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Integration of 3-D and site survey seismic data in analysis of near-surface hazards to platform location at Dulang Field, Malay Basin

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Abstract: At Dulang Field a near-surface Pleistocene channel creates potential hazards to production platform installation. Selection of a location for the Dulang "A" platform was conducted by integrating 3-D seismic data, shot for exploration and development purposes, with site survey data, acquired specifically to address seabed and near-surface hazards. This approach provides a more efficient and comprehensive interpretation than is achievable by the more conventional approach of interpreting the site survey data alone.

INTRODUCTION

Dulang Field is located in the Malay Basin approximately 130 km northeast of Kuala Terengganu in about 75 m of water (Fig. 1). The field is a complexly faulted anticline (Fig. 2), with oil reservoired in late Miocene Group D and Group E sands. Development started in 1990 with the commencement of drilling from the "A" and "B" platforms and 48 development wells have been drilled to date. The field is operated by PETRONAS Carigali Sdn. Bhd. (PCSB) in a unit area with Esso Production Malaysia Inc. (EPMI).

The objective of this paper is to illustrate the integration of 3-D and site survey data in evaluating seabed and near-surface hazards. The combination of these datasets provided a faster and more effective method of assessing shallow hazards to platform installation than using the site survey data alone. The use of 3-D data for this application was not anticipated at the time of acquisition.

The main hazard to platform location at Dulang "A" was a near-surface Pleistocene channel nearly 80 m deep and about 500 m wide. Channels of this age are commonly observed on 3-D and site surveys near the axis of the Malay Basin. Soil borings taken for engineering tests showed the channel-fill to comprise mainly stiff clays with significant organic material and minor coarser-grained, basal clastics including fine-grained sand and rare pebbles.

In this study, 3-D timeslices provided almost instantaneous maps of the gross morphology of the channel. Boomer data, with far greater resolution of the near-surface, enabled interpretation of rising gas plumes at the channel margins and

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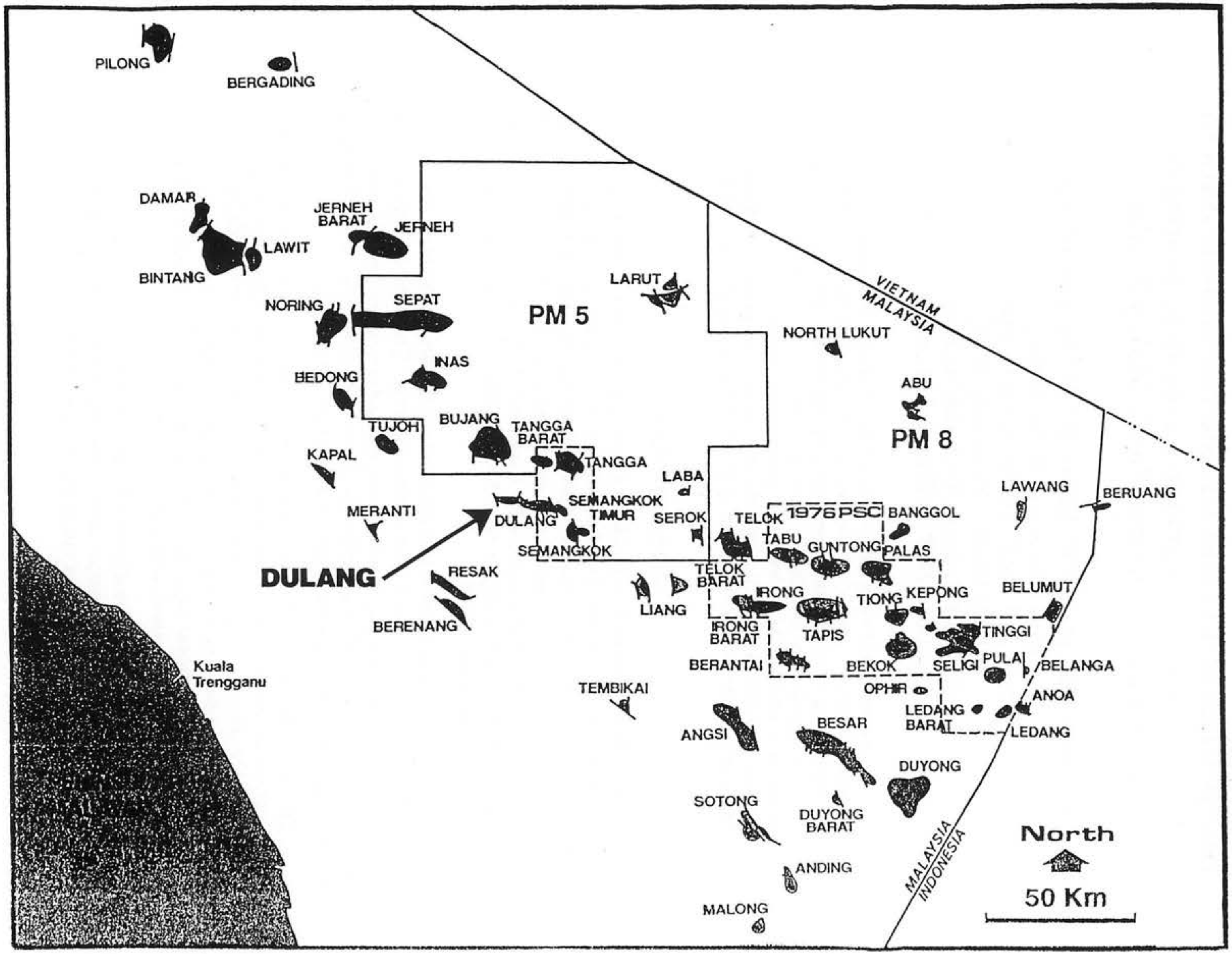

Figure. 1: Dulang Field location in the Malay Basin.

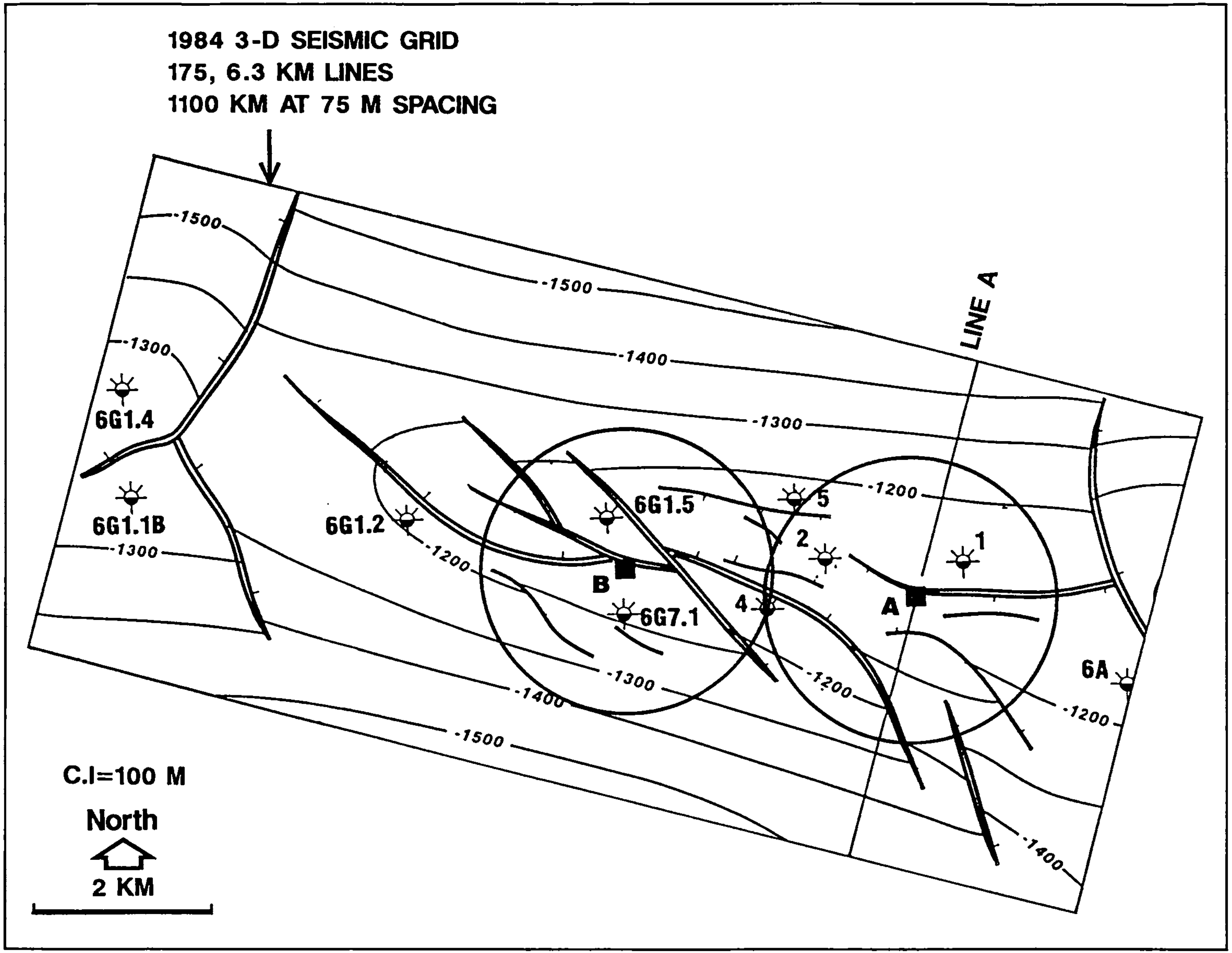

Figure 2: Structure top of Group E in Dulang Field showing "A" and "B" Platforms.

sidescan sonar data, which image the seabed, showed these interpreted plumes to be associated with extensive pockmarking and subsidence.

The coincidence of these channel-margin features suggest a common mechanism – possibly differential compaction between channel-fill sediments and adjacent sediments outside the channel has localised dewatering and evacuation of low-saturation biogenic gas at the channel margins.

Key considerations for platform installation are to avoid seabed irregularities (which could cause instability prior to piling), inhomogeneities between piles (which could cause differential stress) and hazards associated with evacuating fluids (gas or water). It also is important to avoid any hazards while acquiring soil borings for engineering tests.

At Dulang "A", this in effect meant avoiding a platform location at the channel margins. Two potential platform locations were identified on the basis of this geophysical interpretation; an optimum location (for drilling considerations) at the channel centre and an alternative location outside the channel. Subsequent soil borings and engineering tests showed both locations to be acceptable and the "A" platform was successfully installed at the channel centre location without encountering any hazards.

SEISMIC DATA

3-D Survey

A total of approximately 1100 line km of 3-D data over the unit area was jointly acquired by PCSB and EPMI in 1984, using an 840 in^3 4500 psi air gun array of 13 guns. Inline spacing is 75 m, the shot interval is 12.5 m and sample rate is 2.0 milliseconds. The cable length was 1800 m with 72 groups of 32 hydrophones/group at 25 m spacing. The primary navigation system used was hyperfix. A conventional 3-D processing sequence was carried out with two pass migration. The data were stacked at 72-fold with a 3-D bin size of 75 m x 12.5 m. The bandwidth of the 3-D survey is about 10-100 Hz, with penetration up to about 2.0 seconds.

Site Survey

The site survey comprised the following four datasets with a 100 m line spacing:

- High resolution digital seismic data. The shooting parameters were designed for high resolution in the uppermost 500–1000 m. The source, a high resolution water gun array gives frequencies from about 10 to 250 Hz.
- Boomer data. Employing an implosive source, these are analogue reflection seismic data, recorded on paper, which have peak frequencies in the range of 2–7 kHz. Boomer data provide very high resolution but limited penetration (about 60 m into the seabed).
- Sidescan sonar data. These very high frequency analogue data are generated by transducers, which emit 105 kHz pulses. The sidescan sonar

images the seabed obliquely, about 100 m on either side of the ship's track and provides a detailed imaging of seabed irregularities.

- Echo sounder data. The echo sounder data provide detailed water depth information, using a high frequency transducer source.

3-D SEISMIC INTERPRETATION

A structure map at Top Group E level of Dulang Field as interpreted from the 1984 3-D seismic survey is shown in Figure 2. 3-D inline A (Fig. 3) illustrates the structure in profile beneath the "A" platform. Strong reflections within the Group E reservoir interval are generally due to coals although there are some direct hydrocarbon indicators (DHIs). Above the reservoir interval, keystone faults extend to the near-surface. Also evident are a channel in the Group B at 1.0 second TWT and a Pleistocene channel between 100 and 200 milliseconds which was the issue of concern in locating the "A" platform.

Figure 4 (at 112 milliseconds) and Figure 5 (at 120 milliseconds) are representative of structural (horizontal) timeslices through the 3-D cube which were displayed on the seismic workstation at 2.0 milliseconds interval. These timeslices effectively provide instantaneous maps of the channel identified on 3-D inlines and the site survey data. Both the abandoned channel and the lateral accretion surfaces of the associated point bar are vividly illustrated. In addition, small tributary channels can be seen on each timeslice. Figure 6 shows a pseudo-perspective view of the channel and point bar, looking west from Dulang "A". This is particularly effective in showing the shingled reflection geometry of the point bar.

Because of the high asymmetry of the bins in the 3-D survey these structural timeslices are displayed to maximum effect with scale distortion of about 1:2. The abandoned channel outline is shown at true scale in Figure 7 overlain on the Top Group E structure map of Dulang Field.

SITE SURVEY INTERPRETATION

The site survey at Dulang "A" covers an area of 1.6 x 1.6 km^2 and is shown relative to the 3-D survey area in Figure 8. Whereas 3-D data provide rapid mapping and interpretation of the overall Pleistocene channel and point bar geometries, the site survey datasets provide the detail needed to recognize and map potential hazards.

A detailed map of the site survey area (Fig. 9) shows the initial proposed platform location (location 1) prior to the Dulang 6a delineation well. A soil boring was taken in 1986 at this location. Location 2 was the proposed platform location incorporating the Dulang 6a results but prior to shallow hazards analysis. Two possible locations were selected based on the shallow hazards analysis. The platform was installed at the preferred location within the channel, but an alternative location (location 3) was selected outside the channel in case soil borings showed the channel location to be unsuitable.

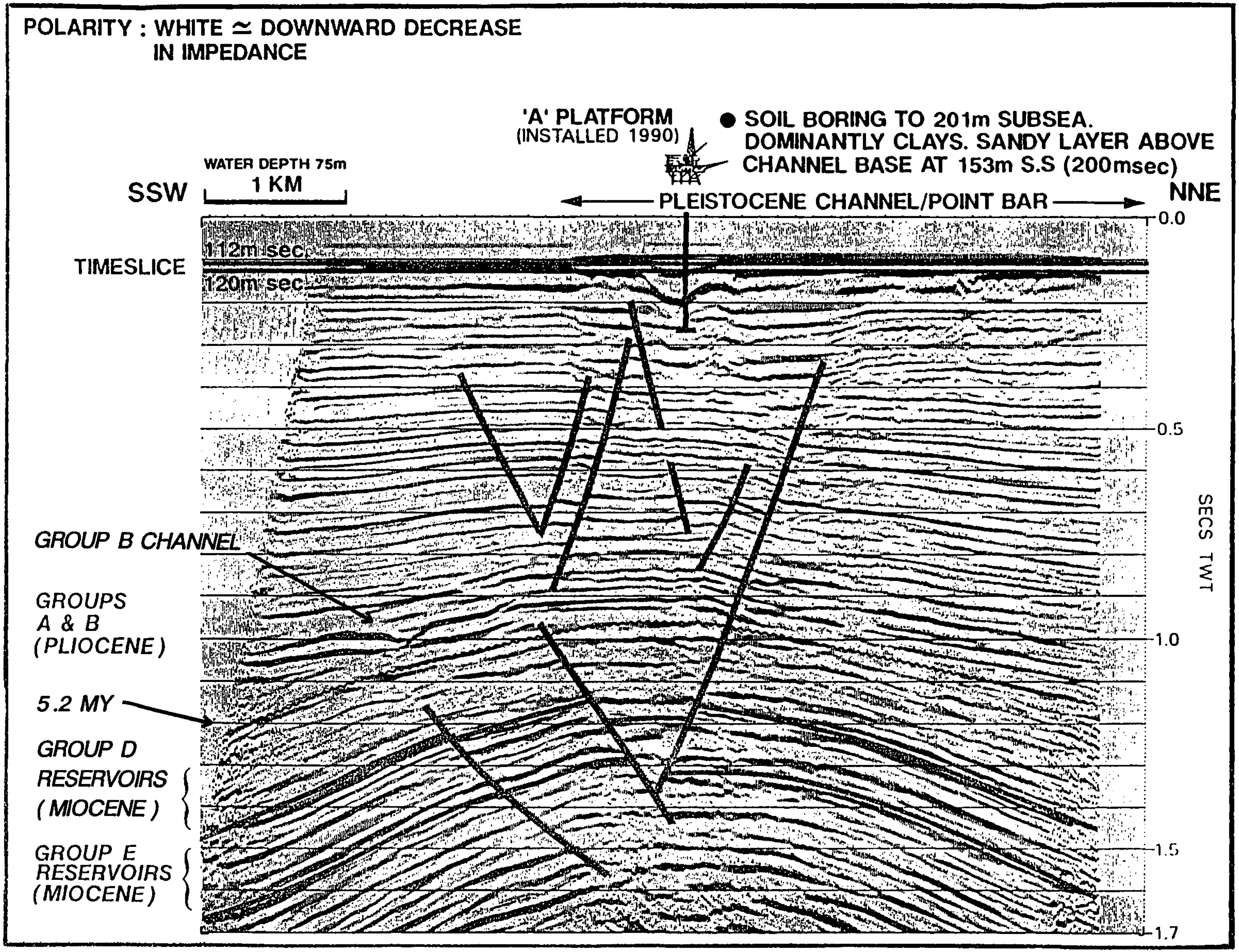

Figure 3: 1984 3-D Line A through the "A" platform.

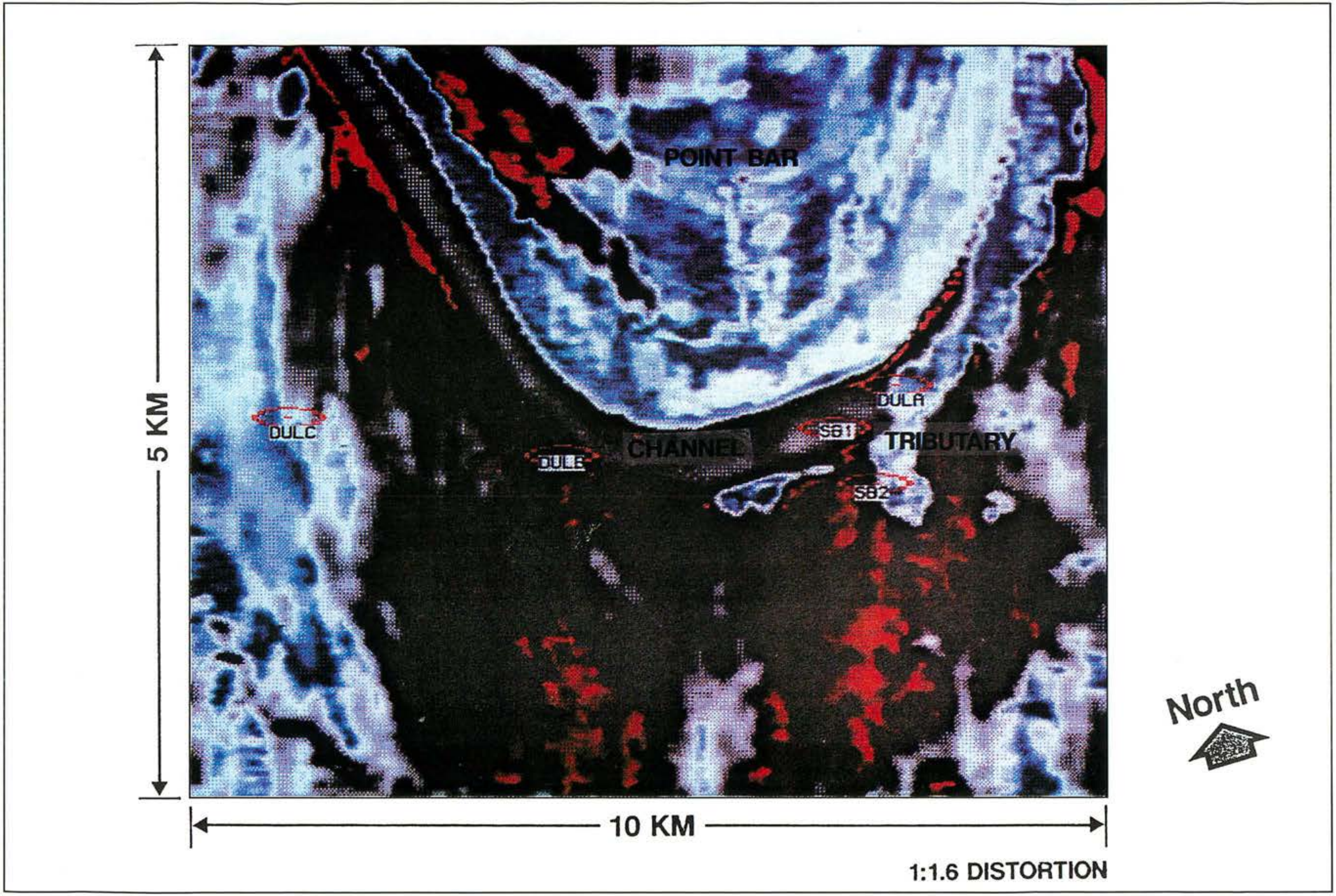

Figure 4: Structural timeslice at 112 msec showing Pleistocene channel and point bar.

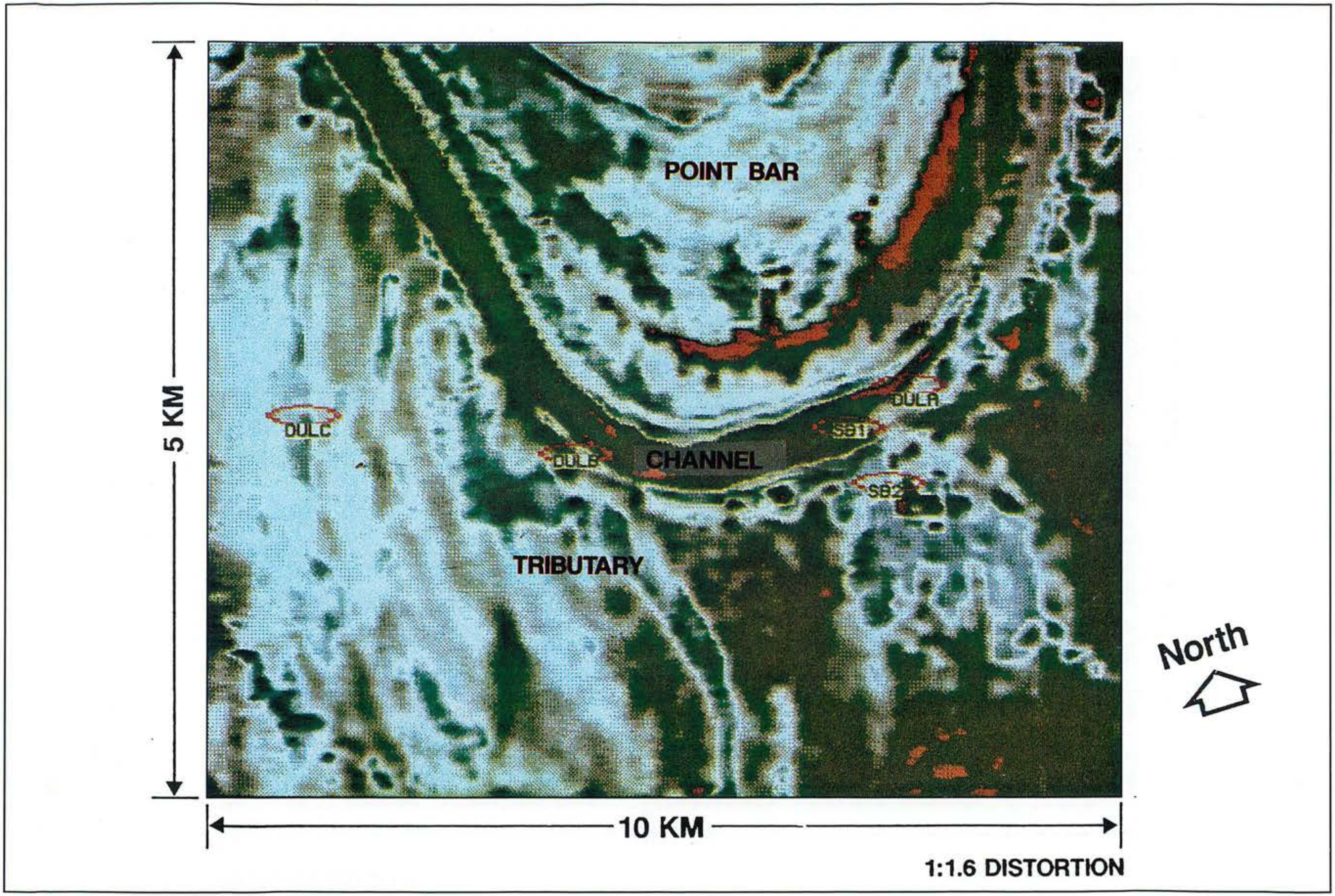

Figure 5: Structural timeslice at 120 msec showing Pleistocene channel and point bar.

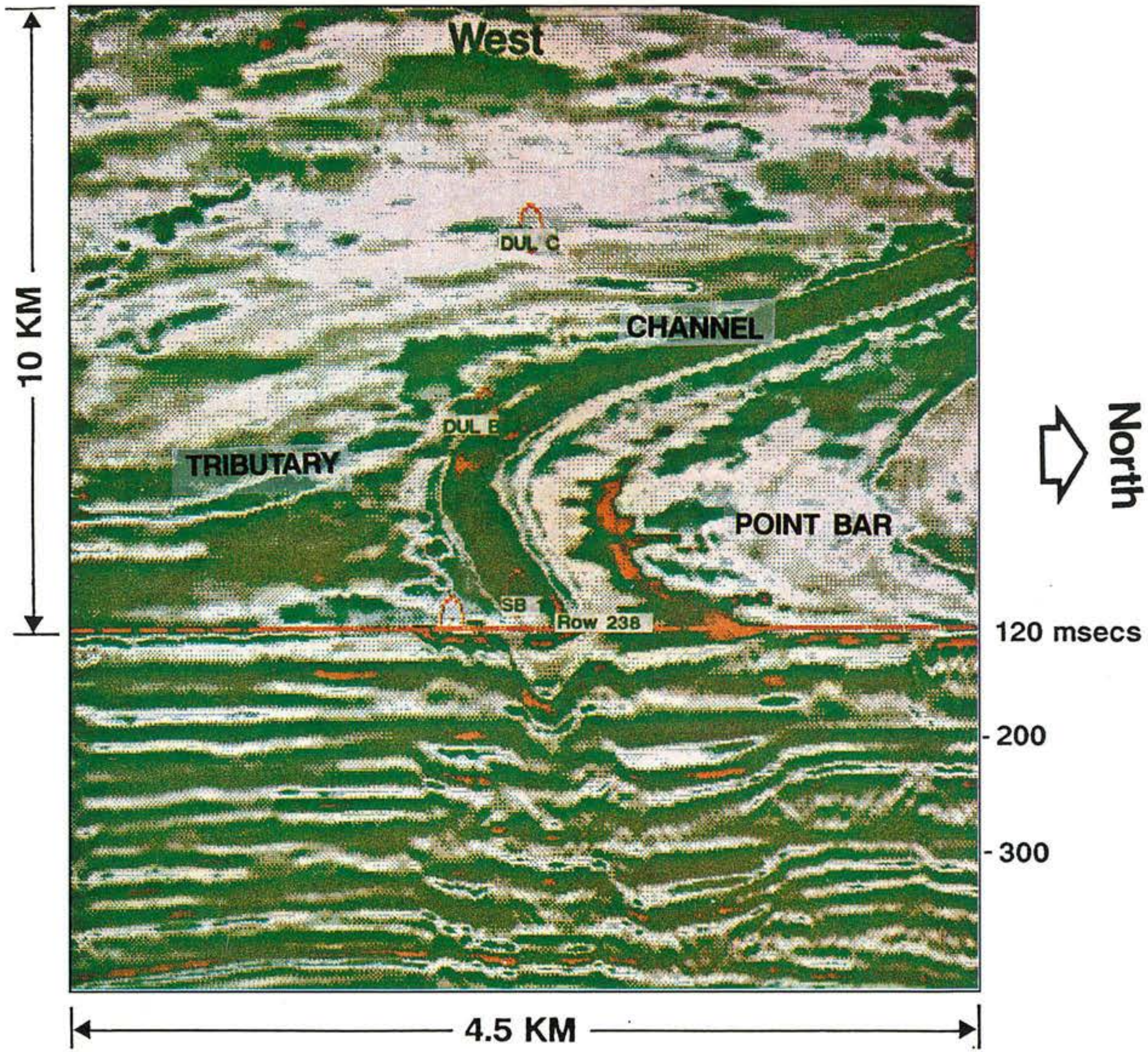

Figure 6: Pseudo-perspective view of the Pleistocene channel and point bar.

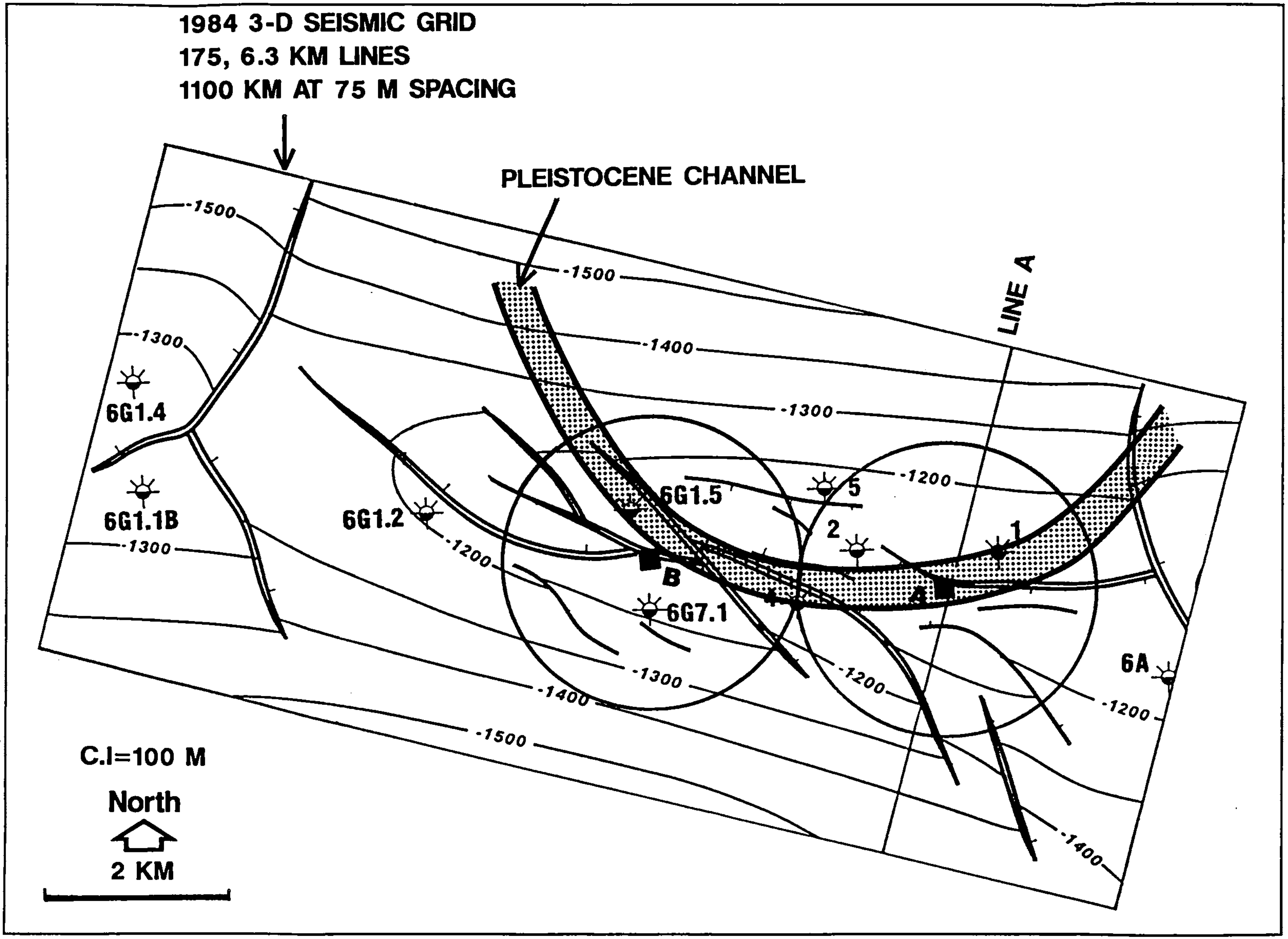

Figure 7: Outline of shallow Pleistocene channel with respect to platform locations at Top Group E.

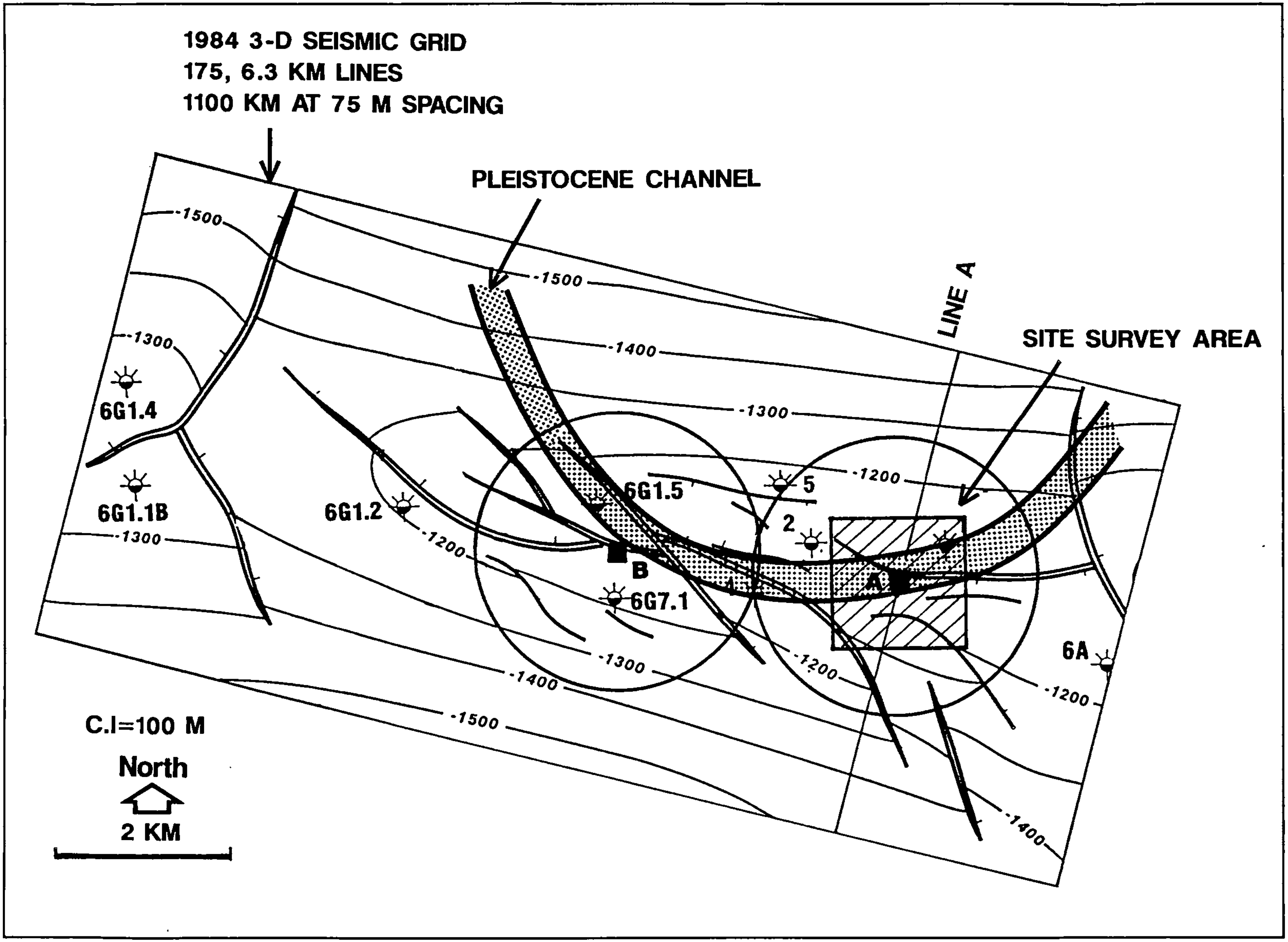

Figure 8: Area of detailed site survey interpretation with respect to channel outline and platform locations at Top Group E.

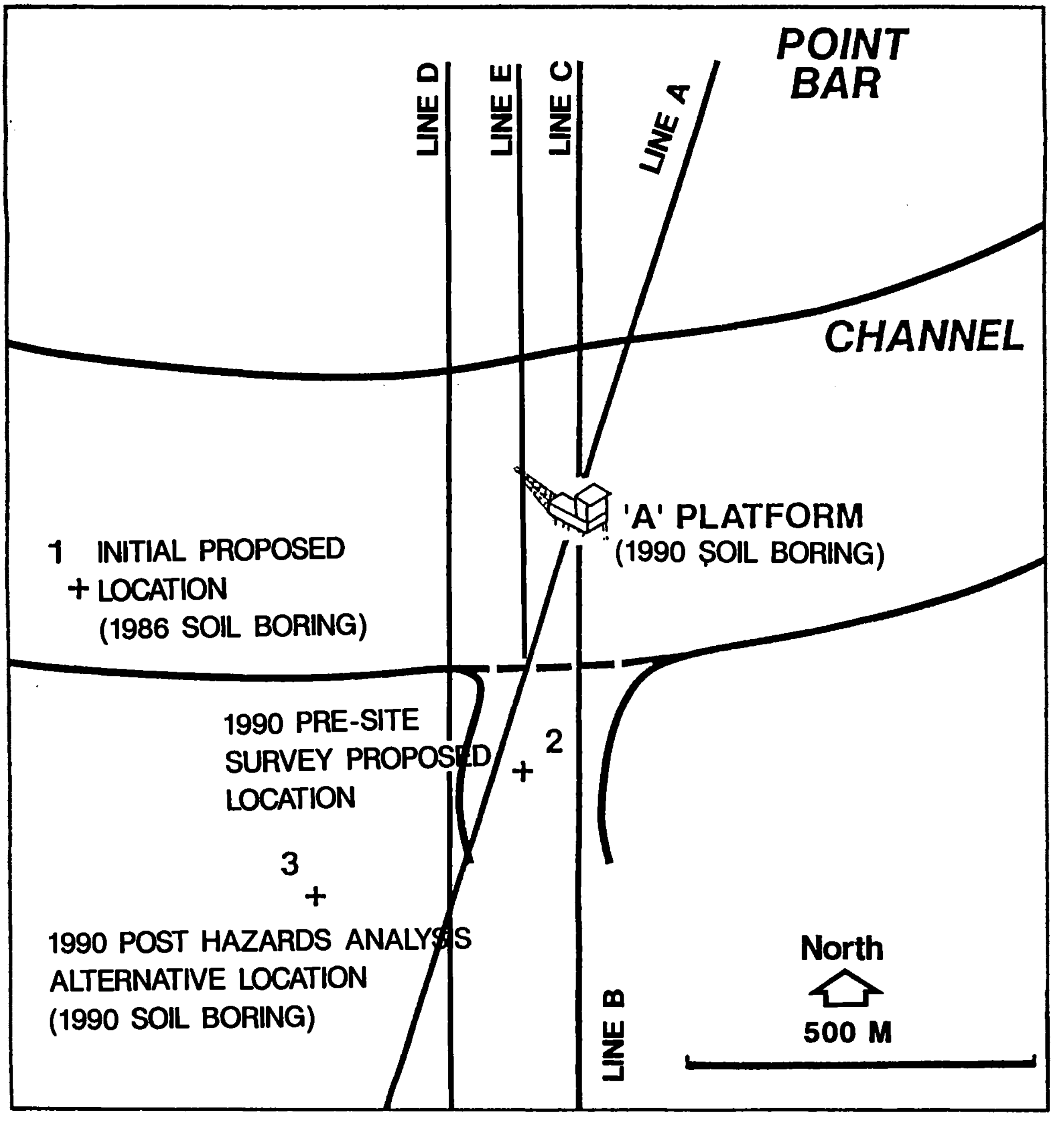

Figure 9: Possible locations of Dulang "A" platform with respect to channel outline interpreted from 3-D data.

High resolution digital seismic Line B (Fig. 10), shows features similar to the 3-D inline but with somewhat higher resolution due to greater bandwidth (i.e more than 200 Hz compared to about 100 Hz top end on the 3-D inline). Despite the higher resolution, these data do not have any significant advantage over the 3-D data in this particular interpretation.

Boomer data, Line C (Fig. 11) and Line D (Figs. 9 and 13), have much wider bandwidth (2–7 kHz) and provide very detailed imaging of the near-surface, but with corresponding lack of penetration. There are few reflections from the bottom part of the channel between 160 and 180 milliseconds.

The main feature identified from the Boomer data is an area of increased reflectivity and reduced signal penetration associated with the channel flanks. This is termed acoustic masking and is interpreted to be the expression of low-saturation biogenic gas contained in formation water. Two upward extensions of this zone of acoustic masking are interpreted as 'rising gas plumes' where formation water containing low-saturation biogenic gas is seeping towards the surface (Fig. 12).

On Line C (Fig. 11), the more northerly of these two plumes underlies a seabed depression approximately 1–2 m deep. Line D (Fig. 13) shows that where this plume reaches the seabed, a much deeper depression, up to 5 m deep, has developed. This juxtaposition of plumes and seabed depression suggests that evacuation of fluids has caused the seabed disturbance. On the southern flank of the channel, it is reasonable to predict that plumes currently 10–15 m below the seabed will ultimately result in similar seabed depressions.

This area of seabed disturbance is seen in greater detail on sidescan sonar data (Line E, Fig. 14). Sidescan sonar data, with a 105 kHz high frequency source, provide continuous imaging of the seabed for a distance of about 100 m on each side of the ship's track. Irregularities in the seabed are expressed by decreased (white) and increased (black) reflectivity and so pockmarks caused by escape of fluids and subsequent collapse, are typically expressed as a white shadow zone followed by a black high-intensity reflection. On Line E, the ship's track trends from right (south) to left (north). Therefore, the upper part of the line is imaging the seabed to the east of the ship's track. A pockmark cluster can be seen here, above the point where there is a shallow depression seen on Boomer Line C. In the lower part of the diagram, the image of the seabed to the west of the ship's track shows a cluster of coalesced pockmarks corresponding to the deep depression seen on Boomer Line D.

Figure 15 summarizes in map view the features identified from 3-D, Boomer and sidescan sonar data. Channel margins are defined from 3-D timeslices, areas of acoustic masking and rising gas plumes from Boomer data and pockmark clusters and seabed depressions from sidescan sonar data (and although not shown here, echo sounder data).

The coincidence of these features suggests that fluid evacuation occurs preferentially at the channel margins, possibly due to stresses caused by different plasticity or compaction rate between sediments within and sediments outside the channel.

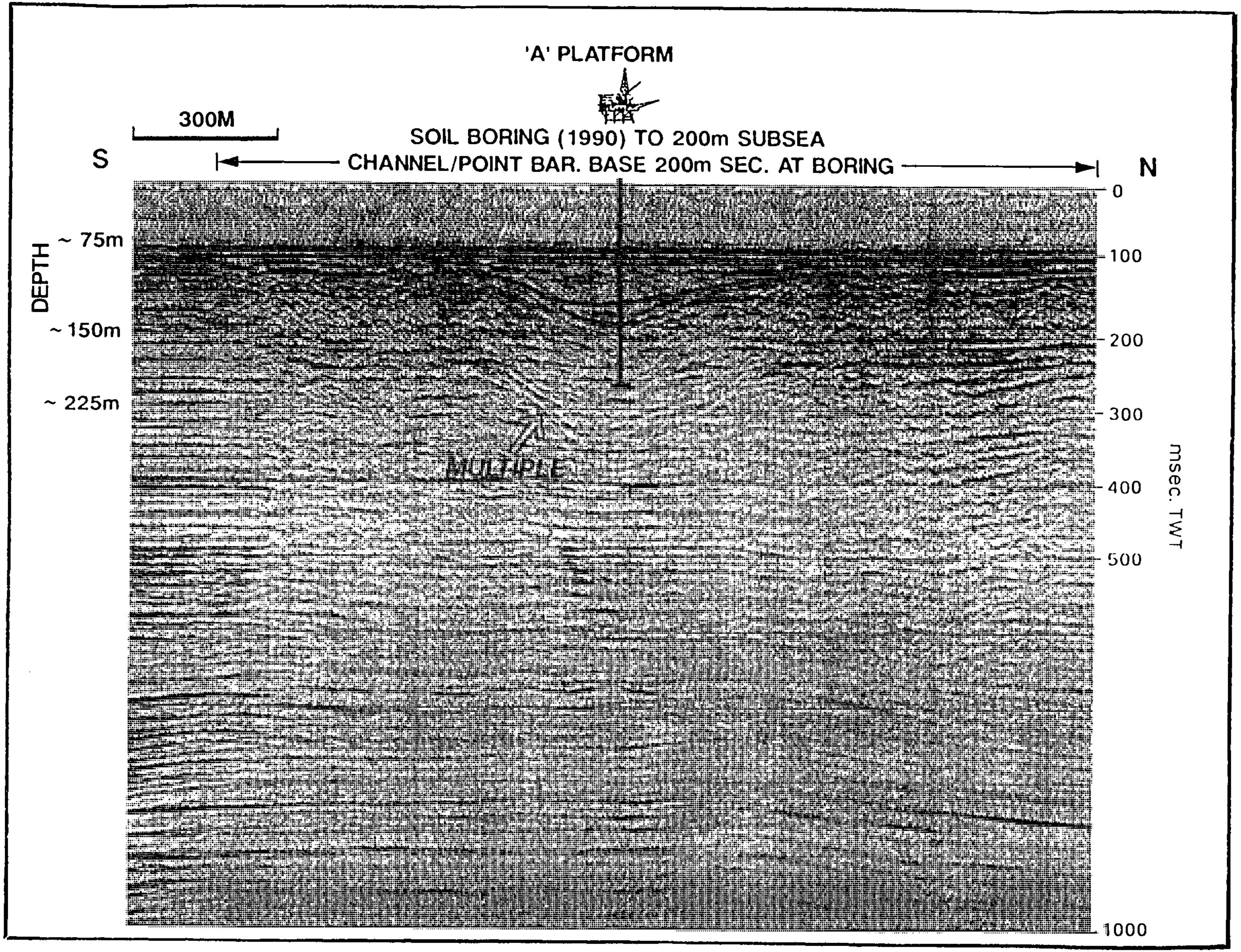

Figure 10: Water gun line B through Dulang "A" platform.

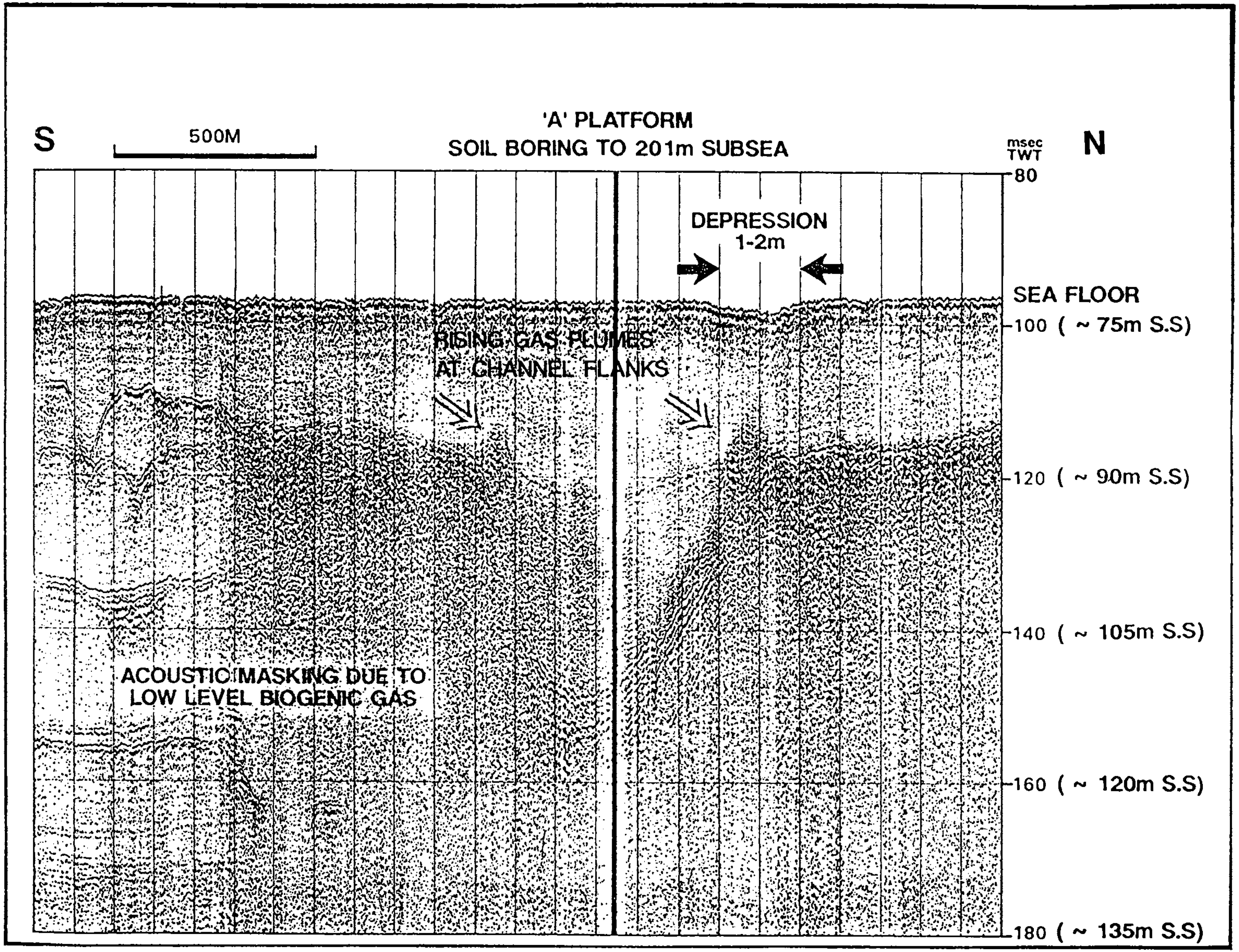

Figure 11: Boomer line C through Dulang "A" platform.

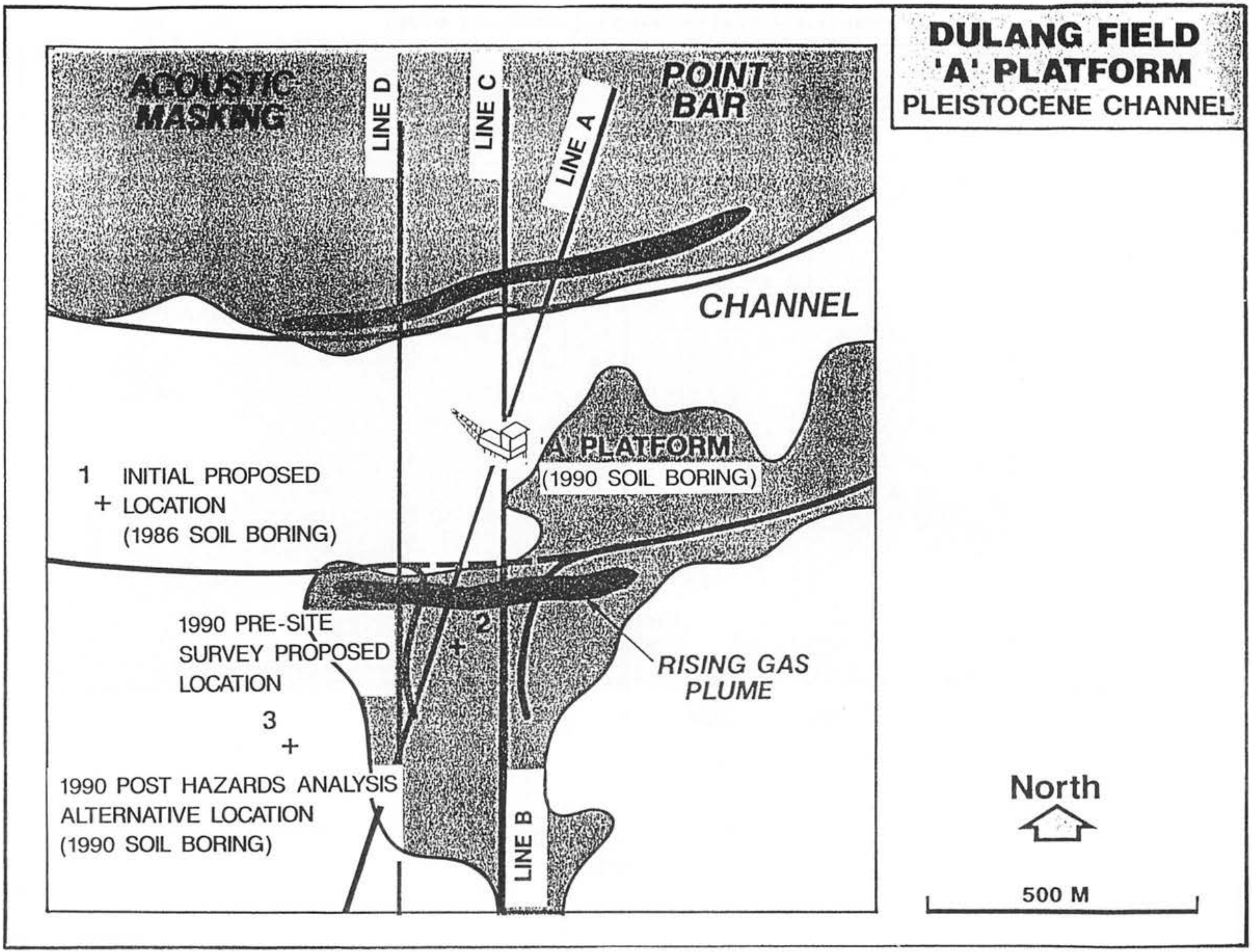

Figure 12: Area of acoustic masking and rising gas plumes interpreted from Boomer data.

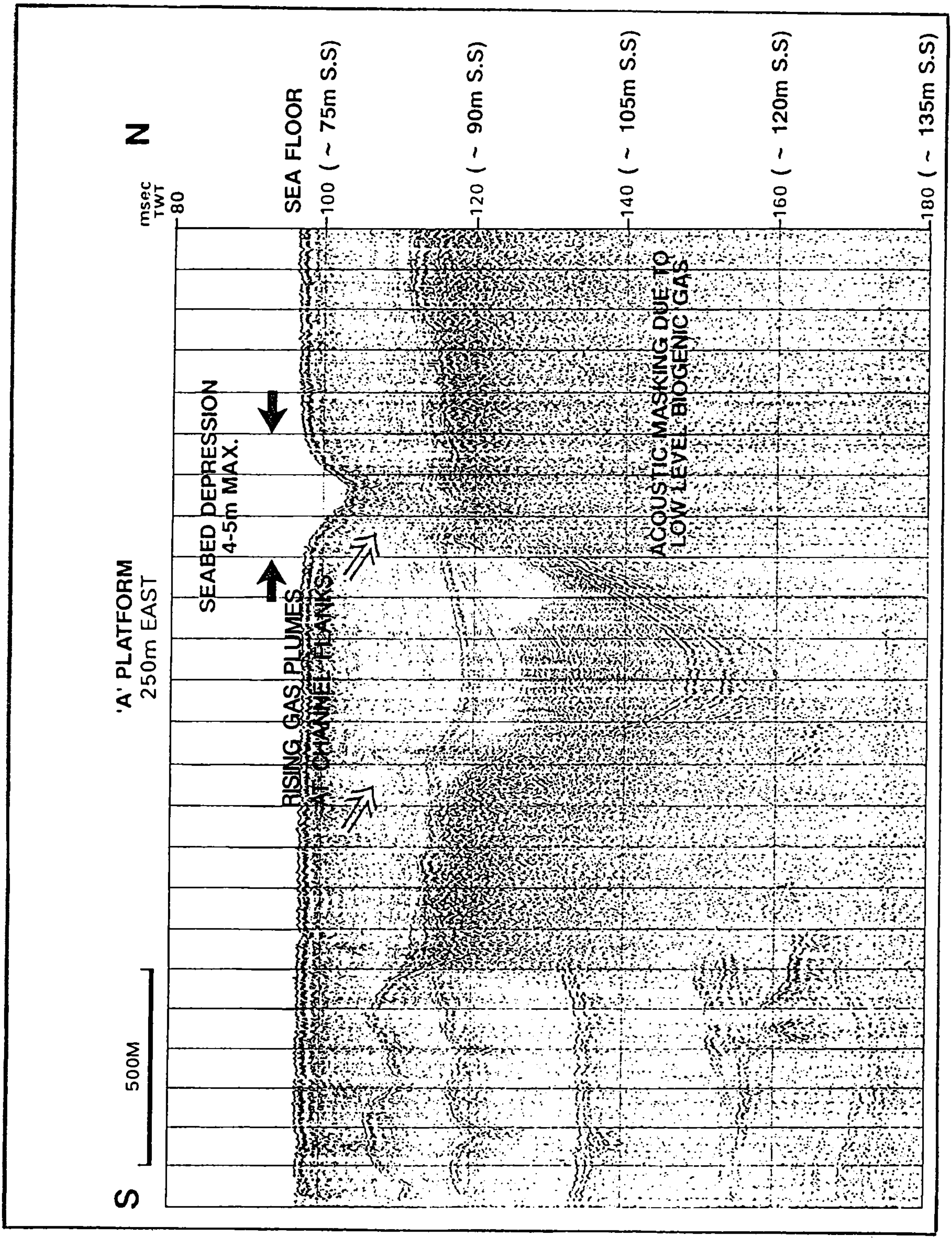

Figure 13: Boomer line D showing pronounced seabed depression.

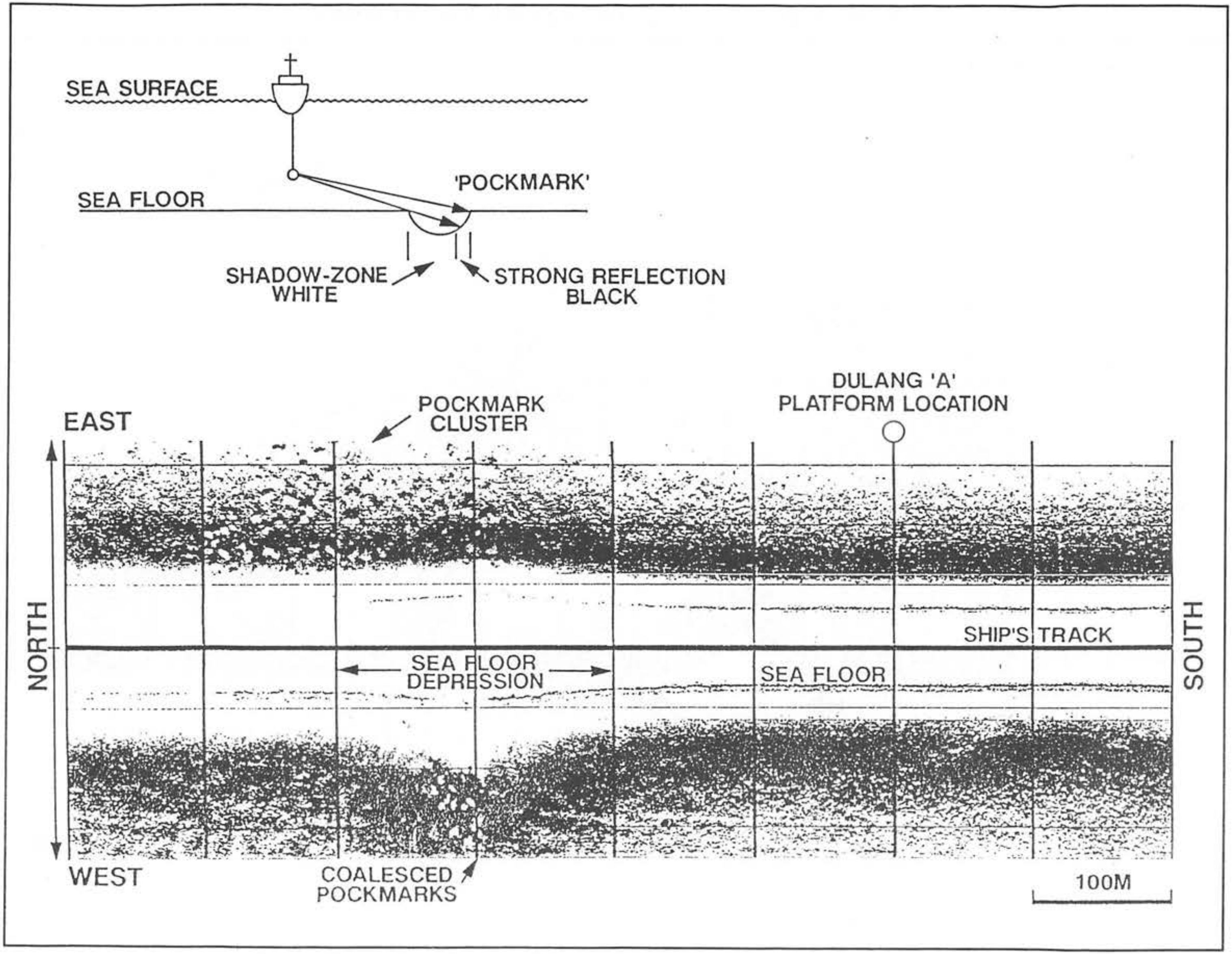

Figure 14: Sidescan sonar line E through Dulang "A" platform.

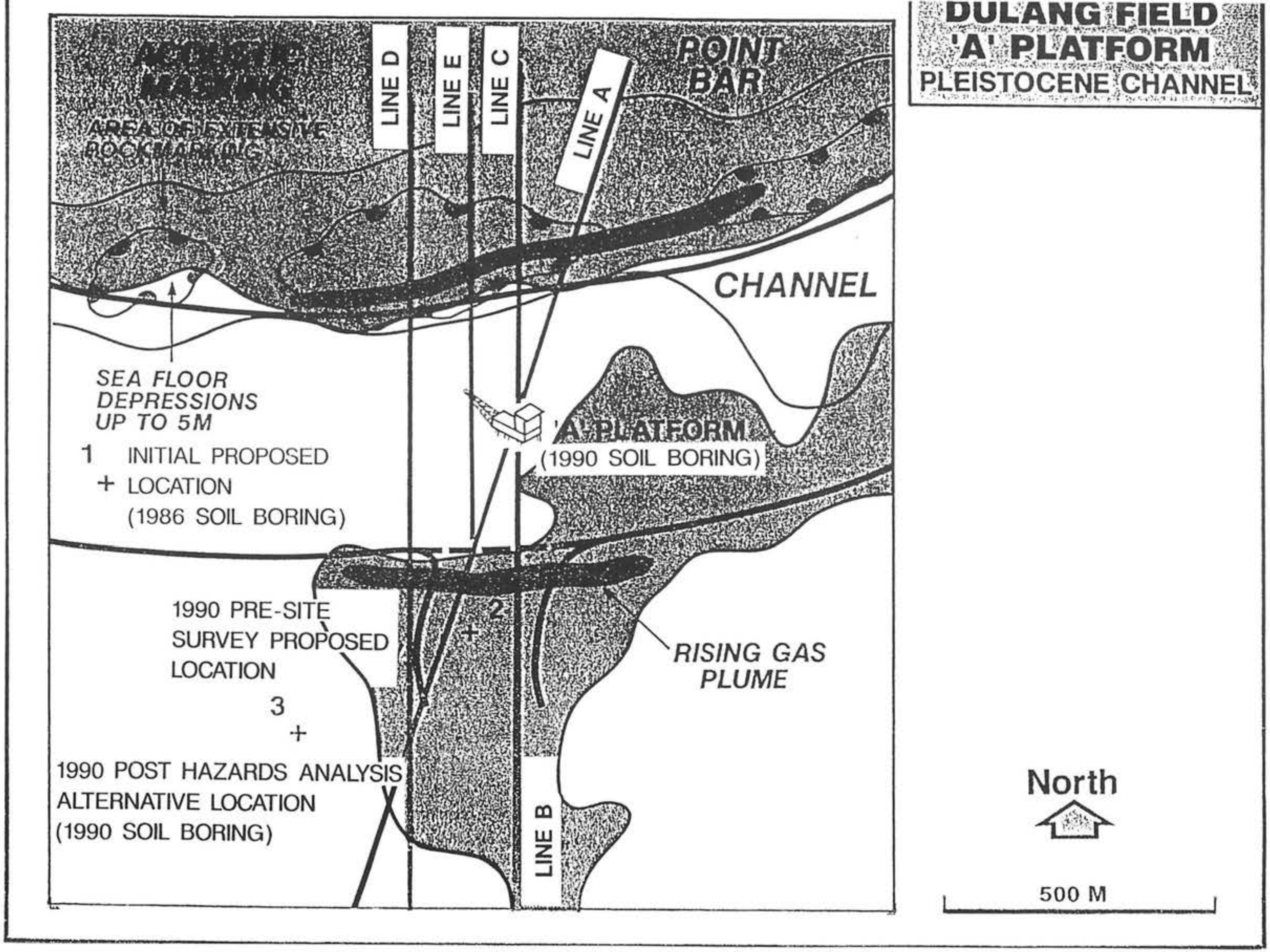

Figure 15: Combination of seabed and near-surface hazards mapped from 3-D seismic and site survey data.

CONCLUSION

Integrated interpretation of 3-D and site survey data at Dulang "A" provided an efficient, coherent interpretation of relatively complex near-surface and seabed features. Use of all datasets enabled a better genetic understanding of possible hazards and greater confidence in selecting the platform location.

Based on geophysical interpretation and subsequent engineering tests of soil borings, the Dulang "A" platform was installed at the centre of the Pleistocene channel. No hazards were encountered.

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