SEISMIC STRATIGRAPHY OF THE LAURENTIAN FAN

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Geological Survey of Canada Open File Report # 1231

December 1985

ABSTRACT

Seismic reflection profiles from seven cruises to the Laurentian Fan and adjacent continental slope have been interpreted and correlated. Key reflectors have been identified in each survey area and have been tentatively dated by correlation with the Dauntless D-35 well. This suggests that the thickness of Quaternary sediments on the Laurentian Fan is about half that previously proposed. The Laurentian Fan consists of a sequence of Quaternary sediments that is similar to that seen elsewhere on the Scotian margin.

In the upper Tertiary, channels with low levees crossed the Laurentian Fan north of 43°N and opened onto a broad sandy valley termination zone. Levees in the Pliocene grew higher and spread southward, thus prograding over the older valley-termination zone which must have also shifted southwards. With continued slumping of material off the continental slope down the channels in the Quaternary, the Laurentian Fan continues its migration in a southeast direction, and much of the upper part of the fan was dissected.

This Open File report presents a description of the profiles and their correlation, and about 30 examples of seismic reflection profiles with interpreted key reflectors.

INTRODUCTION

The Laurentian Fan is the largest Quaternary sediment accumulation on the southeastern margin of Canada, and is the site of a turbidite triggered by the 1929 Grand Banks earthquake (Doxee, 1948). As part of a regional study of Quaternary sediment instability on the continental slopes off southeastern Canada, we have examined the growth pattern of the Laurentian Fan, for information on its geologic history and how this relates to sediment instability on the adjacent continental margin.

Previous seismic reflection surveys of the late Cenozoic of the Laurentian Fan area have either been of a reconnaissance nature (Uchupi and Austin, 1979), or have examined a small and isolated area of the fan in more detail (Piper and Normark, 1982; Normark et al., 1983). Since these surveys, new seismic data has been collected on several Geological Survey of Canada cruises (Fig. 1). The purpose of this study is to synthesize the previous interpretation and the newly acquired data to better define the seismic stratigraphy of the late Cenozoic sediments of the Laurentian Fan.

The Laurentian Fan is a complex deep sea fan that lies between the continental slope off the Laurentian Channel to the north, and the Sohm Abyssal Plain to the south. The continental slope off the Laurentian Channel is highly dissected and irregular, and leads downslope into two prominent fan valleys (Eastern and Western Valley) with high levees. The valleys terminate at about the 4900 m isobath where a transition occurs to the broad sandy lobe of the northern Sohm Abyssal Plain.

GEOLOGICAL SETTING

The Laurentian Fan is located off the eastern continental shelf of Canada between the rifted continental margin of Nova Scotia and the inactive transform margin of the southwest Grand Banks. This margin developed during the Early Jurassic opening of the central Atlantic Ocean. Since that time, a thick Jurassic to Tertiary continental margin sequence has been deposited, over which Quaternary sediments accumulated.

The Laurentian Channel, which lies to the north of the fan, is a glacially modified trough that crosses the continental shelf (King and MacLean, 1970). It is 700 km long and 80 km wide and has been carved 300 m below the regional depth of the shelf. The Laurentian Channel probably acted as a main discharge route for ice from Atlantic Canada during major Pleistocene ice advances. Melting of this ice as it left the channel resulted in deposition of glacial till and glaciomarine sediments over the continental slope, just above the Laurentian Fan. Turbidity currents transported sediments across the fan, and out to the Sohm Abyssal Plain.

In 1929, the Laurentian Fan was the site of the magnitude 7.2 "Grand Banks" earthquake. The turbidity currents and debris flows that were generated resulted in the redeposition of large amounts of glaciomarine sediments from the continental slope down onto the fan and abyssal plain (Piper et al., 1984).

The Laurentian Fan is composed of two main fan valleys that coalesce into a depositional lobe (Fig. 2). The two valleys, termed Eastern and Western, extend seaward for 400 km in water depths of 2000 to 4500 metres. Numerous coalescing smaller valleys and local submarine slide areas (Piper et al., 1984) provide sediment to the two valleys from the continental slope. This area between the 2000 and 3000 metres isobath is called the slope-valley transition zone. Both Eastern and Western Valleys have asymmetric levees with a relief of up to 700 metres.

From the 4600 to the 5000 m isobath (the valley termination zone), the relief of both fan valleys becomes progressively smaller until they eventually shallow out to form a depositional lobe. The Eastern Valley splits into two distributaries, with a levee-like "interdistributary high" between them. Uchupi and Austin (1979) suggest that the depositional lobe is fed predominantly by the Western Valley, whereas the Eastern Valley swings eastward against the Fogo Seamounts at the base of the southwest Grand Banks Rise.

Piston cores examined by Stow (1977, 1978), revealed that the valleys are floored by turbidite sand and gravel, whereas the intervalley areas and levees are covered by Holocene hemipelagic mud and Late Pleistocene turbidite mud. Sand is the dominant sediment on the depositional lobe of the Northern Sohm Abyssal Plain.

DATA

The control for the data used in this study is illustrated in Fig. 1. It includes 1967 Woods Hole profiles (Emery et al., 1970); multichannel profiles collected in the early 1970s by Imperial Oil (Parsons, 1974); line drawings of the Woods Hole profiles interpreted by Uchupi and Austin (1979); profiles interpreted by Piper and Normark (1982) and Normark et al. (1983); and seismic profiles collected by the G.S.C. in 1984 and 1985.

The 1967 Woods Hole data consisted of two single channel seismic profiles (numbers 263 and 266). The 1977 Woods Hole data consisted of one six channel (AII 2-4) seismic profile. Both profiles 263 and AII2-4 were NW-SE profiles running down the west side of the Eastern Valley, while the east-west profile, 266, crossed over the Eastern and Western Valley. The seismic source for the reflection profiling ranged from a 80 cubic inch air gun to a gun array consisting of 40, 80, 120, 300, and 1000 cubic inch guns. The firing rate was 36 seconds and the ship's speed was 4 kts.

The Imperial Oil multichannel profiles collected over the upper Laurentian Fan were collected in 1972 and 1973 (Parsons, 1975). The three profiles used in this report are I-14, I-59, and I-60.

The remaining profiles (collected in 1978, 1981, 1984, and 1985) were collected by the Atlantic Geoscience Centre. The 78-022 Dawson survey was in two areas. One consists of 600 km of single-channel seismic reflection profiles, obtained over a 70 by 150 km area below the terminus of the western valley (41°N). In the second, principally on the western levee of eastern Valley, 400 km of single channel data from 42°30'N to 44°20'N were collected. The seismic profiles were obtained using a 160 KJ sparker towed at 5-6 kts.

A high-resolution multichannel survey on cruise 81-044 just north of the Laurentian Fan on St. Pierre Slope, can be correlated with the other profiles reported here. It is described in detail by Meagher (1984).

The 1984 Hudson 84-040 survey was also conducted on two parts of the fan. On the upper fan, a zig-zag line was run down the Eastern Valley from 44°30' to 42°20'N, while during the second phase on the lower fan, an elongated loop was made at around 41°N to the east of the 1978 survey. These seismic profiles were obtained using either a 40 cubic inch airgun or a 160 cubic inch pneumatic water gun, both towed at 2 kts.

We have also made use of the interpretation by Wade and MacLean (pers. comm., 1984) of a multichannel profile from the area of St. Pierre Slope, which allows the stratigraphy in the Dauntless well (Barss *et al.*,

1979) to be correlated into the 1981 survey and to the northern end of the 1984 survey.

The 1985 survey provided a tie profile from the terminus of the upper 1984 profile (42°10'N) down to the loop in the lower fan (41°40'N). Two shorter profiles in the upper fan connect the Imperial Oil profile (I-14) to the 1984 profile. A 40 cubic inch airgun, towed at 5 kts was employed.

PREVIOUS SEISMIC STRATIGRAPHIC ANALYSIS

Uchupi and Austin (1979) described the evolution of the Laurentian fan. They defined a prominent reflection, Horizon L, at approximately 5.8 seconds (upper fan) which could be traced throughout much of the fan area. They suggested that reflector L marks the change from pelagic to terrigenous turbidite sedimentation and therefore represents the boundary between Tertiary and Quaternary deposition.

Piper and Normark (1982) traced Horizon L from Uchupi and Austin's AII-4 profile to their 78-022 upper levee survey. Piper and Normark concentrated their study on sediments above Horizon L, whereas Uchupi and Austin concentrated on the sediments below L. From the 1978 survey, Piper and Normark picked two prominent reflections. The first, named horizon A, lies 600-1100 m above L. The second, named horizon Q, lies 400 to 500 m above A and is the uppermost of a closely spaced pair of strong reflections. Normark *et al.* (1983) were also able to correlate horizon L. They defined two shallower reflections, termed R and S, but could not extend correlation of these reflections with the upper fan study of Piper and Normark (1982).

DEFINITION OF KEY REFLECTIONS

A sequence of eight key reflectors is defined in the study on the upper fan. Reflectors P, O, A, U, Y and B are defined along Imperial Oil profile I-59 at sp. 673 (Fig. 3); reflectors R and Q were defined at 205/0400 in the 78-022 profiles (Fig. 4).

The shallowest reflector in the type section, B, is a planar, high amplitude coherent reflection, found at two way travel times below the sea surface of between 3.7 sec. (2775 m) near the slope, to greater than 5.0 sec (3750 m) near 43°N. (Because of the irregular erosion of the upper Laurentian Fan, sub-bottom depths are very variable.) It is continuous through the Eastern and Western intervalley areas. Often reflector Q lies so closely below B that the two pinch together to form one prominent reflection (Fig. 4).

Reflector Q is a planar, coherent, high amplitude reflection that is only apparent along certain profiles of the 1978 upper fan survey. It has been eroded out from the valleys and is indistinguishable from B in the Eastern Valley area. Q is equivalent to the Horizon Q picked by Piper and Normark (1982) (Fig. 5).

Reflector Y is in most sections a planar, coherent, reflection with moderate amplitude, and is found in both valley areas. It is usually equivalent in depth to the valley floor, and therefore is difficult to trace through the valleys (Fig. 3).

Reflector U is not a prominent reflector in the type section as it can not be traced over much of the survey area. It does appear as a high amplitude, undulating, fairly coherent reflector along the I-59 and I-14 profiles, where it lies between Y and A (Fig. 6). U marks a change in reflection character from mostly planar reflection above, to a rough irregular pattern below. This irregular acoustic facies rests on reflection A and is approximately 0.1 sec (75 m) thick (Figs. 6 and 8).

Reflector A, which corresponds to the horizon A picked by Piper and Normark (1982), is the most prominent in the type section and can be traced almost continuously across the valley floors (Fig. 9). It is the first reflector of the type section to appear on the I-60 profile, although it is discontinuous and undulating (Fig. 10). Along the other upper fan profiles, excluding the 1984 profile, A is a coherent, high amplitude, slightly undulating reflection found at 4.0 sec (3000 m) TWTT near the slope-valley transition, down to 6.0 sec (4500 m) at 42°30'N, in the Western Valley. On many profiles, reflector A shows more local relief than either overlying or underlying reflections.

Horizon O is a low amplitude fairly coherent reflection which can be traced beneath the valley floors. It is usually undulating, especially along the I-60 profile and often overlies very incoherent reflections (Fig. 10 and 11). O is not easily recognized in the 78-022 survey, but where it does occur, O is more planar. The TWTT to O is 3.3 sec (2475 m) on the slope edge, down to 5.7 sec (4275 m) at its last recognizable occurrence before the valley termination zone.

Reflector P is not a prominent reflector in the type section, as it is restricted to the Western Valley region (Fig. 12). Where it does occur, P is a coherent, moderately high amplitude, undulating reflector occurring 0.1 sec (75 meters) below O. It is generally apparent in the 78-022 survey. It is a discontinuous, coherent reflection through the valley but becomes more continuous on either side (Fig. 9).

Reflector R is the deepest reflection defined in the type section and is the only horizon that can be traced throughout the entire fan. In the upper fan, R occurs at 5.7-6 sec (4275-4500 m) TWTT and nears 7.1 sec (5325 m) beyond the valley termination zone (Figs. 13 and 14) Acoustic penetration at this depth is often limited, so that the correlation of R may be speculative in certain sections (Fig. 15). R is a very incoherent, low-medium amplitude reflection, usually occurring in undulating segments (Fig. 3), until it reaches the valley termination zone, where it becomes more planar (Fig. 16). The reflectors surrounding R show a similar pattern.

REFLECTOR CONTINUITY

In general, reflectors can be traced confidently through levee areas (Fig. 17), except on the uppermost fan where there has been considerable dissection. Reflectors are difficult to trace beneath valley floors (Fig. 18) and side-echoes appear at valley margins. In the valley termination zone, it is more difficult to discriminate between reflectors and trace them for long distances even though many continuous reflectors are visable (Fig. 16).

All the reflectors in the type section, with the exception of U, can be correlated with the 78-022 survey of the upper levees (Piper and Normark, 1982). The deep erosion of Eastern Valley results in only A and O being traceable as continuous reflectors beneath this feature in profile I-59 (Fig. 19). There are a series of prominent planar reflections above u, but we have been unable to correlate them across Eastern Valley on the basis of similar reflection character (Fig. 7). Upslope from the type section, the sea floor becomes more dissected, and it is difficult to correlate the shallower reflections (Fig. 6).

It is difficult to discriminate between original reflector relief and velocity drawdowns across Eastern Valley. At the eastern margin of the valley and in the Grand Banks Valley, horizon O shows no apparent drawdown despite a 400 m change in surface relief (Fig. 19). This suggests that the travel time through coarse material on the valley floor, with a higher velocity than the muddy levee sediments, approximately compensates for the greater water depth. All reflectors between O and R inclusive show a v-shaped reflection pattern beneath the lower part of the eastern wall of Eastern Valley (Fig. 19).

Reflector O can be traced from the type section beneath Eastern Valley to profile I-14 and thence upslope onto the northern end of 84-040 on the St. Pierre Slope (Figs. 20 and 21). This profile intersects with an A.G.C. multichannel profile, in which J.A. Wade and B. MacLean (pers. comm. 1984) correlated reflector 4 of Meagher (1984) on the St. Pierre Slope with the Oligocene-Miocene boundary in the Dauntless D-35 well identified biostratigraphically by Barss et al. (1979). Using this correlation, we have traced this basal Miocene marker onto profile 84-040 (Figs. 20 and 21), where it falls 0.5 sec below reflector O. Reflector O is therefore tentatively identified as being of lower Miocene age.

Reflector R can be traced from the type section in the upper levee survey of 78-022 to I-59 and I-60, where it corresponds to horizon "L" of Uchupi and Austin (1979). It can also be traced down the western levee of Eastern Valley. In the detailed survey area on the upper levee, R is 1.3 secs below Y. At 42°40'N it is approximately 0.85 secs below Y (the precise level of R is a little uncertain, but there is a strong reflectors grouping at this depth). This reflector grouping can be correlated through to the east-west 84-040 profile at this latitude, so that R can be correlated to area of the Eastern Valley at about 42°20'N. This correlation is verified by the tracing of a discontinuous strong reflector grouping beneath the Eastern Valley down the north-south 84-040 profile. Horizon R can then be traced using 84-040 and 85-001 profiles to the valley termination zone (Figs. 13, 14). At 086/0030 in 85-001 it can be transferred at a close approach on the basis of reflector depth and character to the seismic survey of Normark et al. (1983) at 202/1500. This reflector can then be traced continuously to the west, where it corresponds to a reflection 0.1 sec below L as defined by Normark et al. (1983). The strata above the horizon that these authors term "R" thin out towards the western valley in their profiles, so that none of their shallower marker horizons can be correlated with our surveys in the Eastern Valley area. Normark et al. (1983) identified L from the crossover of their survey with profile AII-2 illustrated in Fig. 5 and 6 of Uchupi and Austin (1979). The northern extension of this profile (AII-4) crosses 85-001 086/0900 and confirms the correlation of our R reflector with their L in the valley termination zone. R can also be correlated to Woods Hole lines 263 and 266 (Fig. 22).

Reflector A can be traced south down the levee between the Eastern and Western Valleys from the type section, using the 78-022 profiles (Fig. 17). At the intersection with the east-west 84-040 profile, a prominent reflection about 0.1 sec below A can be traced to the Eastern Valley. Just above this reflection in the valley termination zone, another persistent reflection (Fig. 23) approximately corresponds to A. This reflection can be traced via the 85-001 profiles to the 78-022 survey in the valley termination zone east of Western Valley. Correlation across Western Valley is difficult, but this reflection approximately equivalent to A appears to correspond to "R" of Normark et al. (1983). Like reflector A in the channel-levee complex, their "R" shows more local relief than under- and overlying reflectors.

Most of the correlatable reflectors can be traced from the type section through the 78-022 survey to the western levee of Eastern Valley at about 43°N. These reflectors can be correlated to the segment of 84-040 at 43°N on the eastern levee of Eastern Valley (Fig. 24) using reflection character, particularly the behaviour of reflections at the valley margin. Over much of the fan, reflector A shows substantially more relief than immediately underlying reflectors (Fig. 7, 8, and Figs. 3 and 6 of Normark et al., 1983), and may thus correspond to a regional erosional event on the continental slope that rejuvenated the fan valley system. A is thus recognized as the prominent reflector that cuts down at valley margins unconformably over older strata (Fig. 26). The relative spacing of reflectors above A is similar on both sides of the valley, but A occurs 0.9 sec. subbottom on the western levee and only 0.5 sec subbottom on the eastern levee. Reflector R has been identified using the L-reflector on the Woods Hole lines, with which it is correlated, shows that the western levee has grown faster than the eastern levee.

The correlation at 43°N can be tentatively extended north, again on reflection character, to 85-001 and I-14 at 43°30'N (Fig. 8).

AGE OF THE LAURENTIAN FAN SEQUENCE

Uchupi and Austin suggested on "stratigraphic considerations" that horizon "L" (our reflector R in the channel levee complex and a slightly shallower level than R in the valley termination zone) was of Plio-Pleistocene age. However, the correlation by Wade and Maclean suggests that reflector O is of basal Miocene age, which would place R within the Oligocene, since the deep reflector "A" of Uchupi and Austin is of late Eocene to early Oligocene age (Parsons, 1975).

LATE CENOZOIC EVOLUTION OF LAURENTIAN FAN

Using the widely correlated reflectors R, A and Y, we can divide the Laurentian Fan into three seismostratigraphic units. The sequence between reflectors A and R is of probable upper Tertiary age. Reflector R generally has little relief, although there are some undulations of up to 0.1 sec which do not appear to be velocity related. On profile I-59, using reflector O as a datum, reflector R appears to show a levee - channel pattern both beneath the western edge of Eastern Valley and 25 km farther west (Fig. 20). Because R is recognisable on only a few profiles, however, it has not been possible to systematically identify relief on this reflector. Beneath the upper part of the channel-levee complex (above the 4000 m isobath), sediment thickness between R and A ranges from 0.7 to 0.95 secs. Piper and Normark (1982) identified a shallow "ancestral valley" below reflector A to the west of Eastern Valley which corresponds to the channel-levee system on profile I-59 and is probably a tributary to Eastern Valley. The greatest thickness of sediment (0.9-0.95 sec.) occur on the SW levee of this valley (Figs. 5, 17); elsewhere thicknesses lie between 0.7 and 0.8 secs.

South of the present 4000 m isobath, sediment thickness between R and A decreases to between 0.3 and 0.45 secs, and this thickness is maintained over 200 km downslope as far as the lower detailed survey area of Normark *et al.* (1983). We intepret this abrupt thickness change as analogous to the rapid decrease in levee relief in the modern valley termination zone. In 40 cubic inch airgun profiles near the levee part of Eastern Valley (Figs. 16, 23), the acoustic character of the R to A interval in many areas is similar to that beneath the channels in the modern valley termination zone. Locally, however, this channel-floor facies passes laterally into a more stratified transparent facies (Fig. 25) interpreted as levee deposits, with interval thickness increasing by up to 0.1 sec from the channels. There appears to have been an ancestral Eastern Valley as far south as 41°45'N.

Thus in the interval R to A (probably upper Tertiary) the channel-levee complex of Laurentian Fan extended only to 43°N, with a channel pattern different from the present, and levee elevations of only about 100 m. There was then a broad sandy depositional lobe passing up-fan into broad channels with low levees beneath the modern valley termination zone and the southern part of the modern channel-levee complex.

The widespread erosional event at horizon A correlates with a change in valley pattern at 44°N at this time, with the development of the modern Western Valley (Piper and Normark, 1982). This valley-cutting event may correlate with widespread slope valley development on the Scotian Slope tentatively dated as early Pleistocene (Piper _et al._, in prep.).

Reflector Y has been removed by erosion of Eastern Valley. It can be traced only beneath the modern levee system. In this area, the interval A to Y is of approximately uniform thickness of 0.3 secs. The present asymmetry of levees across Eastern Valley was present at this time: the eastern levee has an interval thickness of less than 0.2 secs (Fig. 26). The total post-A sediment accumulation in Eastern Valley and the modern valley termination zone is no greater than this thickness. Thus in the interval A to Y, levees appear to have extended south from 43°N to 42°N, prograding over the older valley termination zone which must have shifted southwards.

It is difficult to systematically correlate reflectors above Y because of valley erosion, except in the upper detailed survey area of Piper and Normark (1982). The greatest thickness from Y to the surface occurs at about 43°30'N and is thickest near Western Valley. None of these younger sediments have been removed by widespread erosion (Piper and Normark, 1982). Southwards, there is a progressive thinning. For example, on the eastern levee of Eastern Valley, interval thickness decreases from 0.6 secs at 43°20'N (Fig. 17) to 0.4 secs at 42°30'N. In the levees of Western Valley, thickness decreases from 0.8 secs (Fig. 12) to 0.7 secs (Fig. 4) from 43°40'N to 43°30'N. Most of this variation takes place above reflector B; sedimentation is more uniform below it. Sedimentation in the interval B to surface thus contrasts with that below B in that there is a more pronounced southward decrease in levee thickness, and greater erosion in the slope-valley transition zone.

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FIGURES

Figure 1. Seismic control from study area illustrating figure locations.

Figure 2. Bathymetry of Laurentian Fan showing the slope-valley transition zone, channel-level complex, and valley termination zone. Modified from Piper et al. (1984).

Figure 3. Imperial Oil multichannel seismic profile, I-59 from SP529 to SP 1249. Top photograph shows profile; bottom photograph shows interpretation. Illustrates:

(a) type section.

(b) continuation of A and O across western valley floor.

(c) reflector R as a discontinuous, incoherent, medium amplitude horizon.

(d) reflector P as a reflection that shows more relief than overlying reflections and is discontinuous through the Western Valley.

Figure 4. 78-022 seismic profile, 205/0400 to 205/0500 showing reflections B, Y, A and P correlated from the Imperial Oil profiles Reflectors Q and R are defined at the western end of the section.

Figure 5. 78-022 seismic profile, from 204/2000 to 204/2100 illustrating how reflectors B, Q, Y, A and P become discontinuous at the Western Valley edge.

Figure 6. Imperial Oil multichannel seismic profile I-14 from sp289 to sp1009. Illustrates:

(a) roughness, and the thinning and thickening between reflections U and A.

(b) lack of coherent reflections immediately beneath A and O.

Figure 7. Imperial Oil multichannel seismic profile, I-59 from sp2305 to sp2977. Illustrates:

(a) east levee of the Eastern Valley with reflections B, Y, U, A and O.

(b) lack of coherent reflections where reflector spacing is large between U and A, and A and O.

(c) the variable sediment thickness between reflector U and A.

Figure 8. Imperial Oil multichannel seismic profile, I-14 from sp1057 to sp1753. Illustrates the transition of reflector type below reflector U, from planar, coherent to rough and incoherent.

Figure 9. 78-022 seismic profile from 205/0000 to 205/0130. A portion of the Western Valley illustrating the discontinuity of reflectors B, Y, U, A, O, P and R beneath the valley.

Figure 10. Imperial Oil multichannel seismic profile, I-60 from sp2329 to sp2963. Ilustrating:

(a) lack of correlable reflections above A.

(b) reflectors A and O as discontinuous incoherent horizons occurring in undulating segments.

Reflection O correlated with the type sector on profile I-14; reflection A correlated on the basis of similarity in reflection character with profiles I-14 and I-59.

Figure 11. Imperial Oil multichannel seismic profile, I-60 from sp1225 to sp1945 located within the slope-valley transition zone. Horizon O is the only key reflector that can be traced in this area.

Figure 21. Seismic profile 84-040 281/1320-281/1530. Shows reflection O lying immediately above a reflection correlated with the Miocene/Oligocene boundary on the upper slope.

Figure 22. Seismic profile 263 from Emery _et al._ (1970) down western levee of Eastern Valley showing prominent reflector R in the north correlated from the 78-022 survey. The prominent reflector at the southern end of the line is above R: 84-040 284/1250 to 285/0700 shows that the prominent reflectors in this area of the fan are not all synchronous, but interfinger. R in this area is correlated from 78-022 via the E-W 84-040 line.

Figure 23. 84-040 seismic profile from 284/1900 to 284/2330 illustrating seismic sequence along the Eastern Valley levee.

Figure 24. 84-040 seismic profile from 283/1500 to 283/1930 showing a larger, thicker levee along the eastern levee of Eastern Valley (see text for discussion).

Figure 25. 84-040 seismic profile from 086/0721 to 086/0930. This figure is a continuation of Figure 14.

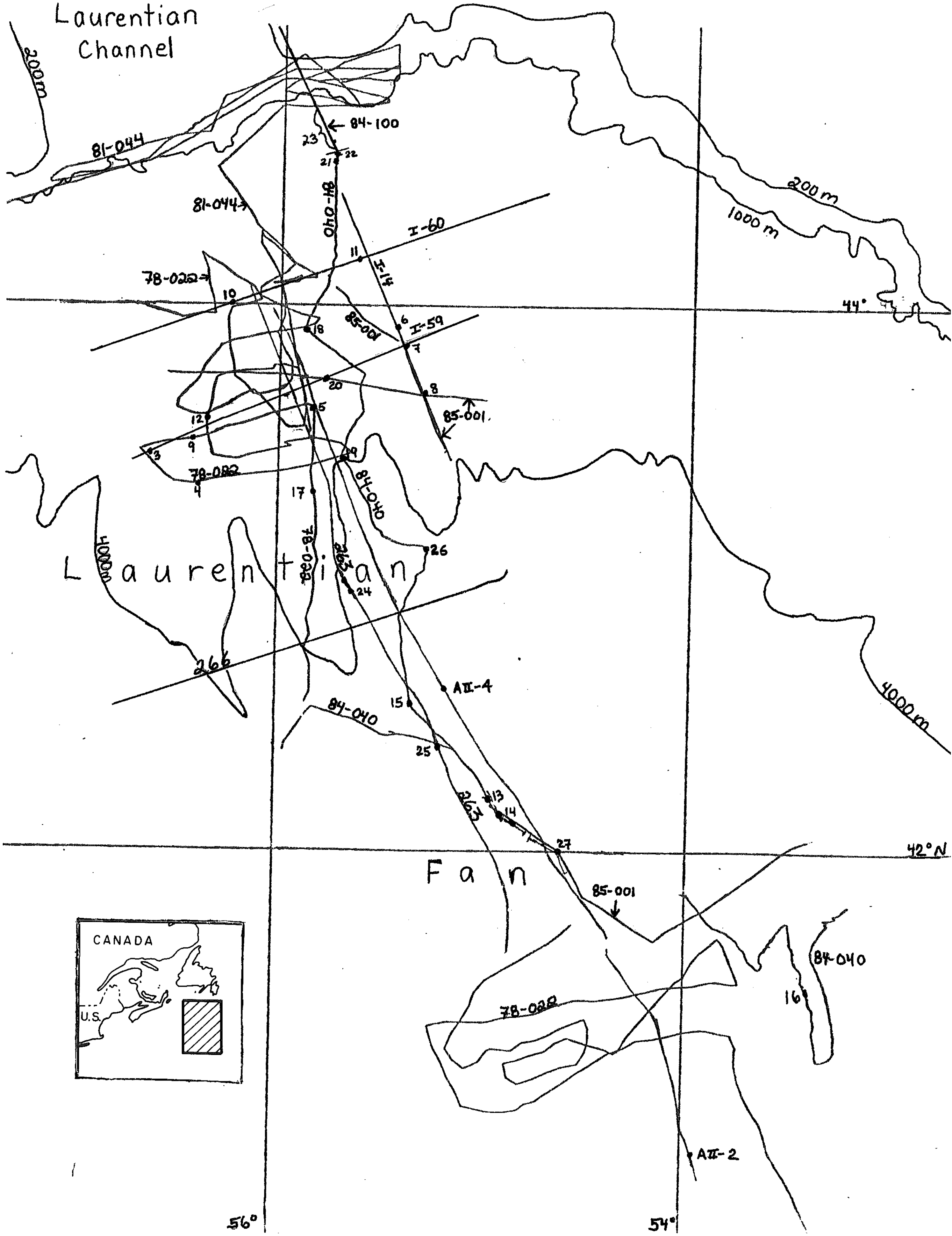
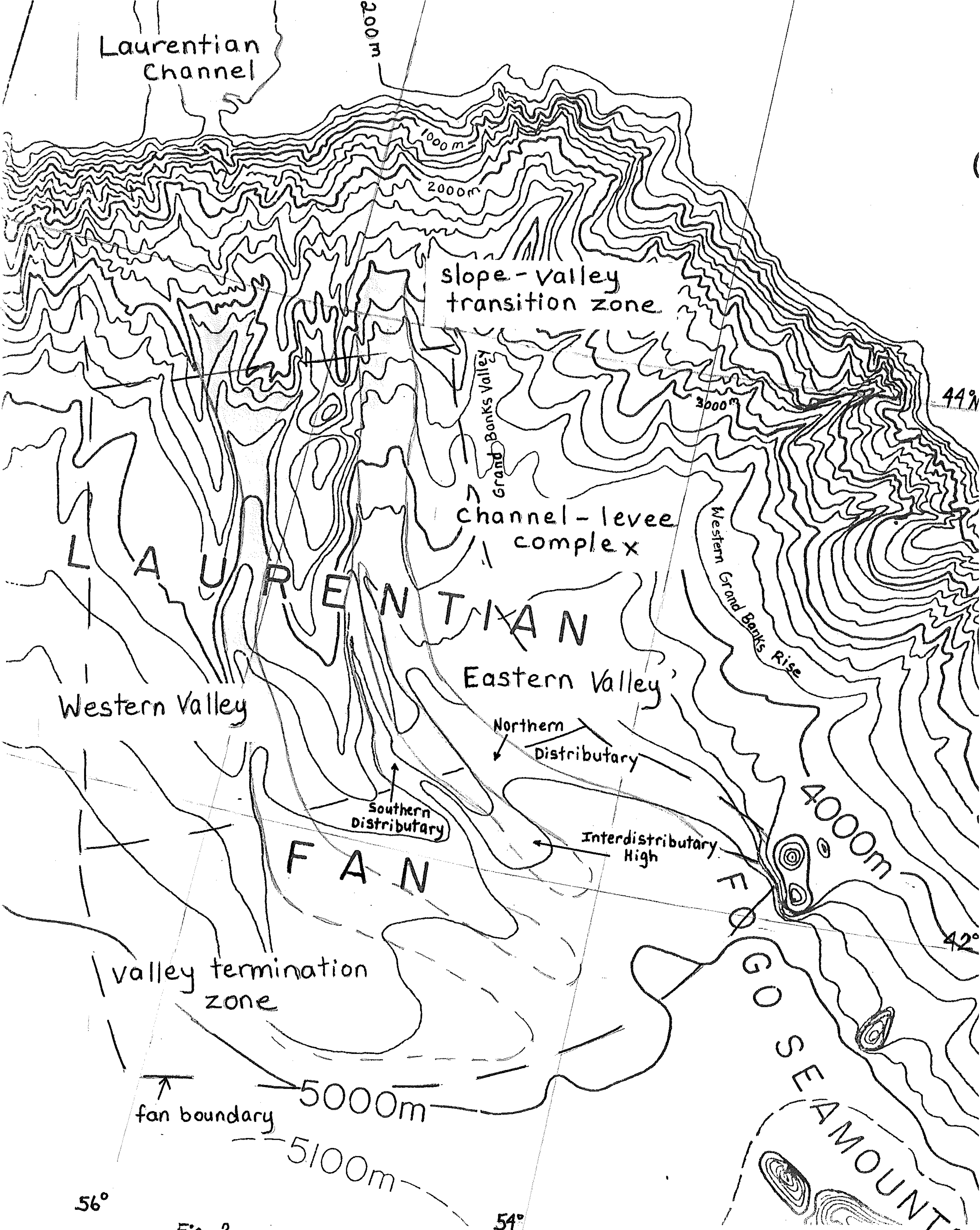
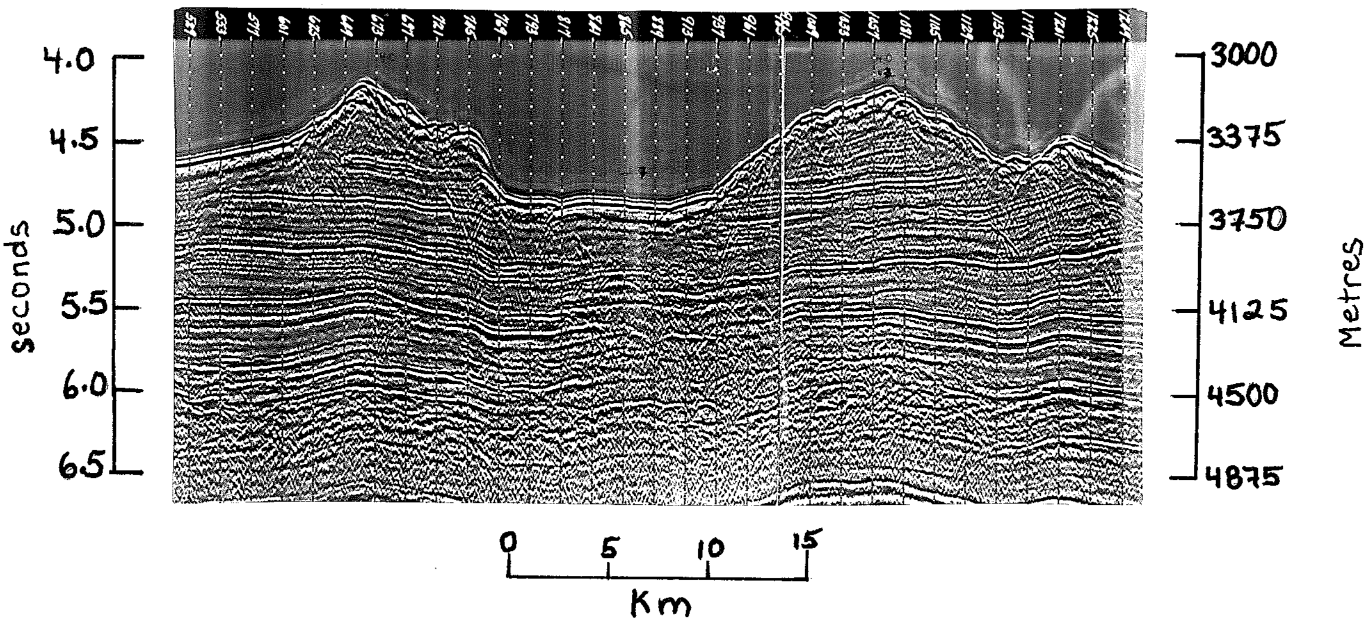

Laurentian
Channel
200m
81-044
84-100
23
21
22
84-040
81-044
I-60
11
I-41
78-022
10
44°
6
85-001
I-59
18
7
20
8
85-001
12
5
9
3
19
78-022
4
17
84-040
26
4000m
84-038
263
24
Laurentian
266
AII-4
15
84-040
25
263
13
14
27
42°N
Fan
85-001
200 m
1000 m
4000 m
CANADA
U.S.
78-028
84-040
16
AII-2
56°
54°

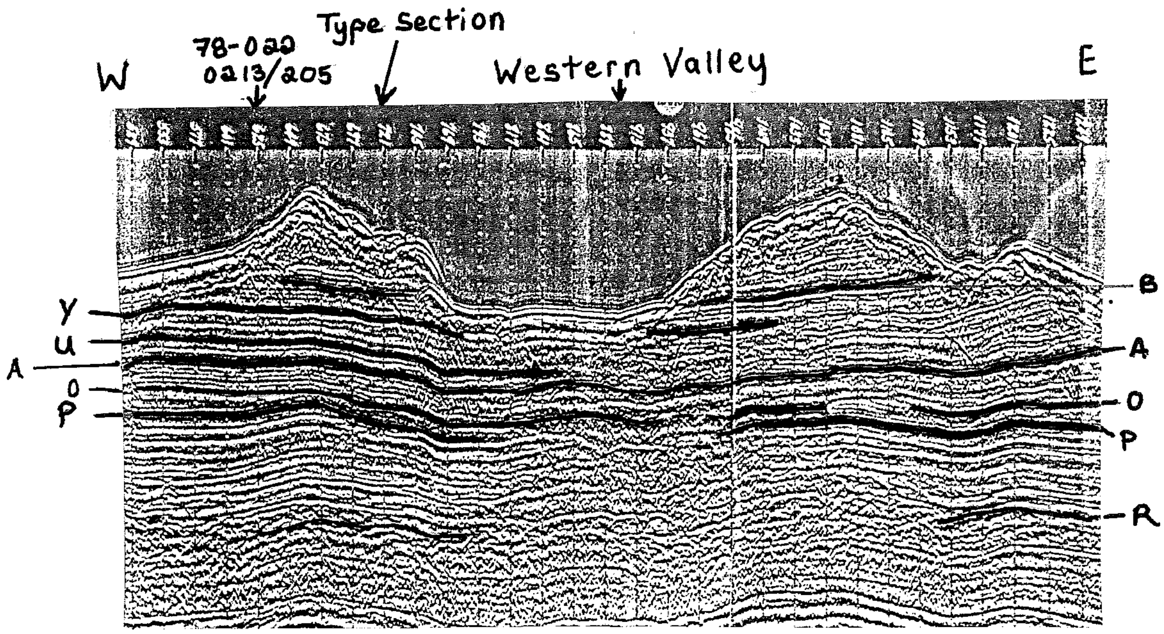
Fig. 1



Laurentian Channel
200m
1000m
2000m
3000m
slope-valley transition zone
Grand Banks Valley
channel-levee complex
LAURENTIAN
Western Grand Banks Rise
44°N
Eastern Valley
Western Valley
Northern Distributary
4000m
Southern Distributary
Interdistributary High
FAN
FOGO SEAMOUNTS
42°
valley termination zone
5000m
fan boundary
5100m
56°
54°

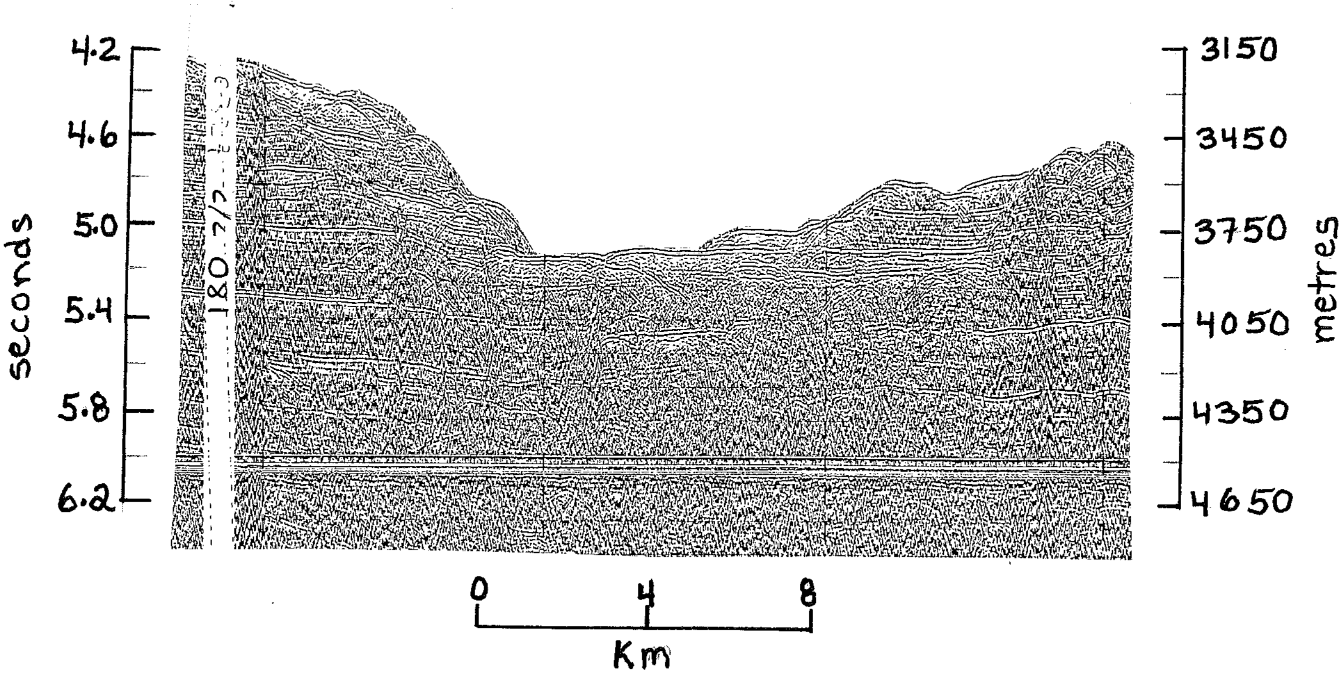
Fig. 2

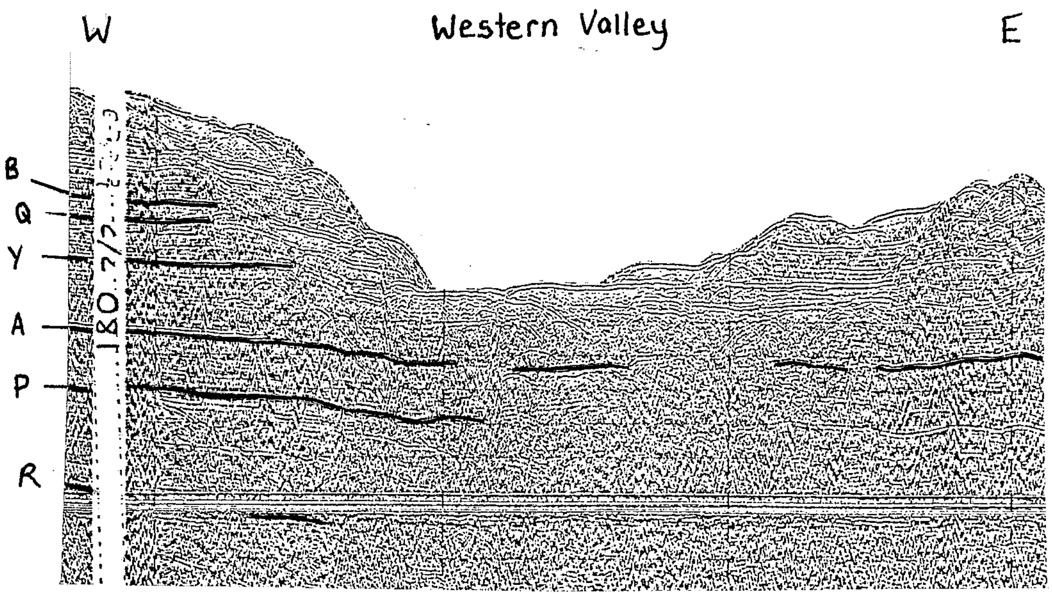

4.0
4.5
5.0
5.5
6.0
6.5
seconds
3000
3375
3750
4125
4500
4875
Metres
0
5
10
15
Km


Type Section
78-022
0213/205
Western Valley
W
E
Y
U
A
O
P
B
A
O
P
R

I-59

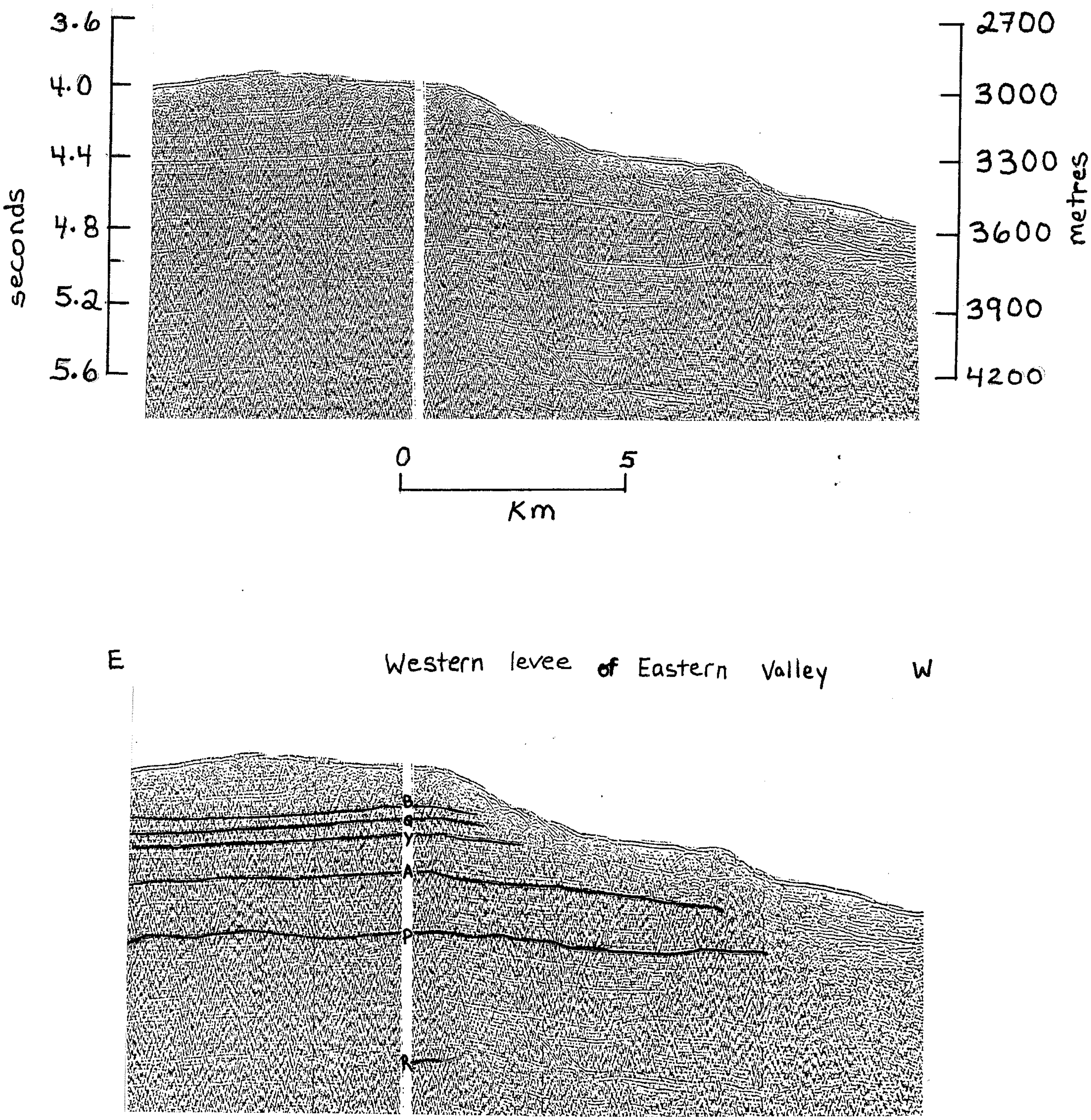
Fig. 3


4.2
4.6
5.0
5.4
5.8
6.2
seconds
3150
3450
3750
4050
4350
4650
metres
0
4
8
Km


W
Western Valley
E
B
Q
Y
A
P
R

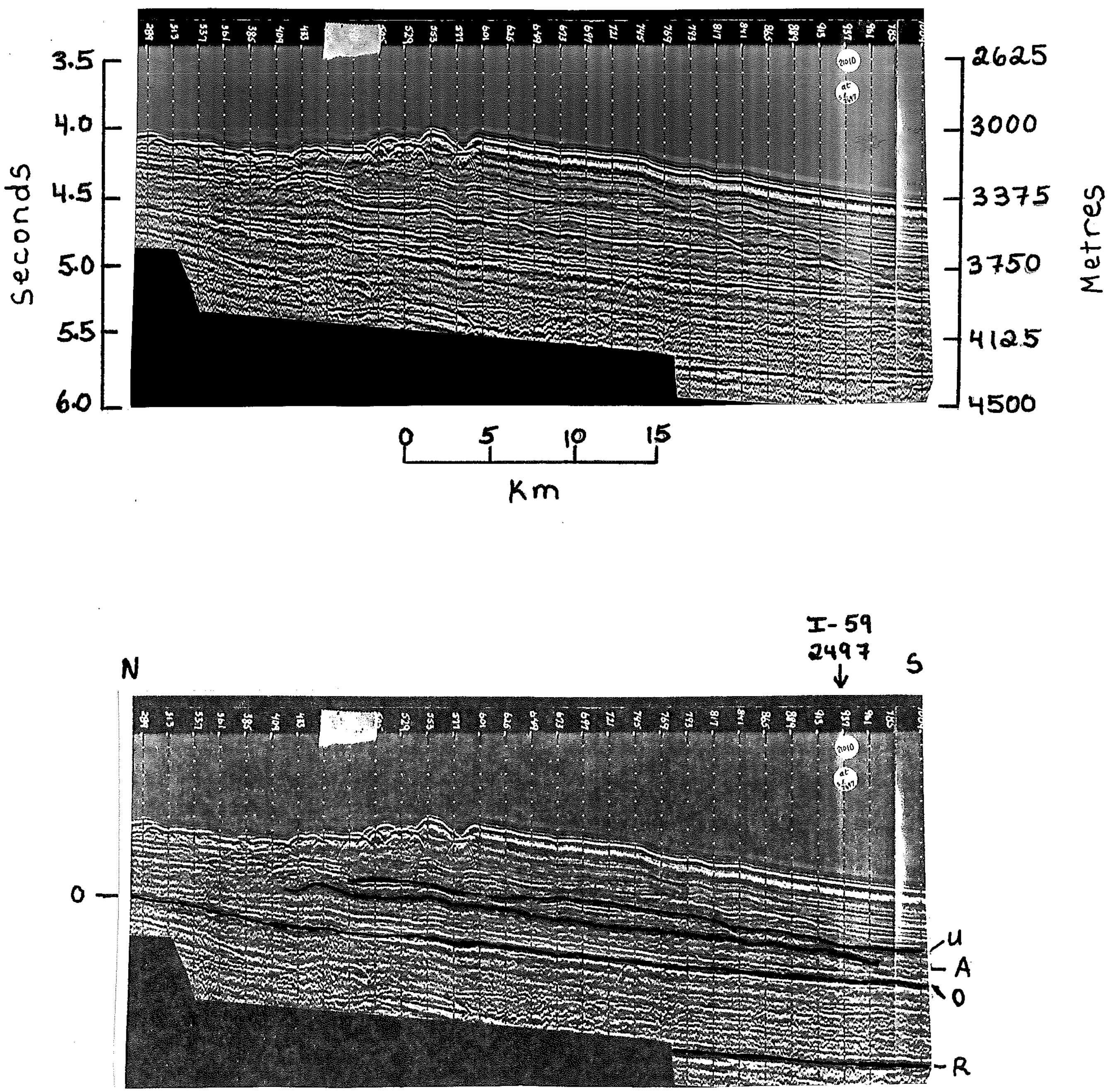
78- 022

Fig. 4


3.6
4.0
4.4
4.8
5.2
5.6
seconds
2700
3000
3300
3600
3900
4200
metres
0
5
Km
E
Western levee of Eastern Valley
W

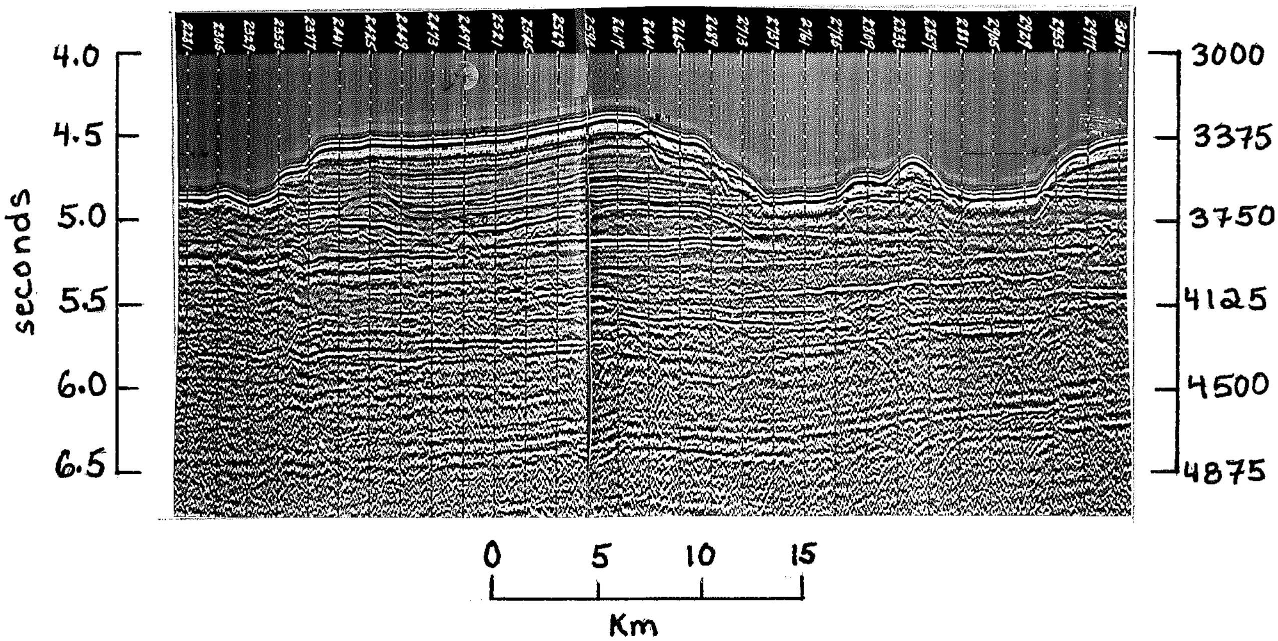
78-022

Fig. 5


3.5
4.0
4.5
5.0
5.5
6.0
Seconds
2625
3000
3375
3750
4125
4500
Metres
0 5 10 15
Km
N
S
I-59
2497
0
U
A
O
R

I-14

Fig. 6


4.0
4.5
5.0
5.5
6.0
6.5
seconds
3000
3375
3750
4125
4500
4875
metres
0
5
10
15
Km

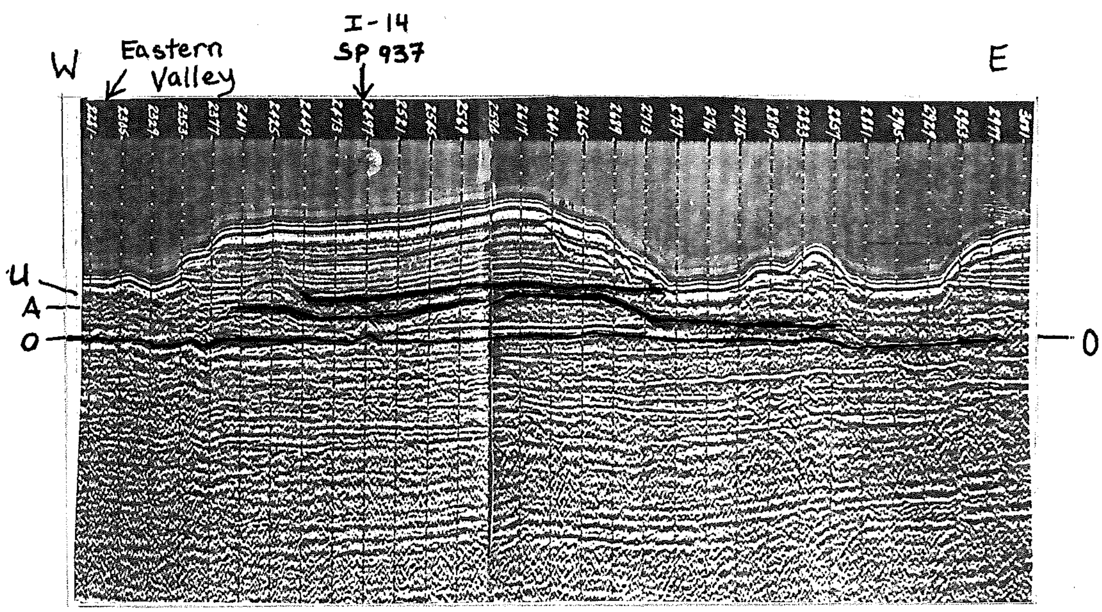
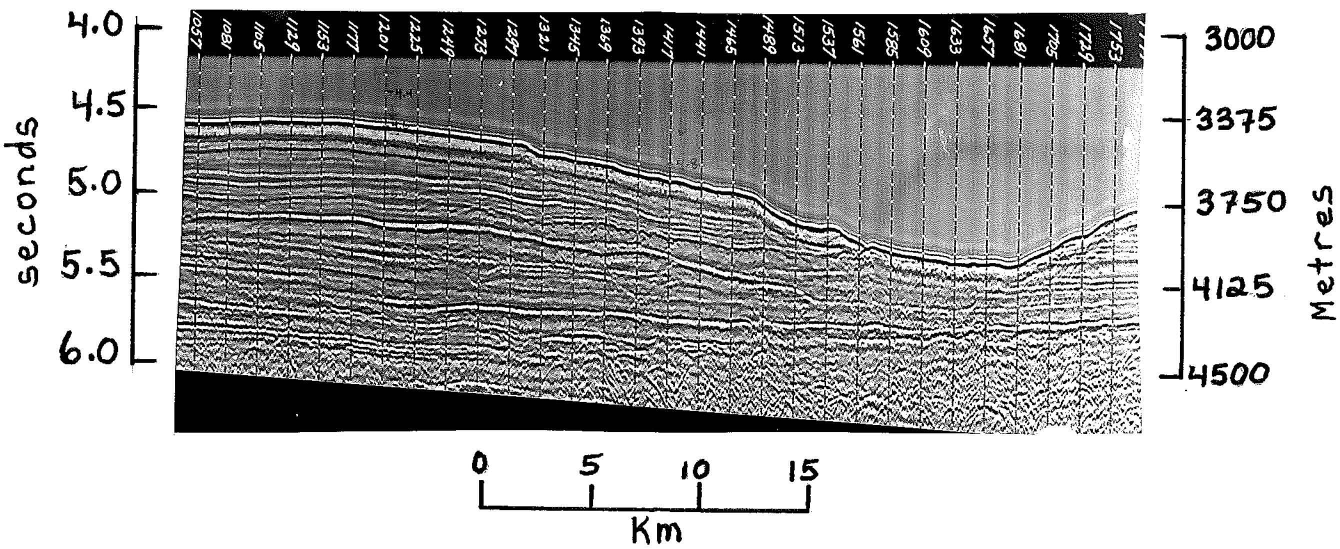
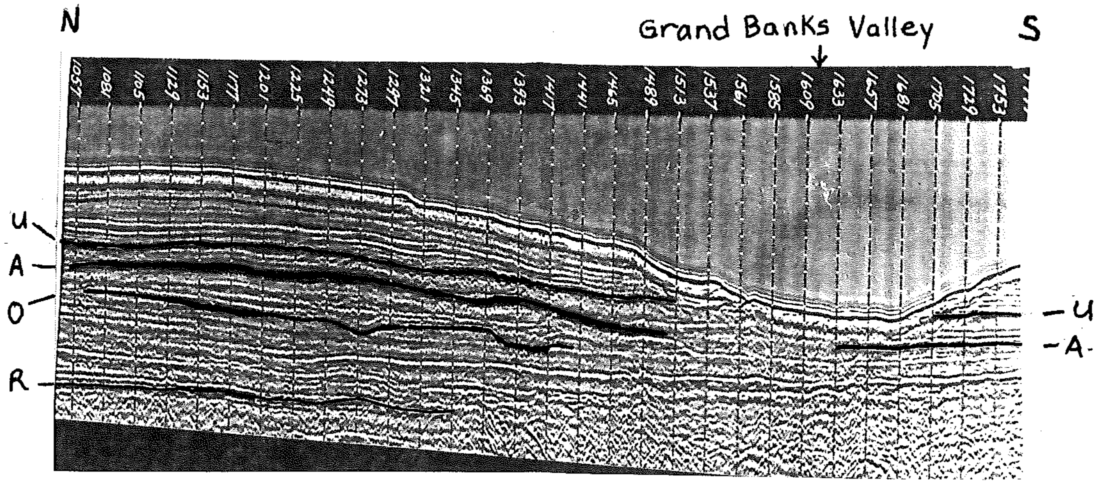

W
Eastern Valley
I-14
SP 937
E
U
A
O
0

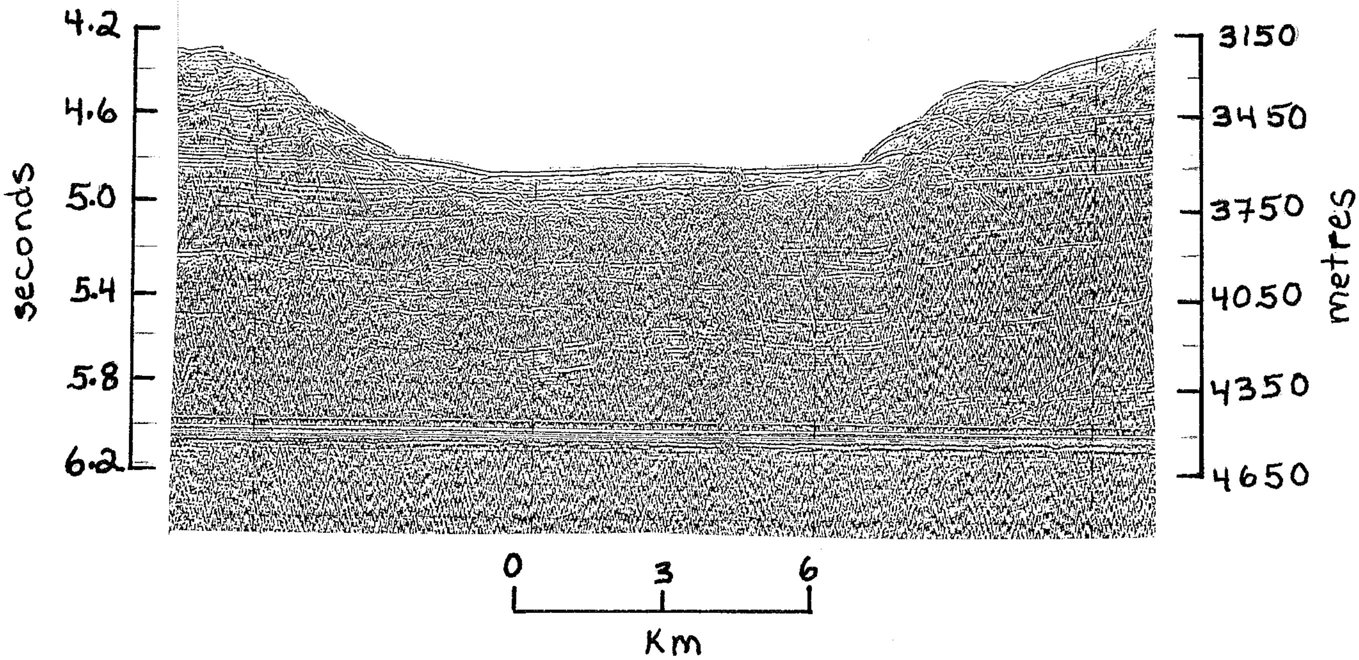
Fig. 7


4.0
4.5
5.0
5.5
6.0
seconds
3000
3375
3750
4125
4500
Metres
0
5
10
15
Km

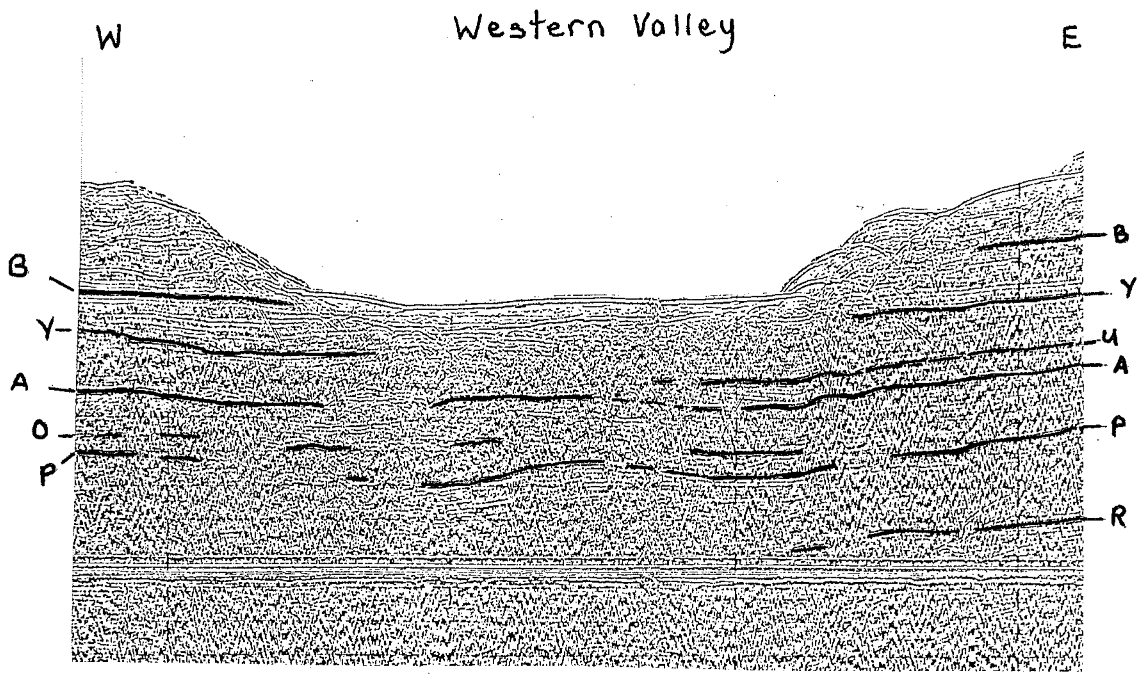

N
Grand Banks Valley
S
U
A
O
R
U
A

I-14

Fig. 8



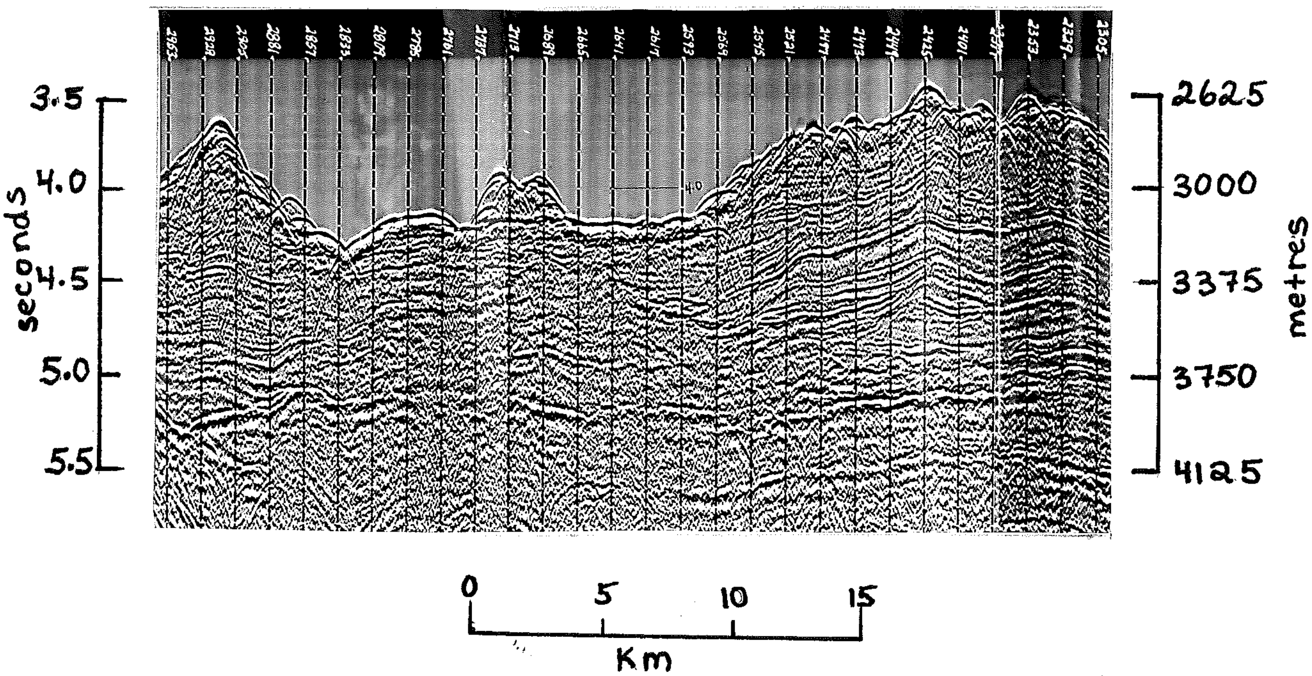
4.2
4.6
5.0
5.4
5.8
6.2
seconds
3150
3450
3750
4050
4350
4650
metres
0
3
6
Km

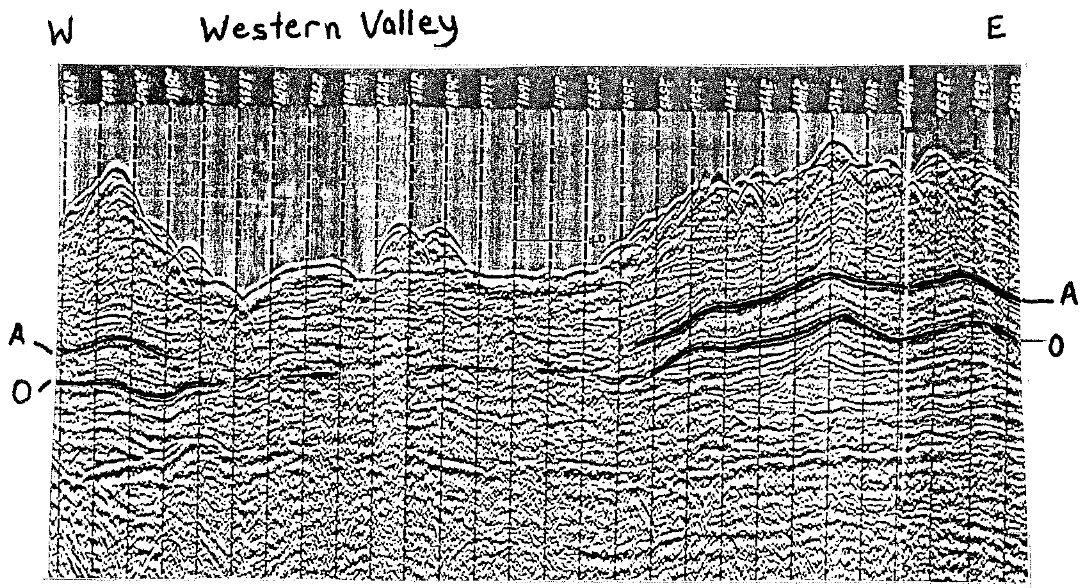


Western Valley
W
E
B
Y
A
O
P
B
Y
U
A
P
R

78-022

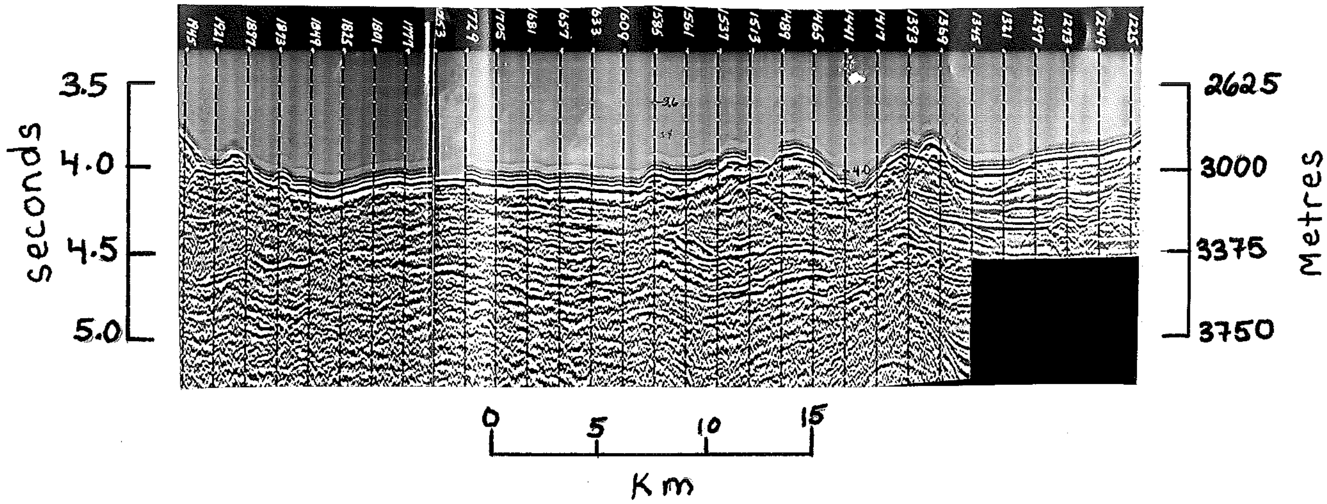
Fig. 9

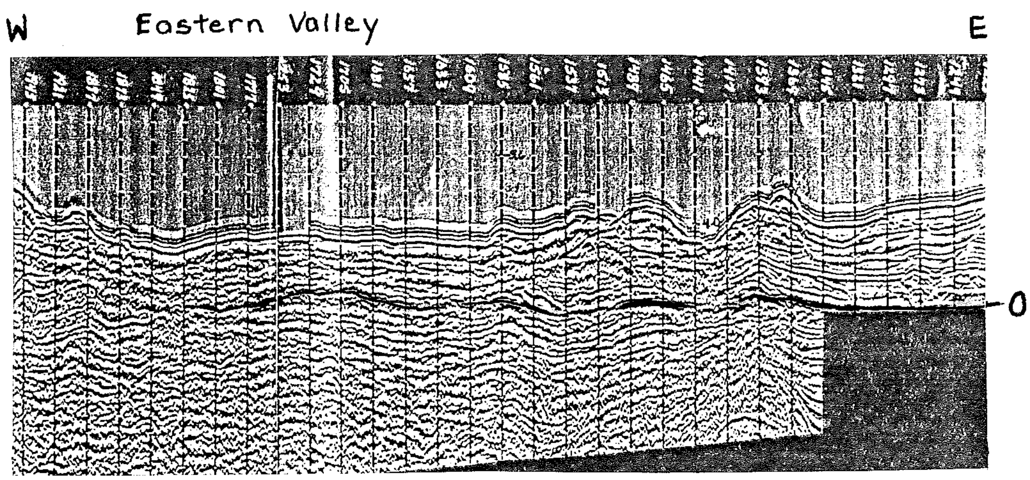

3.5
4.0
4.5
5.0
5.5
seconds
2625
3000
3375
3750
4125
metres
0
5
10
15
Km


W
Western Valley
E
A
O
A
O

I-60

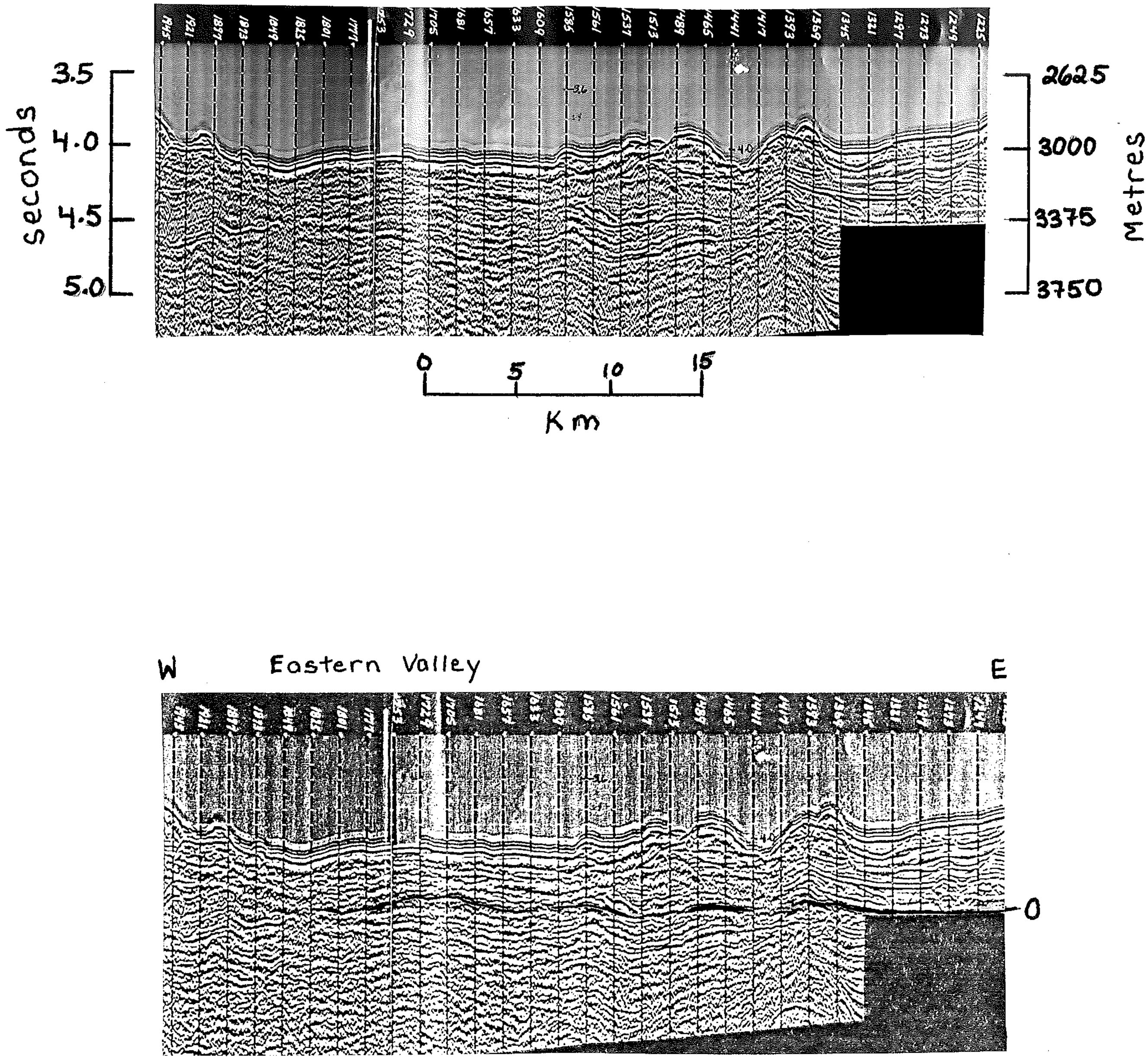
Fig. 10


3.5
4.0
4.5
5.0
seconds
2625
3000
3375
3750
Metres
0
5
10
15
Km


W
Eastern Valley
E
0

I - 60

Fig. 11


3.5
4.0
4.5
5.0
seconds
2625
3000
3375
3750
Metres
0
5
10
15
Km
W
Eastern Valley
E
0

I - 60

Fig. 11

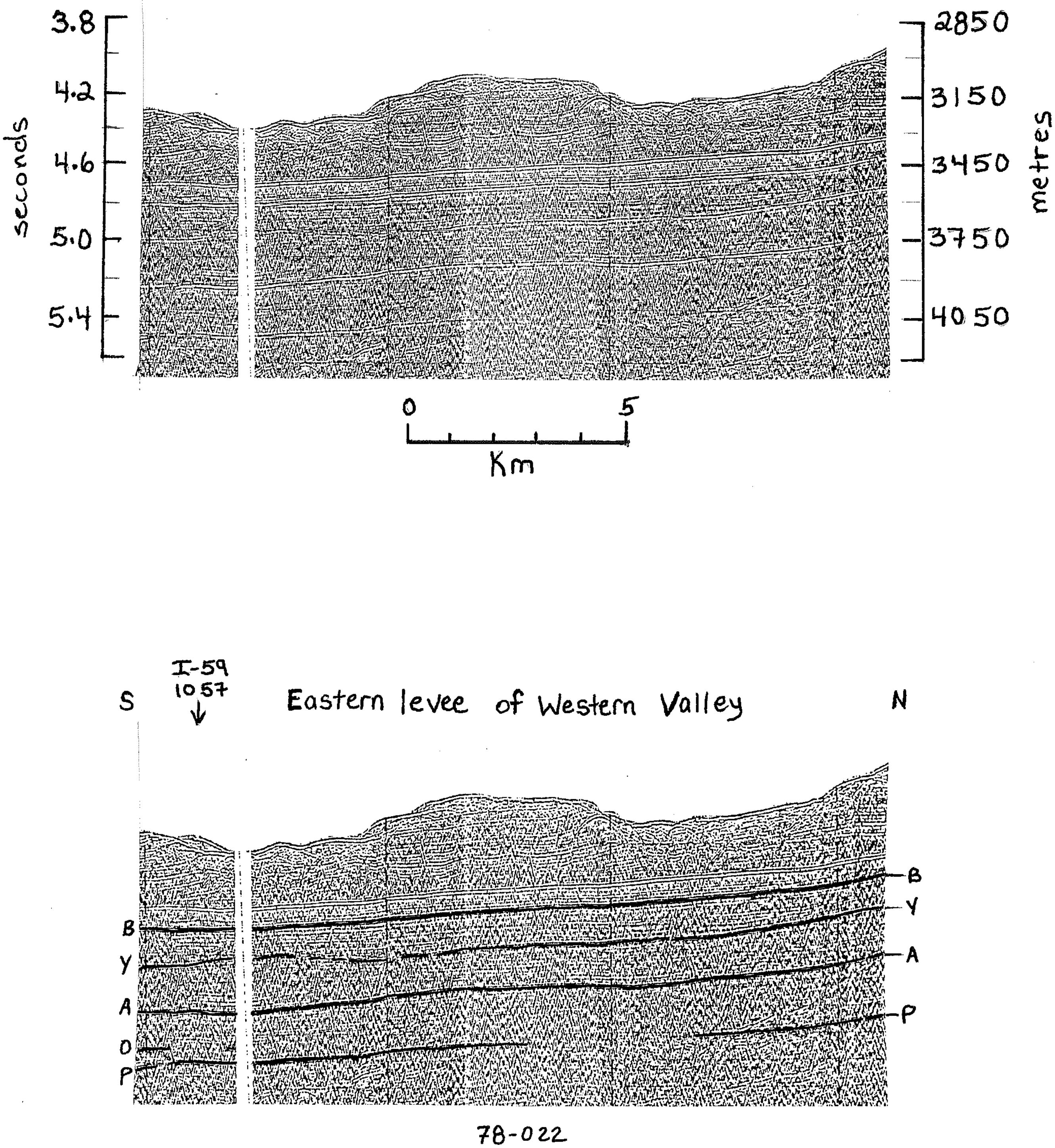

3.8
4.2
4.6
5.0
5.4
seconds
2850
3150
3450
3750
4050
metres
0
5
Km
I-59
1057
S
Eastern levee of Western Valley
N
B
Y
A
O
P
B
Y
A
P
78-022

Fig. 12

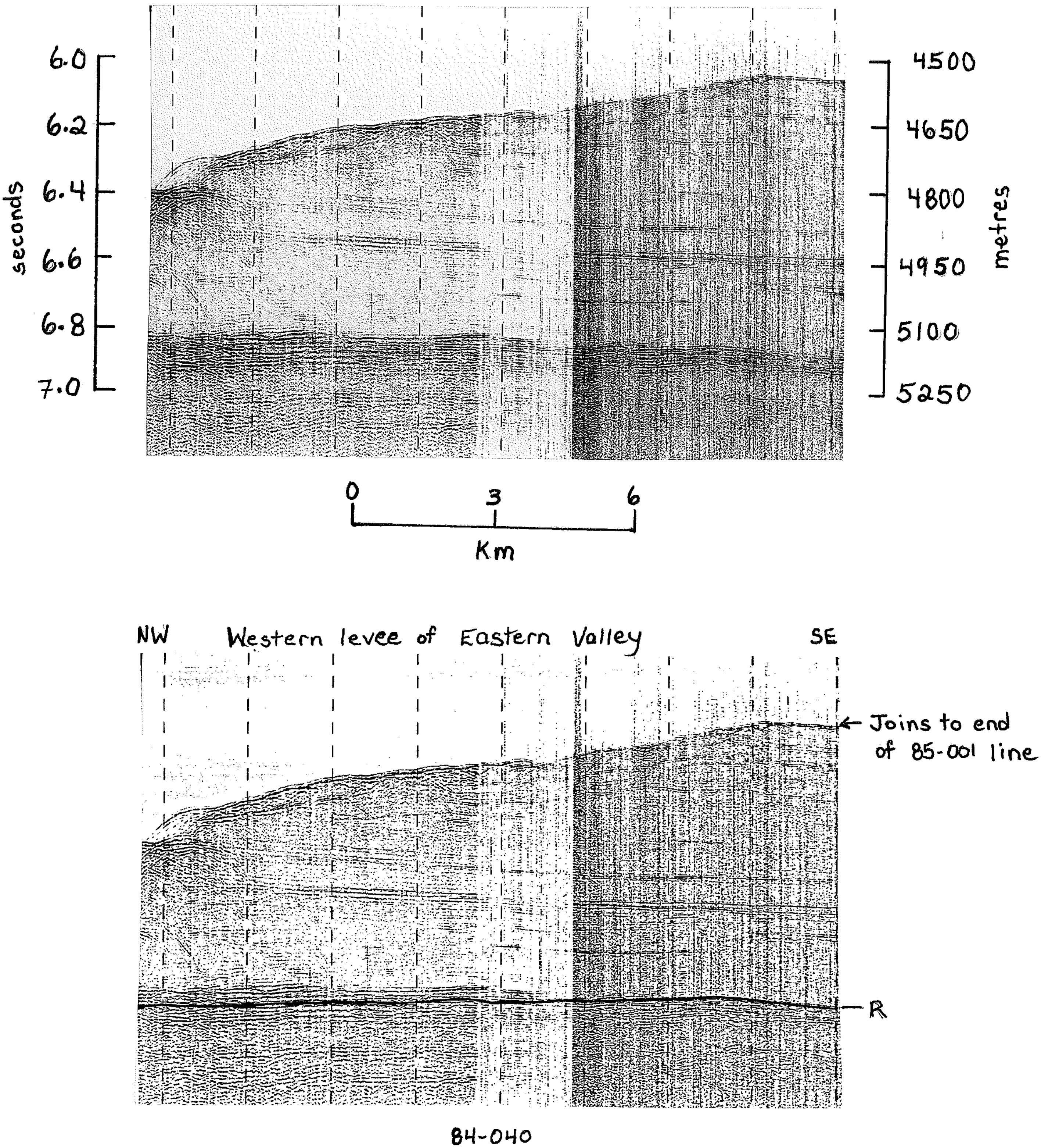
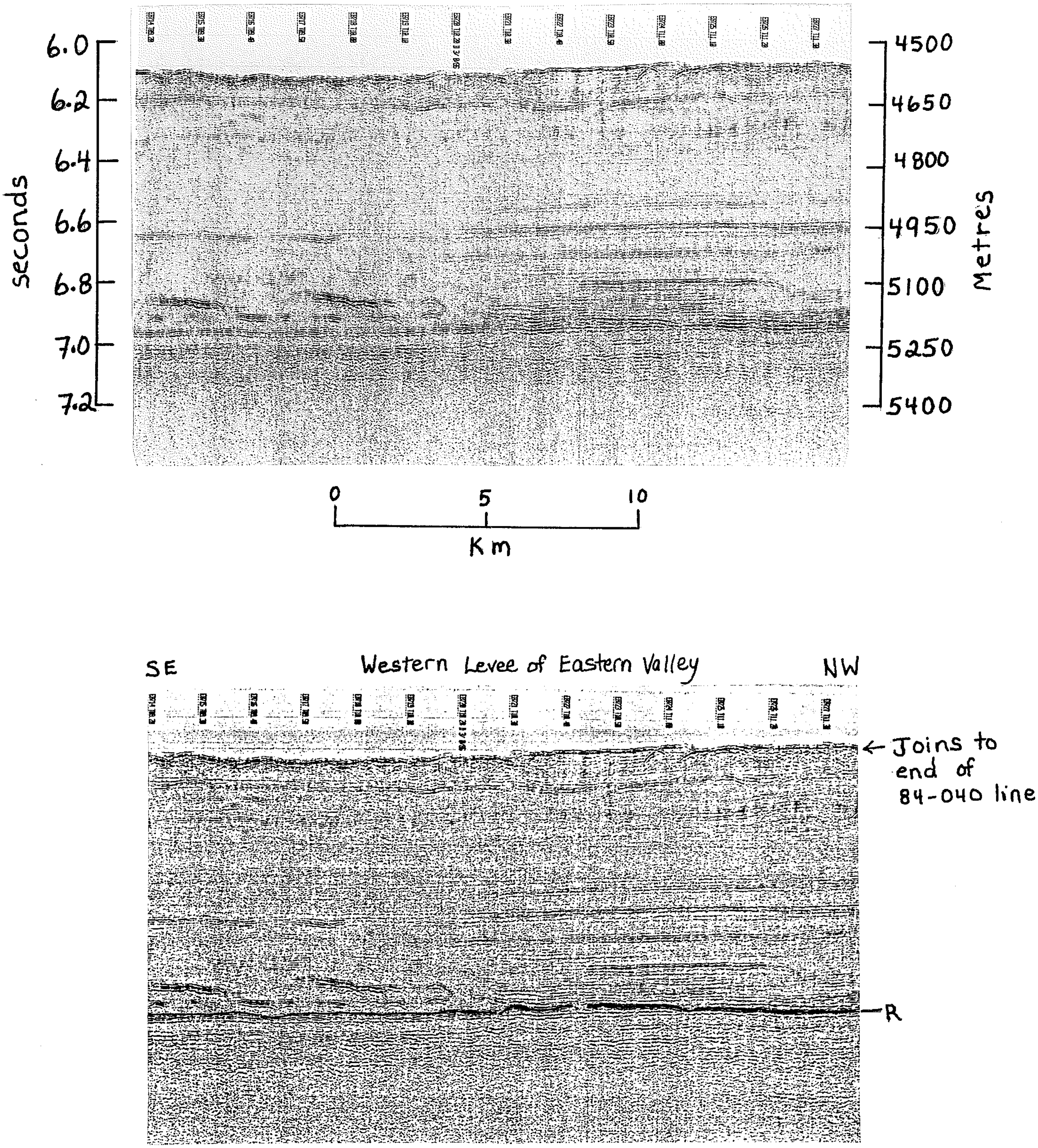

6.0
6.2
6.4
6.6
6.8
7.0
seconds
4500
4650
4800
4950
5100
5250
metres
0
3
6
Km
NW
Western levee of Eastern Valley
SE
Joins to end of 85-001 line
R
84-040

Fig. 13



6.0
6.2
6.4
6.6
6.8
7.0
7.2
seconds
4500
4650
4800
4950
5100
5250
5400
Metres
0
5
10
Km
SE
Western Levee of Eastern Valley
NW
← Joins to end of 84-040 line
R

85-001

Fig. 14

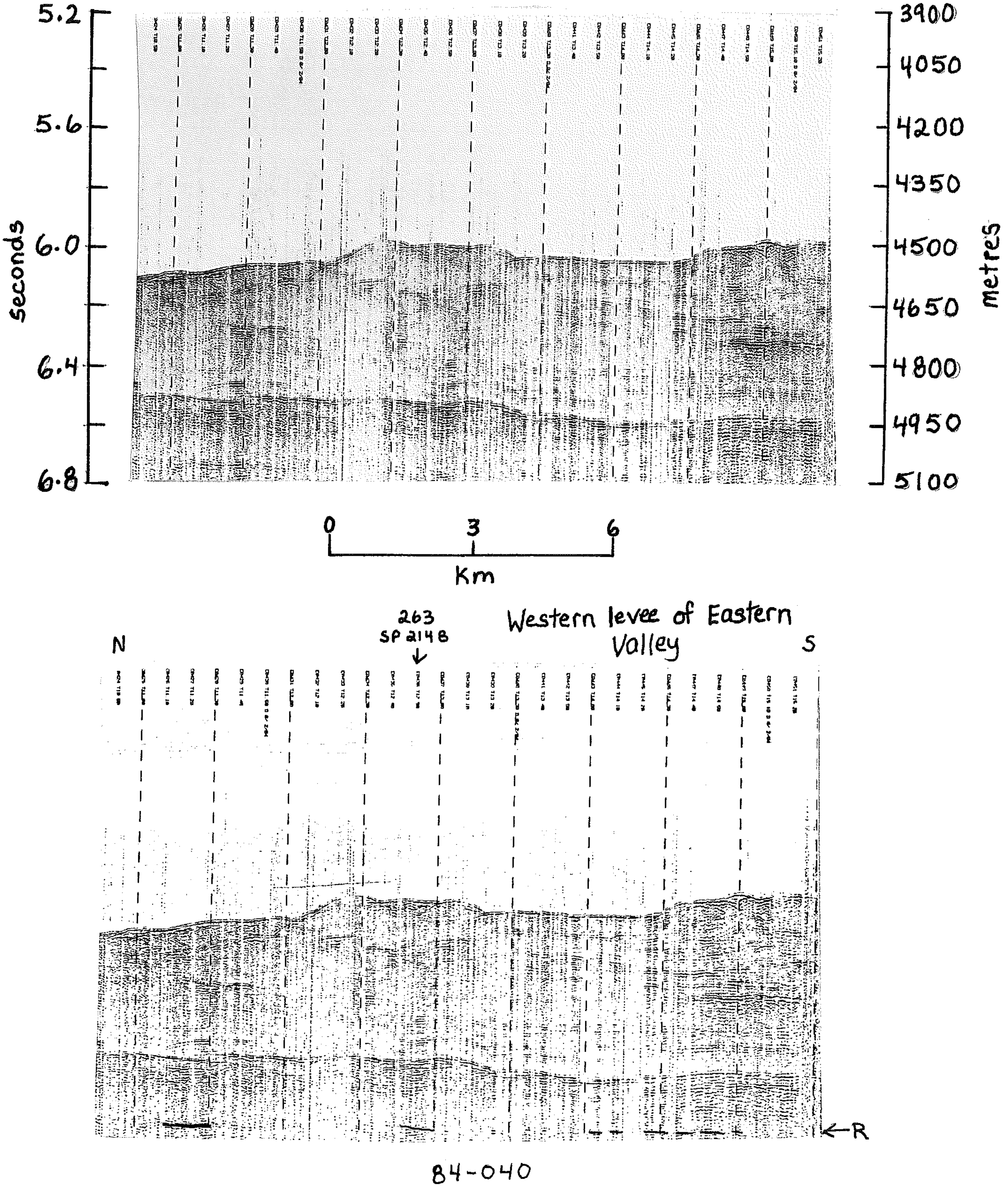
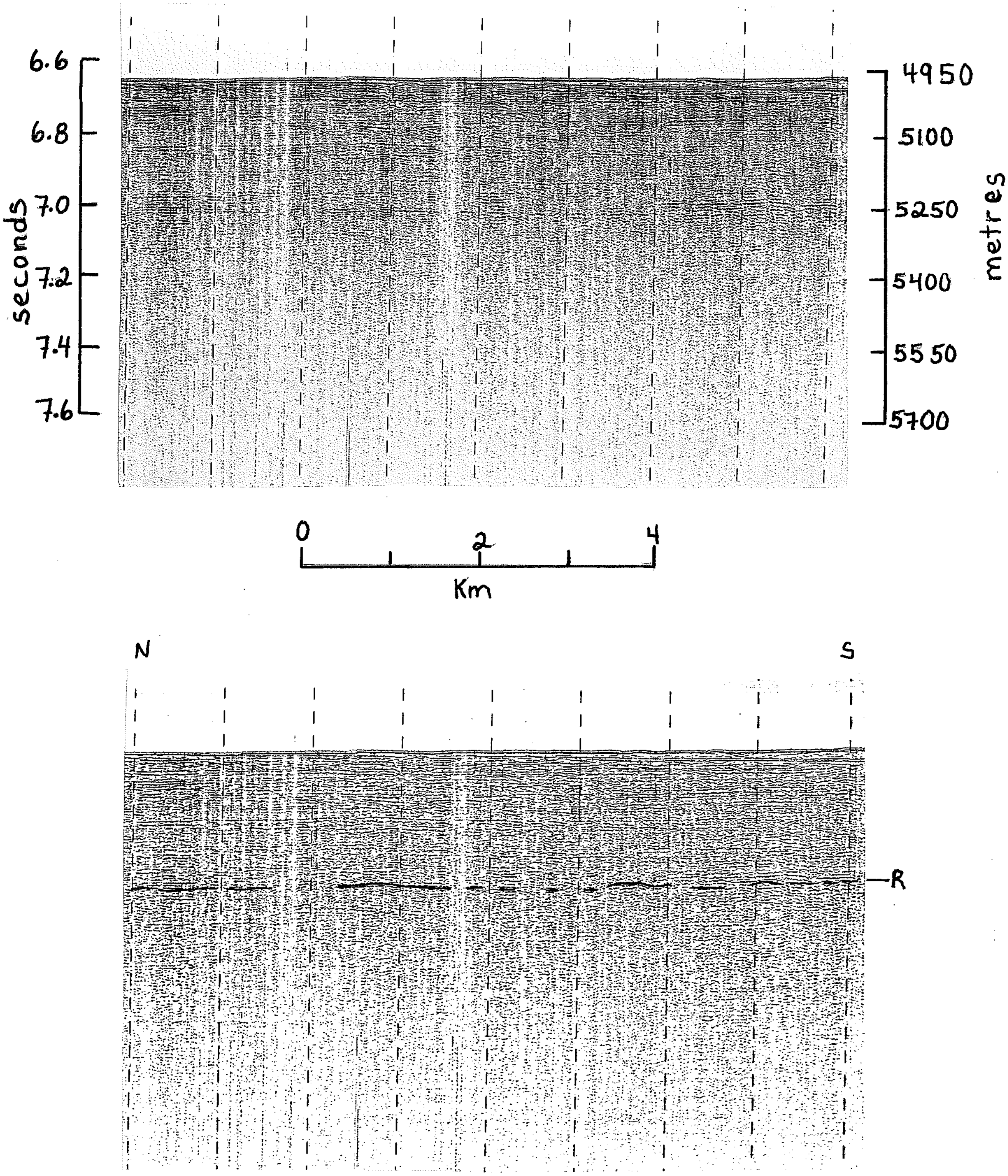

5.2
5.6
6.0
6.4
6.8
seconds
3900
4050
4200
4350
4500
4650
4800
4950
5100
metres
0
3
6
Km
263
SP 214B
Western levee of Eastern Valley
N
S
R
84-040

Fig. 15



6.6
6.8
7.0
7.2
7.4
7.6
seconds
4950
5100
5250
5400
5550
5700
metres
0
2
4
Km
N
S
R

84-040

Fig. 16

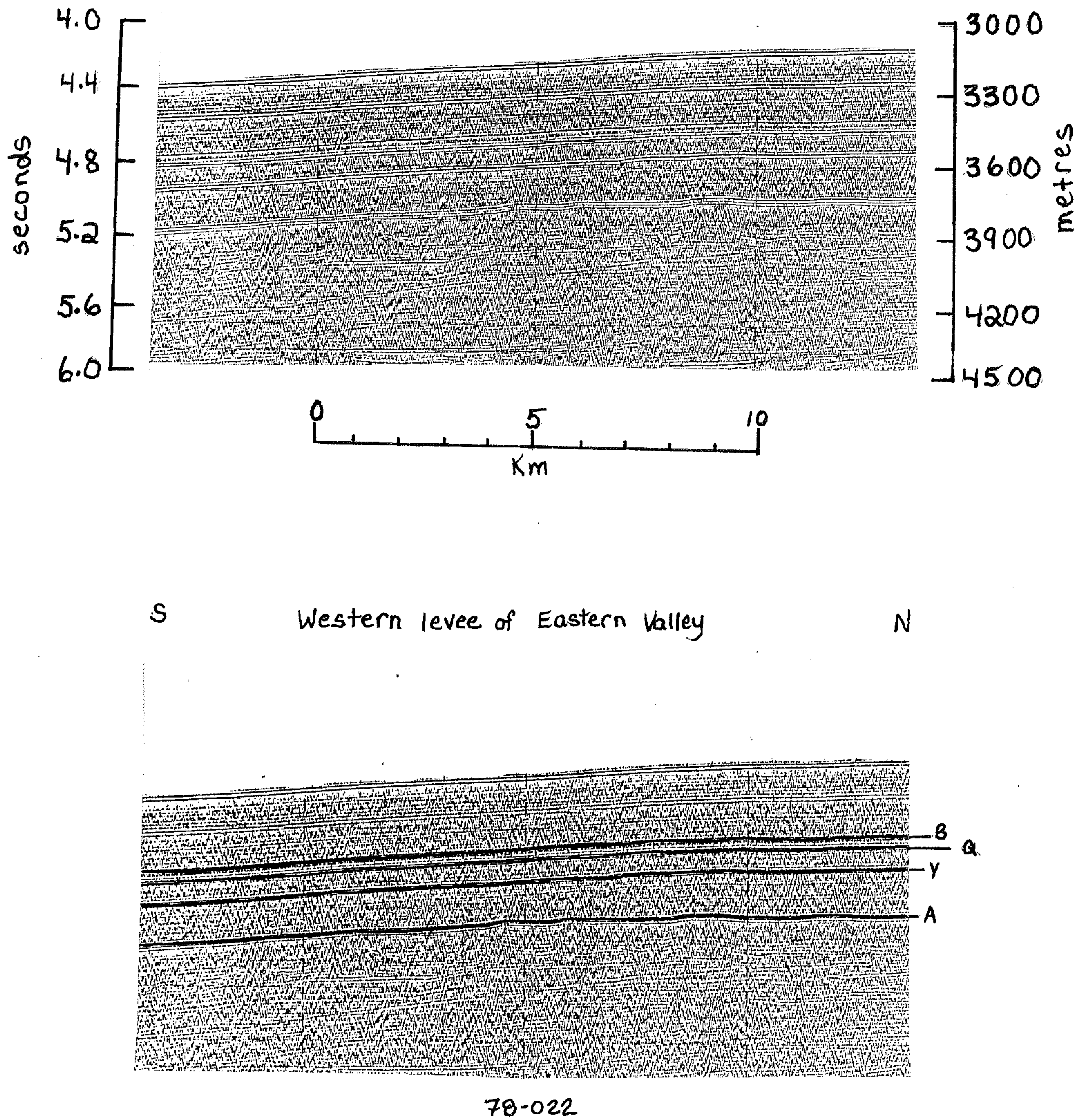
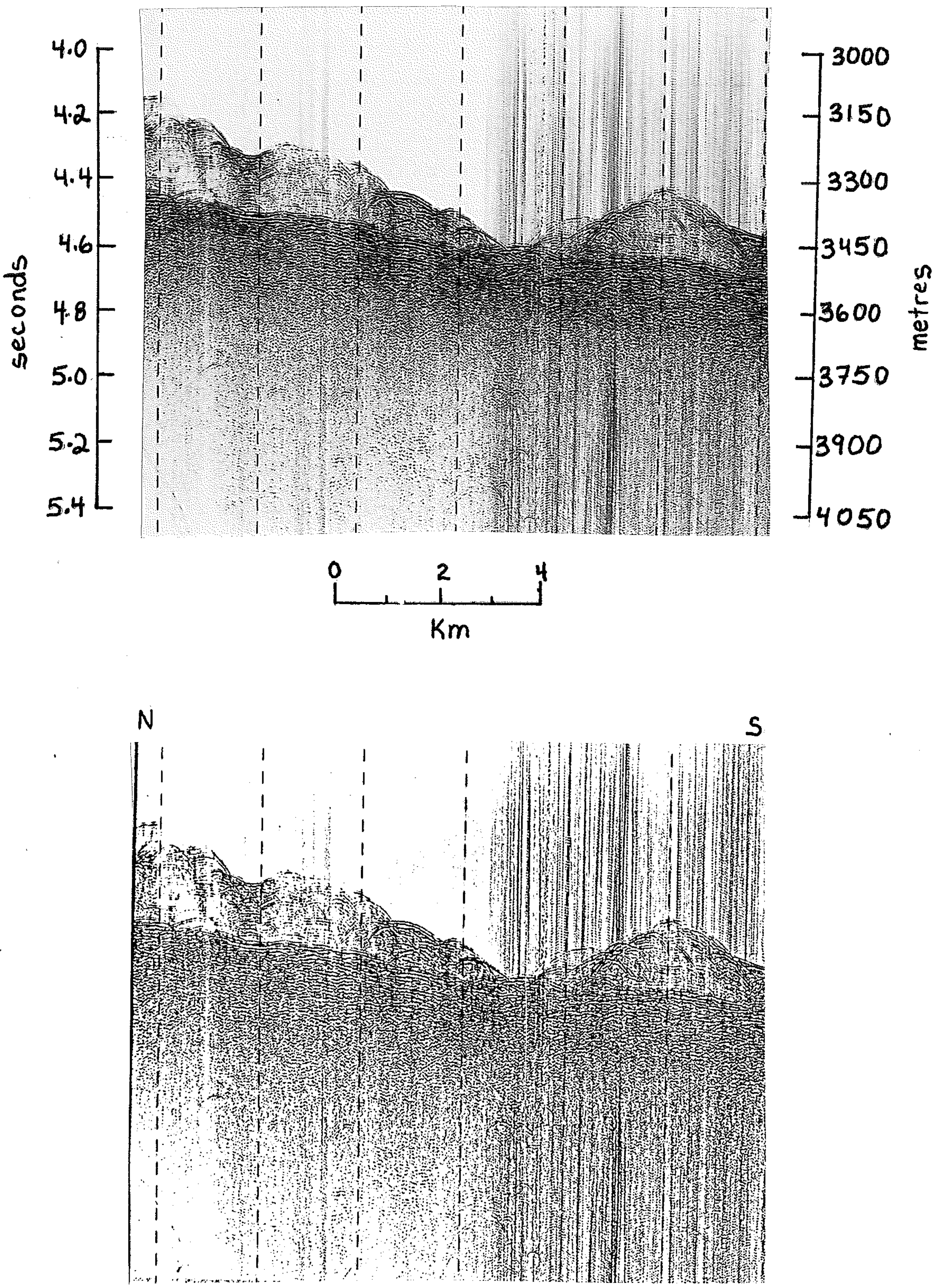

4.0
4.4
4.8
5.2
5.6
6.0
seconds
3000
3300
3600
3900
4200
4500
metres
0
5
10
Km
S
Western levee of Eastern Valley
N
B
a
Y
A
78-022

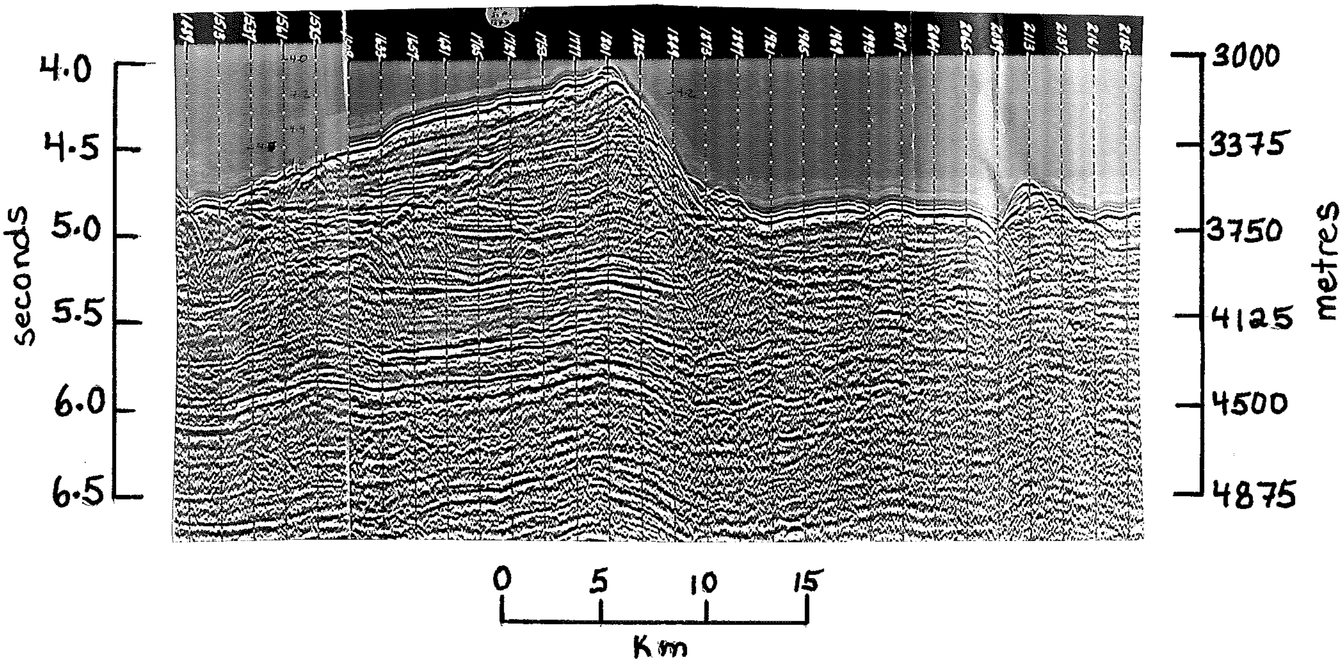
Fig. 17

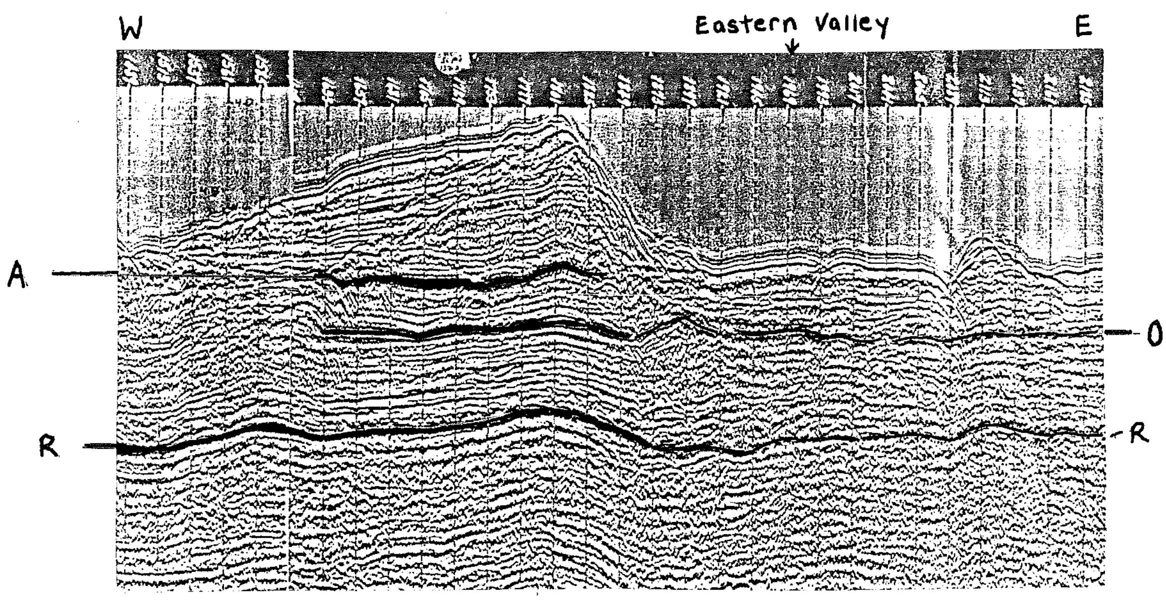


4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
seconds
3000
3150
3300
3450
3600
3750
3900
4050
metres
0
2
4
Km
N
S

84-040

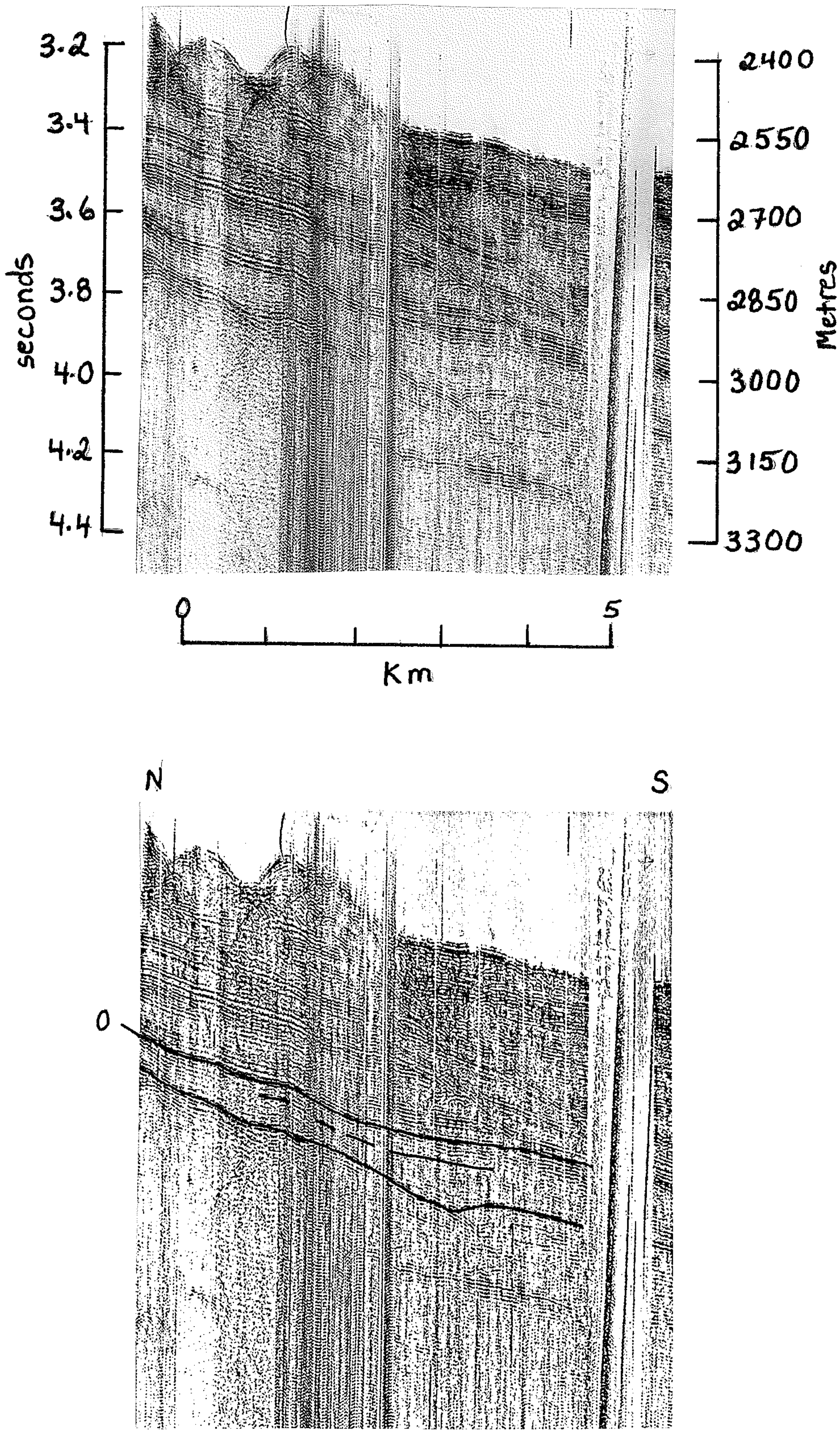
Fig. 18


4.0
4.5
5.0
5.5
6.0
6.5
seconds
3000
3375
3750
4125
4500
4875
metres
0
5
10
15
Km


W
Eastern Valley
E
A
0
R
R

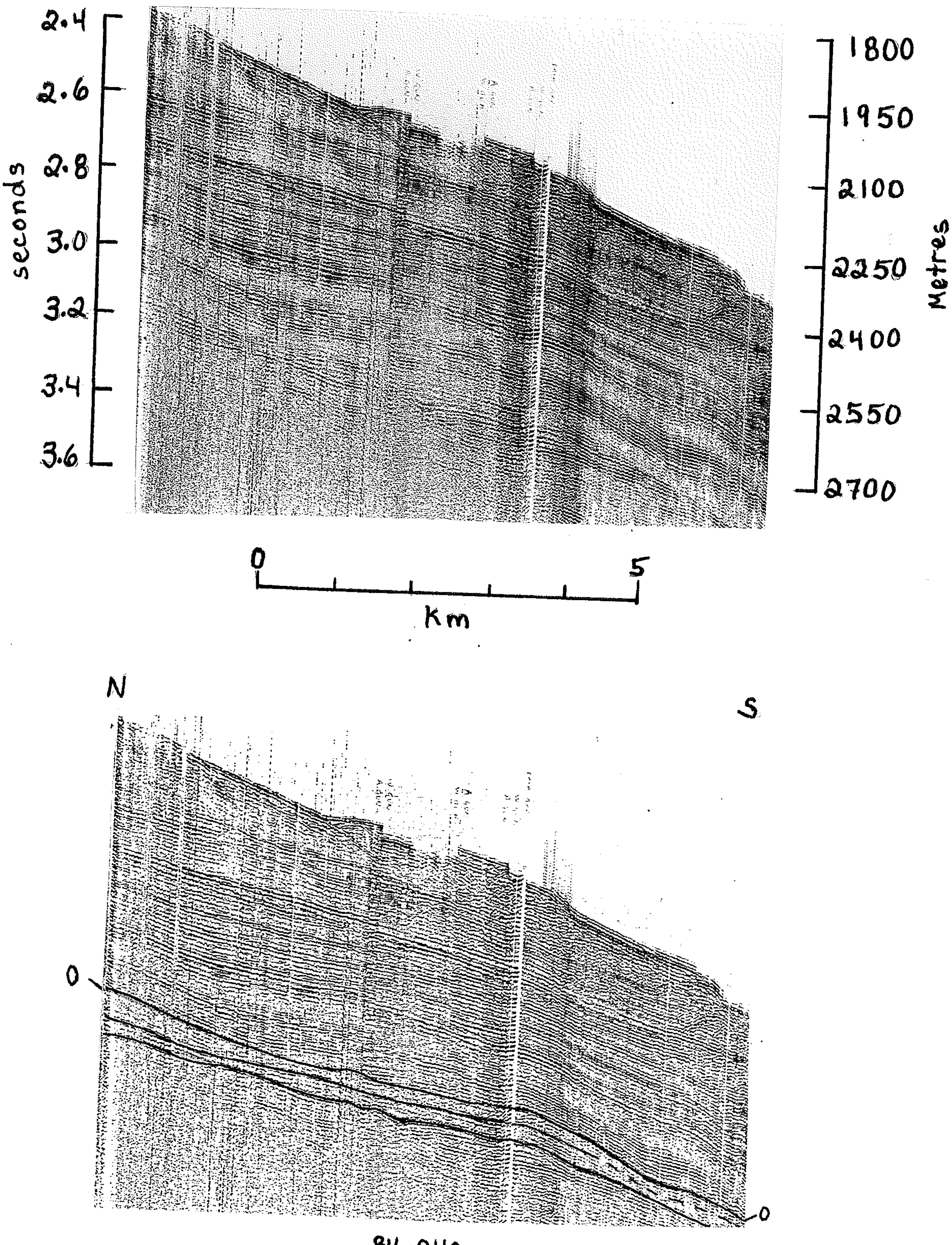
I-59

Fig. 19


3.2
3.4
3.6
3.8
4.0
4.2
4.4
seconds
2400
2550
2700
2850
3000
3150
3300
Metres
0
5
Km
N
S
0

84-040

Fig. 20



2.4
2.6
2.8
3.0
3.2
3.4
3.6
seconds
1800
1950
2100
2250
2400
2550
2700
Metres
0
5
Km
N
S
0
0

84-040

Fig. 21

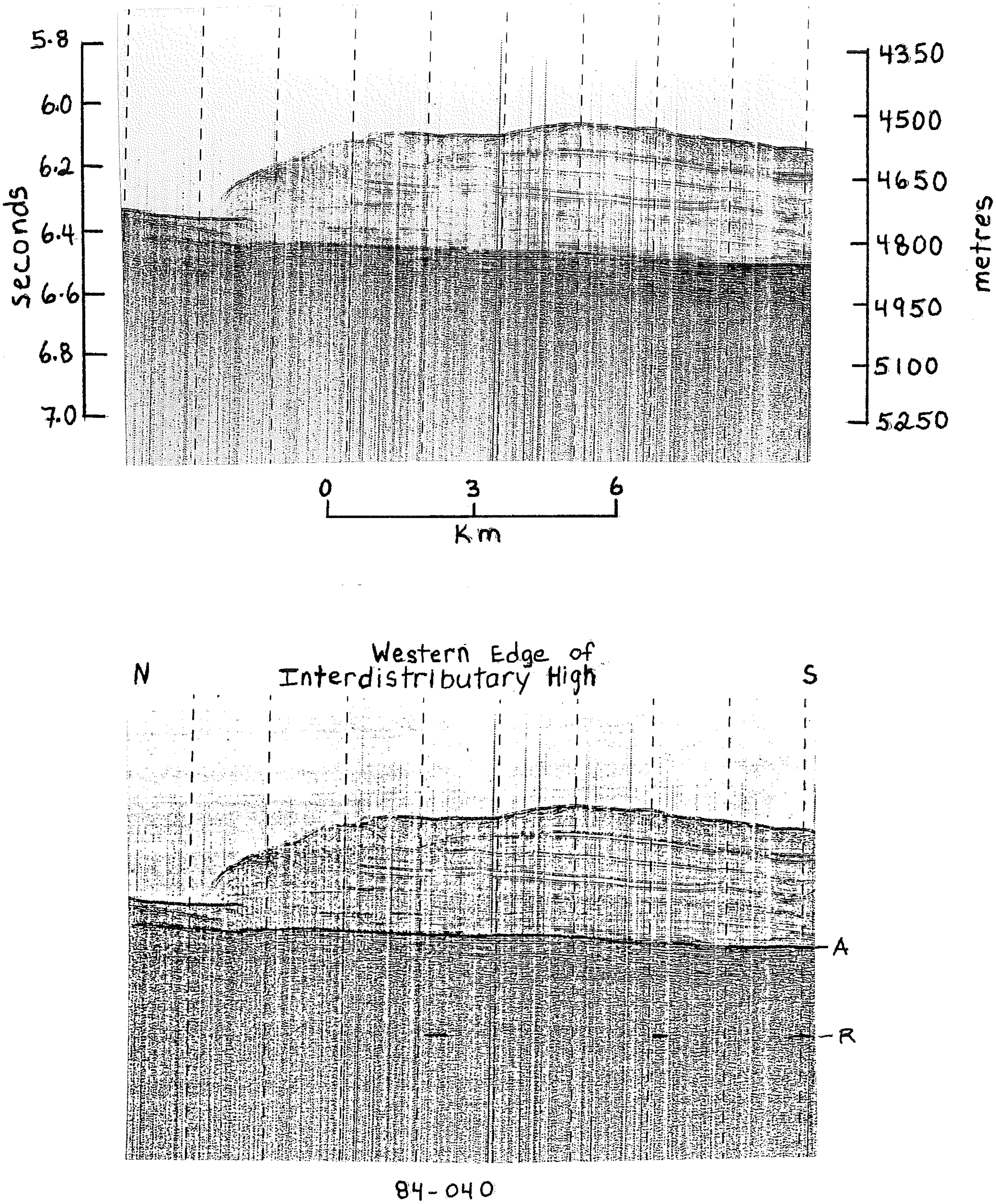

5.8
6.0
6.2
6.4
6.6
6.8
7.0
seconds
4350
4500
4650
4800
4950
5100
5250
metres
0
3
6
Km
Western Edge of
Interdistributary High
N
S
A
R
84-040

Fig. 23

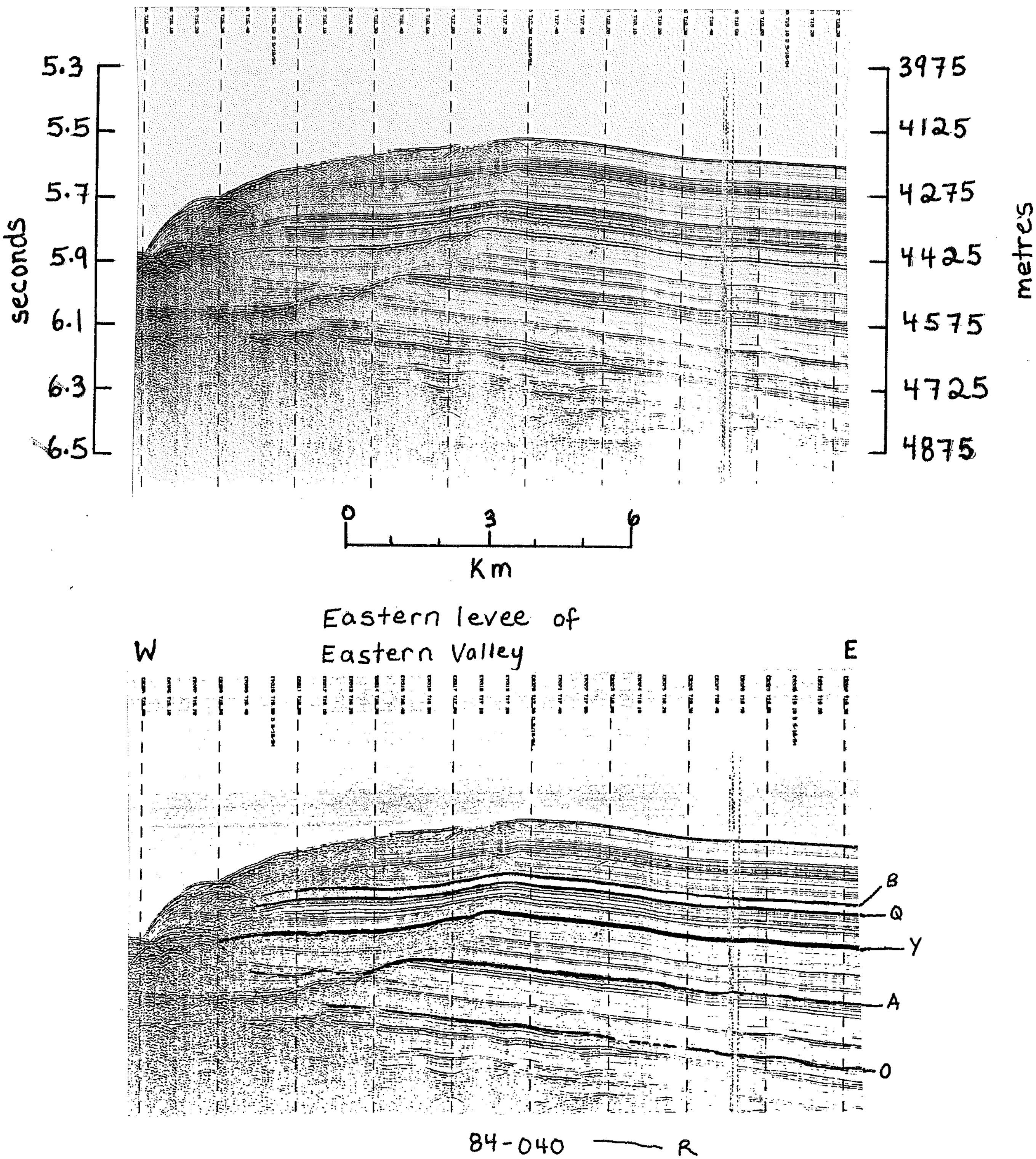
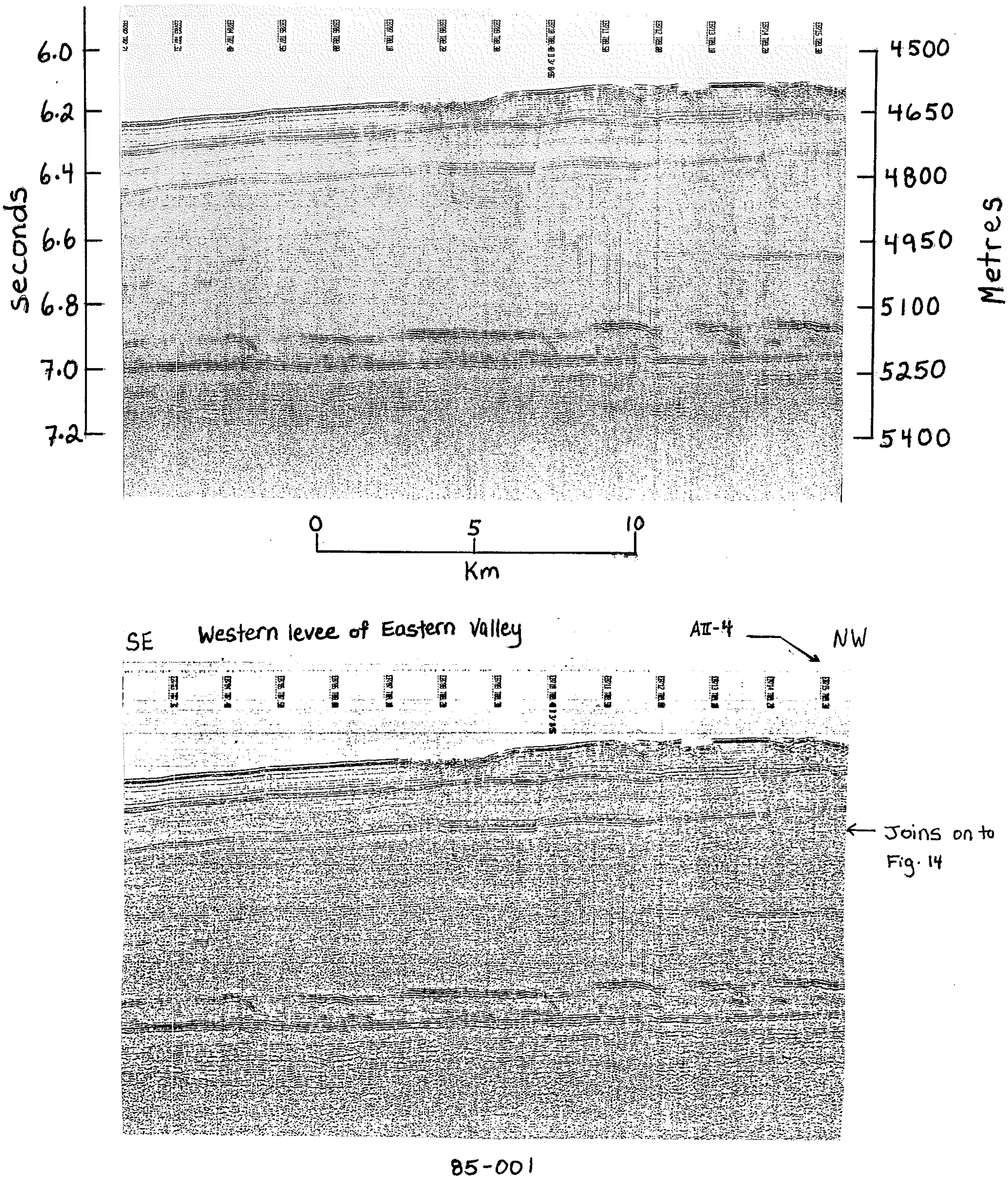

5.3
5.5
5.7
5.9
6.1
6.3
6.5
seconds
3975
4125
4275
4425
4575
4725
4875
metres
0
3
6
Km
Eastern levee of
Eastern Valley
W
E
B
Q
Y
A
O
84-040 —— R

Fig. 24



6.0
6.2
6.4
6.6
6.8
7.0
7.2
Seconds
4500
4650
4800
4950
5100
5250
5400
Metres
0
5
10
Km
SE
Western levee of Eastern Valley
AII-4
NW
Joins on to Fig. 14
85-001

Fig. 25