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INTERNAL DOCUMENT 69

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[EV]ALUATION OF WESTERN SPECULATIVE SEISMIC SURVEY OFF N. ICELAND (WESTERN GEOPHYSICAL)

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1. Background

During November 1976 Western Geophysical Corporation made a small (852 km) speculative seismic survey of the insular shelf and slope off Northern Iceland (Fig. 1). The Dept. of Energy had previously suggested that IOS investigate the survey with a view to purchase. This was done in August and Roberts subsequently reported verbally to Scott that there would be little point in purchasing the survey in view of its location astride the axis of the mid-ocean ridge north of Iceland.

Subsequently papers have been circulated by Richard and Garthwaite of CIP to Shell, BNOC, BGC, BP and others reporting the views of Nordahl (Chairman, Central Bank of Iceland) that 'there is section and structure no great distance offshore.' G. Dodsworth of Western recently presented a short paper on the data at the Tromso meeting. No interpretation report exists, however. This report briefly evaluates the seismic survey and comments on its usefulness.

2. Data

The data were acquired from M.V. Karen Bravo using maxipulse and a 2400 m streamer with 20 pops per km. Record lengths were 8 seconds. The data were sampled at 4 ms and after editing and debubbling subjected to DBS, NMO (2400% weighted stack) DAS and displayed using TVF. The final data package includes sections migrated after DAS as well as gravity (857 km) and magnetics (754.2 kms)

3. Geology of Iceland

A few remarks on Icelandic geology are necessary to provide the reader with background to this assessment of the Western data.

It is crucial to understand that Iceland is entirely composed of oceanic i.e. igneous crust. The exposed rocks in Iceland range in age from only 15 my in the westernmost part of Iceland to zero at the axis of ths so-called Eastern Neovolcanic zone. The Eastern Neovolcanic zone of Iceland corresponds to the axis of the Mid-Atlantic whch can be traced right through Iceland from the Kolbeinsey Ridge in the North to the Reykjanes Ridge in the south (Fig. 2) Iceland is considered to have been formed by some type of sea floor spreading process that is still extant involving voluminous extrusive and intrusive activity. From the viewpoint of petroleum exploration the relevant point is that the 'basement' is nowhere older than 15 My and on the axis of the mid-ocean ridge can only be of zero age.

3. Area of the Western Speculative Seismic Survey

The Western seismic lines comprise rather a widely spaced grid on the insular shelf off Northern Iceland (Fig. 1,2). The principal geologic features of the shelf are:-

(a) A series of deep troughs originating in the mouths of the deeper fjords and crossing the shelf. These troughs are paths by which large volumes of sediment are transported oceanward from the Icelandic land mass.

(b) The Kolbeinsey Ridge is the axis of the mid-ocean ridge north of Iceland. It can be followed across the shelf as a zone of distinctly irregular topography that breaks surface as the volcanic islands of Grimsey and Kolbeinsey (Fig. 3). The ridge is seismically active and is associated with a prominent gravity high. The ridge and gravity high terminate just south of the island of Grimsey where the belt of active seismicity and volcanism are displaced eastward by the Tjornes Fracture zone or a series of en-echelon fractures, to reappear on land as the Eastern Neovolcanic zone at Iceland. The Tjornes Fracture Zone is revealed by a prominent gravity minimum (Fig. 4), The south-eastern part of line ICE-C cuts the gravity minimum (Fig. 4)

4. Evaluation

I have examined the Western area on two separate occasions and have obtained the enclosed samples of part of line ICE-C (Fig. 5). Between 2.0 and 3.0 seconds of section are locally developed along line ICE-C, the NE part of line ICE-A and along the central part of line ICE-D. These basins all exhibit structure of various types e.g. contemporaneous faulting, on lap, off lap etc.

From my brief inspection. The basins appear to be of two types

(a) Fracture zone:

Thick section is developed along the Tjornes Fracture zone (sp.120 -320 on sample section). The oblique orientation of Line ICE-C relative to the fracture zone (Fig. 3) gives the appearance of a spuriously wide basin on the profile. The thick section here is not likely to be older than 5 my in view of its proximity to the mid-ocean ridge thus very rapid sedmimentation is indicated.

(b) Ridge Flank Basins

Thick section also appears to be present west and east of the Kolbeinsey Ridge on parts of lines ICE-A, ICE-C and ICE-D. Here again the section is unlikely to be older than 5 my and possibly a good deal less. These basins were crossed by R.V. Starella en route to Greenland.

Development of a thick section can be attributed to the voluminous sediments eroded from the glaciated, active volcanic, hinterland of Iceland and that have been ponded in basins provided by fracture zones and the general basinal character of the shelf-ridge flank topography. The complex structure is simply attributed to active tectonism associated with sea floor spreading along the Kolbeinsey Ridge. Many faults intersect the seabed indicating continuing tectonism as evidenced by the seismicity of the Kolbeinsey Ridge.

(c) Reservoir

Without the benefit of offshore drilling data it is difficult to comment in other than generalities. Based on the active volcanism of Iceland and the deeply eroded and glaciated terrain, the section is likely to consist of pyroclastics and volcanoclastics e.g. ash layers, muddy tuffs etc. Intrusions and extrusions are also likely to be present.

Part of the section may well consist of coarse sands representing outwash from the rivers and glaciers. Pelagic oozes are probably present further offshore. A possibly analogous section may be represented by the Eocene volcanoclastics drilled at sites 403 and 404 during leg 48.

(d) Oil generation

By virtue of its position on the mid-ocean ridge, Iceland is characterised by high heat flow values and geothermal gradients. In the Akureyri area to the south of the western survey, gradients of 56-64^{o}C km^{-1} have been recorded (Palmason, 1967). On the western flank of Reykjanes Ridge, gradients of 63.6^{o}C km^{-1} and 53.8^{o}C km^{-1} were recorded at DSDP sites 407 and 408. (Luyendyk, Cann et al 1979). Gradients recorded on Iceland must be treated with caution as they were measured in basaltic lava

flows within which there may be considerable free convection. Geothermal gradients within the overlying sediments may be two or even three times as high.
It should be noted that these gradients considerably exceed those recorded on passive margins e.g. site 402 28.5 $\pm$ 9.5^{o}C km^{-1} (Montadert, Roberts et al 1979). The difference has important implications for the early thermal history of passive margins. During the initial opening phase of any ocean basin, when the mid-ocean ridge lies adjacent to the young margin, heat flow values and geothermal gradients will be high. The thickly sedimented mid-ocean ridge north of Iceland can be considered as directly analogous to this phase although there is no passive margin. The analogy suggests that geothermal gradients on passive margins may be substantially higher during the early opening phase. Geothermal gradients subsequently decrease as the ocean basin widens and the hot mid-ocean ridge moves away from the margin.
If an oil generation threshold of 50-150^{o}C is assumed, the geothermal gradients observed on Iceland indicate that this temperature will be exceeded at depths of 1 km. Interval velocities indicate that the thicknesses in the basins exceed this depth thus showing that oil generation is theoretically possible. However, the essential prerequisite that source rocks containing organic matter of appropriate type and amount may not be met off Iceland in view of its isolated position is the north Atlantic Ocean. An evaluation of the flux of organic matter (marine and terrestrial) in the shelf cannot be made from the data available. However, the rapid sedimentation rate suggests that organic matter at present is likely to be highly diluted.

5. Conclusions

1. The Western Speculative seismic survey shows both structure and section beneath the insular shelf off Northern Iceland.
2. The sedimentary section is not likely to be older than My and may be substantially younger than 2 My close to the axis of the Kolbeinsey ridge. The underlying basement is likely to be basaltic and was produced by sea floor

spreading.

3. The section probably consists of pyroclastics and volcano-clastics deposited at rapid ratios of c.
4. Geothermal gradients are high and the oil generation threshold may have been exceeded in one of the basins shown on the survey.
5. Although firm conclusions cannot be drawn concerning reservoir characteristics and oil potential from the available data, the position of these basins in a volcanic terrain astride the mid-ocean ridge argues for a negative appraisal of the potential of these basins.

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References

Palmason, G 1967 On heat flow in Iceland in relation to the Mid-Atlantic Ridge. Pp 111-127 in Iceland and the Mid-Ocean Ridges. Visindatelág Islandica.

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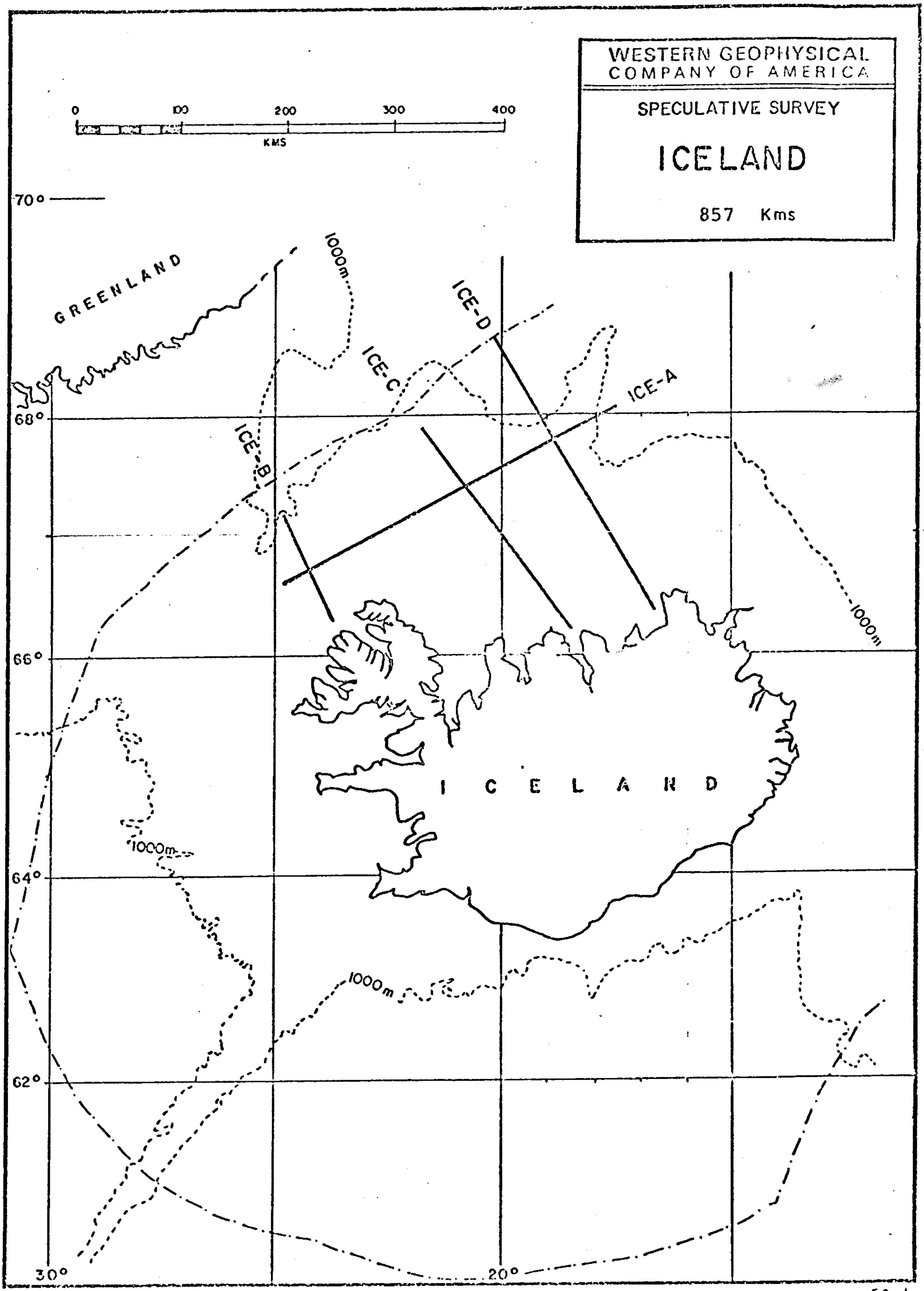

WESTERN GEOPHYSICAL
COMPANY OF AMERICA
SPECULATIVE SURVEY
ICELAND
857 Kms
0
100
200
300
400
KMS
70°
68°
66°
64°
62°
30°
20°
GREENLAND
1000m
ICE-A
ICE-B
ICE-C
ICE-D
I C E L A N D

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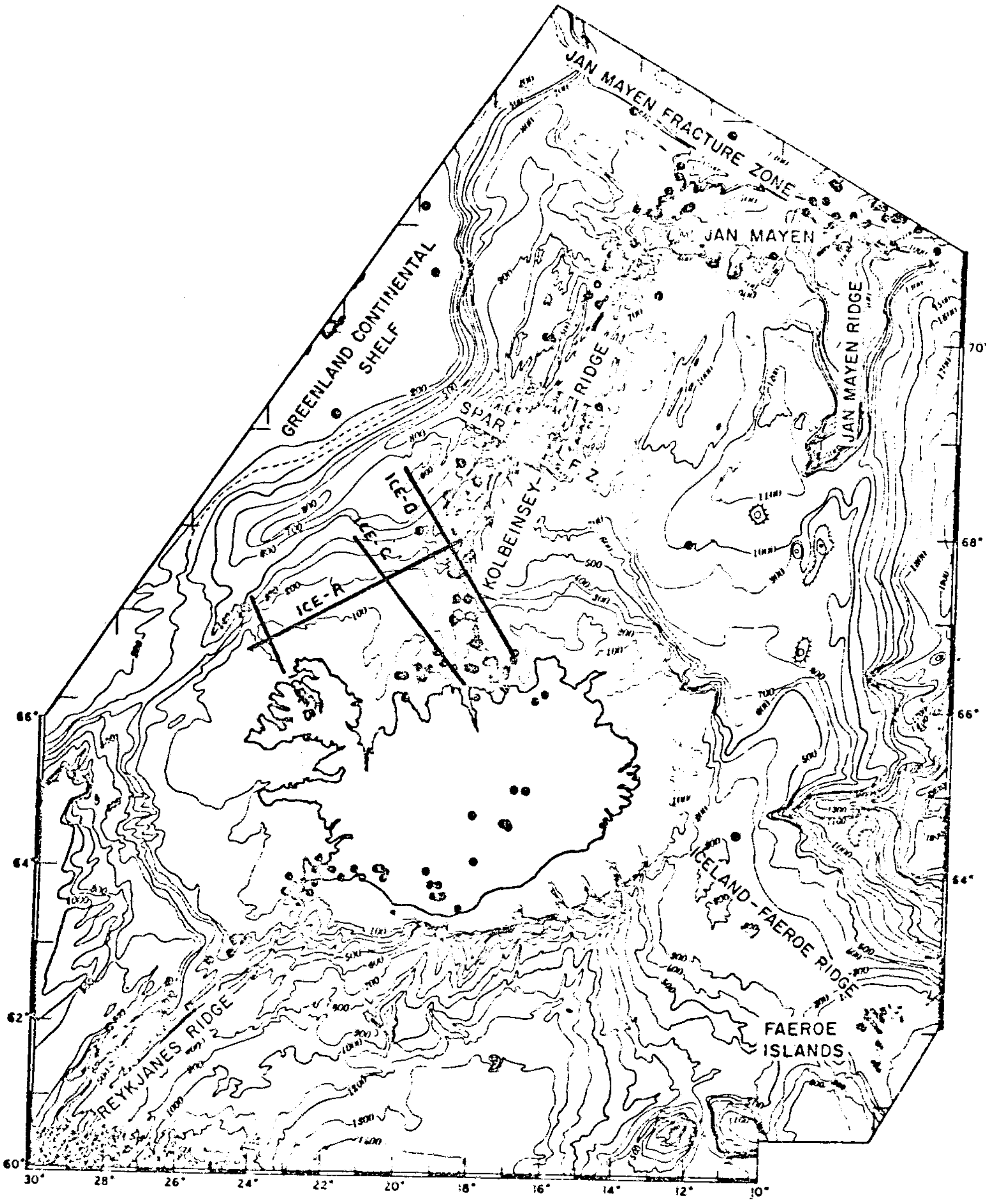


Fig.2. Bathymetric map of the Iceland area, showing the insular shelf and the epicenter belt along the axis of the Mid-Atlantic Ridge. Bathymetry from Johnson et al. (1972). Depths are in nominal fathoms (1 fm/400 sec travel time). Modified from Pálmason and Saemundsson (1974).

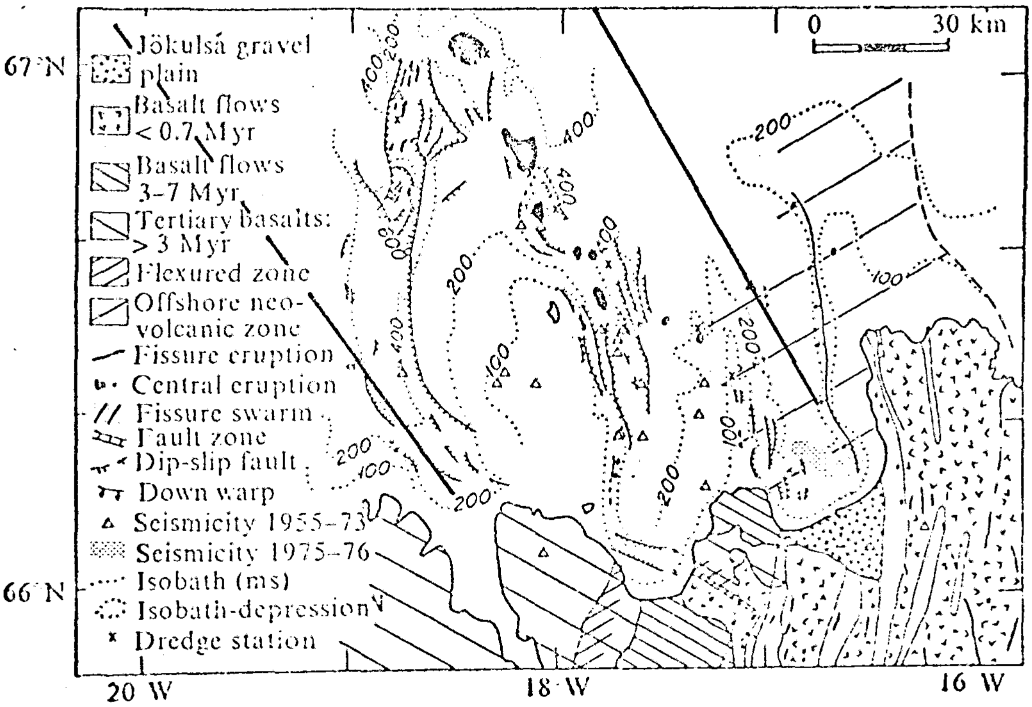


Fig. 3 Summary geology map. Earthquake epicentre locations (refs 13, 21); 1964–73 epicentres from Preliminary Determination of Epicenters Monthly Listing published by US Coast and Geodetic Survey and successor organisations through 1972 and jointly by NOAA/USGS thereafter.

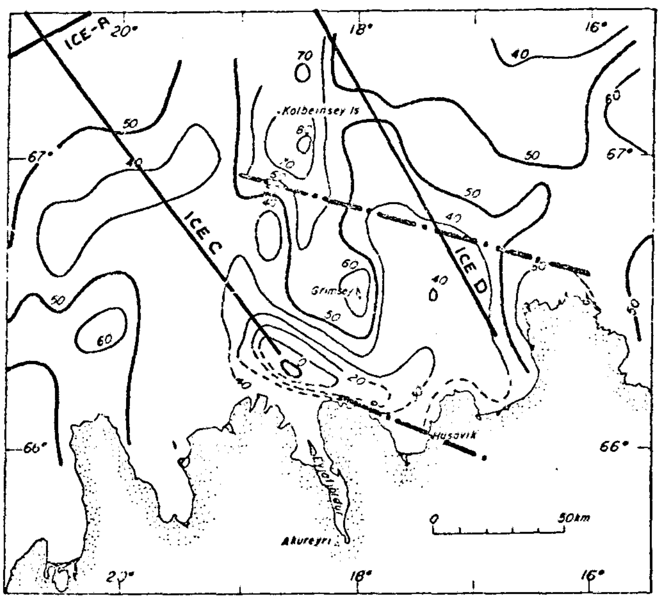
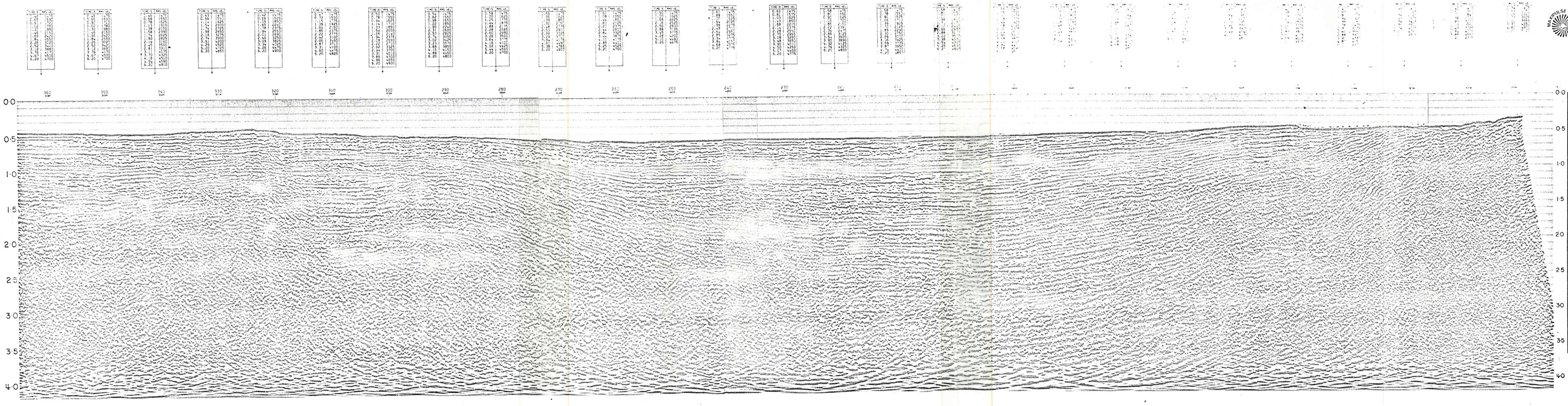


Fig. 4 Free-air gravity anomaly map of the central northern Icelandic insular shelf. The straight dash-dot lines show the boundaries of the Tjörnes Fracture Zone, as suggested by Saemundsson (1974).



LINE-ICE-C

PROPRIETARY DATA

NORTHWEST

MIGRATION AFTER DAS

WESTERN GEOPHYSICAL

COMPANY OF AMERICA

AREA: ICELAND

SPECULATIVE SURVEY

RECORDING DATA

PROCESSING SEQUENCE

COMMENTS

LINE LOCATION MAP