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Geological Studies Around the Grand Banks I: The North West Atlantic Mid-Ocean Channel

David G. Roberts and Peter M. Hunter

Internal Document No. 115

December 1980

NATURAL ENVIRONMENT RESEARCH COUNCIL

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INTRODUCTION

The Northwest Atlantic Mid-Ocean Channel of the Labrador Sea extends for about 4,000km from the vicinity of Hudson Strait in the Labrador Sea to ultimately merge with the Sohm Abyssal Plain south of the Grand Banks of Newfoundland (Ewing et al., 1975). More recent descriptions show that it is more aptly defined as a leveed deep-ocean channel rather than a canyon (Egloff and Johnson, 1975; Chough and Hesse, 1976) and that strictly it is not a mid-ocean feature because it does not follow the axis of maximum depth of the Labrador Sea.

Deep ocean channels of comparable length have been described from the equatorial Atlantic (Damuth and Gorini, 1976) and from the Northeast Atlantic where the Maury Mid-Ocean Channel can be traced from the insular slope of Iceland perhaps as far as the Bay of Biscay (Cherkis et al., 1973). These channels are considered to be important avenues for the longitudinal transport of sediments by mass flow processes for considerable distances. However, present understanding of their development is based on the view of their morphology and section obtained from rather widely spaced echo-sounder or seismic profiler traverses aided in some cases by limited coring of the channel floor. Results from more closely spaced echo-sounder traverses and a DEEPTOW survey have revealed the presence of meanders and point bars (Chough and Hesse, 1976; Lonsdale and Hollister, 1979). Clearly an overview of the morphology of the channel and its floor is desirable to establish the continuity and importance of such features.

In this paper, we report the results of a long-range sonar survey of the middle reaches of the Northwest Atlantic Mid-Ocean Channel (hereafter referred to as NWAMOC) between 52° and 54°N in the Labrador Sea.

The survey was made from R.V. Starella using the GLORIA of the Institute of Oceanographic Sciences, UK, whilst on passage from Greenland to Newfoundland in 1979.

2. Long-range side scan sonar - GLORIA

The Geological LOng Range Inclined Asdic (GLORIA) used to make the survey is a development of the short-range sonars used on the shelf (Rusby, 1970; Somers et al., 1978). The present Mk-II version (Somers et al., 1978) is a dual-scan sonar housed in a towed body. Sound is transmitted at frequencies of 6.5 and 6.7 kHz and the beam width is about 2.7^{o} in azimuth and 10^{o} in the vertical. The recorded signals were subjected to automatic and fixed gain controls prior to tape recording and subsequently photographically anamorphosed to adjust the slant range. The anamorphosed sonographs illustrated in this paper are correctly scaled in horizontal range except for near field distortion. During the survey, useful data were obtained out to an average total cross track range of about 38km.

The survey was made at speeds of 6.8 kts using satellite and LORAN-C navigation. In addition to the usual echo-sounder profile, a seismic reflection profile was acquired simultaneously using a 160 in^3 airgun and a 2-channel Geomechanique array.

RESULTS

1. Seismic reflection profiles

During the survey, the NWAMOC was crossed at three places (I, II, III, Figs. 1, 3, 4, 5 and 6) and a further channel like feature at point A (Fig. 2). Additional crossings of the NWAMOC in the survey area have been illustrated by Egloff and Johnson (1975) and Laughton (1972). The track of D.V. Glomar Challenger across the survey area is shown in Figure 4 (Ruffman, 1972).

In the area of survey, the NWAMOC has a sinuous but general NW-SE trend. Regional seismic profiles (Laughton, 1972; Egloff and Johnson, 1975) show that the NWAMOC lies in a depression between the contourites of the Gloria sediment drift to the east and the prograding sediments of the Labrador continental rise to the west.

The traverse reported here begins on the flanks of the Gloria drift situated east of the NWAMOC. The channel-like feature crossed at A (Figs. 2, 5A) seems to be more closely related to sedimentary processes associated with the development of the Gloria drift than to the NWAMOC. This feature, situated on the east side of the NWAMOC, is a broad low developed between a basement ridge that is thickly draped with pelagic sediments and an adjoining sediment drift here recognised by the characteristic whale back form of the reflectors defining the internal structure of the drift (Jones et al., 1970; Roberts, 1975).

At crossing I, the NWAMOC is about 5.2km wide and is strongly asymmetric in cross section (Figs. 5B, 6A). The west bank is considerably steeper than the east although the relief of both is about 90-100m. The thalweg, which here has a depth of 4049m (uncorrected) and a width of 450m, lies immediately adjacent to the west bank. Reflectors observed beneath the channel floor east of the thalweg (Fig. 5B) are apparently truncated at the sea bed and dip northward. The foot of the east bank of the channel is defined by a prominent step possibly caused by erosion of the transparent sediments (contourites?) that seem to encroach on the channel from the east and to in part unconformably overly the dipping reflectors. To the south of the channel, an unconformity above reflector A that dips in toward the axis of the present channel may represent an ancestral and a wider NWAMOC. The seismic profile also demonstrates the lateral change in seismic stratigraphy across the region of the NWAMOC. To the west, reflectors are more numerous in the thicker interval above A compared to the thinner and more transparent interval above A to the east (Fig. 5B). A similar pattern is present in the interval between reflector A and underlying reflector U of Early Oligocene age (Laughton, Berggren et al., 1972).

At crossing II, the channel has a greater width of 7km. The thalweg is also wider (1.5km) and lies adjacent to the steeper west bank (Fig. 5C, 6B). Somewhat surprisingly, the depth of the thalweg is less (4035 uncorrected metres) than at crossing I upstream (4049 uncorrected metres). The east bank is gentler, lower in relief and relatively featureless except for a small 5m step that defines the eastern edge of the channel. The west bank is irregular and less steep than at crossings I and III and here consists of transparent sediments that may be eroded or possibly slumped. The interval above reflector A is characterised by abundant reflectors that continue east of the present NWAMOC to pond against transparent pelagic sediments draped over a buried basement ridge (Fig. 5C). The present NWAMOC has cut down through this earlier fill and flat-lying reflectors beneath the present channel floor that are absent at crossings I and III (Fig. 5B, D) may indicate subsequent infilling. Reflectors in the underlying A-U interval are again more abundant to the west. However, the gentle whale back form of these reflectors where they unconformably infill a trough in the topography of U may indicate accumulation as a sediment drift. The incised channels observed to the west of crossing II are discussed later in the context of the GLORIA data.

At crossing III, the NWAMOC has a width of about 9km (Fig. 5D, 6C). In contrast to the previous crossings, two thalwegs separated by a low-declivity are present.

The deeper western thalweg (4098 uncorrected metres) has a width of 700m and lies adjacent to the steeper west bank. The slope adjacent to the shallower eastern thalweg (4072 uncorrected metres) is gentler and characterised by two distinct breaks in slope. The declivity comprises a lens shaped body of sediments characterised by poor eastward dipping internal reflectors (labelled X on Fig. 5D) that may represent a point bar (c.f. Chough and Hesse, 1976). Above reflector U, reflectors are again more numerous than below U (c.f. Figs. 4A, 4B, 4C) but become wave like toward the east side of the channel suggesting a more pervasive influence of bottom currents. Cut and fill observed both beneath the western thalweg and bank indicate earlier phases of NWAMOC development.

2. GLORIA observations

Between channel-like feature A and crossing I, the sonographs view the eastern flank of the NWAMOC (Figs. 1, 2, 3). A number of diffuse lineaments of a general N-S trend are present, that may possibly be related to a minor 2m relief observed on the accompanying echo-sounder profile, and terminate at the edge of A and the NWAMOC. An origin related to overspill is not favoured since they parallel the trend of the NWAMOC and lie on the western flank of the Gloria drift, and because the top of nearby core V27-21 contained foraminiferal marl ooze indicative of pelagic sedimentation. In view of the presence of an underlying sediment drift (Fig. 5A) and their development on the east flank of the channel adjacent to the Gloria drift (Fig. 1; Egloff and Johnson, 1975), it seems more reasonable to interpret these lineaments as bedform(s) associated with the bottom circulation that shaped the Gloria drift (Jones et al., 1971; Egloff and Johnson, 1975).

At crossing I, the sonograph clearly shows the linear thalweg which apparently lies adjacent to the west bank of the NWAMOC throughout the insonified area (Figs. 1B, 3A, 3B). Other variations in backscattering are evident on the channel floor, but their origin is not clear although they must be of the order of one wavelength (25cm) in size. Speculatively they may represent old thalwegs characterised by coarser lag deposits (Chough and Hesse, 1976) or small scale variations in roughness due to megaflutes, erosional grooves or small ripples which may be responsible for the variations in backscattering (Lonsdale and Hollister, 1979). The eastern edge and bank of the channel are less clear but seem to be sinuous in comparison to the relatively straight west bank. The sinuousity may reflect the degree of encroachment upon the channel by contourites (Fig. 5B) or perhaps changes in the slope of the east bank that may also cause the weak lineations that parallel the trend of the channel.

The west flank of the NWAMOC between crossings I and II is relatively featureless with the exception of the curious circular echoes observed near 21.30 (Figs. 1B, 3A, 3B) that have no sub-surface expression on the seismic profile (Fig. 5). Weak lineaments observed shortly before the eastward turn trend NW-SE subparallel to the NWAMOC. These lineaments can be followed beyond the gap in sonar coverage at the turn and ultimately curve eastward shortly before their confluence with the NWAMOC (B on Fig. 1B, 4A, 4B). A prominent southward shadow associated with the northern edge of the lineaments suggests that they may arise from a channel. The incised channel (Figs. 5C, 6B) observed during the turn may correspond to an oblique crossing of the inferred channel. The bank of a second incised channel (Figs. 5C, 6B) situated only 3.5 km west of crossing II is shown as a weak lineament at first parallel to the NWAMOC that ultimately joins it at the confluence discussed above (Figs. 1B, 4A, 4B). The irregular interfluve is shown as a zone of brighter backscattering that does not continue downstream of the confluence. The downchannel view of the length of the NWAMOC between crossings II and III (Figs. 1B, 4A, 4B) suggests that the channel narrows to about 3.5km immediately downstream of the confluence but subsequently widens to about 9km at crossing III. At the most constricted part of the channel south of the confluence, a zone of brighter scattering extends across the width of the channel (C on Figs.1B, 4A, 4B). The downchannel looking sonograph shows that the thalweg upstream widens and becomes sinuous towards the confluence where it seems to be diverted eastward and may be joined by the tributary channel. The thalweg may have cut through the constriction or barrier adjacent to the east bank of the channel. South of the constriction, two thalwegs are present and originate at the eastern end of the constriction (Figs. 1B, 4A, 4B). The constriction and the shallower depth of the thalweg at crossing II are here considered to have a common origin. In the absence of direct evidence from cores, the constriction is most simply interpreted as a point bar that has developed below the confluence and migrated across the NWAMOC forming a barrier that may now be partly breached by diversion of the upstream thalweg. The shallower depth of the thalweg at crossing II can be accounted for by ponding of sediments in the thalweg upstream. The actual relief across the interpreted point bar is not known but cannot be presumably less than the 49m change in depth between crossings II and III. The bar need not of course have acted as a total barrier to subsequent turbidity currents flowing downchannel.

Below the constriction, two thalwegs are present and can be clearly seen on the sonograph (Figs. 3 and 4) and the channel as a whole curves gently to follow a N-S trend. The intervening declivity apparently appears and disappears as the deeper western thalweg widens from 2 to 3.2 km and extends or meanders across almost the entire width of the channel. On the west flank of the channel, a number of diffuse lineaments are present that trend NW-SE and oblique to the channel. Not all of these have an expression on the echo-sounder profile but one (D on Figs. 1B, 4A, 4B) is a shallow broad depression of about 3m relief. This feature may join the NWAMOC as the sonograph (Fig. 4A) suggests at a break in the west wall of the channel in the area of intersection. Like the channels described earlier, these features trend subparallel to NWAMOC and seem to occur in the col that lies between the western levee of the NWAMOC and the Labrador slope (Egloff and Johnson, 1975). They may represent the paths of turbidity currents that have flowed down this col after their initiation on the Labrador slope.

Near 52°N, the NWAMOC turns eastward to meander southward down the abyssal plain east of Orphan Knoll and south of the Gibbs Fracture Zone. A core taken in this part of the channel (V. 23-21; Chough and Hesse, 1976) contains a thick graded sand and gravel layer.

DISCUSSION AND CONCLUSION

The GLORIA and seismic profiler results show that over the portion of the survey, the NWAMOC follows a sinuous path whose position was at least initially governed by the natural topographic low formed by the junction between the contourites of the Gloria drift and the progradational sediments of the Labrador slope (Figs. 5A, B, C,D; Figs. 13 of Egloff and Johnson, 1975). There is no evidence of tectonic control throughout the larger part of the 200km traverse. The thalweg appears confined to the westward part of the channel as would be predicted from the effects of the Coriolis Force although there are no obvious indications of spillover of turbidity currents (Heezen et al., 1969). In contrast to the results of Chough and Hesse (1976) further north, meandering of the thalweg in response to the sinuousity of the channel is not evident although point bars may be present. There is some evidence of meandering in the straightest parts of the NWAMOC between 53°N and 52°N. Tributary channels join the NWAMOC near 53°00'N. Constriction of the NWAMOC below this confluence has probably resulted from migration of a point bar across the channel. Partial damming of the NWAMOC by the bar may have ponded sediments upstream resulting in the shallower depth of the thalweg at crossing II. Variations in backscattering along the channel floor may be due to lag deposits or to small scale roughness produced by megaflutes and grooves (Lonsdale and Hollister, 1974) below the limit of resolution of the GLORIA equipment. Lineaments observed east of the channel in the northern part of the survey may be bedforms related to the GLORIA drift. The status of present activity within the channel cannot be determined from our data although Chough and Hesse (1976) have argued that the channel north of this survey area is presently inactive.

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FIGURE CAPTIONS

Fig. 1A Location of GLORIA traverse across the North West Atlantic Mid-Ocean Canyon. Inset shows location of the traverse in the Labrador Sea.

Fig. 1B GLORIA sonographs obtained along the entire traverse (location Fig. 1A).

Fig. 2A GLORIA sonographs of channel-like features.

Fig. 2B Line interpretation of the sonographs figued in 2A. A: channel-like features.

Fig. 3A GLORIA sonographs of crossings I and II of the North West Atlantic Mid-Ocean Canyon.

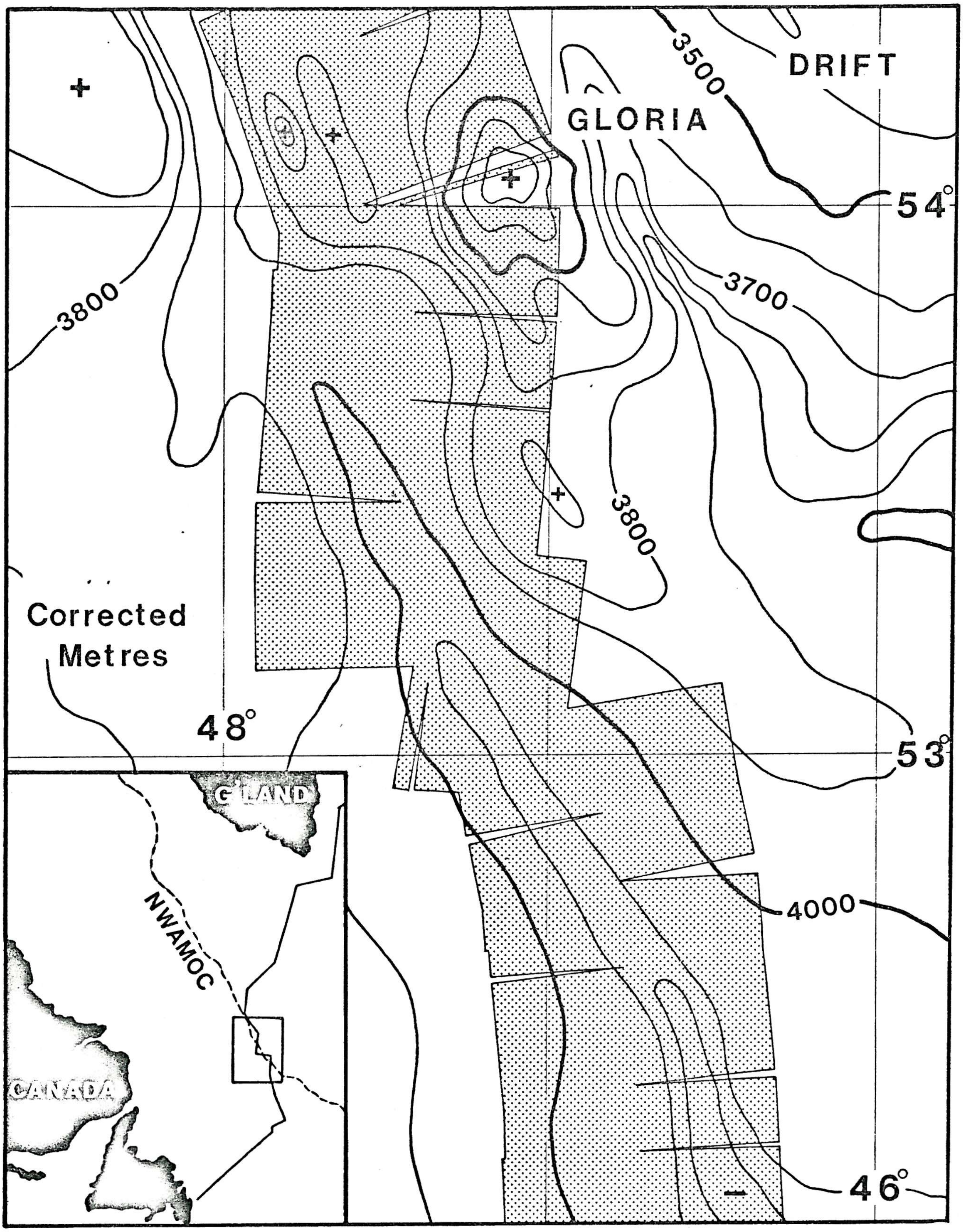
Fig. 3B Line interpretation of sonographs figured in 2A.

Fig. 4A GLORIA sonographs of crossing II and III of the North West Atlantic Mid-Ocean Canyon.

Fig. 4B Line interpretation of the sonograph figured in 3A. B: indicates confluence of channels with NWAMOC; C: zone of brighter scattering interpreted as a point bar; D: tributary channel.

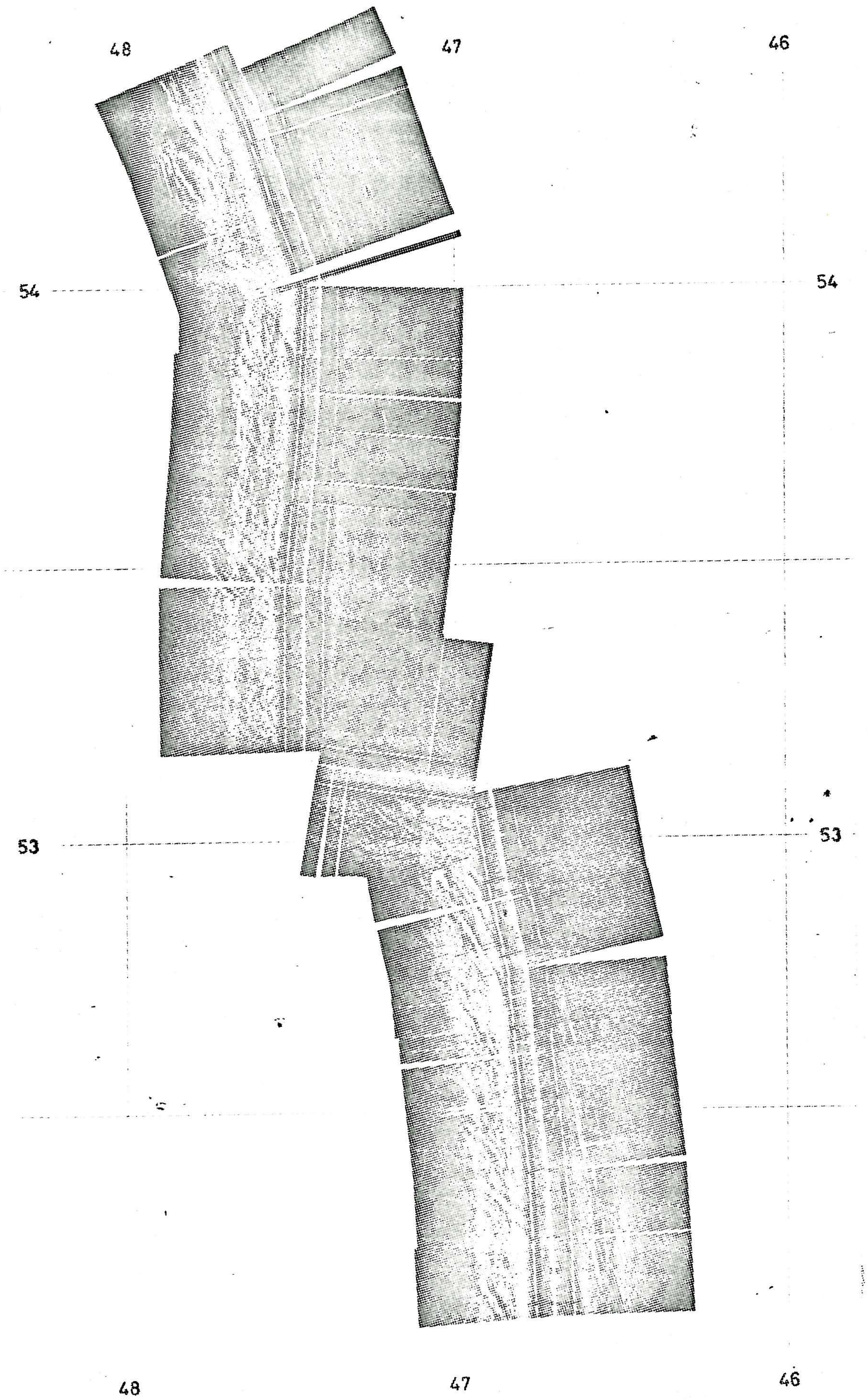
Fig. 5 Seismic reflection profiler traverses of the North West Atlantic Mid-Ocean Canyon and adjacent ground 5A: Channel A; 5B: Crossing I; 5C: Crossing II; 5D: Crossing III. Profiles are located on Figs. 2, 3 and 4. A: Reflector A; U: Reflector U; X: internal stratification within point bar (?).

Fig. 6 Echo-sounder profiles of the North West Atlantic Mid-Ocean Canyon and adjacent ground; 6A: Crossing I; 6B: Crossing II; 6C: Crossing III. Profiles located in Figs. 2, 3 and 4.



3500
DRIFT
GLORIA
54°
3800
3700
3800
Corrected
Metres
48°
53°
G'LAND
NWAMOC
CANADA
4000
46°

1A



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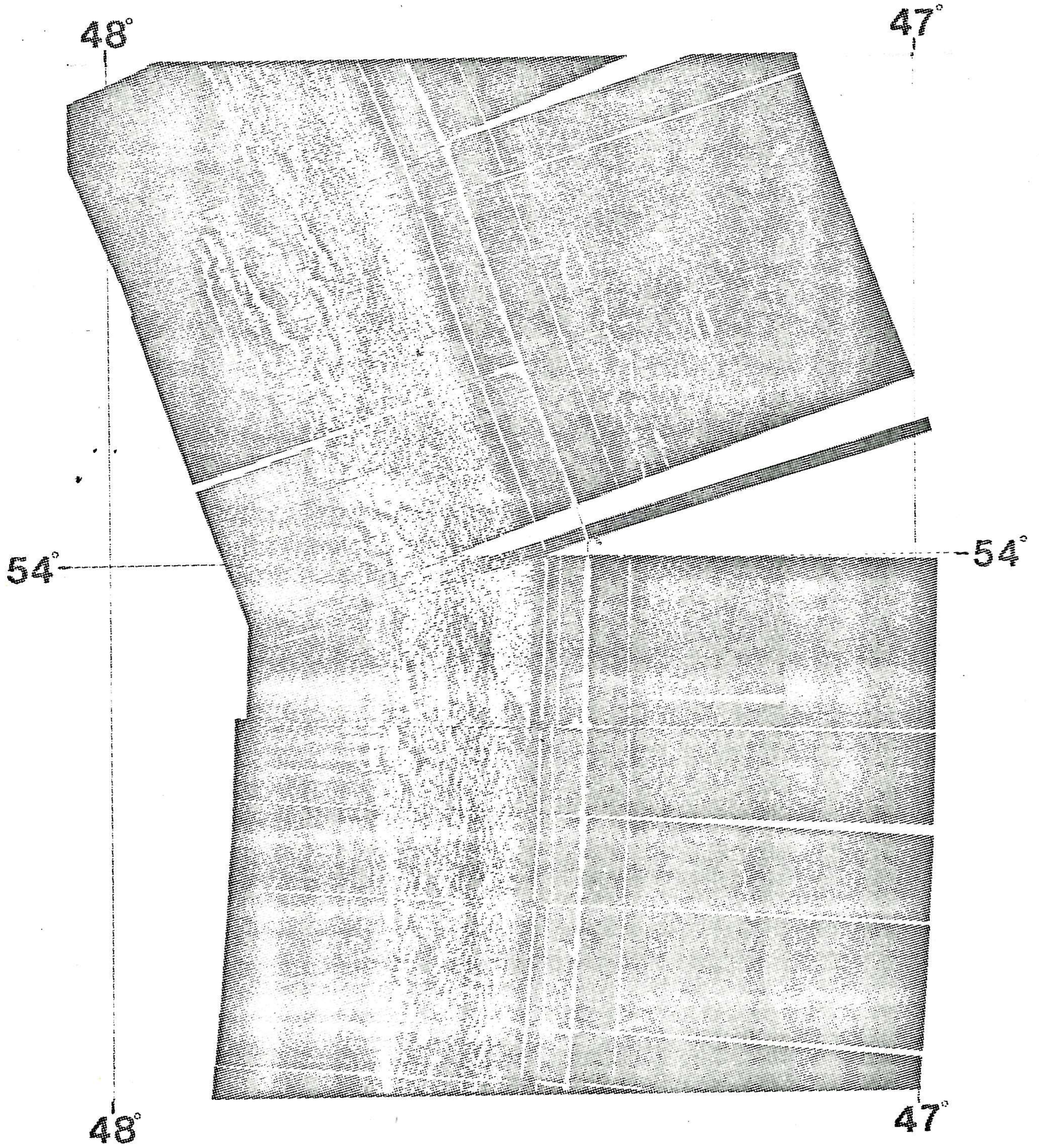

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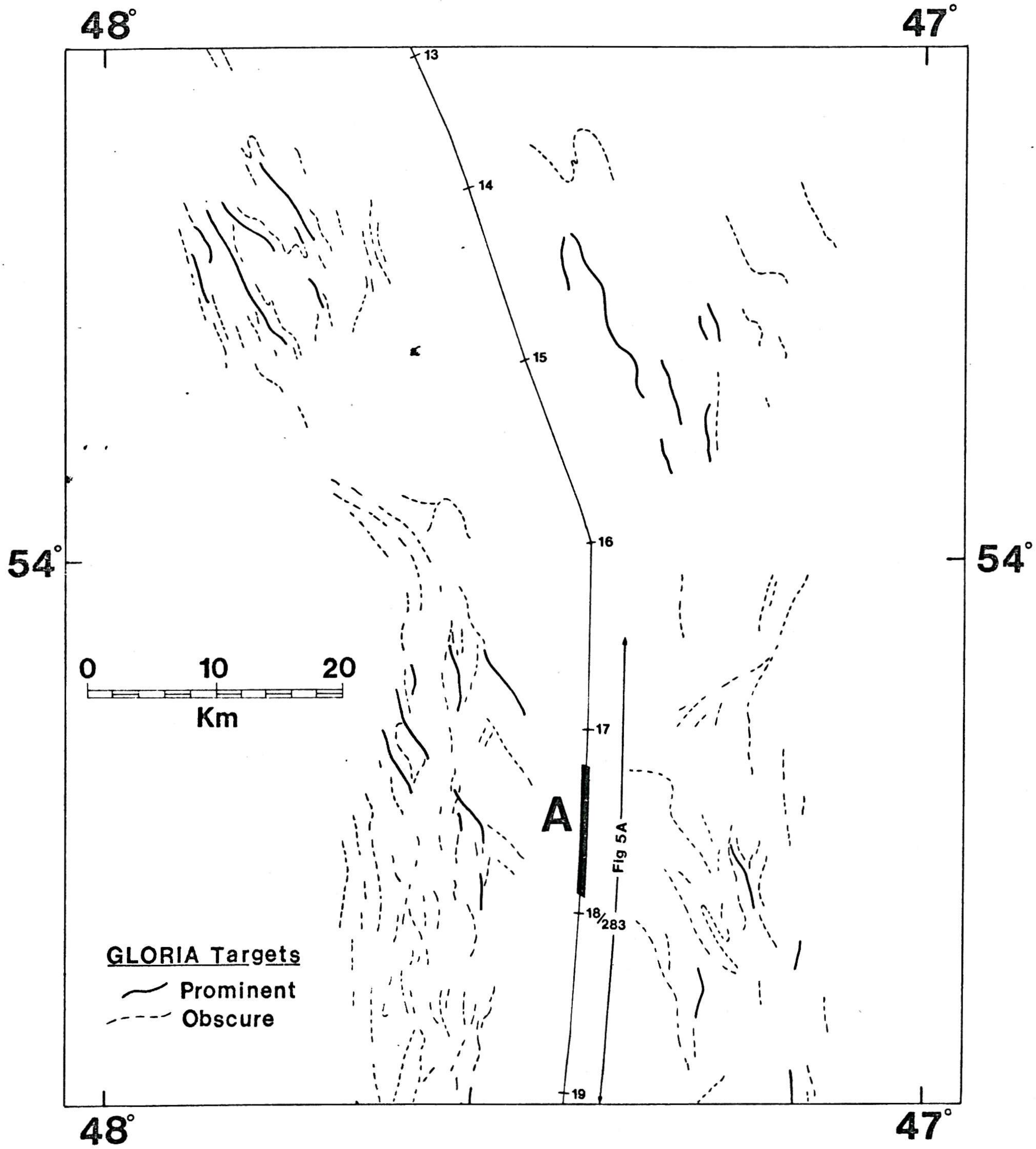
48°
47°
13
14
15
16
17
18/283
19
54°
54°
0
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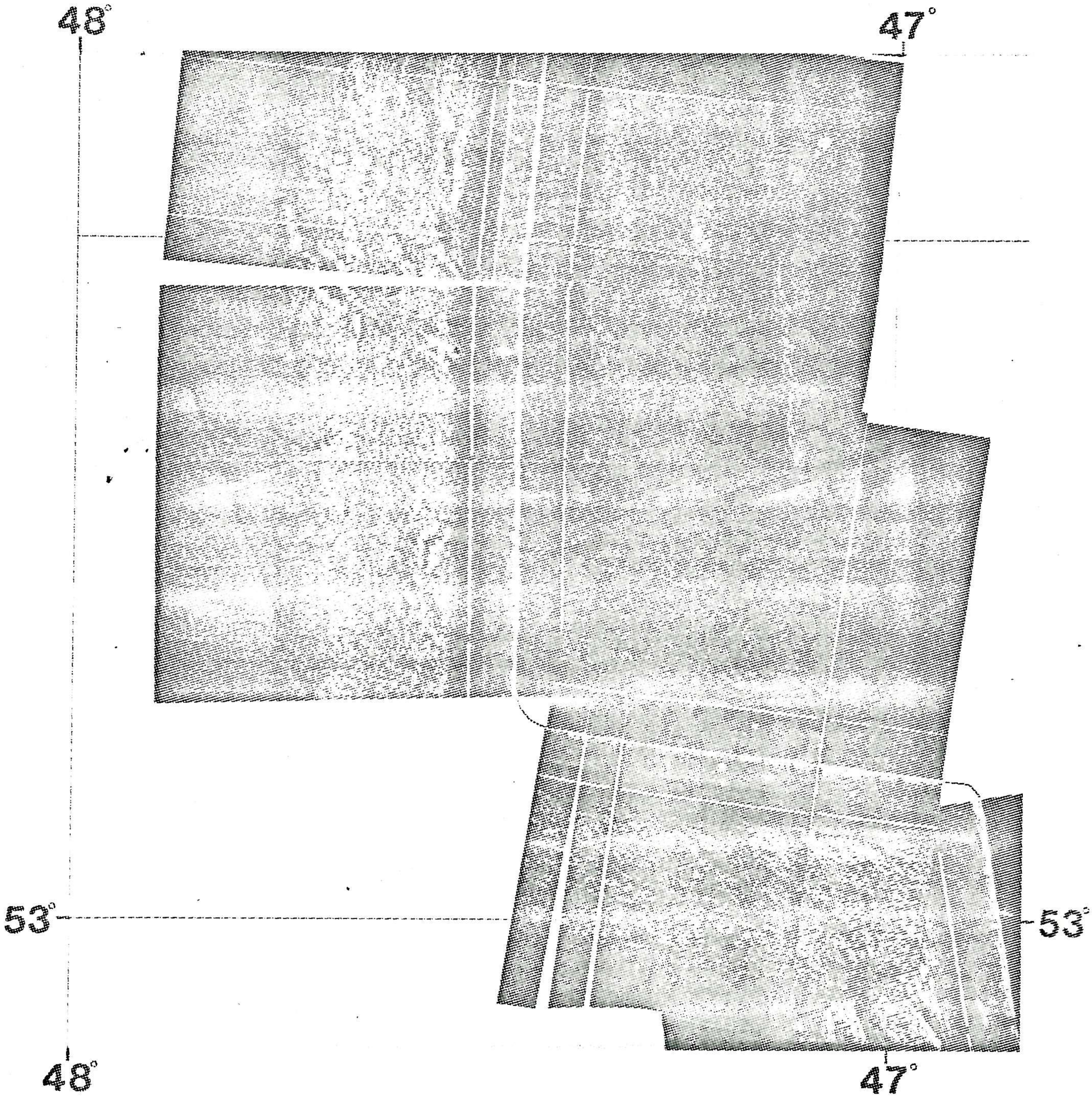
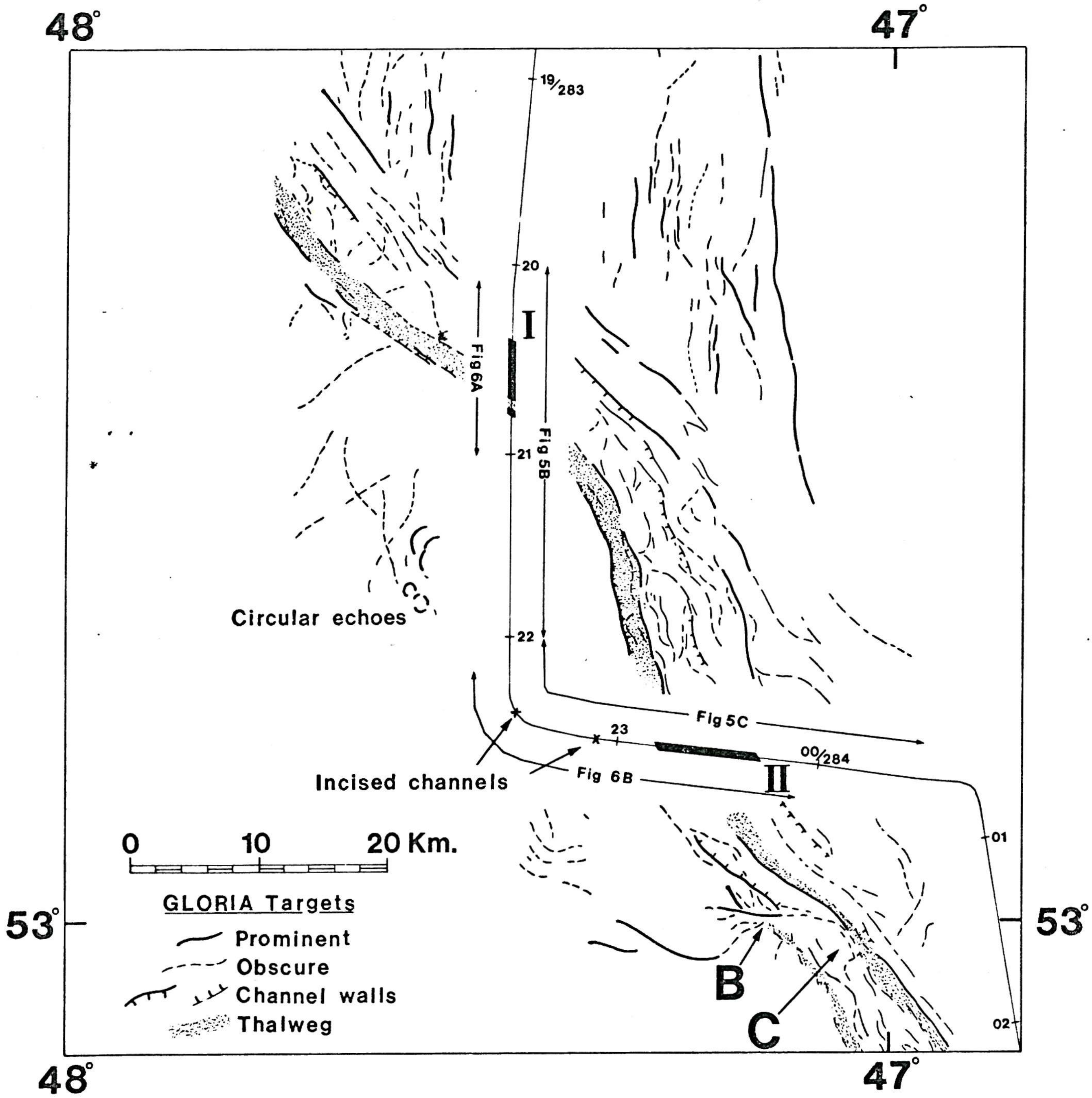
20
Km
A
Fig 5A
GLORIA Targets
Prominent
Obscure
48°
47°

2B



3 A


48°
47°
19/283
20
21
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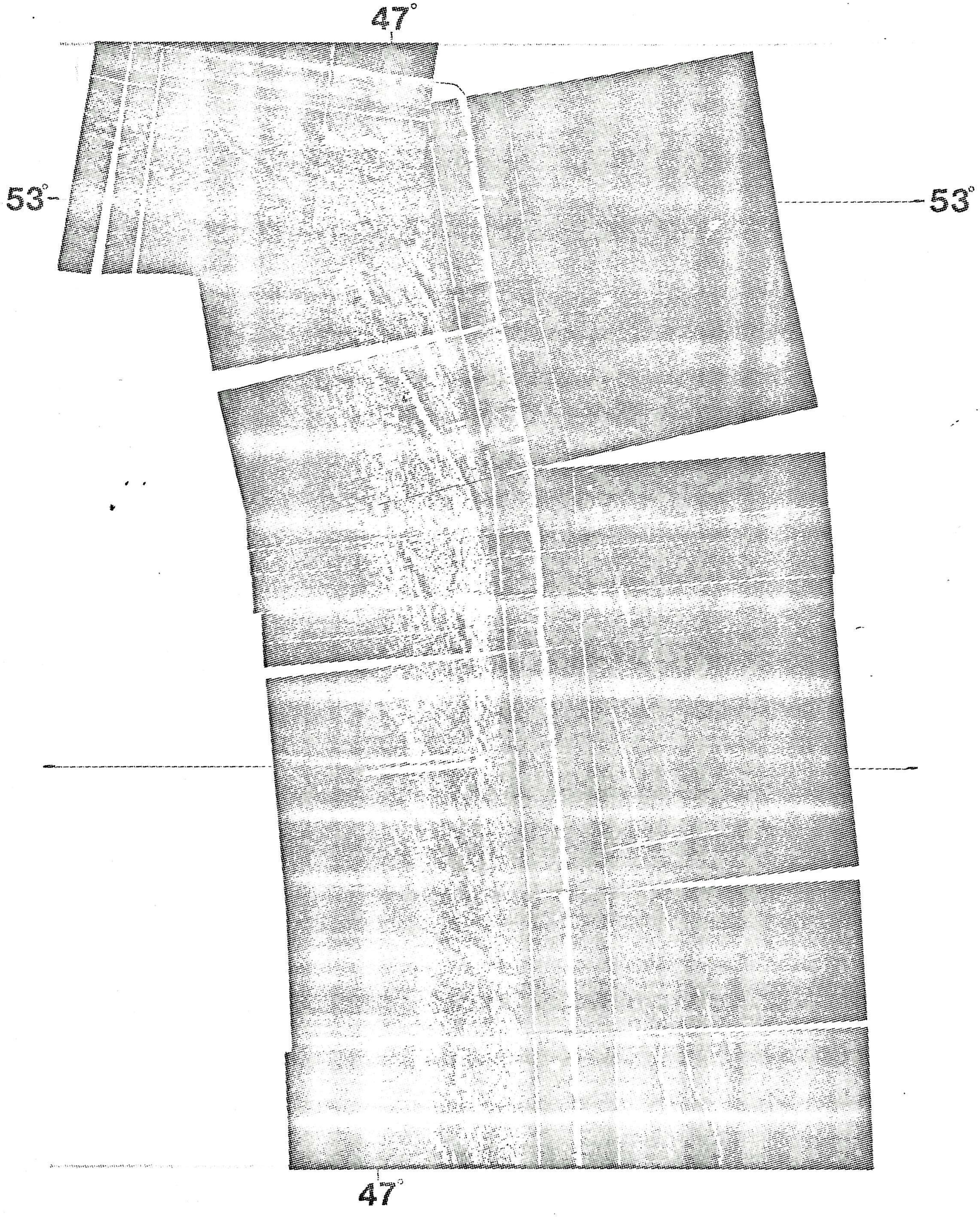
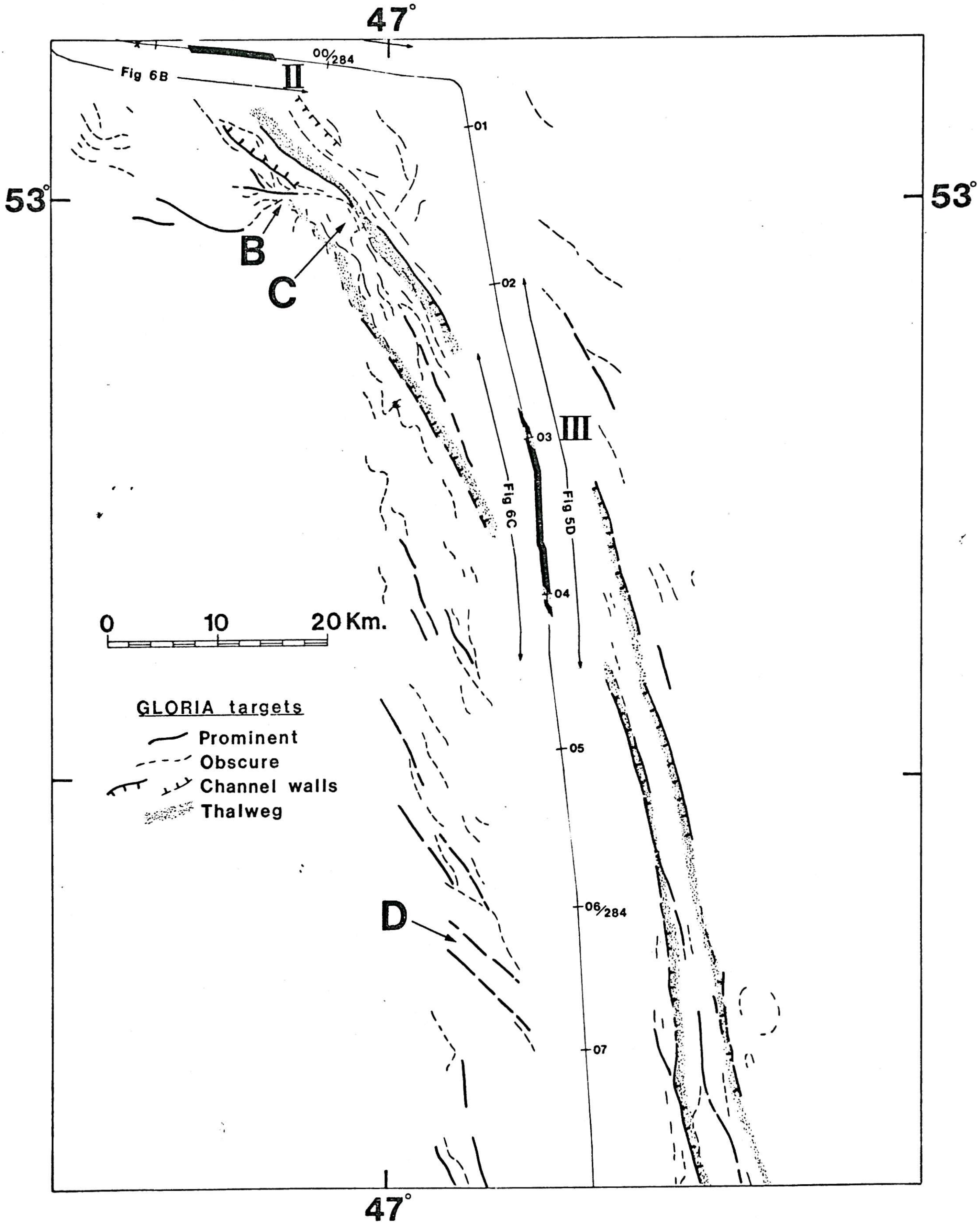
01
02
I
II
Fig 6A
Fig 5B
Fig 5C
Fig 6B
Circular echoes
Incised channels
0
10
20 Km.
GLORIA Targets
Prominent
Obscure
Channel walls
Thalweg
53°
B
C

3B



4 A


47°
00/284
Fig 6B
II
01
53°
53°
B
C
02
III
03
Fig 6C
Fig 5D
04
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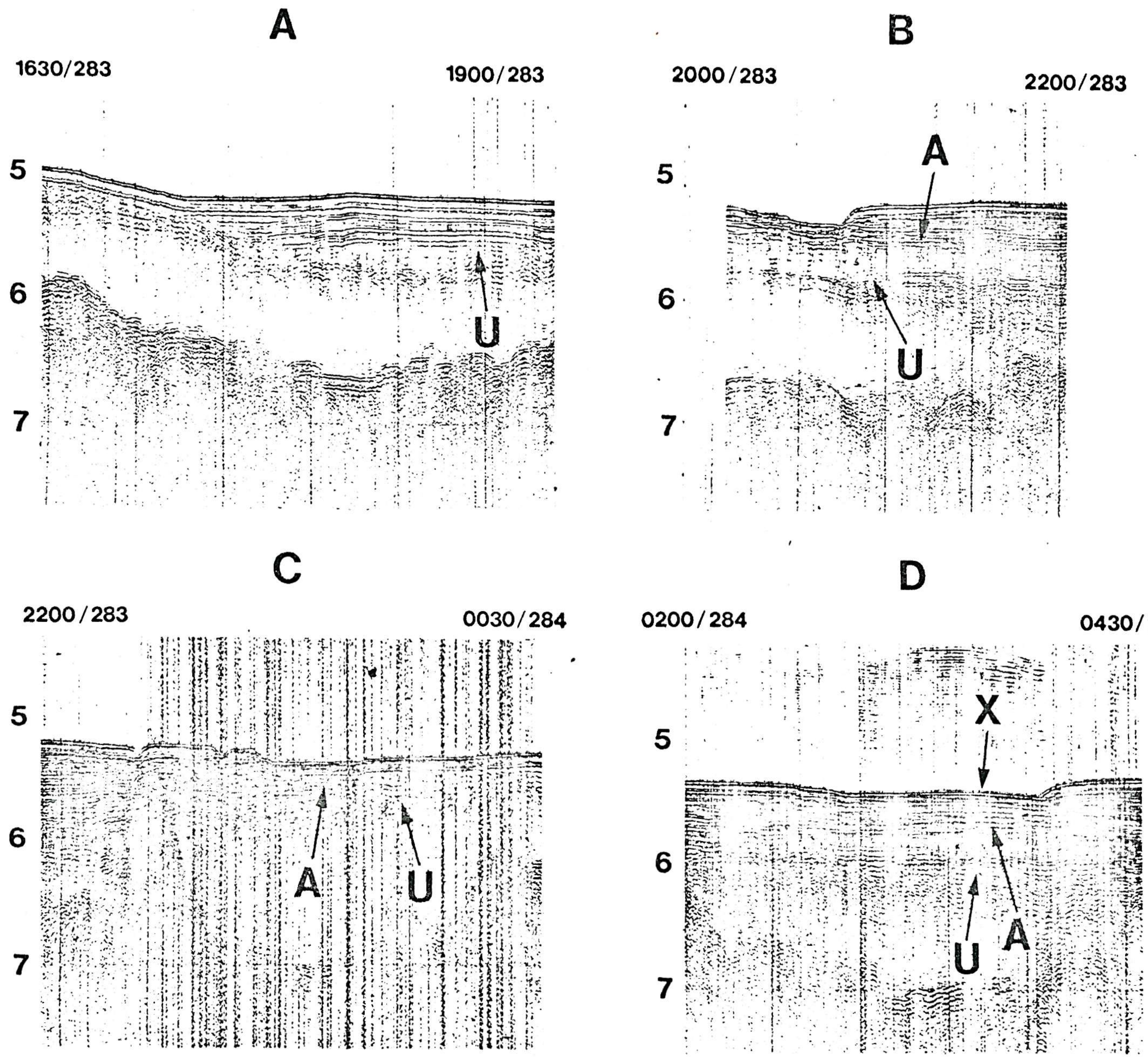
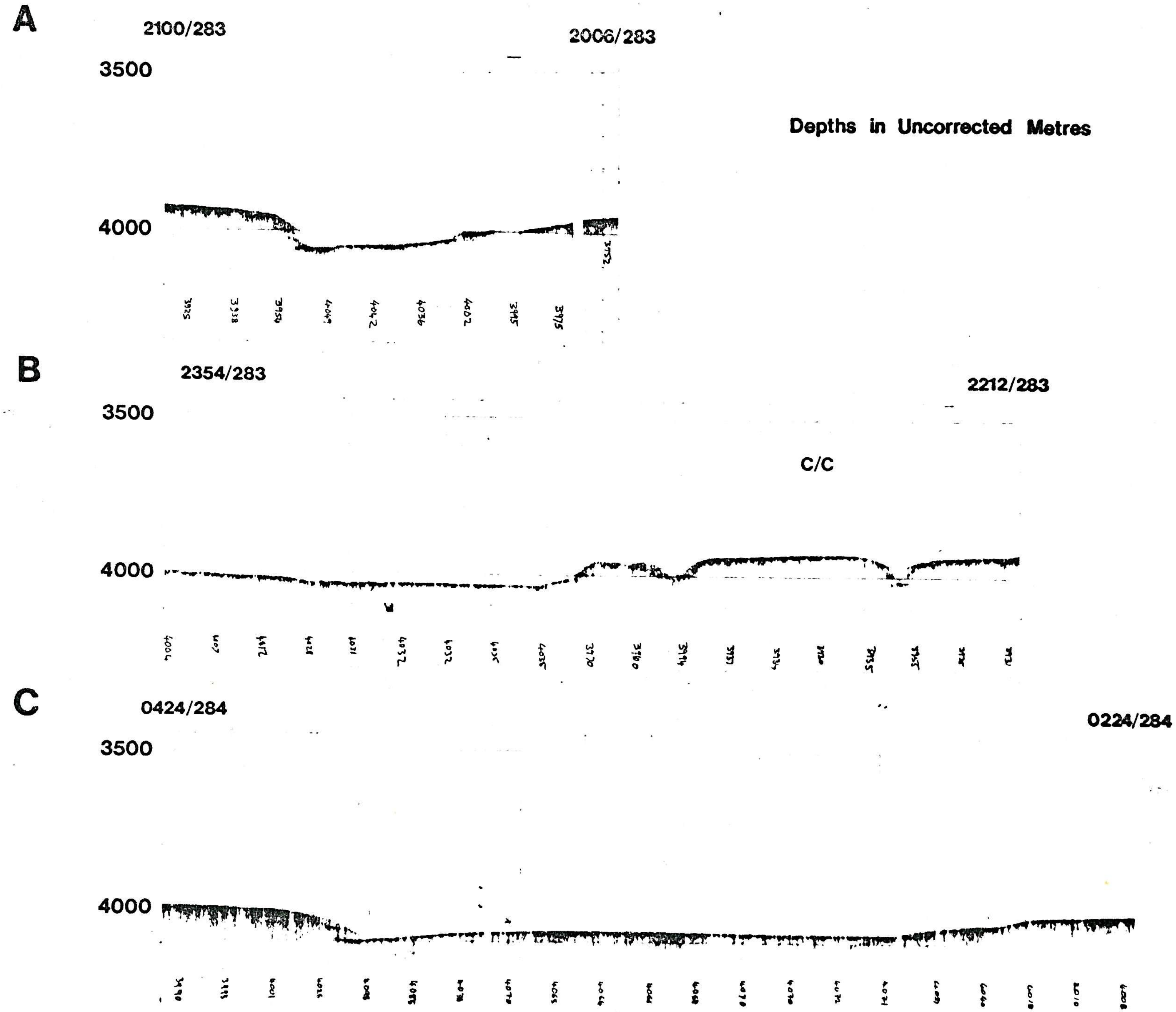
10
20 Km.
GLORIA targets
Prominent
Obscure
Channel walls
Thalweg
05
06/284
D
07
47°

4 B



Two-way Travel Time in Seconds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2100/283
2006/283
3500
4000
Depths in Uncorrected Metres
B
2354/283
2212/283
3500
C/C
4000
C
0424/284
0224/284
3500
4000