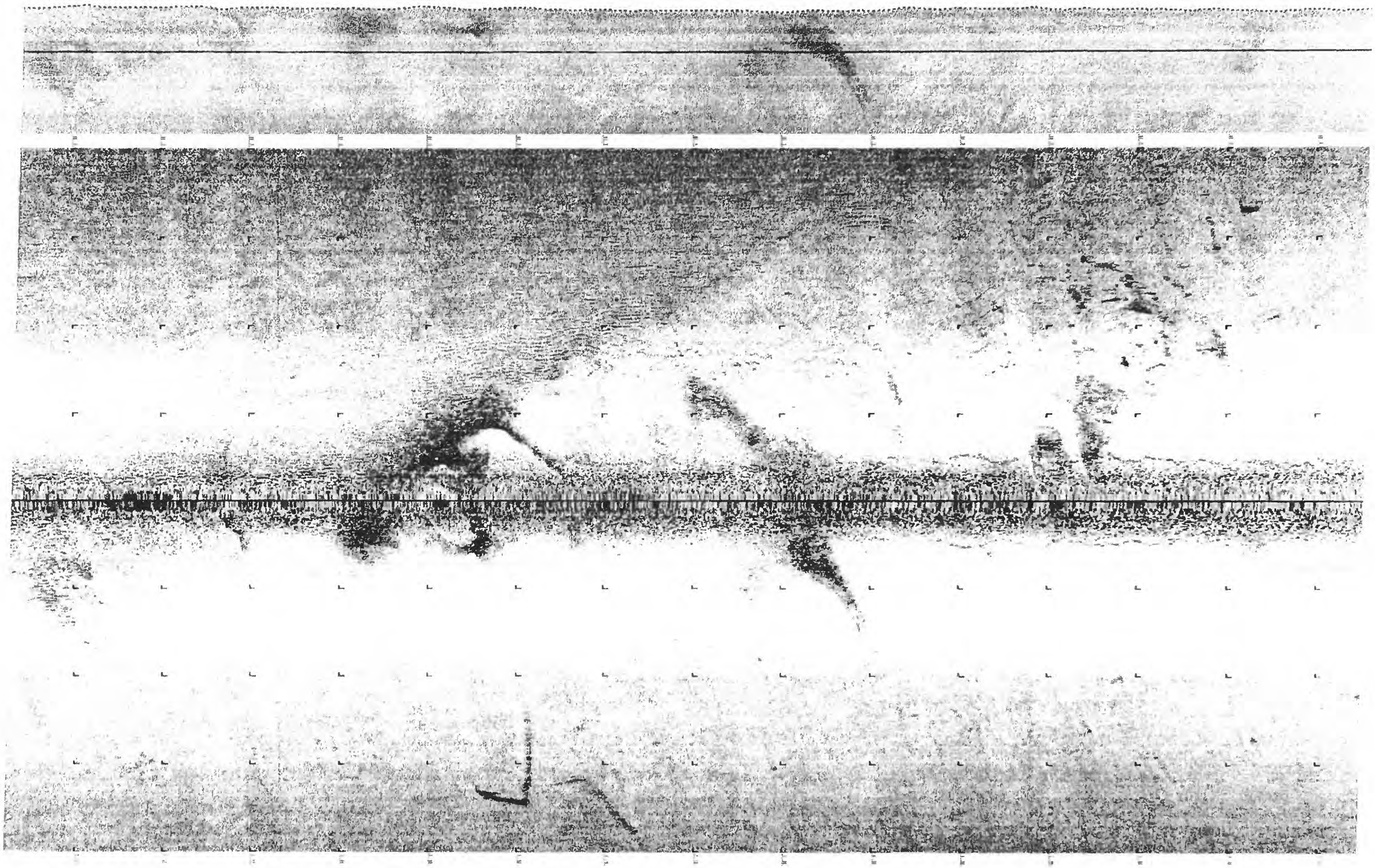

Figure 3. Sonograph of rippled-sand surface of the northwestern "undisturbed" zone. Note the few isolated collapse features. The upper profile shows mid-line bathymetry. The distance between tick-marks is 25 m.

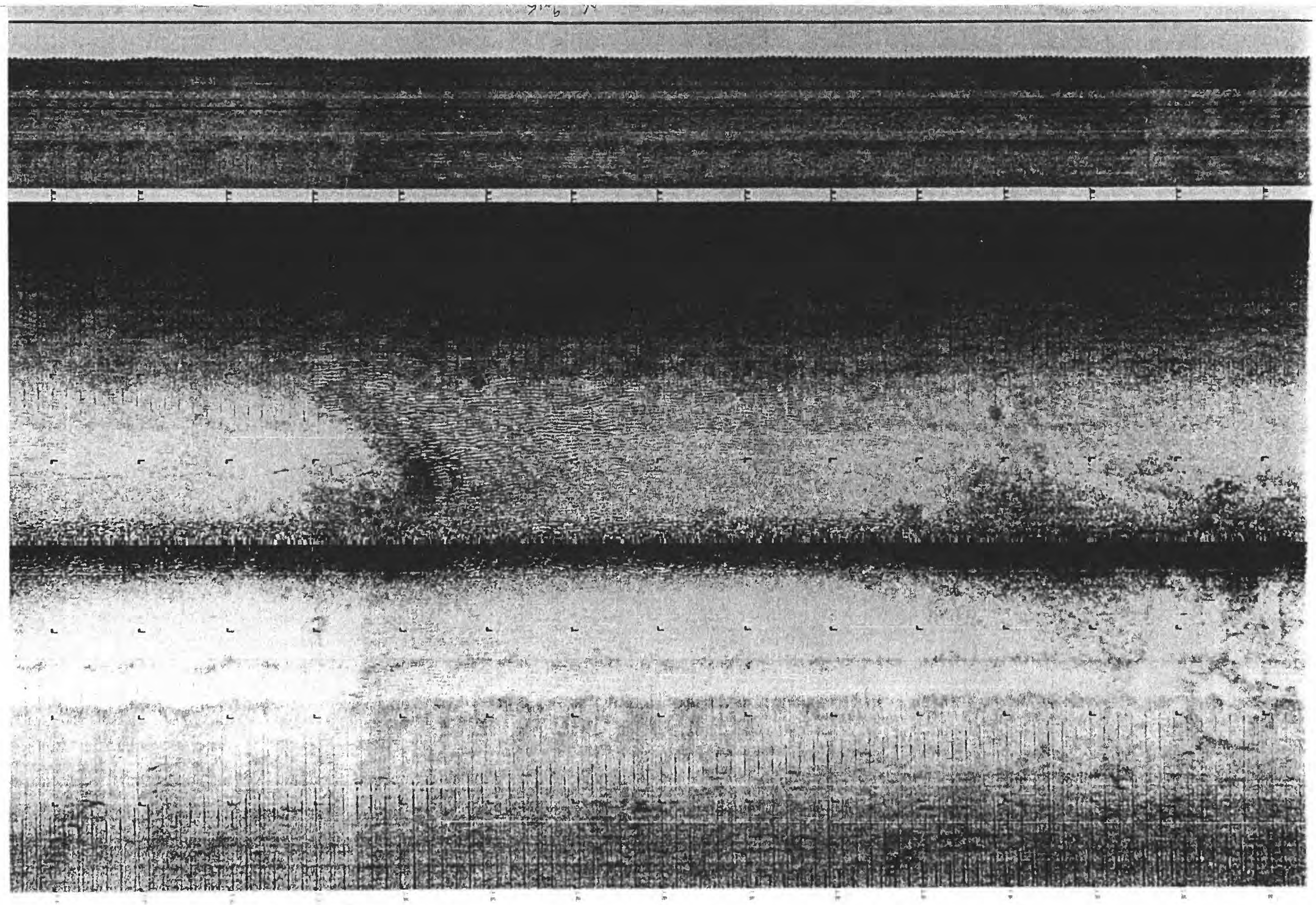

Figure 4. Sonograph of a flat, undisturbed section of the ripple-sand portion of the "undisturbed" zone.

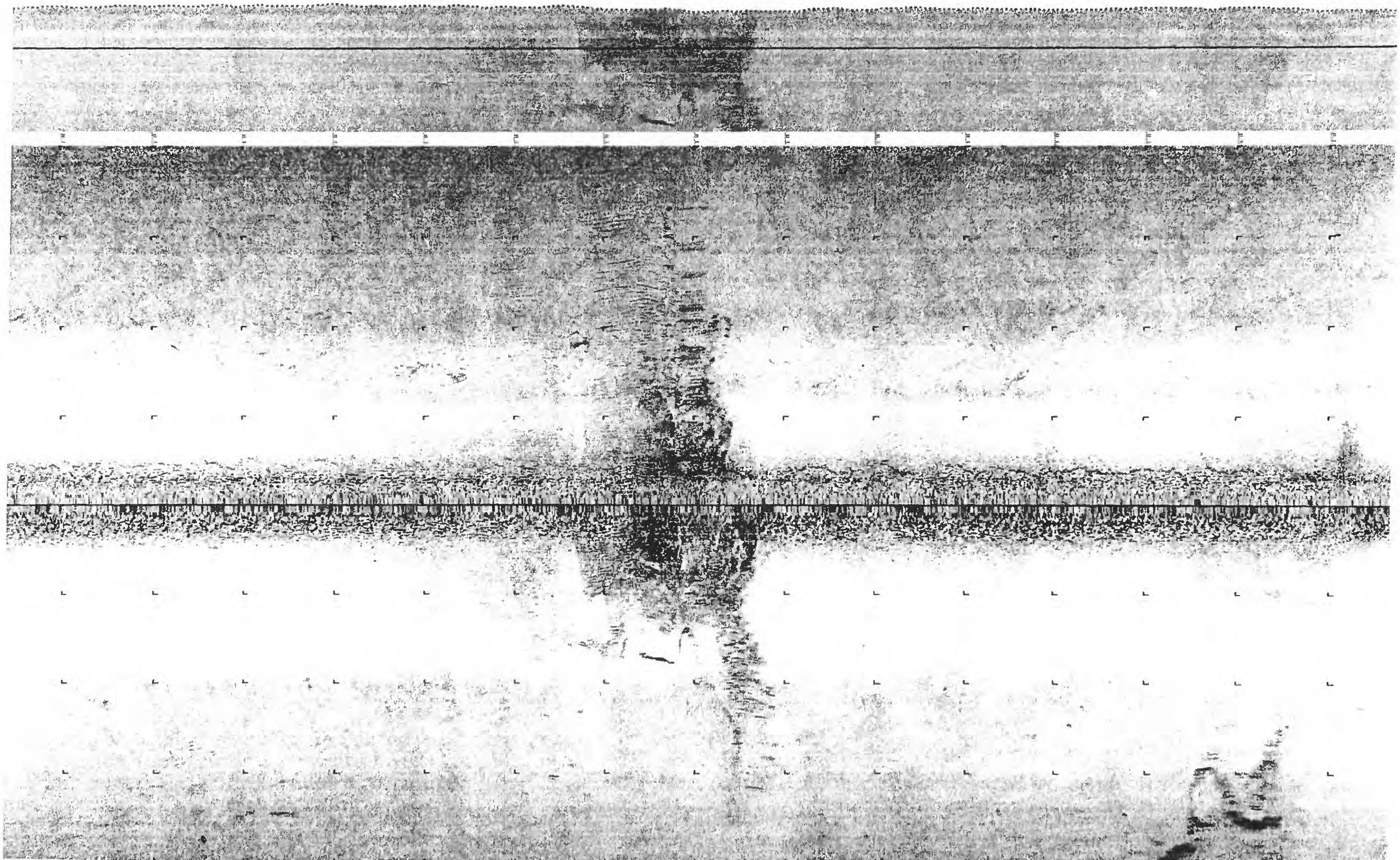

Figure 5. Sonograph of ripples, sand bodies and featureless mud in the northwest "undisturbed" zone.

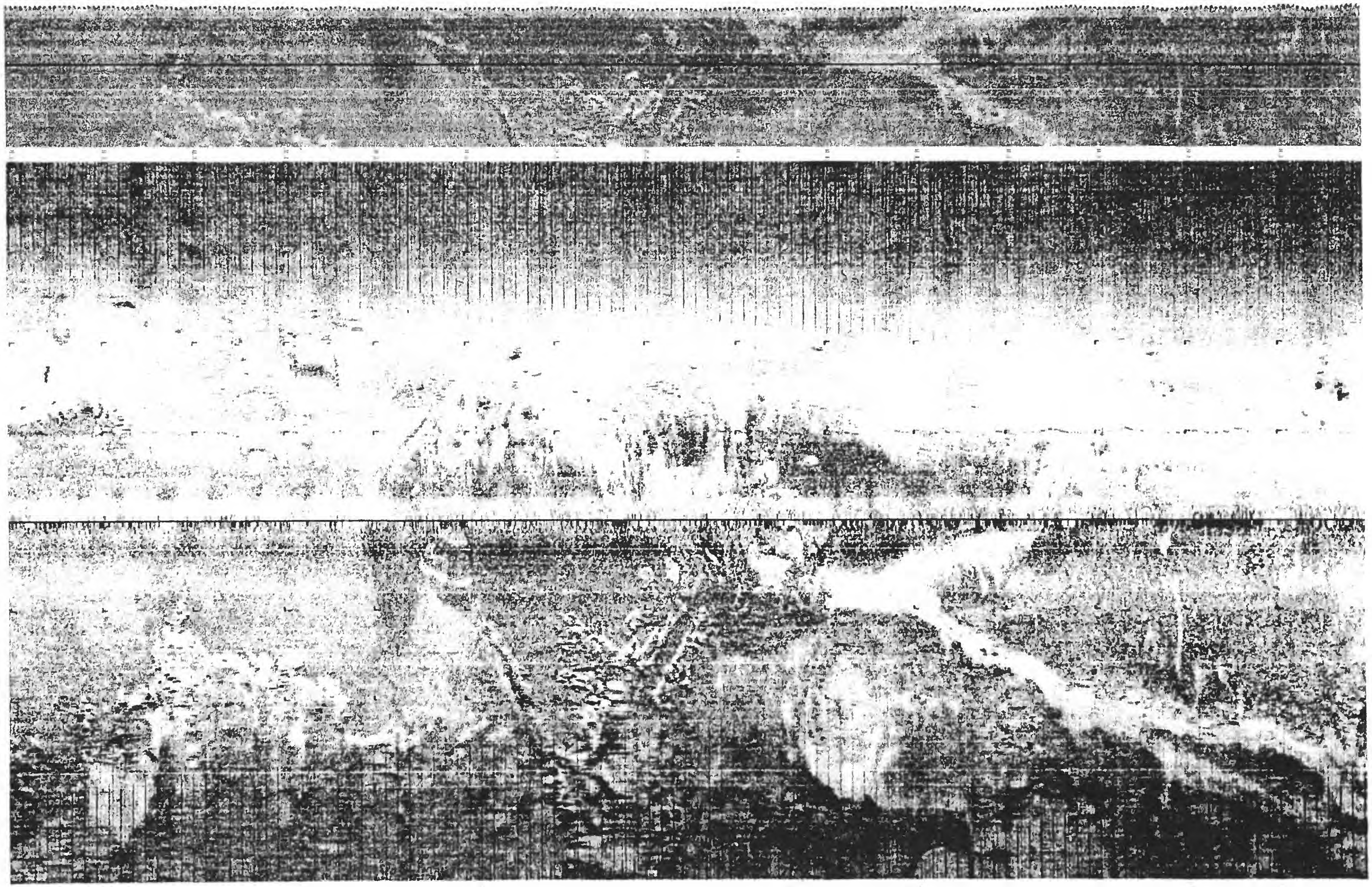

Figure 6. Sonograph of small collapse features, slides, and linear flows in the northcentral zone of small-scale, medium density slumping.

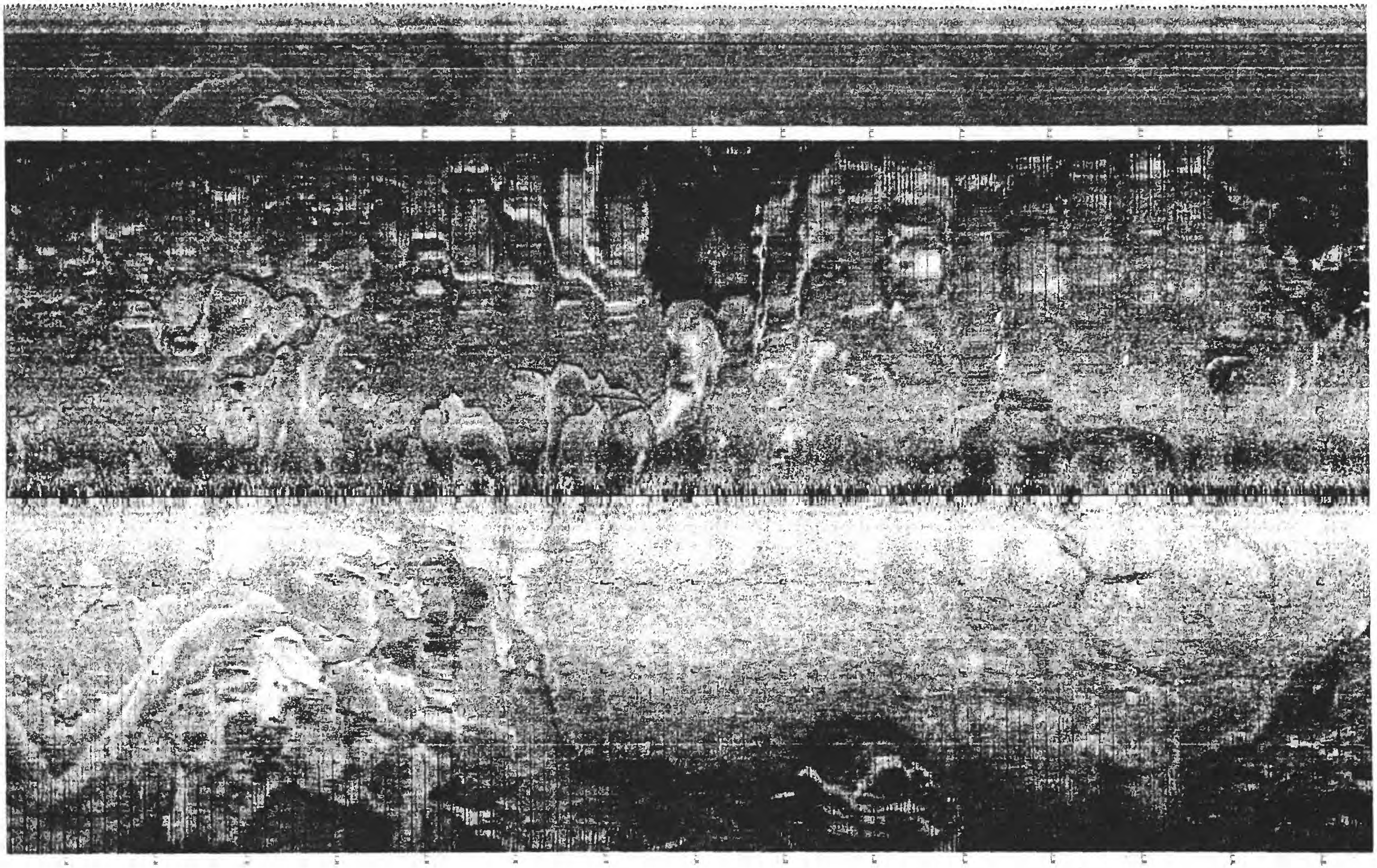

Figure 7. Sonograph of multiple collapse depressions, small slides, slumps and flows in the north-central zone of small -scale medium-density slumping.

Figure 8. Example of surface features at the north end of the south-central zone of intensive and massive sediment disturbance.

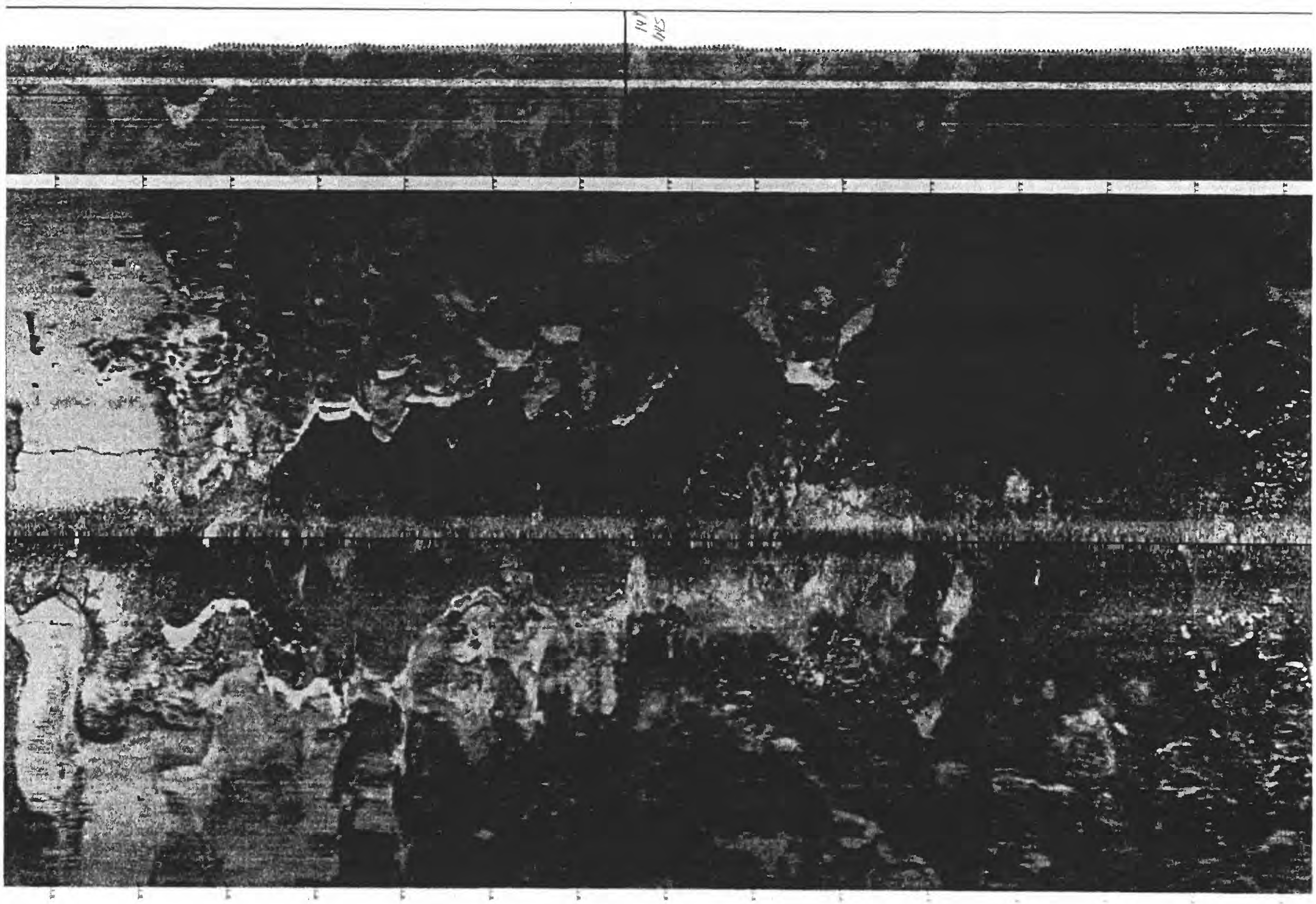

Figure 9. Multiple flows, slumps, and slides in the south-central zone of intensive and massive sediment disturbance.

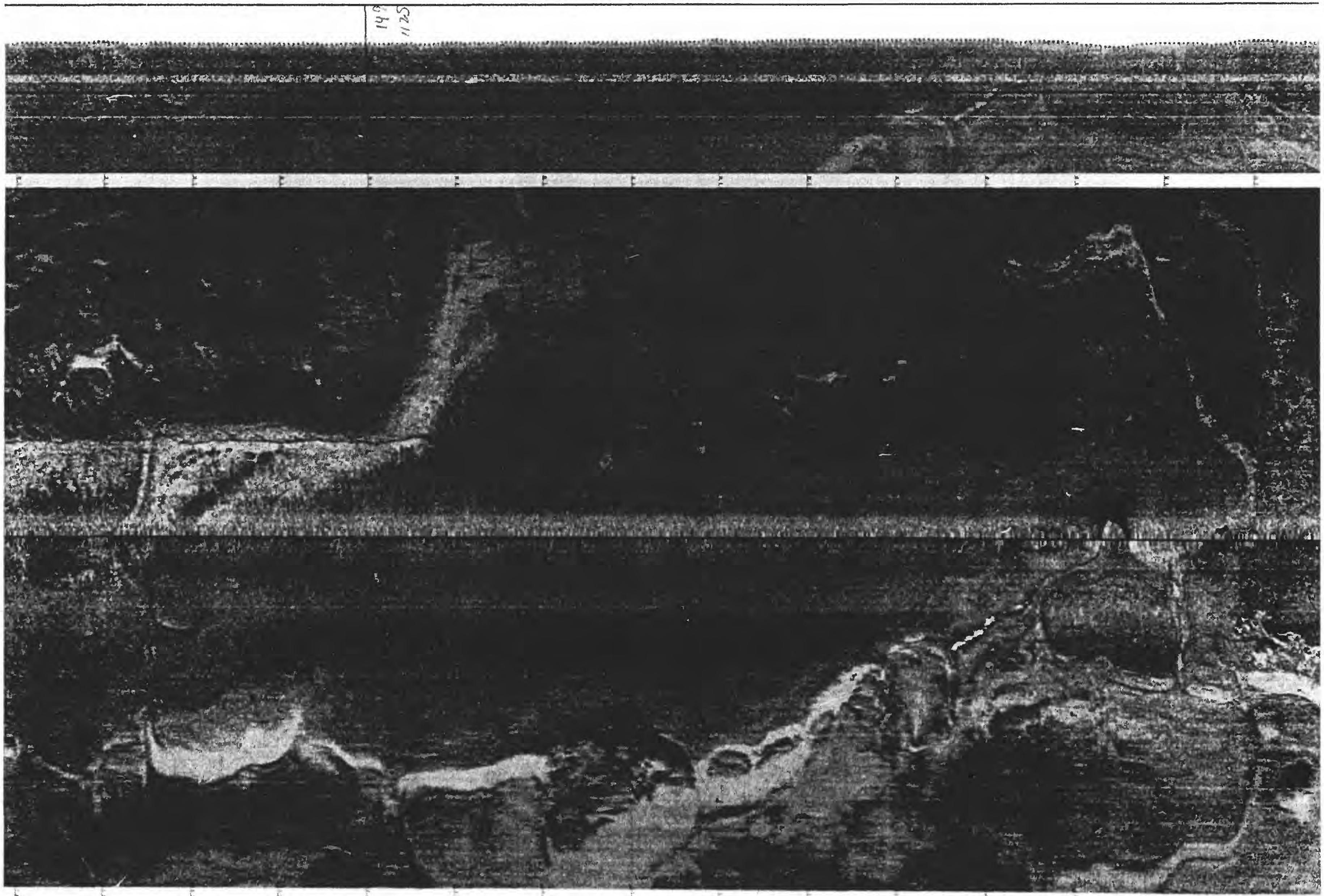

Figure 10. Example of a massive, lobate slide toe and a series of smaller slide toes in the zone of intensive and massive sediment disturbance.

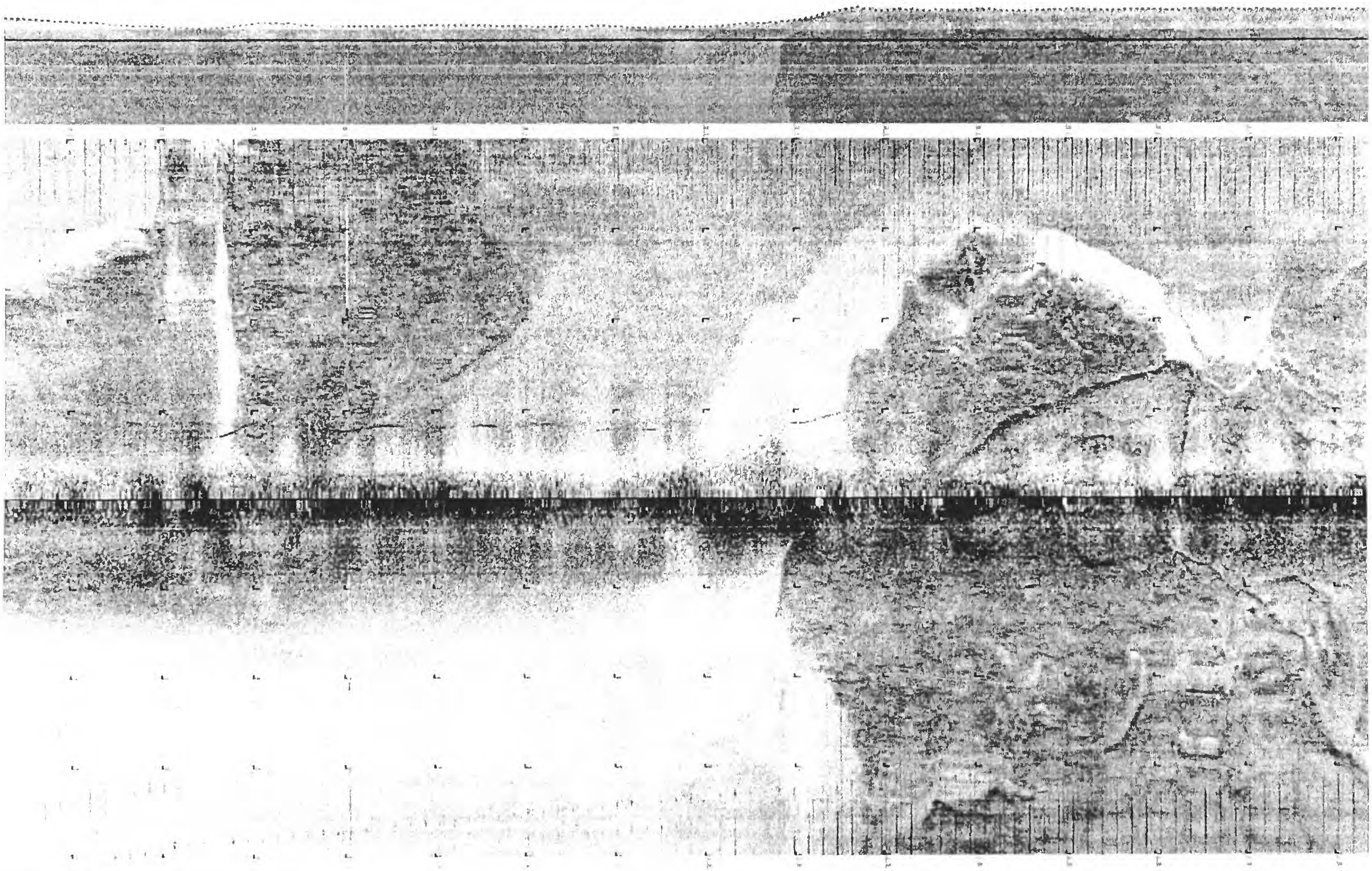

Figure 11. Example of a 150-m-wide channel with wall relief of about 1 m. Features like this are common in the eastern area of channels.

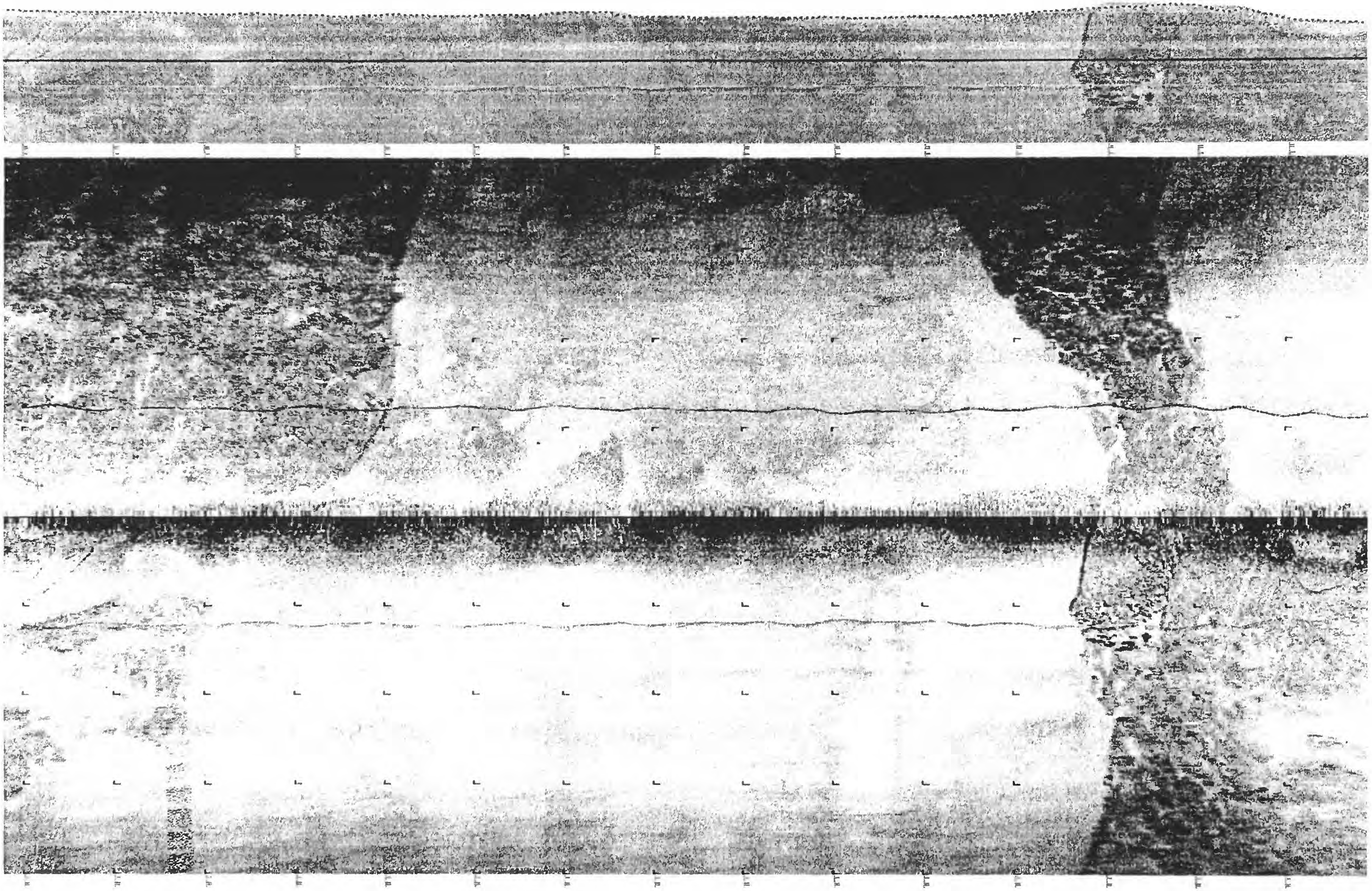

Figure 12. North-south oriented channel in the eastern area of channels and chutes.