COMPARISON OF ACCELEROMETERS AND GEOPHONES

Ralph Knapp and Andrew Kalik

Kansas Geological Survey
The University of Kansas
Lawrence, Kansas 66046

February 4, 1988

Open-file Report No. 88-1

Kansas Geological Survey
Open-file Report

Disclaimer

The Kansas Geological Survey does not guarantee this document to be free from errors or inaccuracies and disclaims any responsibility or liability for interpretations based on data used in the production of this document or decisions based thereon. This report is intended to make results of research available at the earliest possible date, but is not intended to constitute final or formal publication.

ABSTRACT

Terracable accelerometers and Mark Products L40 100 Hz geophones were compared in a side-by-side test to determine the feasibility of improving high-frequency signal response by using accelerometers instead of geophones. The following conclusions are made:

(1) Accelerometers require substantially less recording gain than geophones because of a built-in preamplifier. This difference is about 20 dB.

(2) At frequencies greater than 200 Hz, the accelerometer appears to be modestly more sensitive than an accelerometer-converted geophone by 1-3 dB; however, this apparent increase may be mostly noise perhaps due to the preamplifier.

(3) The geophone output is more stable than the accelerometer output.

(4) The geophone is more convenient to use.

INTRODUCTION

Accelerometers are more sensitive at high frequencies than geophones for two basic reasons: (1) The output of an accelerometer is approximately the derivative of the velocity-sensitive geophone and, hence, has a sensitivity increase of 6 dB/octave; (2) the accelerometer has a smaller mass than the geophone and, hence, has less of an inertial resistance at high frequencies. Within the second advantage lies the true potential value of the accelerometer. Is it a better receiving device?

The first advantage of accelerometers is easily overcome by differentiating the output of the geophone. This is accomplished by one of two methods:

(1) The geophone output can be convolved with a difference operator such as (1, -1) or (1, 0, -1). The latter is preferred because it reduces the amplification of high-frequency noise and does not time shift the data. It accurately approximates differentiation to about one-fourth the Nyquist frequency.

(2) In the frequency domain, differentiation is accomplished by multiplying each frequency component by the frequency value and shifting phase by 90 degrees. Phase shifting is accomplished by mapping real to imaginary and imaginary to negative real.

$$F(\omega) = \mathrm{FFT}[f(t)]$$
$$F^* (\omega) = \mathrm{Imag}\ [F(\omega)] + i\ (\mathrm{Real}[F(\omega)].$$
$$f^*(t) = \mathrm{FFT}^{-1}\ [F^*(\omega)]$$

Note that $f^*(t)$ is the quadrature trace.

FIELD METHOD

Geophones and accelerometers were placed side-by-side at 5-meter group intervals. The accelerometers came three on a string and were bunched together. Single geophones were used. A .50-caliber rifle fired into a 30-inch deep auger hole was used as the source. The source was 29.5 m from the near geophone-accelerometer pair. Figure 1 is the field notes for the project. To compare different frequency bands, four different low-cut filter settings were used. They were low-cut open, 240 Hz, 340 Hz, and 480 Hz. Filter slope is 24 dB/octave. Sample interval is 0.25 milliseconds.

PROCEDURE

Four files were selected; one for each filter setting. These are plotted as Figures 2, 5, 8, and 11. The geophone response traces were converted to acceleration using time domain differentiation [(-1, 0, 1) operator]. These are Figures 3, 6, 9, and 12. Note the visual similarity between accelerometer and accelerometer-converted geophone output responses.

Amplitude spectra were plotted for both accelerometers and accelerometer-converted geophones. A 16 ms window, centered on the strong reflector at 85 ms, was used for the comparison. The spectra are normalized and plotted side-by-side. The difference between the two spectra is also plotted. These are Figures 4, 7, 10, and 13.

The spectra are an average of all traces over a window between 70 and 134 ms designed to test reflection response.

RESULTS

Except on Figure 13, the differences between accelerometer and geophone response are negligible. The extreme difference on Figure 13, due to a "bump" in the accelerometer curve, is interpreted to be a noise instability of the accelerometers. Note on Figure 12 that the accelerometer response appears to be noisier than the geophone response.

CONCLUSIONS

Because accelerometers require batteries and are more fragile than geophones, the use of accelerometers is judged to be less desirable compared to the use of geophones. They are less durable and more prone to physical damage and breakage than geophones. The field durability of geophones is well established.

As expected, accelerometers appear to be more sensitive than geophones at frequencies greater than 200 Hz; however, this sensitivity increase is extremely slight (not greater than 3 dB) and does not offset the hassle factor of the accelerometers. The suspicion that accelerometers have an unstable, inconsistent response is damning in comparison to the very stable and consistent response of geophones.

FIGURE CAPTIONS

FIG. 1. Observer notes for test. Files used for this report are 3, 5, 8, and 11.

FIG. 2. Field files comparing accelerometers and geophones. Low-cut filters are open.

FIG. 3. Field files comparing accelerometers and differentiated geophones. Low-cut filters are open. Dark window for Figure 4 is indicated by the box. Note that the geophone appears to be less susceptible to ground-roll noise.

FIG. 4. Average amplitude spectra of accelerometers and differentiated geophones for the time window indicated in Figure 3. The difference in dB is also plotted.

FIG. 5. Field files comparing accelerometers and geophones. Low-cut filters are 240 Hz, 24 dB/octave.

FIG. 6. Field files comparing accelerometers and differentiated geophones. Low-cut filters are 240 Hz.

FIG. 7. Average amplitude spectra of accelerometers and differentiated geophones. The difference in dB is also plotted.

FIG. 8. Field files comparing accelerometers and geophones. Low-cut filters are 340 Hz, 24 dB/octave.

FIG. 9. Field files comparing accelerometers and differentiated geophones. Low-cut filters are 340 Hz. Note that the data appear to be noisier on the accelerometers beneath 130 ms.

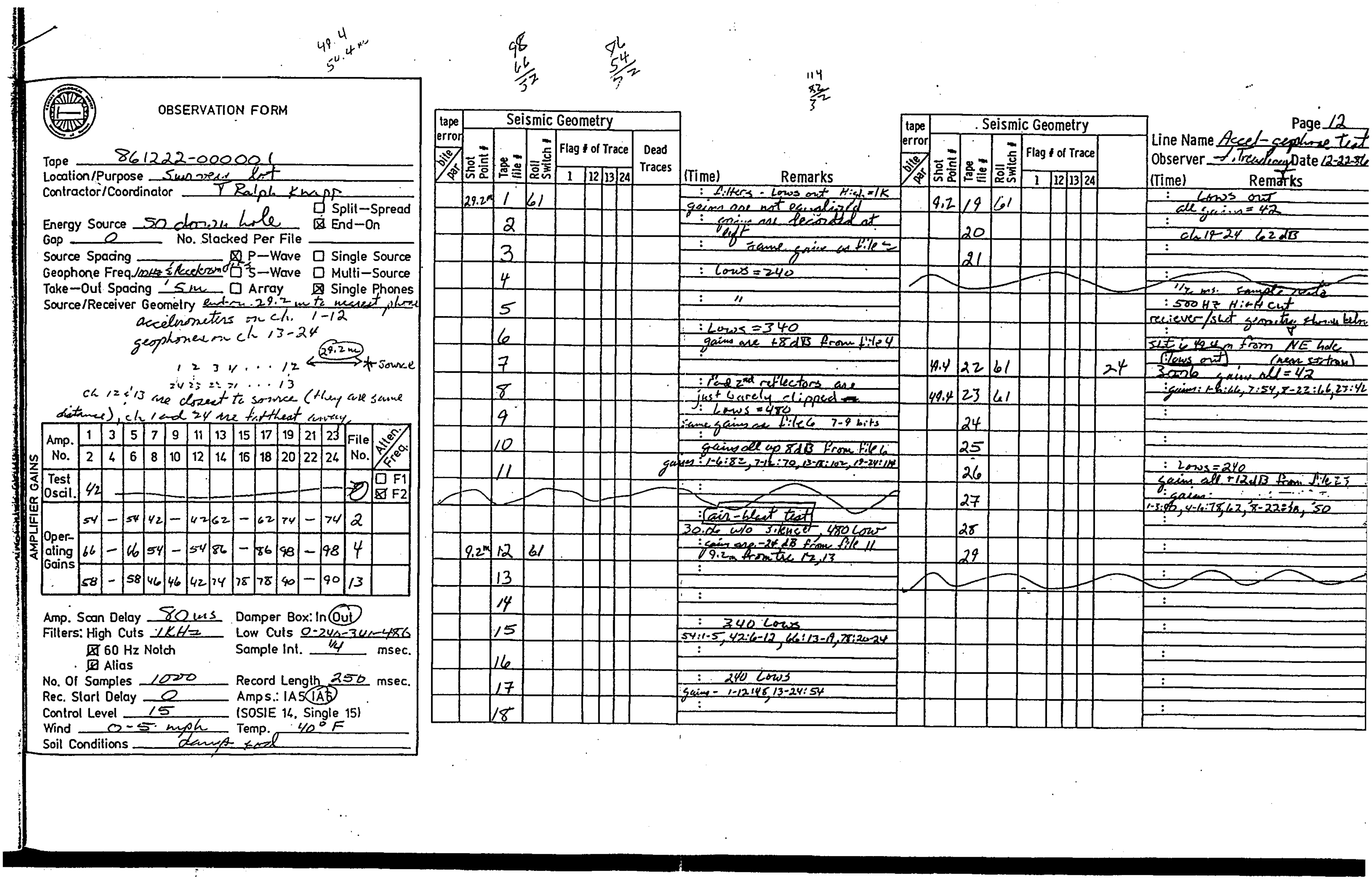
FIG. 10. Average amplitude spectra of accelerometers and accelerometer-converted geophones for the time window

FIG. 11. Field files comparing accelerometers and geophones. Low-cut filters are 480 Hz, 24 dB/octave.

FIG. 12. Field files comparing accelerometers and differentiated geophones, low-cut filters, are 480 Hz. Note that the accelerometer output appears to be noisier than the geophone output.

FIG. 13. Average amplitude spectra of accelerometers and differentiated geophones. The difference in dB is also plotted. Note the

anomalous "bulge" in the accelerometer spectrum between 400 and 1000 Hz. Because it is radically different than the other spectra plotted (Figures 4, 7, and 10), it indicates an instability of the accelerometer output. It is probably the noise seen on Figure 12.



49.4
50.4m

98
66
32

86
54
32

114
82
32

OBSERVATION FORM

Tape 861222-000001
Location/Purpose Sunrise lot
Contractor/Coordinator T Ralph Knapp
Energy Source 50 down hole ☐ Split—Spread ☒ End—On
Gap 0 No. Stacked Per File
Source Spacing ☒ P—Wave ☐ Single Source
Geophone Freq. 100Hz & Accelerometers ☐ S—Wave ☐ Multi—Source
Take—Out Spacing .5m ☐ Array ☒ Single Phones
Source/Receiver Geometry end-on. 29.2 m to nearest phone
accelerometers on ch. 1-12
geophones on ch 13-24

1 2 3 4 . . . 12 ←29.2m→ ✱ Source
24 23 22 21 . . . 13

ch 12 & 13 are closest to source (they are same distance), ch 1 and 24 are farthest away.

AMPLIFIER GAINS

Amp. No.	1 2	3 4	5 6	7 8	9 10	11 12	13 14	15 16	17 18	19 20	21 22	23 24	File No.	Atten. / Freq.
Test Oscil.	42												0	☐ F1 ☒ F2
Operating Gains	54	—	54	42	—	42	62	—	62	74	—	74	2	
	66	—	66	54	—	54	86	—	86	98	—	98	4	
	58	-	58	46	46	42	74	78	78	90	—	90	13	

Amp. Scan Delay 80 ms Damper Box: In [✓ Out]
Filters: High Cuts 1KHz Low Cuts 0-240-340-480
☒ 60 Hz Notch Sample Int. 1/4 msec.
☒ Alias
No. Of Samples 1000 Record Length 250 msec.
Rec. Start Delay 0 Amps.: IA5 [✓ IA6]
Control Level 15 (SOSIE 14, Single 15)
Wind 0-5 mph Temp. 40° F
Soil Conditions damp sod

tape error bite/par	Shot Point #	Tape file #	Roll Switch #	Flag # of Trace 1	12	13	24	Dead Traces	(Time) Remarks
	29.2m	1	61						: filters - Lows out High=1K gains are not equalized
		2							: gains are recorded at left
		3							: same gains as file 2
		4							: Lows = 240
		5							: ″
		6							: Lows = 340 gains are +8dB from file 4
		7							:
		8							: 1st and 2nd reflectors are just barely clipped
		9							: Lows = 480 same gains as file 6 7-9 bits
		10							: gains all up 8dB from file 6
		11							gains: 1-6:82, 7-12:70, 13-18:102, 19-24:114
									:
									: air-blast test 30.06 w/o silencer, 480 Low
	9.2m	12	61						: gains are -24 dB from file 11 9.2m from tr. 12,13
		13							:
		14							:
		15							: 340 Lows 54:1-5, 42:6-12, 66:13-19, 78:20-24
		16							:
		17							: 240 Lows Gains - 1-12:46, 13-24:54
		18							:

Page 12
Line Name Accel-geophone test
Observer J. Treadway Date 12-22-86

tape error bite/par	Shot Point #	Tape file #	Roll Switch #	Flag # of Trace 1	12	13	24		(Time) Remarks
	9.2	19	61						: Lows out all gains = 42
		20							: ch 19-24 62dB
		21							:
									: ½ ms. sample rate : 500 Hz High cut reciever/shot geometry shown below : shot is 49.4 m from NE hole (near station) Lows out
	49.4	22	61					24	30.06 gain all = 42
	49.4	23	61						: gains: 1-6:66, 7:54, 8-22:66, 23:42
		24							:
		25							:
		26							: Lows = 240 gains all +12dB from file 23
		27							: gains: 1-3:90, 4-6:78, 62, 8-22:90, 50
		28							:
		29							:
									:
									:
									:
									:
									:

FIGURE 1

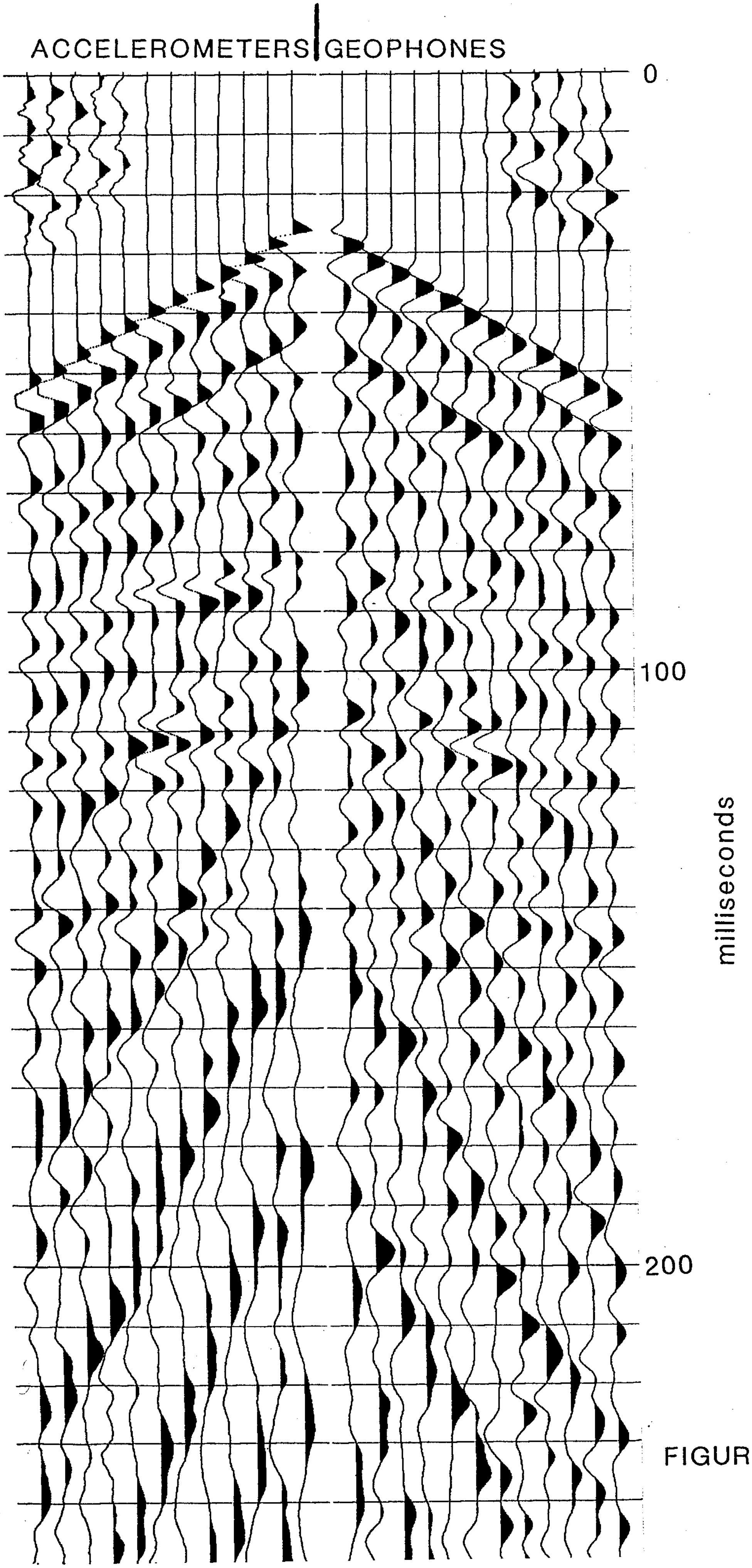


FIGURE 2

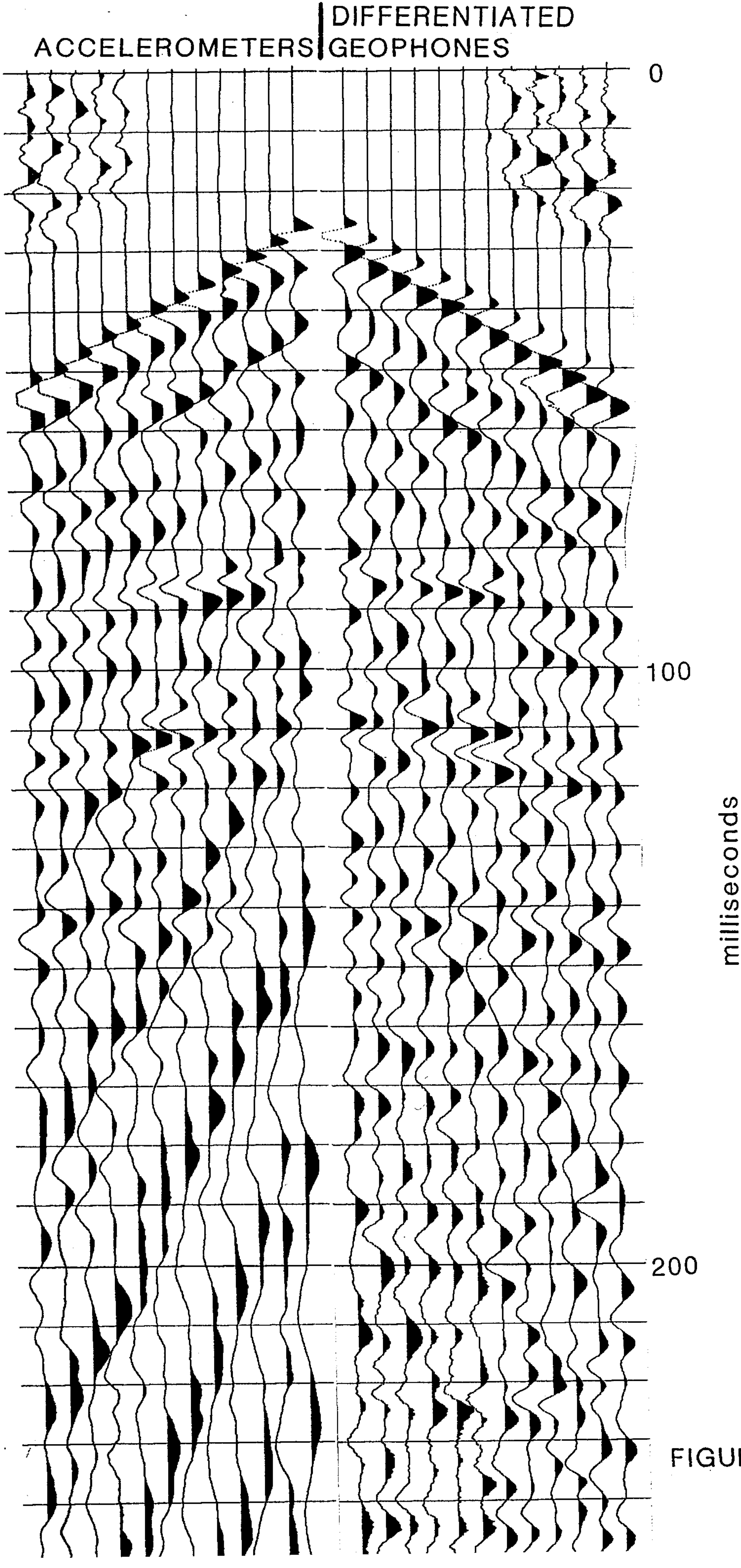

ACCELEROMETERS
DIFFERENTIATED GEOPHONES
0
100
200
milliseconds

FIGURE **3**

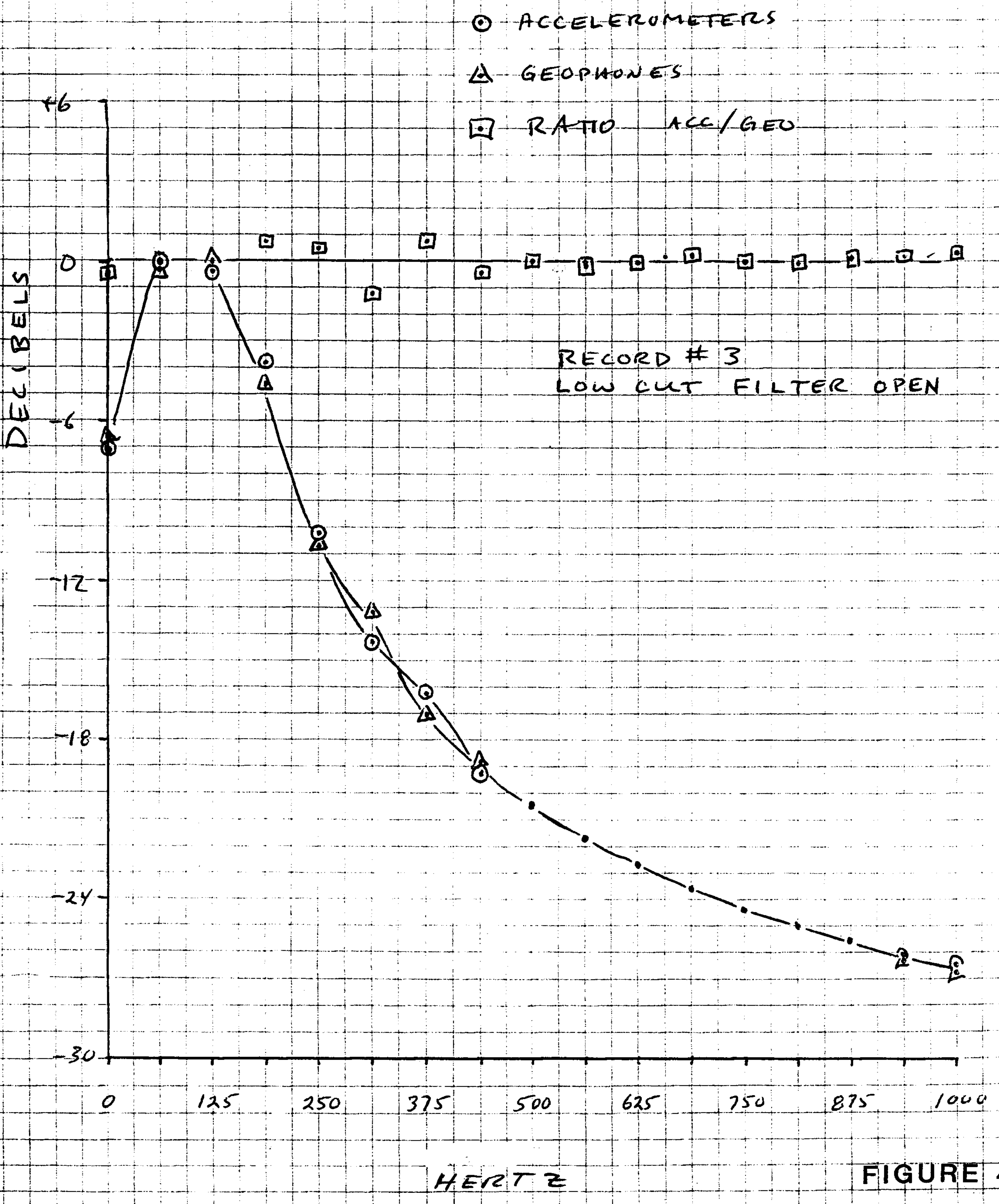

ACCELEROMETERS
GEOPHONES
RATIO ACC/GEO
RECORD # 3
LOW CUT FILTER OPEN
DECIBELS
+6
0
-6
-12
-18
-24
-30
0
125
250
375
500
625
750
875
1000
HERTZ

FIGURE 4

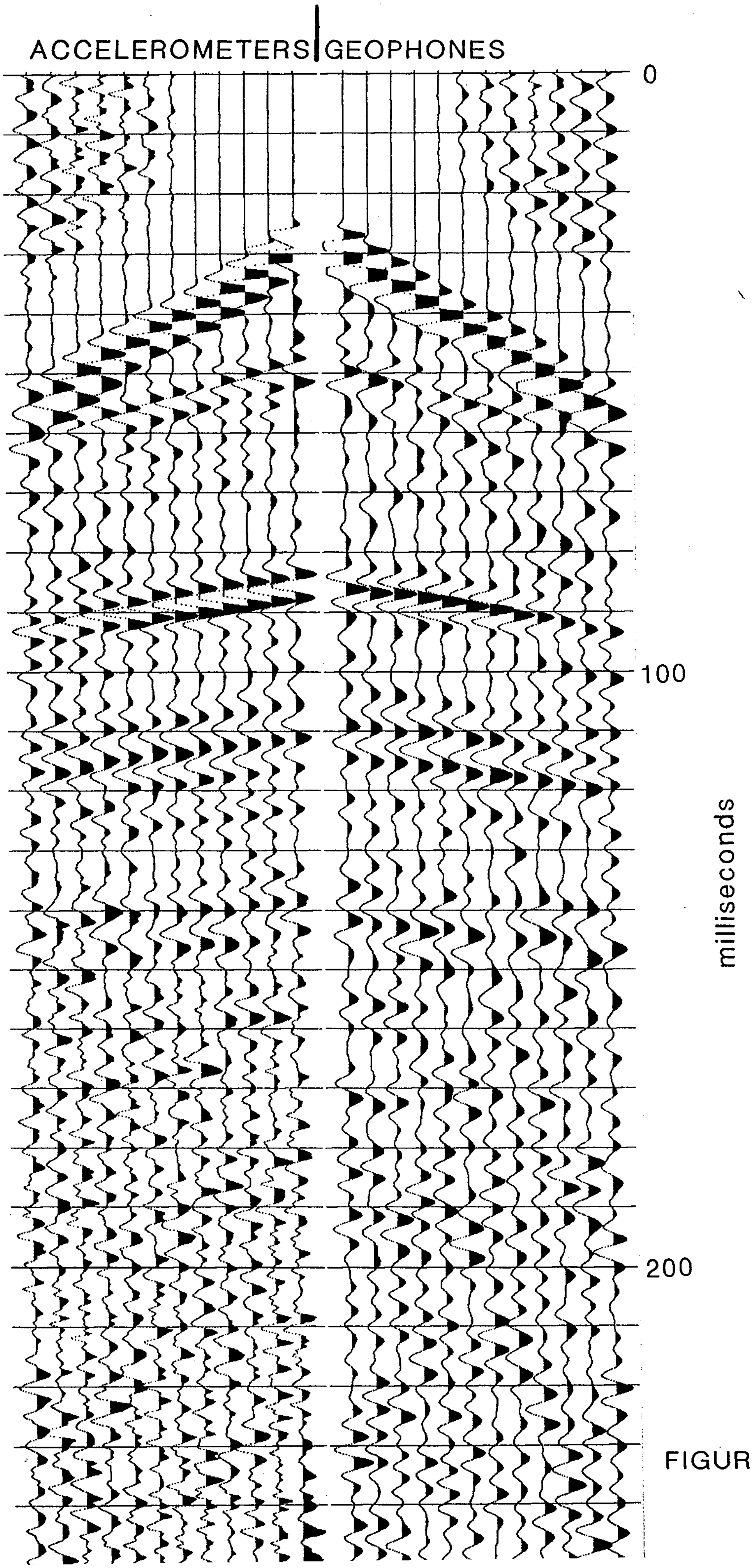


FIGURE **5**

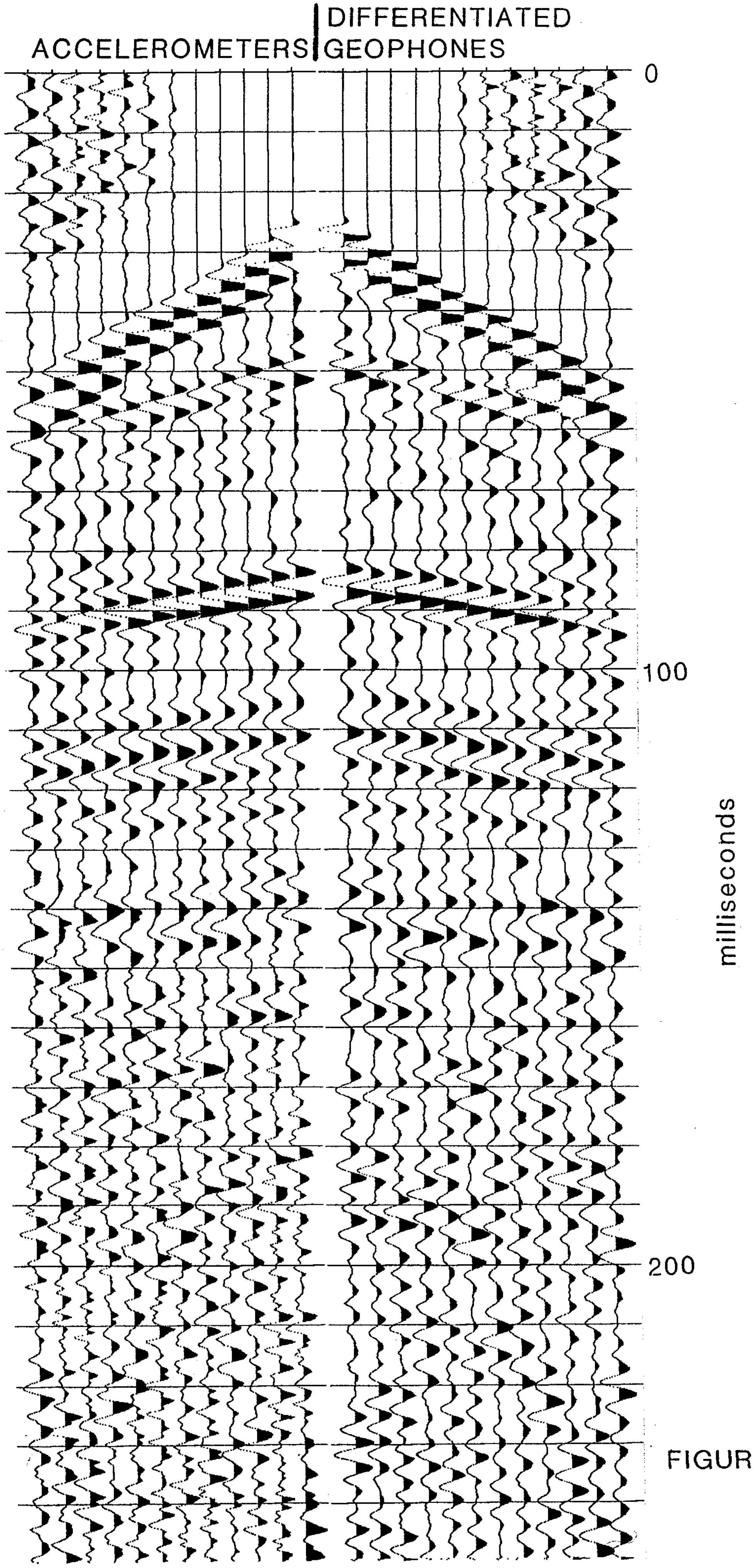

ACCELEROMETERS
DIFFERENTIATED GEOPHONES
0
100
200
milliseconds

FIGURE 6

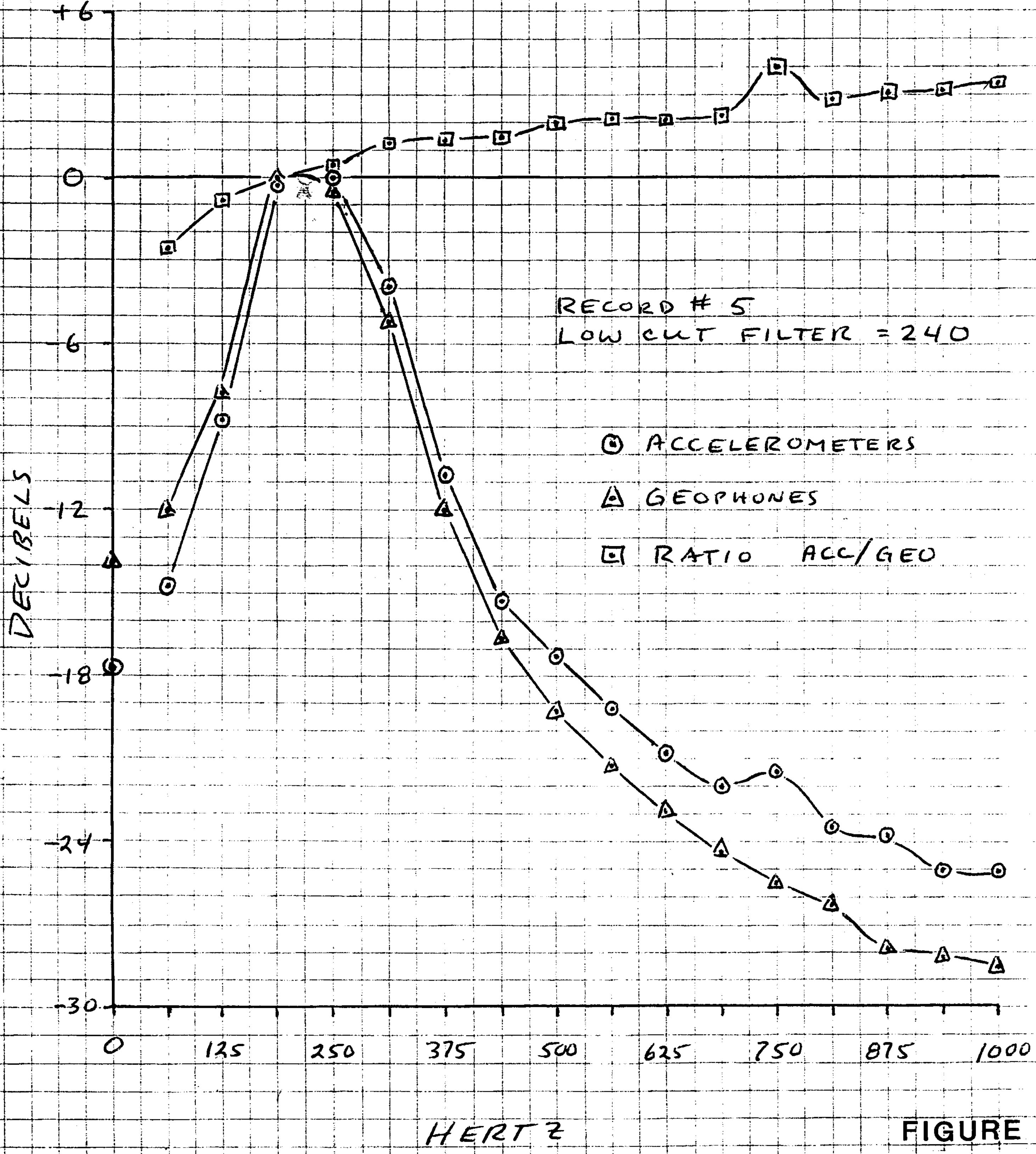

+6
0
-6
-12
-18
-24
-30
DECIBELS
0
125
250
375
500
625
750
875
1000
HERTZ
RECORD # 5
LOW CUT FILTER = 240
⊙ ACCELEROMETERS
△ GEOPHONES
⊡ RATIO ACC/GEO

FIGURE 7

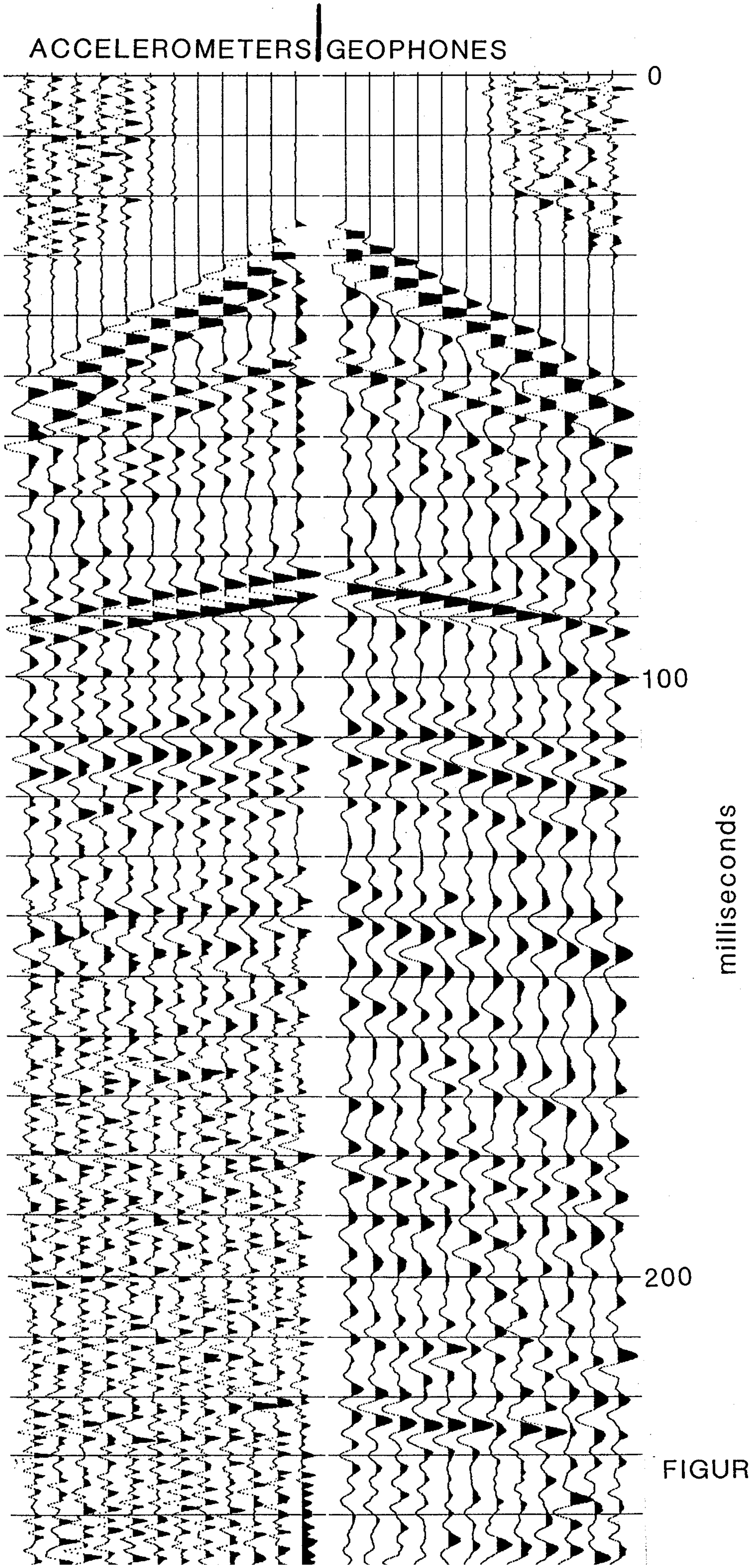


FIGURE **8**

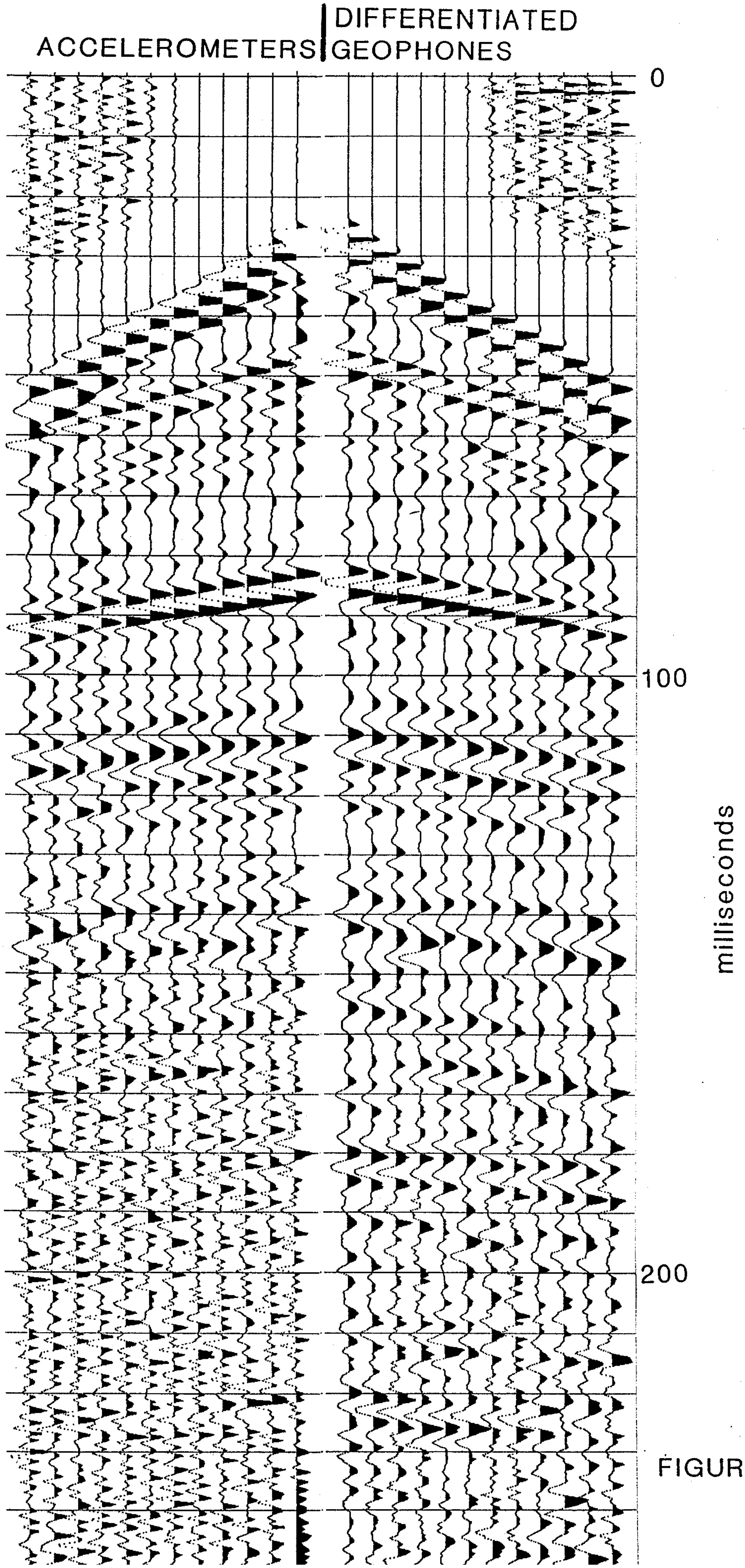

ACCELEROMETERS
DIFFERENTIATED GEOPHONES
0
100
200
milliseconds

FIGURE **9**

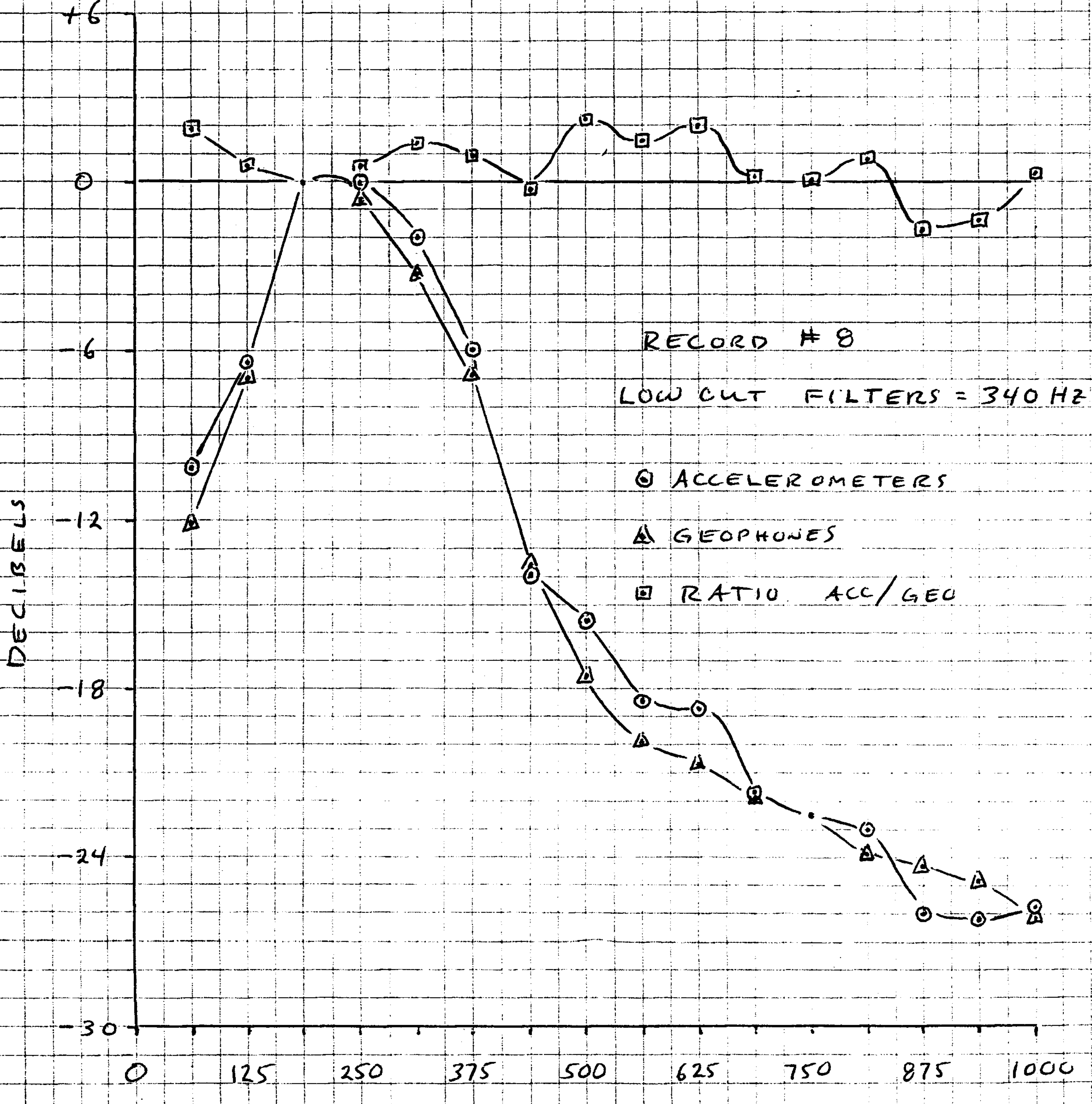

+6
0
-6
-12
-18
-24
-30
DECIBELS
0
125
250
375
500
625
750
875
1000
HERTZ
RECORD # 8
LOW CUT FILTERS = 340 HZ
⊙ ACCELEROMETERS
△ GEOPHONES
⊡ RATIO ACC/GEO

FIGURE 10

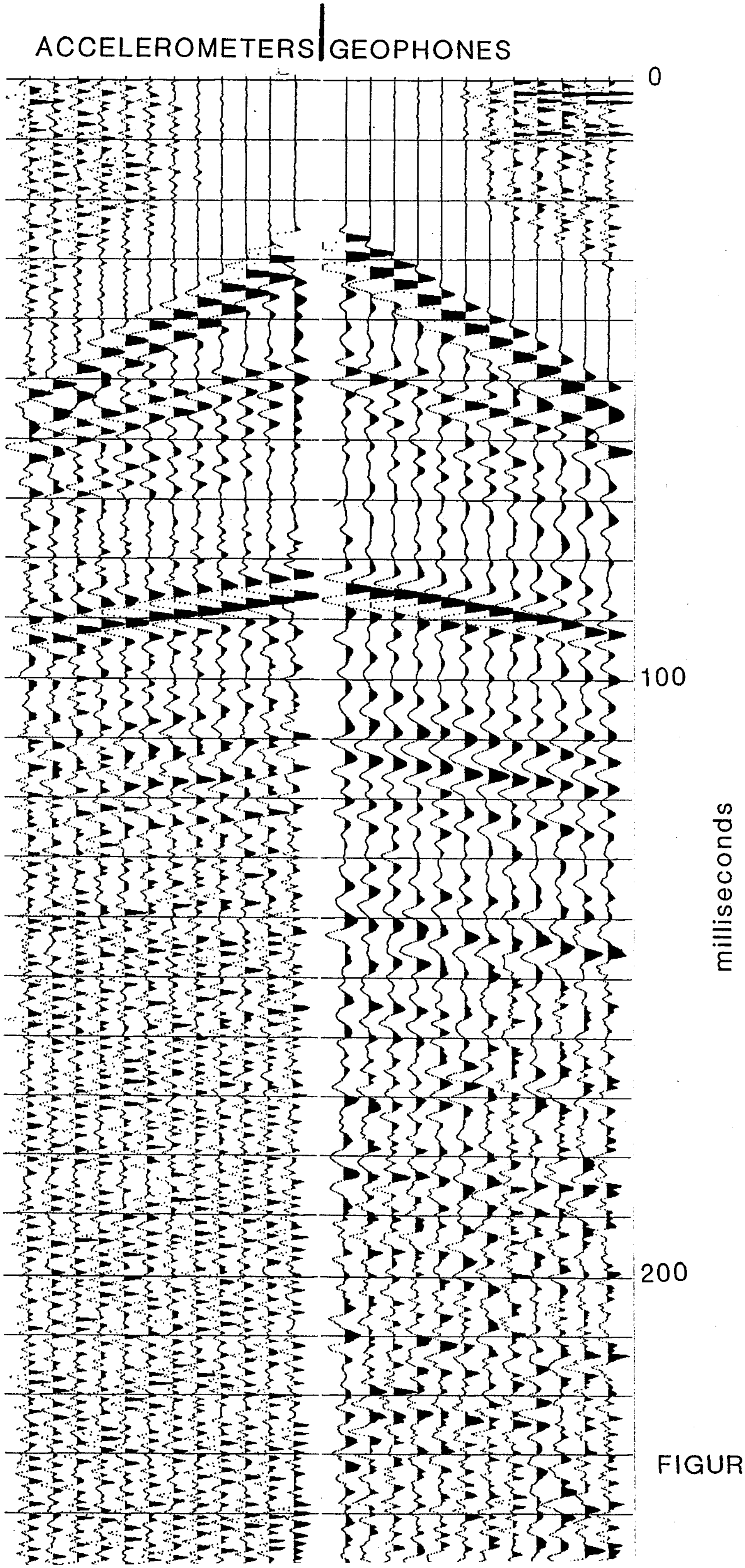


FIGURE 11

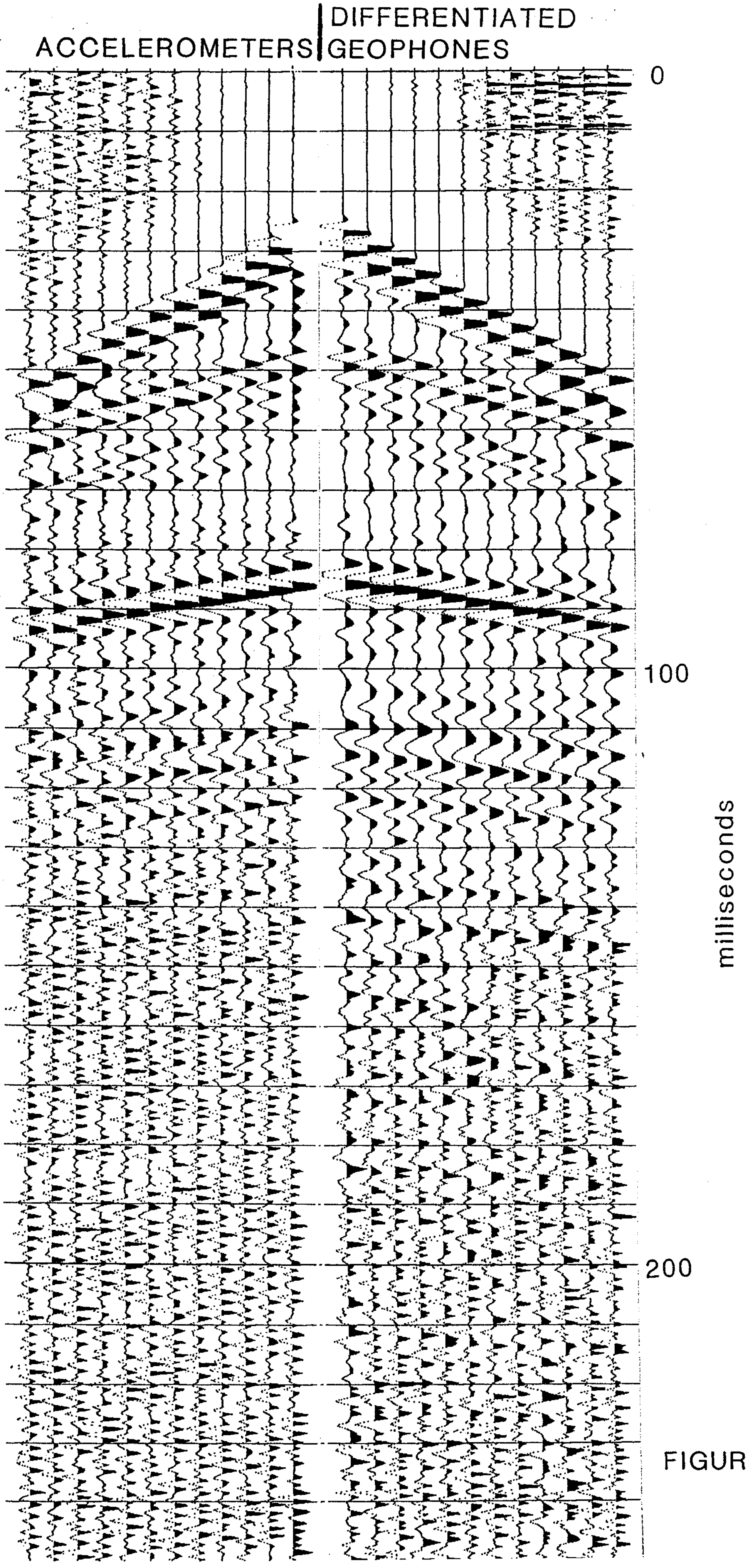

ACCELEROMETERS
DIFFERENTIATED GEOPHONES
0
100
200
milliseconds

FIGURE **12**

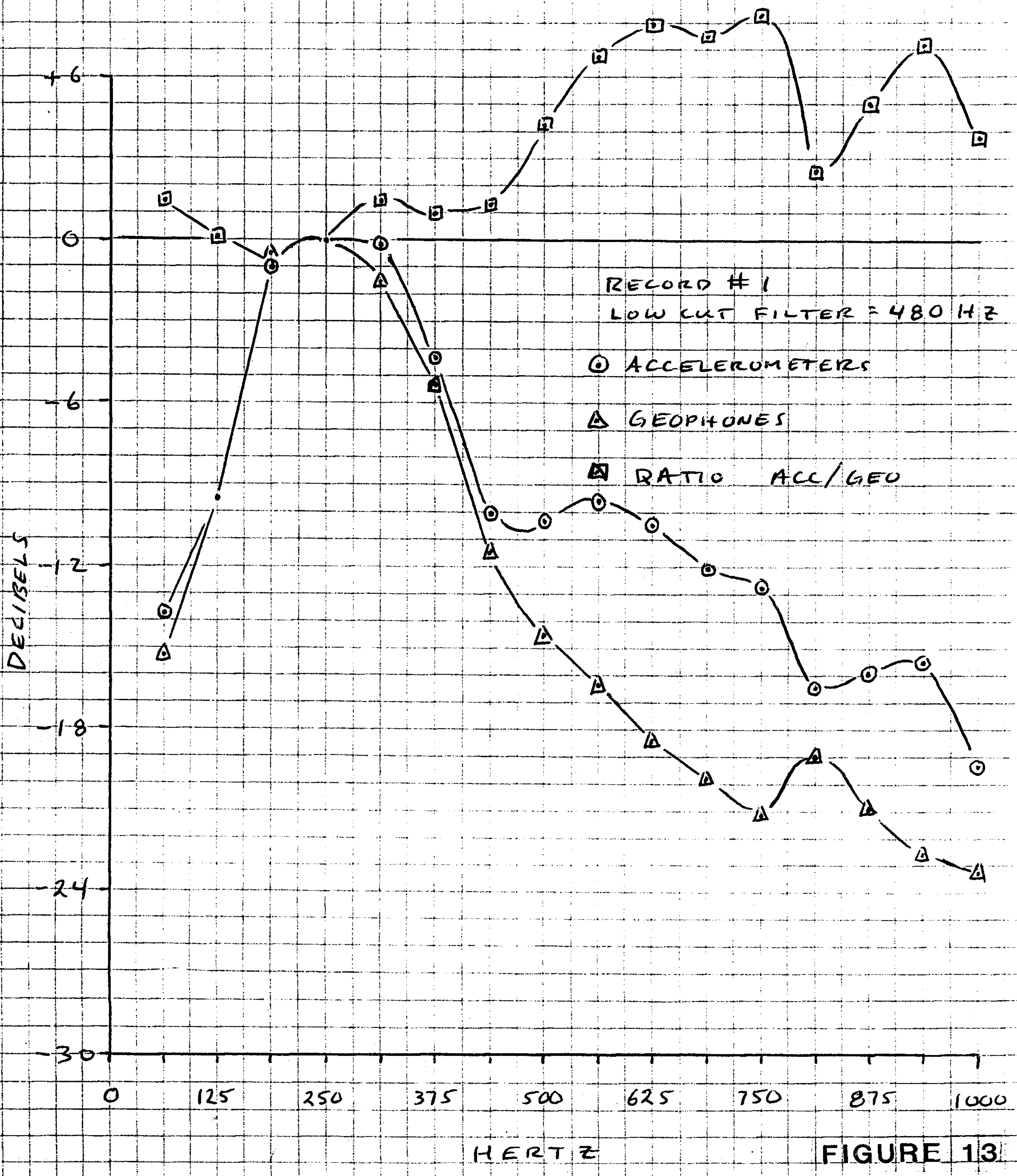

+6
0
-6
-12
-18
-24
-30
DECIBELS
0
125
250
375
500
625
750
875
1000
HERTZ
RECORD # 1
LOW CUT FILTER = 480 HZ
⊙ ACCELEROMETERS
△ GEOPHONES
⊠ RATIO ACC/GEO

FIGURE 13