

BROOKS2

DATA REPORT FOR THE 1990 SEISMIC REFLECTION/REFRACTION EXPERIMENT IN THE BROOKS RANGE, ARCTIC ALASKA

Prepared by

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1993

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IN THE BROOKS RANGE, ARCTIC ALASKA,
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OPEN-FILE REPORT _____

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1993

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INTRODUCTION

In the summer of 1990, the U.S. Geological Survey, Rice University, the Geological Survey of Canada, and IRIS/PASSCAL jointly conducted a seismic experiment across the Brooks Range, Arctic Alaska. The goal of the experiment was to produce a high-resolution image of the crust and upper mantle of the Brooks Range and flanking geologic provinces (Koyukuk basin and North Slope; Figures 1 and 2) by combining refraction and reflection techniques. The U.S. Geological Survey and Rice University jointly led the planning of the experiment, which began in 1985, and also the field execution of the experiment, which occurred in June and July 1990. Persons from the Geological Survey of Canada, IRIS/PASSCAL, University of Alaska, University of Wyoming, Purdue University, and the Air Force Geophysics Laboratory participated in the field. This experiment completes the seismic investigations of the U.S. Geological Survey's Trans-Alaska Crustal Transect (TACT) program, a multidisciplinary investigation of the crust and upper mantle of Alaska from the Pacific to Arctic Oceans along the oil-pipeline corridor (see summary in Nokleberg and Fisher, 1989). Other seismic data reports from TACT are summarized in Table 1. The 1990 Brooks Range experiment represents the first instance in which refraction and reflection techniques are merged in TACT investigations. This experiment also adds an important geophysical dimension to ongoing geologic studies of the Brooks Range at Rice University (see, for example, Oldow and others, 1987).

We used a 700-channel seismograph system (consisting of four different types of instruments) to record 63 shots (Table 2) at 44 separate shotpoint locations (Figures 3). The instruments included 35 PASSCAL Ref Tek 72A-02's, each recording 6 channels, 190 Stanford University Seismic Group Recorders (SGR's), 120 USGS Seismic Cassette Recorders (SCR's), and 180 Geological Survey of Canada Portable Refraction Seismographs (PRS1's). (See below for a detailed description of these seismic recorders.) All seismographs recorded only vertical-component motion. The instruments were deployed five times in abutting and overlapping arrays, producing a 315-km-long profile (Figures 1, 2, 3). Instrument spacing was nominally 100 m. Both small shots (100-600 lbs) and large shots (1500-4000 lbs) were fired to produce a vertical-incidence to wide-angle refraction-reflection data set with continuous offset coverage from 0 km to more than 200 km. Data recovery was about 95 percent, and signal-to-noise ratios were excellent from most shots. The data have been archived at the National Geophysical Data Center in Boulder, Colorado and at the IRIS Data Center in

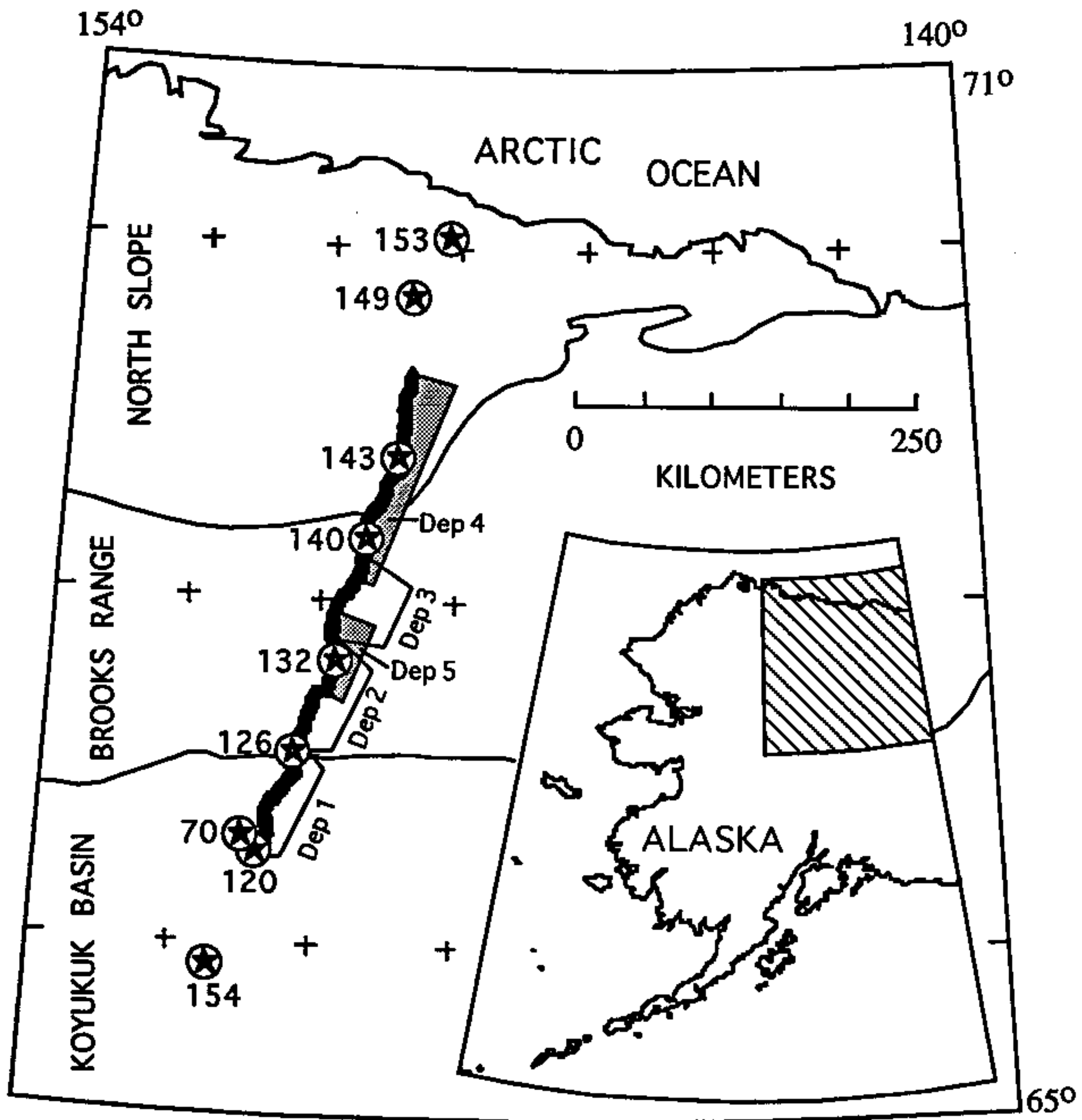


Figure 1. Experiment map showing all instrument locations (triangles) and selected shotpoint locations (circled stars with shotpoint location number). Brackets delineate extent of the deployments.

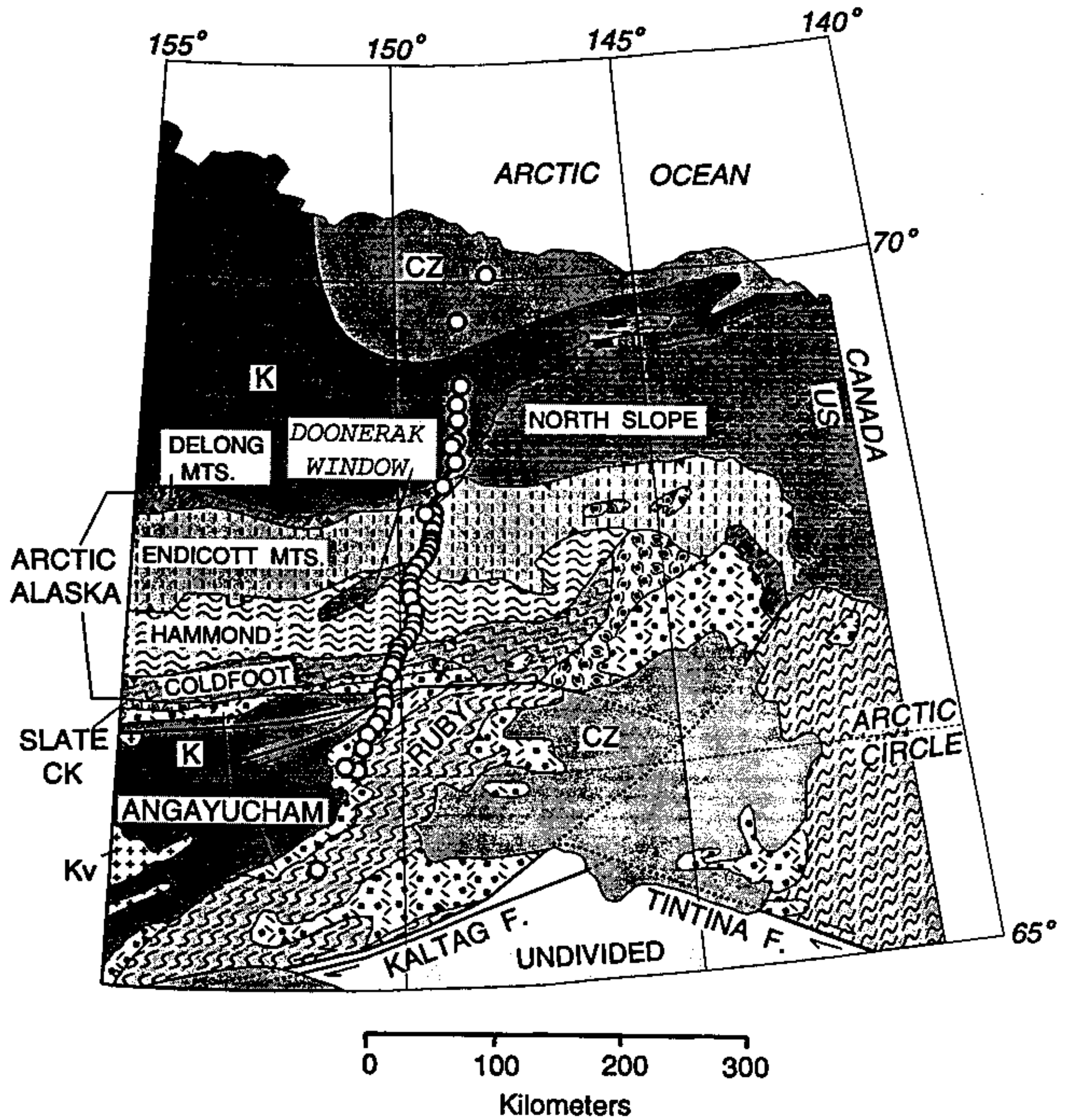


Figure 2. Experiment location map, showing terranes and subterranes. Circles represent shotpoint locations. From south to north terranes include the Ruby, Angayucham, Slate Creek, and Arctic Alaska terranes. Subterranes of the Arctic Alaska terrane include the Coldfoot, Hammond, Endicott Mts., Delong Mts. and North Slope subterranes.

TABLE 1

Seismic data reports produced under the U. S. Geological Survey's
Trans-Alaska Crustal Transect (TACT) program

REGION OF ALASKA/ DATE(S) OF AQUISITION	DATA TYPE	DATA REPORT
Gulf of Alaska/ 1988	Marine reflection/ refraction	Brocher and Moses, 1990
Southern Alaska/ 1984, 1985	Land refraction	Daley and others, 1985 Meador and others, 1986 Wilson and others, 1987 Wilson, 1987
	Land reflection	Fisher and others, 1989
Central Alaska/ 1987	Land refraction	Beaudoin and others, 1989 Goldman and others, 1992
Northern Alaska/ 1990	Land reflection/ reflection	This report

TABLE 2 SHOT LIST

SHOT	LOCATION		ELEV	DEPTH	CHARGE	SHOT TIME	
	NUMBER	LATITUDE				LONGITUDE	(m)
1	154	65.883474	-151.422256	453	2.4	2500	193 06:00:00
2	120	66.557153	-150.811307	357	18.3	1500	193 06:02:00
3	122	66.818726	-150.675938	326	15.2	600	193 06:03:00
4	124	66.972430	-150.334079	444	12.5	200	193 06:04:00
5	170	67.082496	-150.357750	368	14.3	200	193 06:05:00
6	140	68.382100	-149.467612	811	4.0	4000	193 06:06:00
7	121	66.717523	-150.670852	327	17.4	600	193 09:02:00
8	123	66.894944	-150.512740	387	15.2	200	193 09:03:00
9	125	67.039388	-150.304716	522	15.8	600	193 09:04:00
10	126	67.142029	-150.333568	335	4.0	2500	193 09:05:00
11	132	67.680728	-149.740251	474	17.7	2500	193 12:04:00
12	120	66.557153	-150.811307	357	16.8	2500	196 06:00:00
13	127	67.232044	-150.222638	334	14.3	600	196 06:02:00
14	171	67.324269	-150.153394	370	13.1	200	196 06:03:00
15	130	67.435596	-150.092280	389	12.8	600	196 06:04:00
16	132	67.680728	-149.740251	474	14.6	1500	196 06:05:00
17	140	68.382100	-149.467612	811	4.0	2500	196 06:06:00
18	126	67.142029	-150.333568	335	4.0	1500	196 09:00:00
19	128	67.292665	-150.163629	370	16.8	600	196 09:02:00
20	129	67.398463	-150.087932	443	13.1	200	196 09:03:00
21	172	67.459744	-150.039080	381	14.0	100	196 09:04:00
22	143	68.848389	-148.905796	473	8.5	3500	196 09:05:00
23	124	66.972430	-150.334079	444	8.5	200	196 09:07:00
24	70	66.601460	-150.989089	224	3.0	4000	203 05:00:00
25	175	68.012652	-149.727377	741	17.7	200	203 05:02:00

TABLE 2 SHOT LIST (continued)

SHOT NUMBER	LOCATION NUMBER	LATITUDE	LONGITUDE	ELEV (m)	DEPTH (m)	DEPTH (lbs)	CHARGE		SHOT TIME
							J-DAY	HR:MIN:SEC	
26	176	68.087215	-149.561513	1057	12.8	200	203	203	05:03:00
27	138	68.172276	-149.440437	1052	13.4	200	203	203	05:04:00
28	139	68.375031	-149.317897	832	15.2	1500	203	203	05:05:00
29	142	68.567661	-149.166966	907	7.6	600	203	203	05:06:00
30	126	67.142029	-150.333568	335	4.0	2500	203	203	08:00:00
31	136	67.953935	-149.776641	663	12.8	200	203	203	08:02:00
32	137	68.052783	-149.613887	980	15.8	600	203	203	08:03:00
33	177	68.132094	-149.438985	1204	13.1	200	203	203	08:04:00
34	178	68.217446	-149.391466	997	15.2	600	203	203	08:05:00
35	143	68.848389	-148.905796	473	8.5	2500	203	203	08:06:00
36	132	67.680728	-149.740251	474	13.4	1500	203	203	11:00:00
37	130	67.435596	-150.092280	389	10.1	200	203	203	11:01:00
38	135	67.885910	-149.814978	610	12.5	200	203	203	11:02:00
39	126	67.142029	-150.333568	335	4.0	4000	200	200	05:00:00
40	142	68.567661	-149.166966	907	7.6	600	200	200	05:02:00
41	179	68.247330	-149.420864	952	15.8	600	200	200	05:03:00
42	141	68.406008	-149.326622	859	15.2	1000	200	200	05:04:00
43	189	69.282368	-148.737392	246	18.6	2500	200	200	05:05:00
44	153	70.078227	-148.173320	13	2.4	3500	200	200	05:06:00
45	145	69.033481	-148.852984	383	2.1	1000	200	200	07:30:00
46	180	68.313317	-149.346289	910	14.9	600	200	200	07:31:00
47	188	69.146067	-148.830549	293	19.8	200	200	200	07:32:00
48	149	69.744689	-148.787624	98	2.7	3000	200	200	07:33:00
49	186	68.876024	-148.854803	440	14.3	200	200	200	10:00:00
50	132	67.680728	-149.740251	474	15.5	3000	200	200	10:01:00

TABLE 2 SHOT LIST (continued)

SHOT NUMBER	LOCATION NUMBER	LATITUDE	LONGITUDE	ELEV (m)	DEPTH (m)	DEPTH (lbs)	CHARGE		SHOT TIME
							J-DAY	HR:MIN:SEC	
51	139	68.375031	-149.317897	832	13.1	2000	200	200	10:02:00
52	150	68.730744	-148.929179	556	2.7	600	200	200	10:03:00
53	136	67.953935	-149.776641	663	12.8	250	205	205	05:00:00
54	134	67.844424	-149.816350	577	13.1	600	205	205	05:01:00
55	133	67.775798	-149.783164	547	16.2	600	205	205	05:02:00
56	132	67.680728	-149.740251	474	15.5	200	205	205	05:03:00
57	135	67.885910	-149.814978	610	12.5	120	205	205	05:04:00
58	174	67.594497	-149.786844	453	16.2	600	205	205	07:00:00
59	173	67.555575	-149.836354	465	16.8	600	205	205	07:01:00
60	131	67.501135	-149.854582	432	13.7	200	205	205	07:02:00
61	172	67.459744	-150.039080	381	14.0	120	205	205	07:03:00
62	127	67.232044	-150.222638	334	14.3	120	206	206	05:01:00
63	126	67.142029	-150.333568	335	4.0	240	206	206	05:04:00

Note: Shot depths less than 9 m correspond to lake shots; all other shots were drill-hole shots.

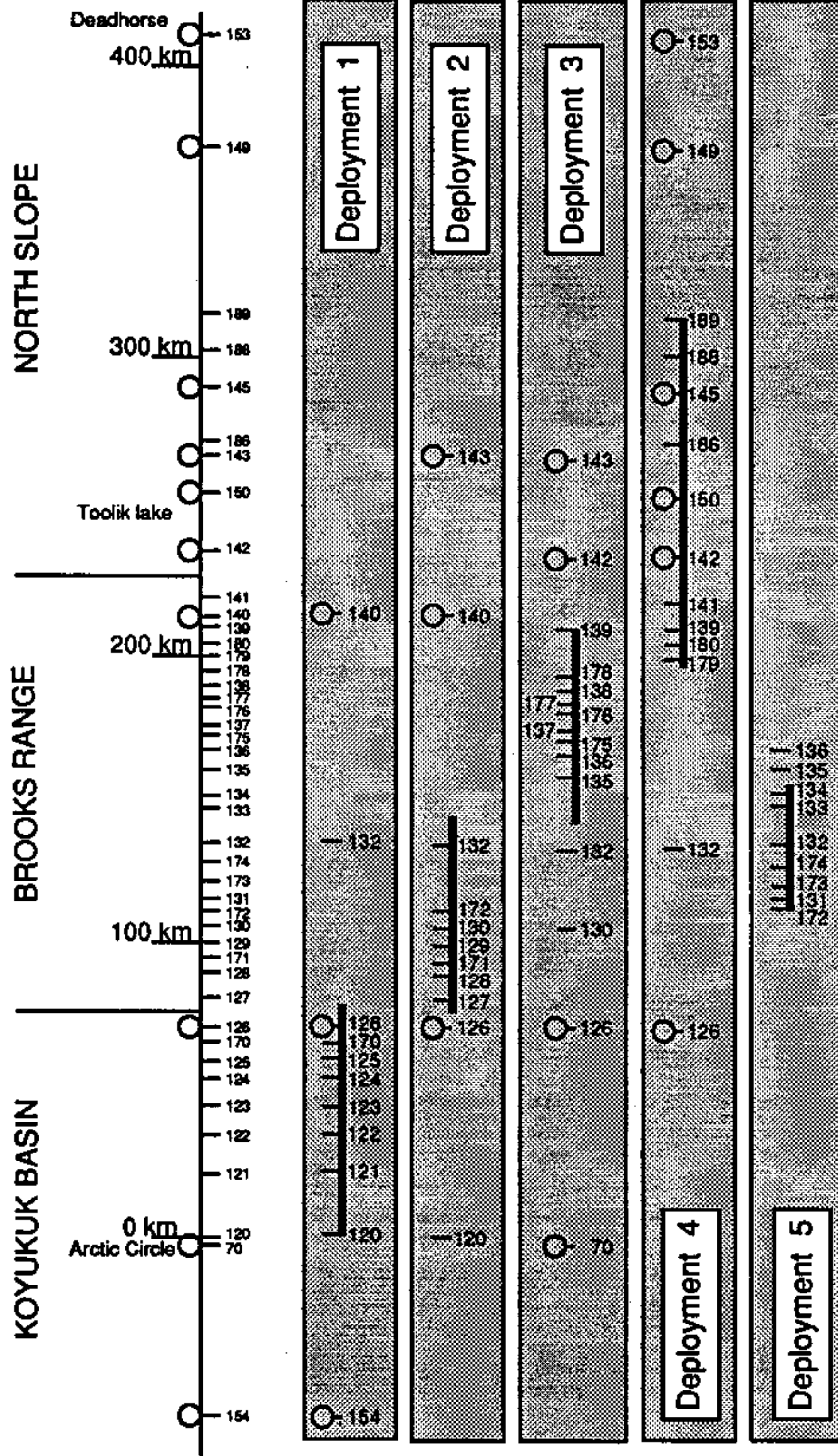


Figure 3. Schematic diagram of experiment. Numbered short lines represent drill-hole shotpoints and short lines with attached circles represent lake shotpoints. Shotpoint location numbers are listed opposite each shotpoint.

Seattle, Washington. SEG Y-format tapes recorded at 6250 BPI are available from:

NOAA
National Geophysical Data Center
E/GC1
325 Broadway
Boulder, CO 80303

Telephone: (303) 497-6123

The data are also available through the IRIS Data Management Center at:

IRIS DMC
1408 NE 45th Street
Seattle, WA 98105

Telephone: (206) 547-0393

A description of the tape format and headers is given below in the Data Processing section.

GEOLOGIC SETTING

The following is summarized from Oldow and others(1987), Grantz and others (1991), and Moore and others (1989). The Brooks Range and North Slope consists of North American continental-marginal rocks, and the Koyukuk basin consists of island-arc and ocean-basin rocks. In a general way, rocks in the northern Brooks Range are younger (Miss.-Jur.), stable-shelf, marine and non-marine sedimentary rocks, and rocks in the southern Brooks Range are older (Precamb.-Dev.), deeper-water, continental-marginal sedimentary rocks. Metamorphic grade increases toward the south to greenschist-blueschist(?) grade. Rocks of the Brooks Range were telescoped and thrust beneath oceanic rocks of the Koyukuk basin, beginning in the Early Cretaceous, as the Canada basin opened to the north. Sediments eroded from the uplifting range were deposited chiefly in the Coleville foredeep basin on the North Slope. Uplift and compression continued into the Cenozoic in the north part of the Range, including the vicinity of the Doonerak window. Collapse and extension of unknown magnitude interpreted as

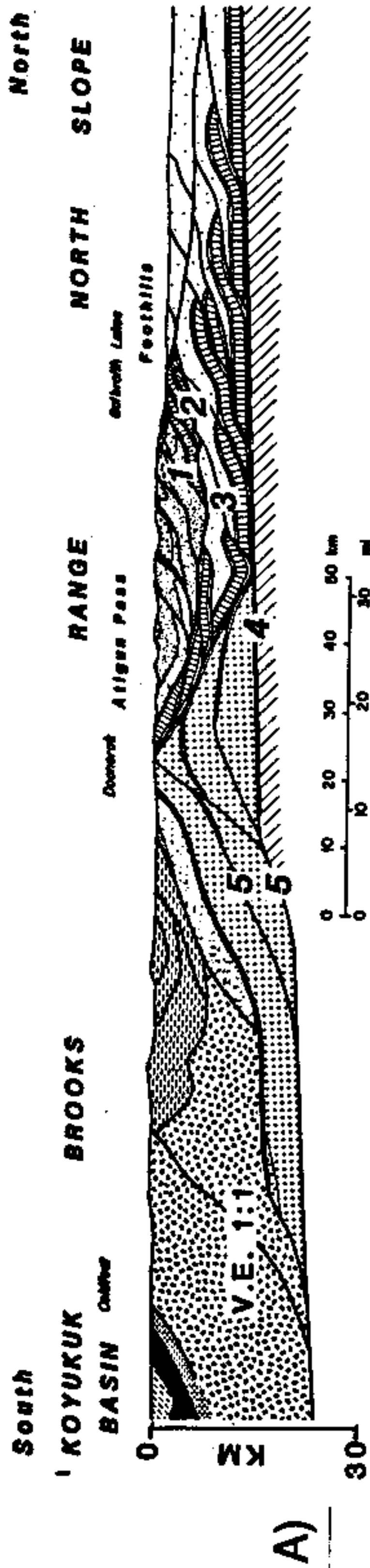
mid-Cretaceous age occurred in the south part of the range (see also Miller and Hudson, 1991; Oldow and others, 1991).

The Brooks Range and North Slope comprise the Arctic Alaska terrane, which has been subdivided, from north to south, into the North Slope, Endicott Mountains, Hammond (or Skajit), and Coldfoot (or Schist) subterrane (Figure 2). On the south, the Arctic Alaska terrane is separated from the Angayucham terrane, consisting of oceanic crust and ultramafic rocks, and the basinal rocks of the Koyukuk basin by melange of the Slate Creek terrane. Vergence is to the north in the Brooks Range structures. The North Slope subterrane is exposed both on the North Slope, where it is overlain by and locally over thrust upon the sedimentary rocks of the Coleville basin, and in the Doonerak window, which is located on an antiform in the central Brooks Range near the contact between the Endicott and Hammond subterrane.

Two cross sections that represent prior, testable models of Brooks Range structure (Oldow and others, 1987; Moore and others, 1991) are reproduced in Figure 4. These both show the following features in the central and northern Brooks Range: (1) the Endicott Mountains allochthon is a lens-shaped body on the north limb of the Doonerak antiform, with internal, north-verging thrust faults; (2) the rocks beneath the Endicott Mountains allochthon include sedimentary rocks of the Coleville basin (explicitly shown in Figure 4A) and displaced rocks of the North Slope subterrane; (3) the Doonerak antiform is underlain by deformed, lens-shaped bodies of rock; and (4) the "master" decollement is subhorizontal beneath the southern North Slope and Endicott Mountains allochthon, but ramps downward on the south side of the Doonerak antiform. The dimensions of rock bodies and depths of interfaces are similar between the two cross sections, although Figure 4B is admittedly schematic. The cross sections differ primarily in interpretation of stratigraphic and structural separation of the Endicott Mountains and Hammond (Skajit) subterrane. The cross section of Grantz and others (1991) is also similar to Figures 4A and 4B, although the depth to the "master" decollement is shallower (< 10 km) and the package of displaced Coleville basin and North Slope rocks beneath the Endicott Mountains allochthon is much thinner (< 2 km).

EXPERIMENT PLANNING AND DESIGN

The 1990 Brooks Range experiment was conceived in 1984 during a planning session for the Trans-Alaska Lithosphere Investigation at the Seismological Society of America annual meeting in Anchorage, Alaska (see Stone



UNIT	UNIT	UNIT
1	5A	7A
2	5B	7B
3	6A	8
4	6B	9
		10

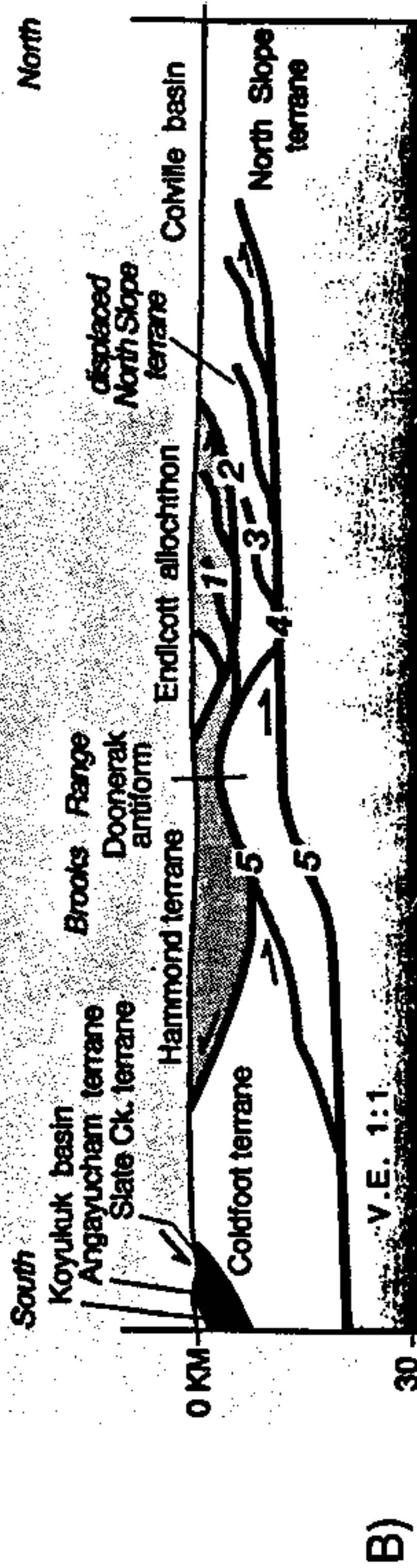


Figure 4. Two possible models for a cross section of the Brooks Range. The explanation is given on the following page.

Explanation for Figure 4.

a) Cross section from Oldow and others (1987: Atigun Pass Transect, Section IIA). Numbered units are 1--Coleville basin sediments; 2--Sadlerochit Group, Shublik Fm., and Kingak Fm.; 3--Lisburne Limestone; 4--Kayak Shale and Kekiktuk Conglomerate; 5A--(not present); 5B--Endicott Mountains Allochthon: Kanayut Conglomerate, Hunt Fork Shale, and Beaucoup Fm.; 6A--Neruokpuk Fm. (basement of North Slope subterrane); 6B--Apoon Fm. (basement of North Slope subterrane seen in Doonerak Window); 7A--Skajit Allochthon; 7B--Rosie Creek Allochthon (oceanic rocks); 8--Schist belt (Coldfoot subterrane); 9--Angayucham subterrane (ophiolite); 10--Cretaceous sedimentary rocks of the Koyukuk basin.

b) Schematic cross section from Moore and others (1991). Numbers on both cross sections 4A and 4B indicate reflecting horizons that are seen in the data (see Levander and others, 1991; Fuis and others, 1991)

et al, 1986). As a first step in the seismic program, we conducted a field trip to the Brooks Range in 1985 to scout refraction shotpoints along the oil-pipeline corridor. During the field trip, we identified and flagged 16 shotpoints and several alternates. Shotpoints required either a biologically dead lake that could be reached by truck or helicopter, or a hard (land) site that could be reached by a truck-mounted drill rig. Hard sites were usually limited to highway turnouts or quarries used during pipeline construction. These sites, however, were frequently too close to the pipeline to safely detonate charges of the size needed for crustal exploration (100-4000 lbs). Potential lake shotpoints were scouted at a later time (1988). We were forced to use shallow lakes (less than 3 meters) for two reasons: 1) deeper lakes are rare and 2) fish can survive over winter in lakes deeper than the freeze-down depth of about 3 meters, and are almost invariably present in such lakes.

In 1987, during a TACT seismic experiment in central Alaska, we began collecting data for an environmental assessment report. To complete environmental assessment studies and to investigate data acquisition and logistical problems anticipated in the Arctic, a pilot seismic experiment was conducted in 1988 - sponsored by IRIS and the USGS (Levander and others, 1988). Radio-controlled Seismic Group Recorders (SGR's) (loaned to Rice/PASSCAL by AMOCO Corporation) were used to record a 50-km-long reversed reflection/refraction profile with receivers spaced 150 to 300 m apart and 3 in-line shot points spaced 15-20 km apart. One offset (80-90 km) lake shot was fired to test long range seismic transmission from a shallow lake source and to assess the impact of shooting in a lake ecosystem. In addition, 3 seismic wave tests were conducted to investigate wave propagation in the shallow perma-frost layer. The pilot experiment demonstrated that high quality seismic data could be acquired in the geologically complex Brooks Range and that we could generate sufficient seismic energy at distances as large as 100 km using a distributed charge in a shallow lake (less than 3 meters depth). The only significant ecological effect of such a shot, in the absence of fish, is to stir up mud that remains in suspension for a period of a few weeks. The wave tests demonstrated that ground roll, a serious source of noise in reflection recording, propagates in the permafrost layer as a relatively compact, high-velocity wave group which can be eliminated with standard reflection processing without employing special recording arrays. A report of the data collected during the pilot experiment has been compiled and is available along with the data from IRIS. An environmental impact report was prepared and filed with the U.S. Bureau of Land Management.

In the years following the 1984 planning meeting for the Brooks Range experiment, IRIS launched the rapid development of the Ref Tek instrument base for academic seismological research. Additionally, in 1989 IRIS and the USGS

provided funds for support and modification of 195 Seismic Group Recorders (SGR) which AMOCO donated to Stanford University. Modification of the SGR's included conversion of the turn-on from radio control to internal clock control; thereby making them suitable for use in the rugged terrain of the Brooks Range. Anticipating the possibility that more instruments would be available in 1990, we logged every location in the Brooks Range, Koyukak basin, and North Slope where a shotpoint (drill-hole or lake) could be located more than 1000 feet from the oil-pipeline. We also established curves relating particle velocity to shot size and distance for our blasts to demonstrate to pipeline officials (Alyesca Pipeline Service Company) that our blasts would not damage any of their equipment (Kohler and Fuis, 1989, 1992).

After receiving permission from state and federal agencies and pipeline officials to proceed, the Brooks Range experiment commenced in May, 1990. An advance team arrived before spring breakup in the Arctic to supervise shot hole drilling. Three parties of surveyors staked and flagged 3200 seismic stations in June and the 45 member seismic crew arrived on July 4 and 5. Data was recorded for 5 deployments from July 12 through July 26. Two cleanup crews remained in the Arctic until August 10.

We designed the experiment so that all shots within the Brooks Range were recorded at smaller ranges (0 - 10 km or more) by instruments with higher-frequency response (Ref Teks and SGR's). For larger ranges of Brooks Range shots and shot points beyond the Brooks Range, data were recorded by instruments with a lower-frequency response (SCR's and PRS1's). A 315 kilometer-long seismic profile was recorded during 5 deployments (Figure 5). Of this length, 200 km was recorded by higher-frequency instruments and is suitable for producing a low-fold, common-midpoint (CMP) stacked section. Instruments were deployed along the edge of the Dalton Highway except for a 45-km-long dogleg in the road between shotpoints 141 and 150. A helicopter was used to deploy instruments cross country along the latter segment of the transect. The first deployment extended from the Arctic Circle through the Koyukuk Basin to the edge of the Brooks Range. Eight in-line shots and three off-end shots were fired into the deployment (Figures 1, 3, 5a). The second deployment extended from the end of deployment 1 half way through the Brooks Range. Seven in-line shots and four off-end shots were fired into the deployment (Figures 1, 3, 5b). The third deployment extended from the end of deployment 2 through the Brooks Range. Nine in-line shots and six off-end shots were fired into the deployment (Figures 1, 3, 5c). Deployment 4 is the northernmost transect. At its southern end, deployment 4 overlapped the northern end of deployment 3, and it extended

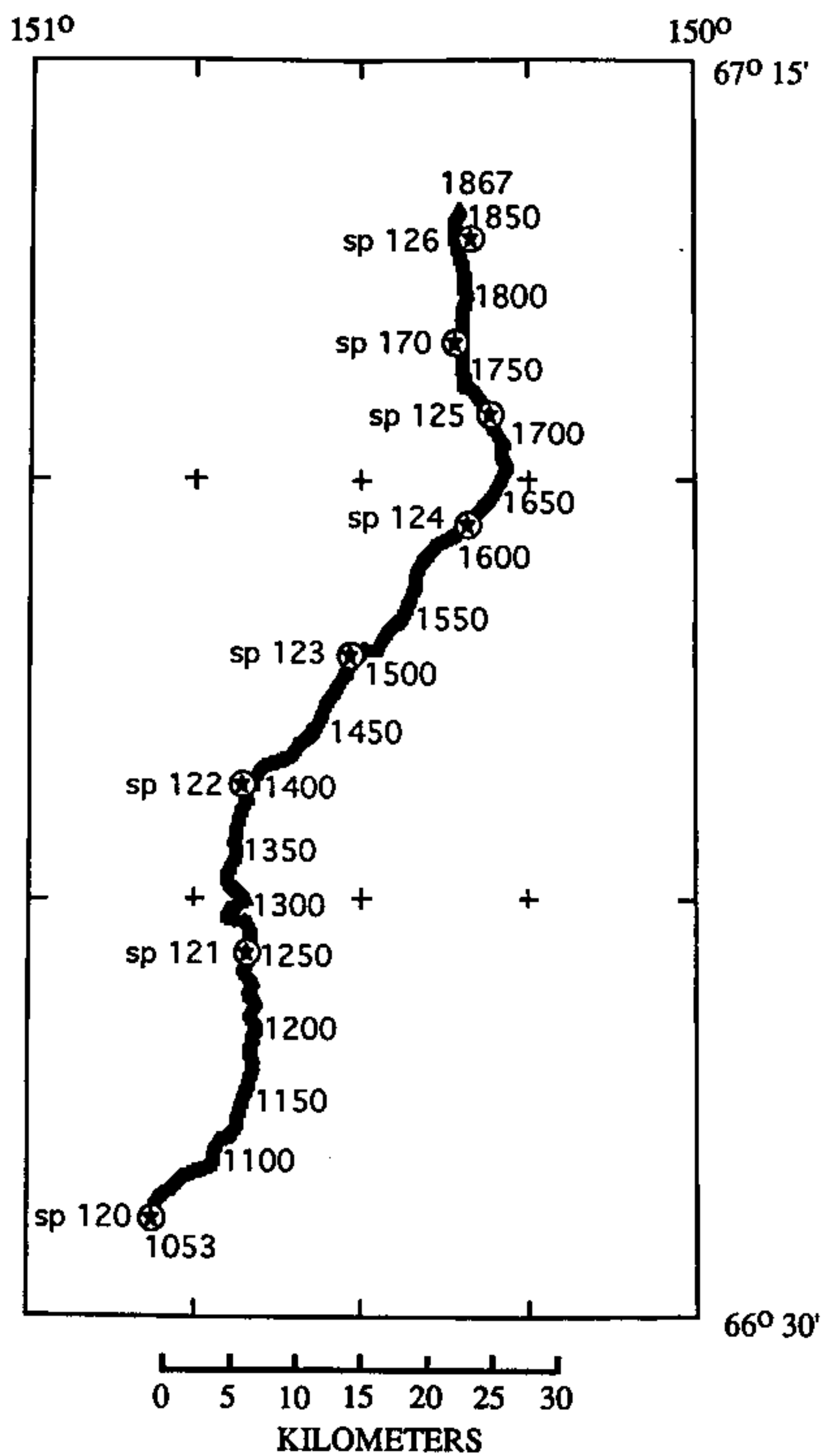


Figure 5a. Deployment 1 location map. Shotpoint location numbers (e.g. sp 120) and selected instrument location numbers (e.g. 1053) are given.

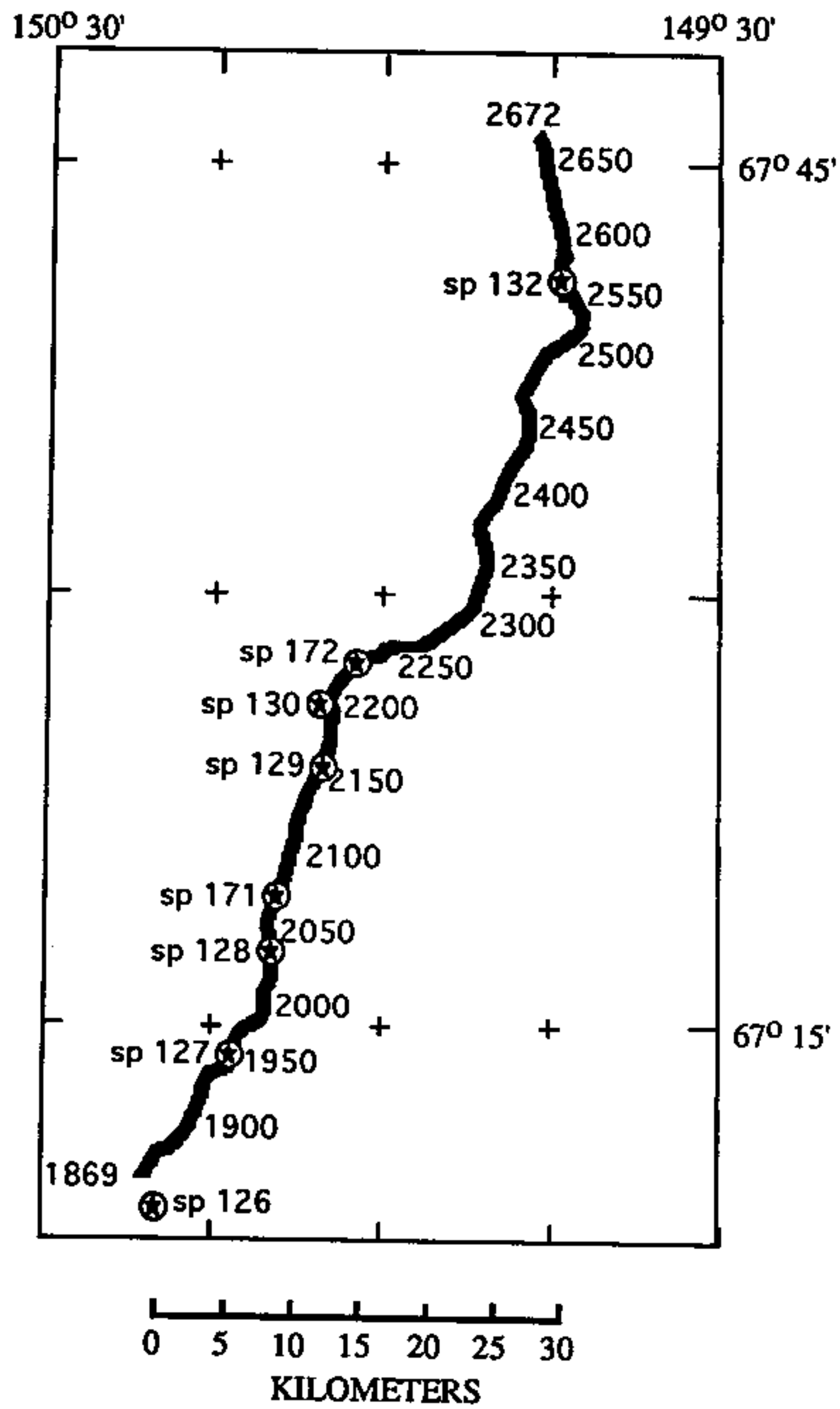


Figure 5b. Deployment 2 location map.

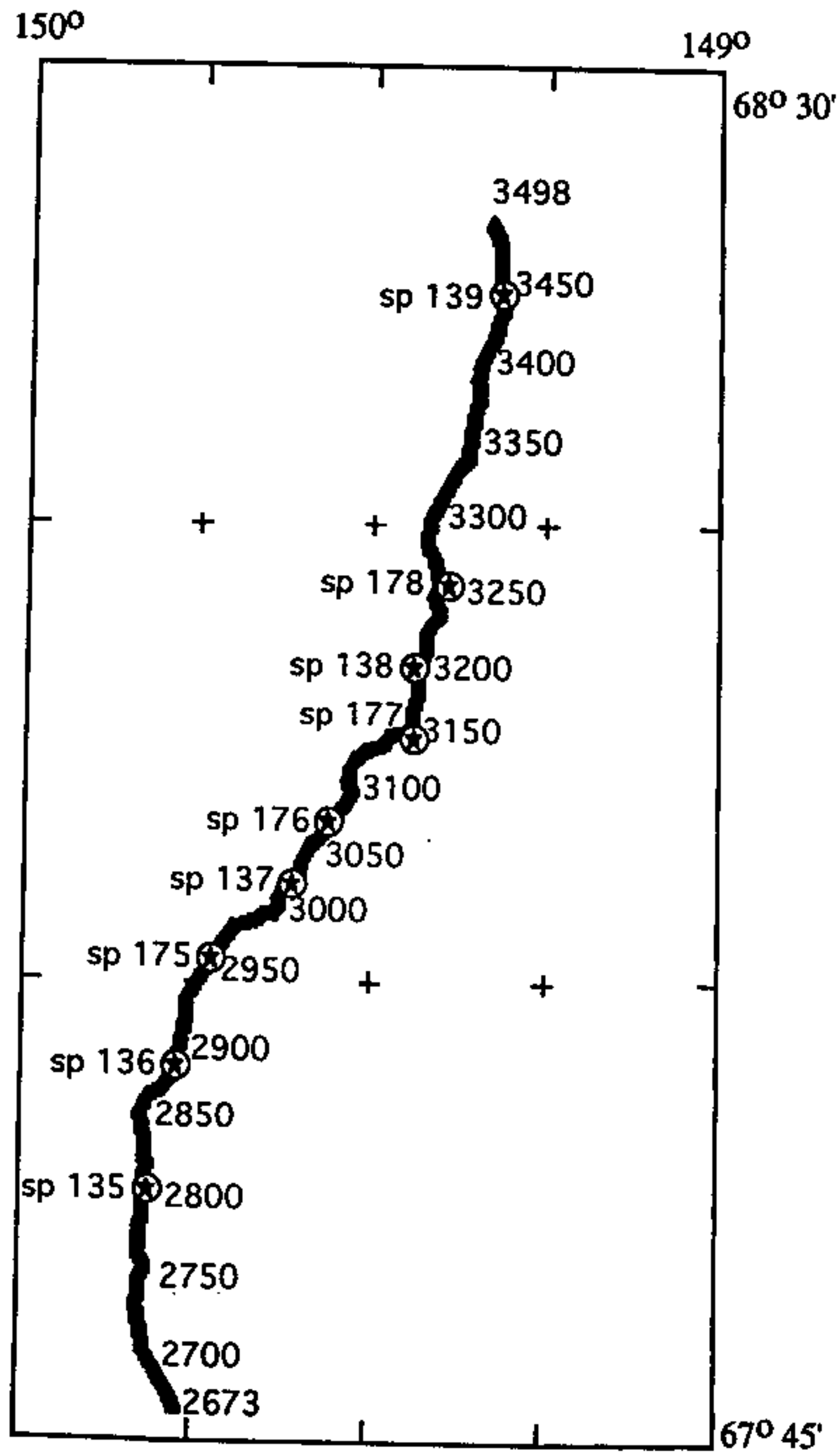


Figure 5c. Deployment 3 location map.

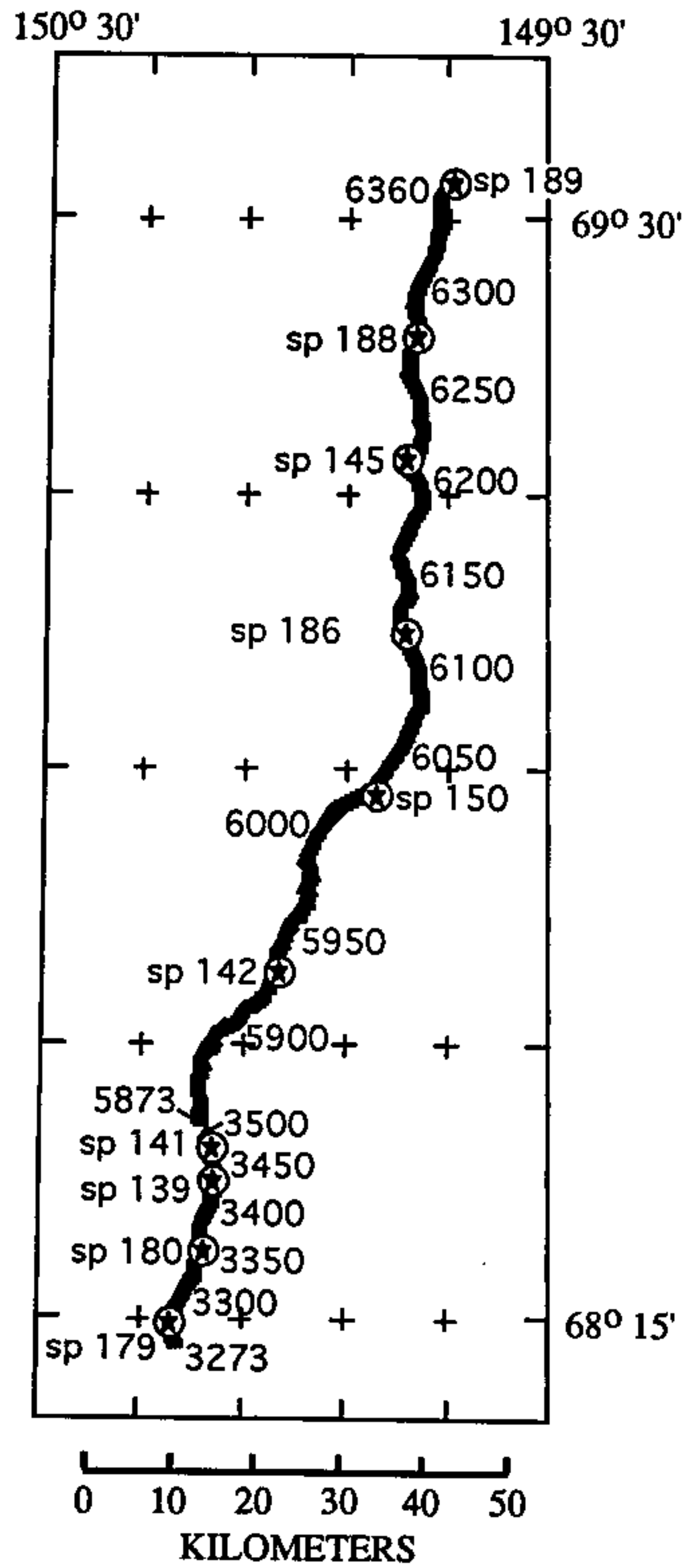


Figure 5d. Deployment 4 location map.

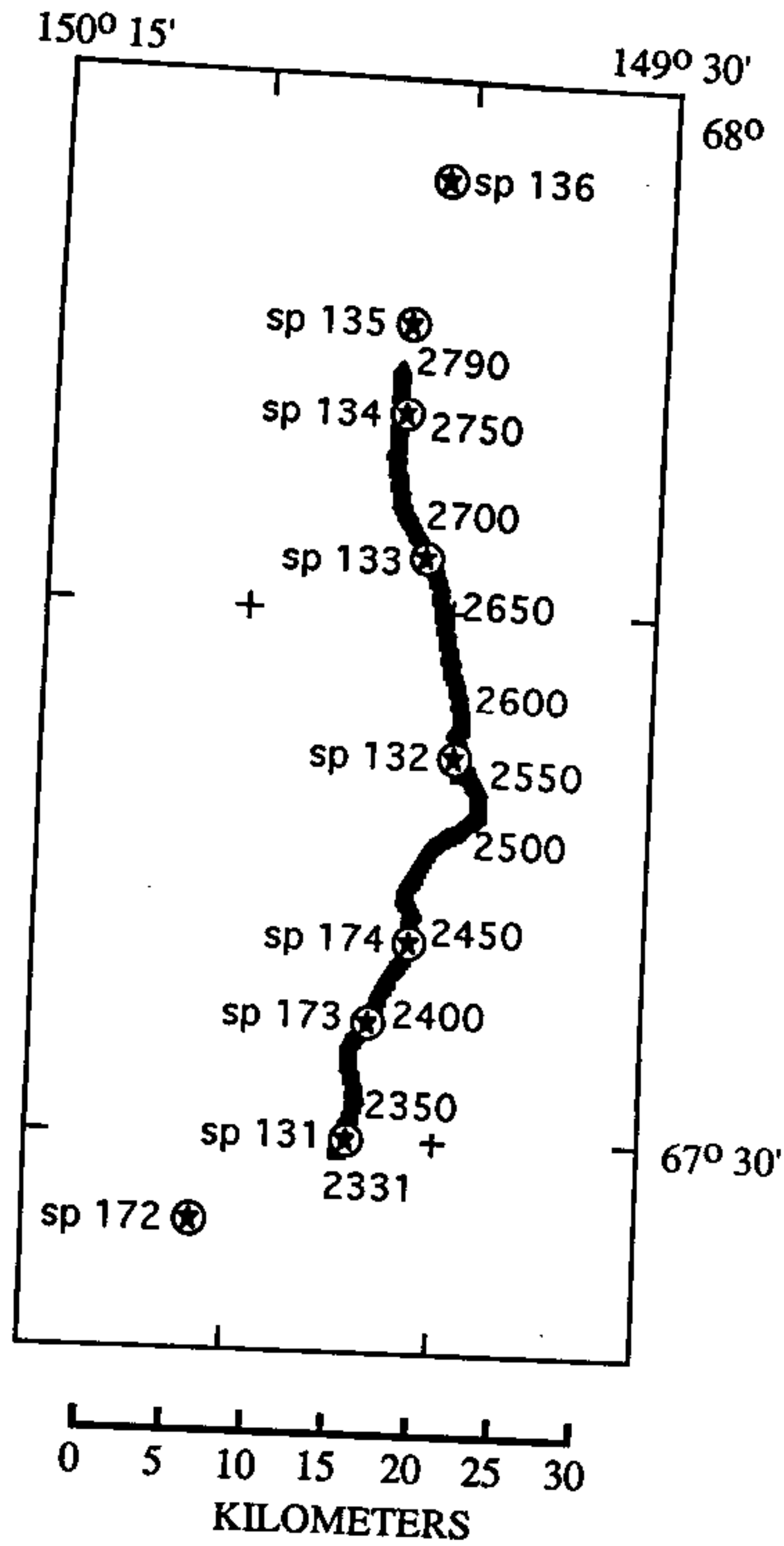


Figure 5e. Deployment 5 location map.

through the Brooks Range onto the North Slope. Ten in-line shots and four off-end shots were fired into the deployment (Figures 1, 3, 5d). Deployment 5 was laid out such that it overlapped both deployments 2 and 3; it filled in a gap in high-frequency coverage. Seven in-line shots and two off-end shots were fired into the deployment (Figures 1, 3, 5e).

Seismic stations and shotpoints were located using two Global Positioning Satellite navigation systems (GPS; the Trimble Navigation Pathfinder). These locations are estimated to be accurate to within ± 10 meters horizontally and ± 30 meters vertically. Seismic sources were produced by explosions in drilled holes and shallow lakes. Drill-hole shotpoints consisted of a 20-cm-diameter drill hole filled with an ammonium-nitrate-based blasting agent, boosters, and detonating cord. Shallow lake shotpoints consisted of a distributed charge at the bottom of the lake with detonating cord extending to shore. The amount of explosive and the depth to the top of the charge for each shotpoint are listed in table 2. At shot time, a signal from a USGS master reference clock triggered the shooting system to fire an electric blasting cap, which sequentially caused the detonating cord, boosters, and blasting agent to detonate. The shot origin times are determined by the master clocks, assuming that the explosives detonated at the exact time of the cap break. Generally, master clocks drift less than 1 millisecond per week. However, during this experiment some master clocks had large errors. These errors were corrected during data processing and are described below (see Data processing section). The corrected shot times are listed in Table 2.

SEISMIC RECORDERS

Four different instruments were used to collect data during this experiment - USGS Seismic Cassette Recorders (SCR), GSC PRS1s, Stanford Seismic Group Recorders (SGR III), and PASSCAL Ref Tek 72A-02s. A general description of each is given here. For more detailed descriptions see Murphy (1988) regarding the SCR's, Asudeh and others (1992) regarding the PRS1's, and the SGR II seismic group recorder field system technical manual and the Mark Products L-10 geophone specifications for the Stanford SGR III's.

The SCR's are a single-channel instrument consisting of a Mark Products L-4A 2-Hz vertical-component geophone, a set of three parallel amplifier boards with adjustable gain settings, a clock (temperature-compensated oscillator, TCXO), a VCO (voltage controlled oscillator), and a cassette recorder (Figure 6). The use of three parallel amplifier boards with gains set so that the dynamic ranges of the

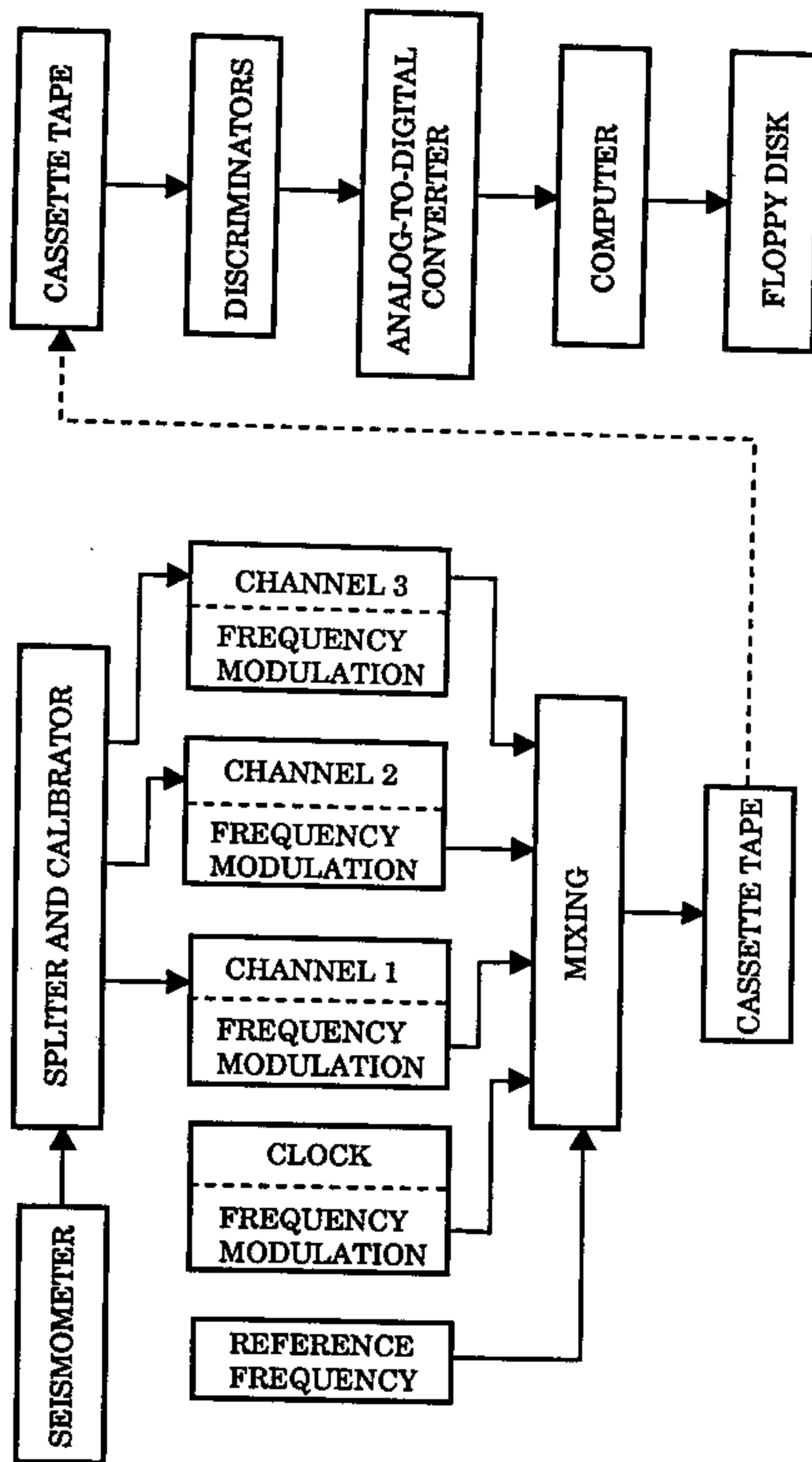


Figure 6. Schematic diagram of the Seismic Cassette Recorder (SCR) data acquisition and processing system

amplifiers overlap, affords a variable total dynamic range. All three data channels and the time code signal (IRIG E) are frequency modulated. The three data carrier frequencies, the clock carrier frequency, and a tape-speed compensation carrier frequency are summed and recorded on cassette tape. During the digitizing process, the cassette tapes are played back and the signals are demultiplexed and demodulated. To prevent accidental shifting of the data-carrier frequencies, the tape-speed compensation carrier frequency is demultiplexed and sent to a circuit board which continuously adjusts the speed of the tape deck such that the tape-speed compensation carrier frequency matches a locally generated reference frequency. A 12-bit analog-to-digital (A/D) converter converts the signals to digital data which are stored on floppy disks. The data are sampled at 200 samples per second. The complete system velocity response is roughly flat between 2 and 30 Hz (Figure 7a) and the approximate ground motion, $A_g(t)$, for this frequency range can be calculated:

$$A_g(t) = \frac{A(t)}{R_{GLE} R_{SA} R_{VCO} D_{DSC} D_{A/D}} = \frac{A(t)}{(409.6) R_{SA}}$$

where $A(t)$ is the amplitude response and R_{GLE} , R_{SA} , R_{VCO} , D_{DSC} , and $D_{A/D}$ are the amplitude factors of the major components (Table 3). Phase characteristics are shown in Figure 7b. Prior to deployment, the clocks in each unit are synchronized to a USGS master clock which drifts approximately one millisecond per week and is checked periodically against satellite clocks. When the cassette recorders are retrieved, a clock drift is measured and these data are used to calculate chronometer corrections at shot time (assuming linear drifts). Most clocks drift less than 20 milliseconds during a 24 hour period.

TABLE 3

<u>Component</u>	<u>Value</u>
R_{GLE}	1 V/cm/sec
R_{SA}	dimensionless gain variable (V/V)
R_{VCO}	25 Hz/V
D_{DSC}	0.04 V/Hz
$D_{A/D}$	409.6 counts/V

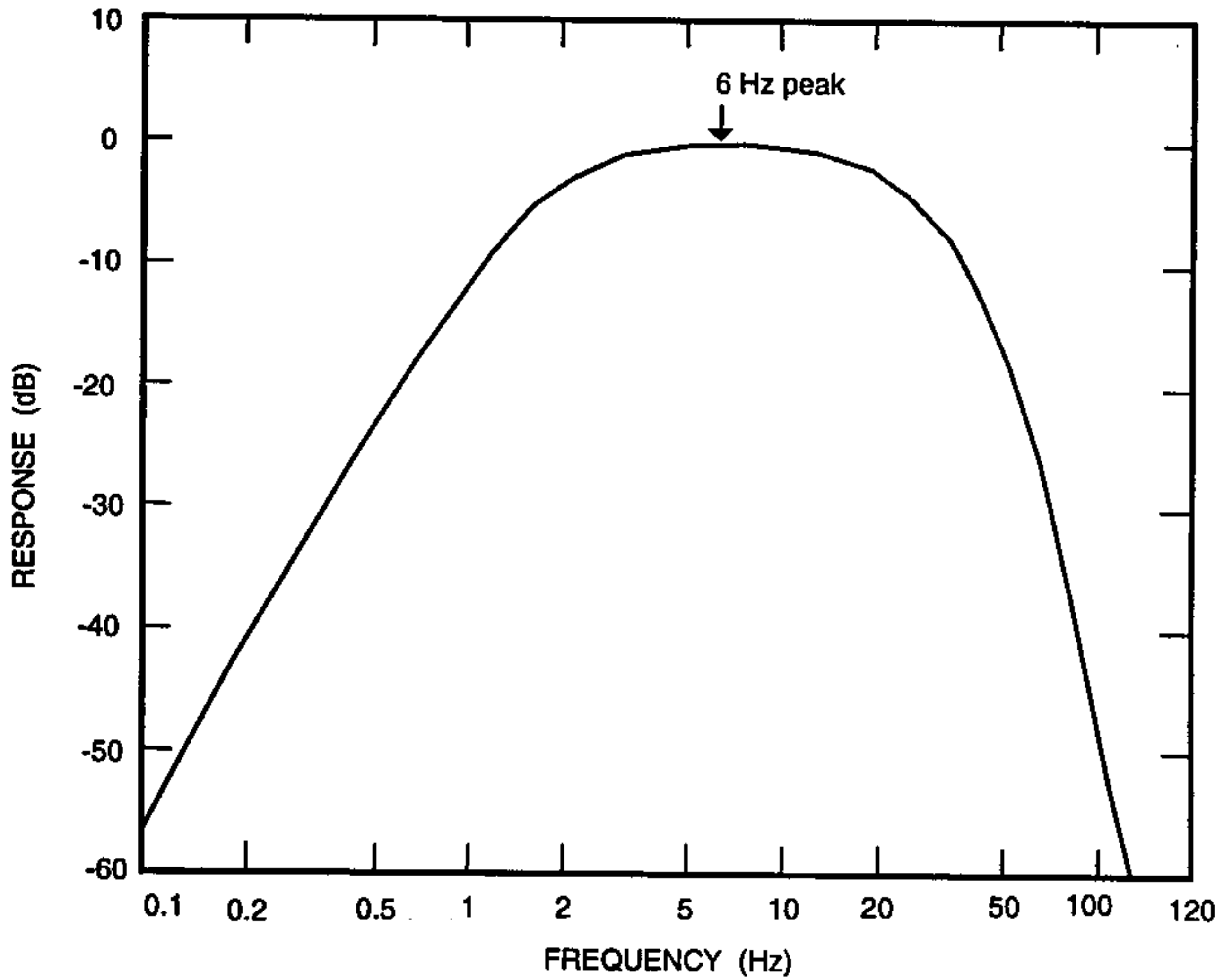


Figure 7a. Theoretical velocity response for the USGS seismic cassette recorder (SCR) and digitizing system with a Mark Products L-4A geophone (2-Hz). (From Dawson and Stauber, 1986)

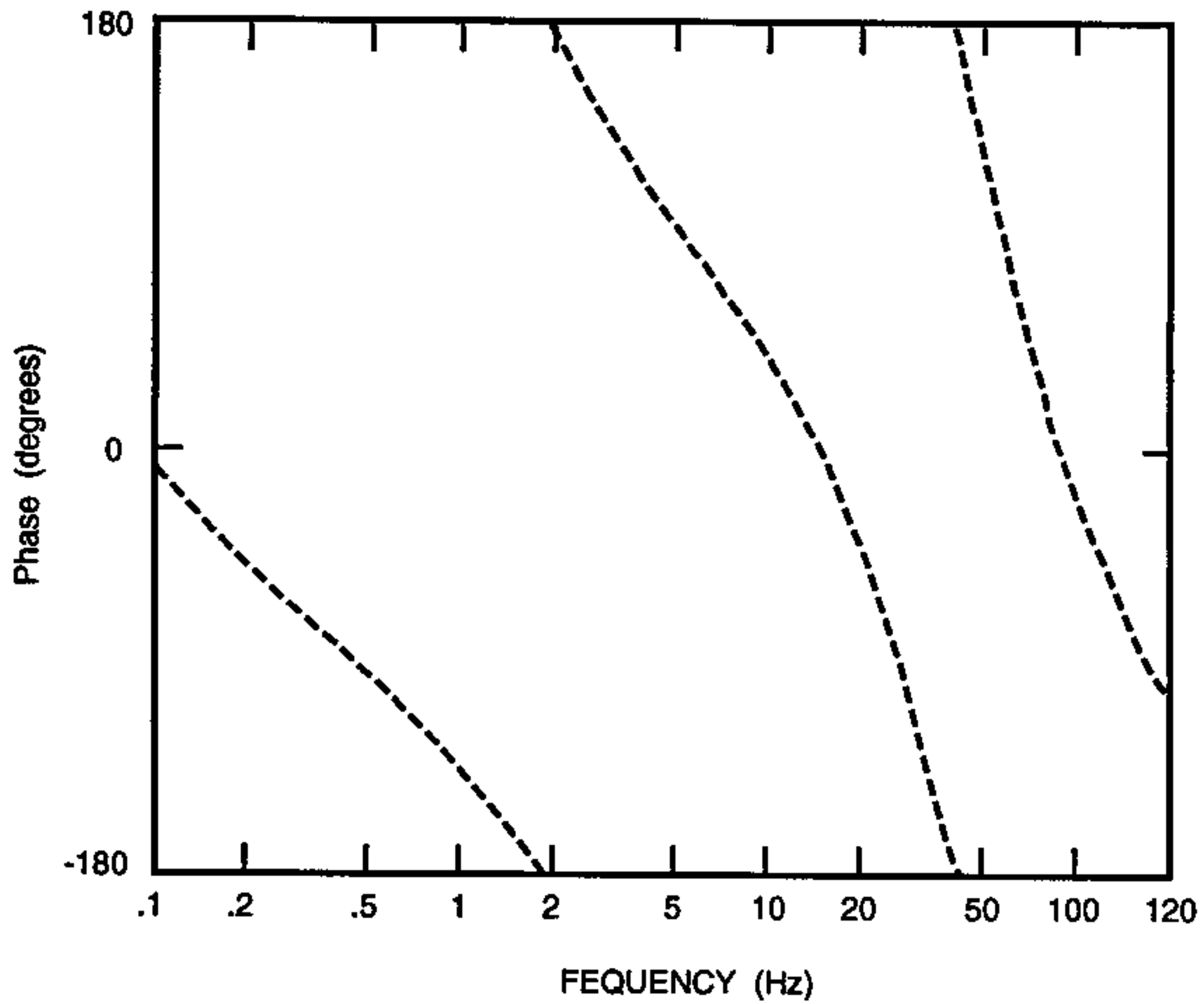


Figure 7b. Phase characteristics of the USGS seismic cassette recorder (SCR) and digitizing system. (From Dawson and Stauber, 1986)

The PRS1's are also single-channel instruments that use a Marks Products L-4A 2-Hz vertical-component geophone. Automatic gain-ranging from 1 to 1024 in binary steps allows a total dynamic range for these instruments of 132 dB. Seismic data are sampled at 120 samples per second by a 12-bit A/D board and stored in memory (DRAM) until the data are uploaded to a PC. Phase and amplitude response curves for the overall system are shown in Figures 8a and 8b, respectively. The amplitude response peaks about 5 Hz. Timing is provided for each unit by a temperature-compensated oscillator (TCXO) that is synchronized to GMT via satellite during the programming (or downloading) process. After retrieval of the instruments, the clock drift is measured for each instrument and clock corrections are made assuming linear drift rates. Most clocks drift less than 20 milliseconds during a 24 hour period. The PRS1 was designed by the Geological Survey of Canada and built by EDA Instruments Ltd.

The SGR III is a single channel, digital seismic recorder with a theoretical dynamic range of 156 dB. Data are sampled at 500 samples per second by a 12-bit A/D board with gain ranging from 0-90 dB in 6 dB steps. The Stanford SGR's have been modified to turn on at preset times instead of using the standard radio turn on. Timing is provided by a temperature-compensated internal oscillator (TXCO) that is synchronized to a USGS master clock prior to deployment. Like the SCR's and the PRS1's, most SGR clocks drift less than 20 milliseconds during a 24 hour period. The digital data and the clock drift at the time of instrument retrieval are recorded on cartridge tape. The drift rates (assumed linear) are used to calculate chronometer corrections at shot time. For this experiment, the SGR III pre-amplifier was set to 50 mV, the low-cut filter was "out", and the 60-Hz notch filter was "in". Figure 9a shows the phase characteristics associated with these filter settings. Each SGR III was connected to a single string of 6 modified Mark Products L-10B vertical component geophones (8 Hz) connected in series. The total system response is shown in Figure 9b. The SGR III recorders were designed by Amoco Production Company, built by Globe Universal Sciences, Inc., and modified by the USGS.

The PASSCAL Ref Tek 72A-02 instruments are a six-channel digital seismic data acquisition systems with a 200 M Byte data disk and an OMEGA clock. The instruments have a variable-gain preamplifier which can be set between a gain of 1 and a gain of 8192. During this experiment most of the instruments had a gain of 256. Cables were extended to 6 sets of Mark Products L-10B vertical-component geophones, similar to ones used with the SGR III's described above. Thus, each Ref Tek recorded data from six separate locations (or stations). The total system response is shown in figure 10.

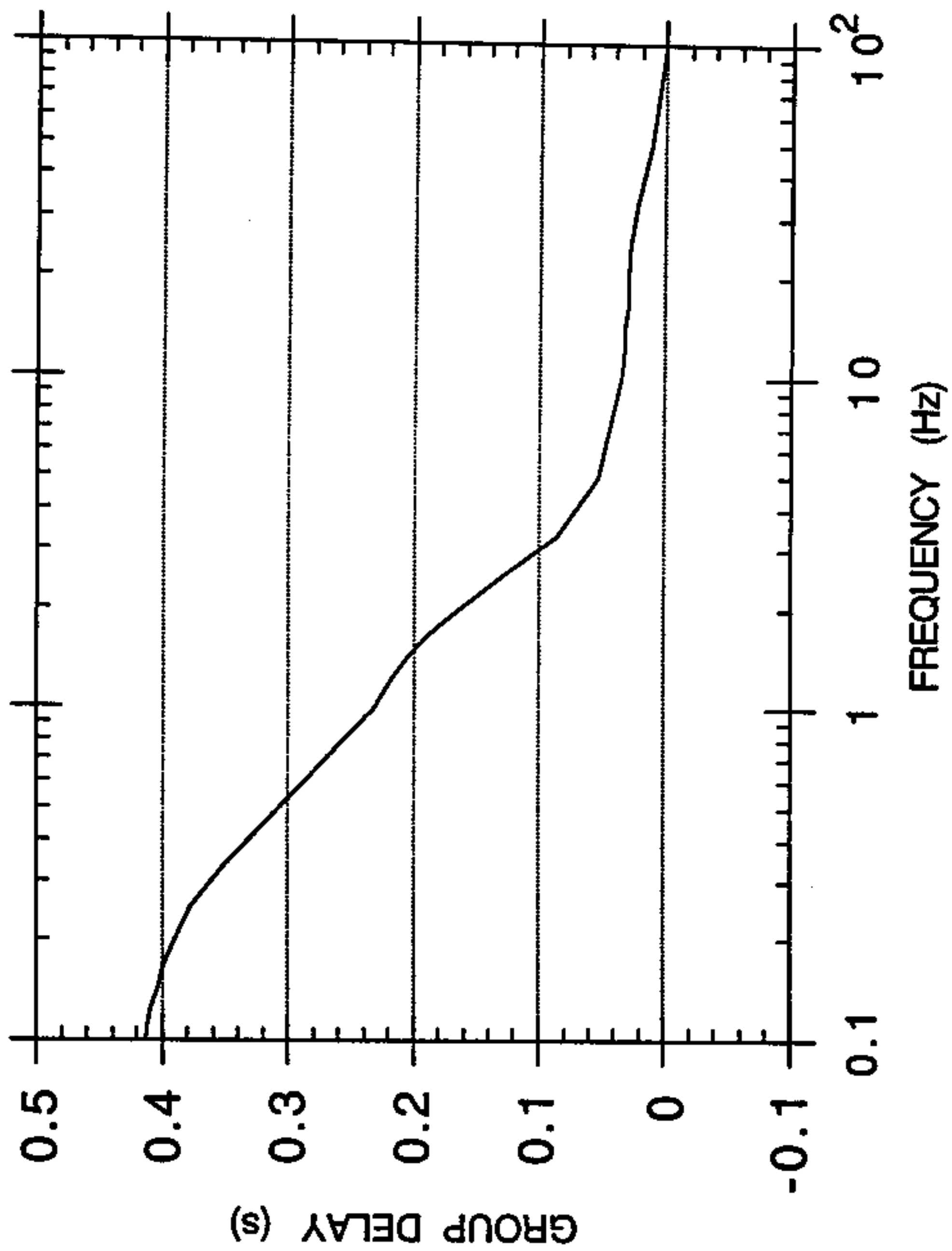


Figure 8a. The phase characteristics of the PRS1.

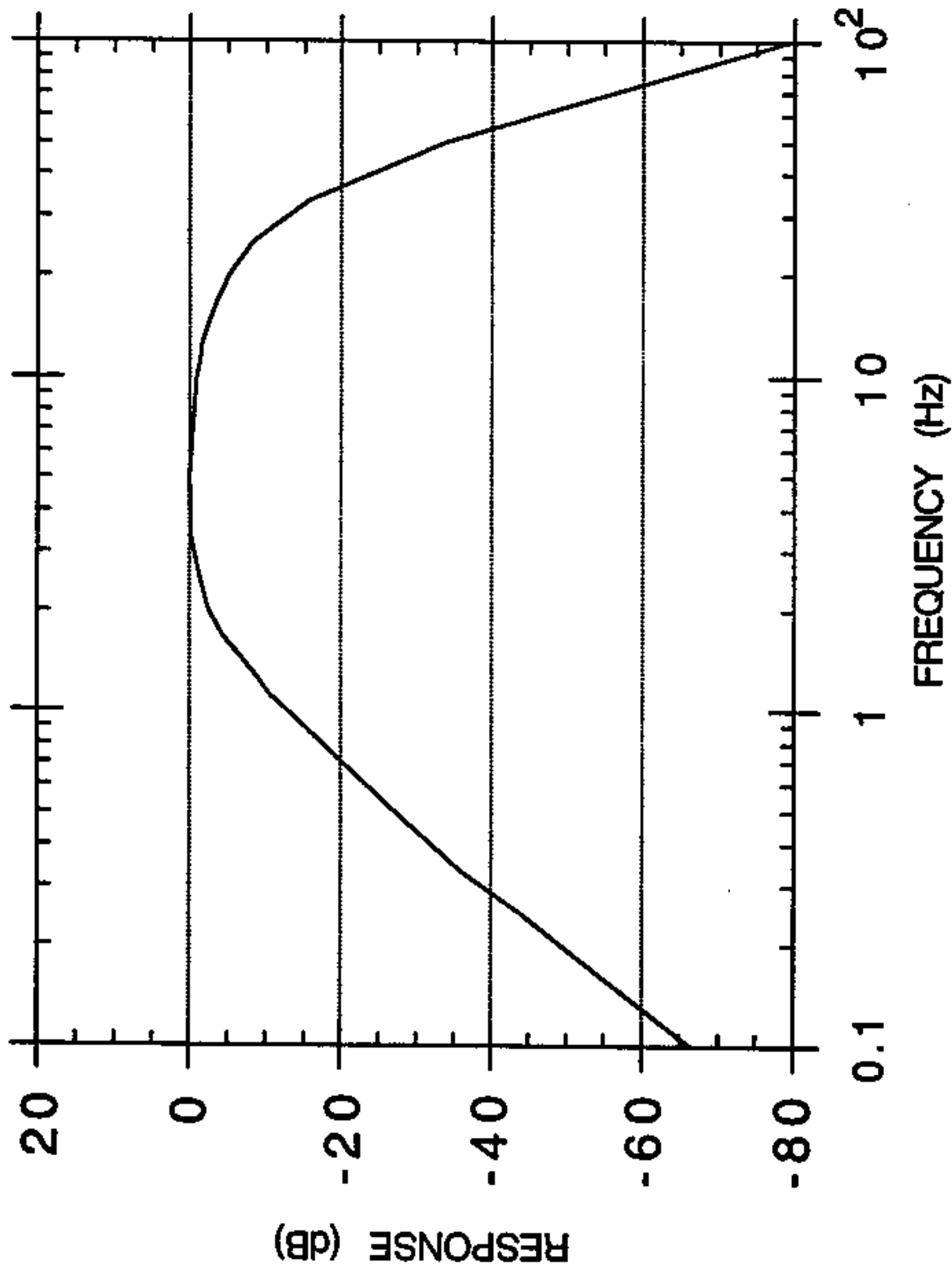


Figure 8b. The amplitude response for the PRS1 with the Mark Products LA-A geophone (2-Hz).

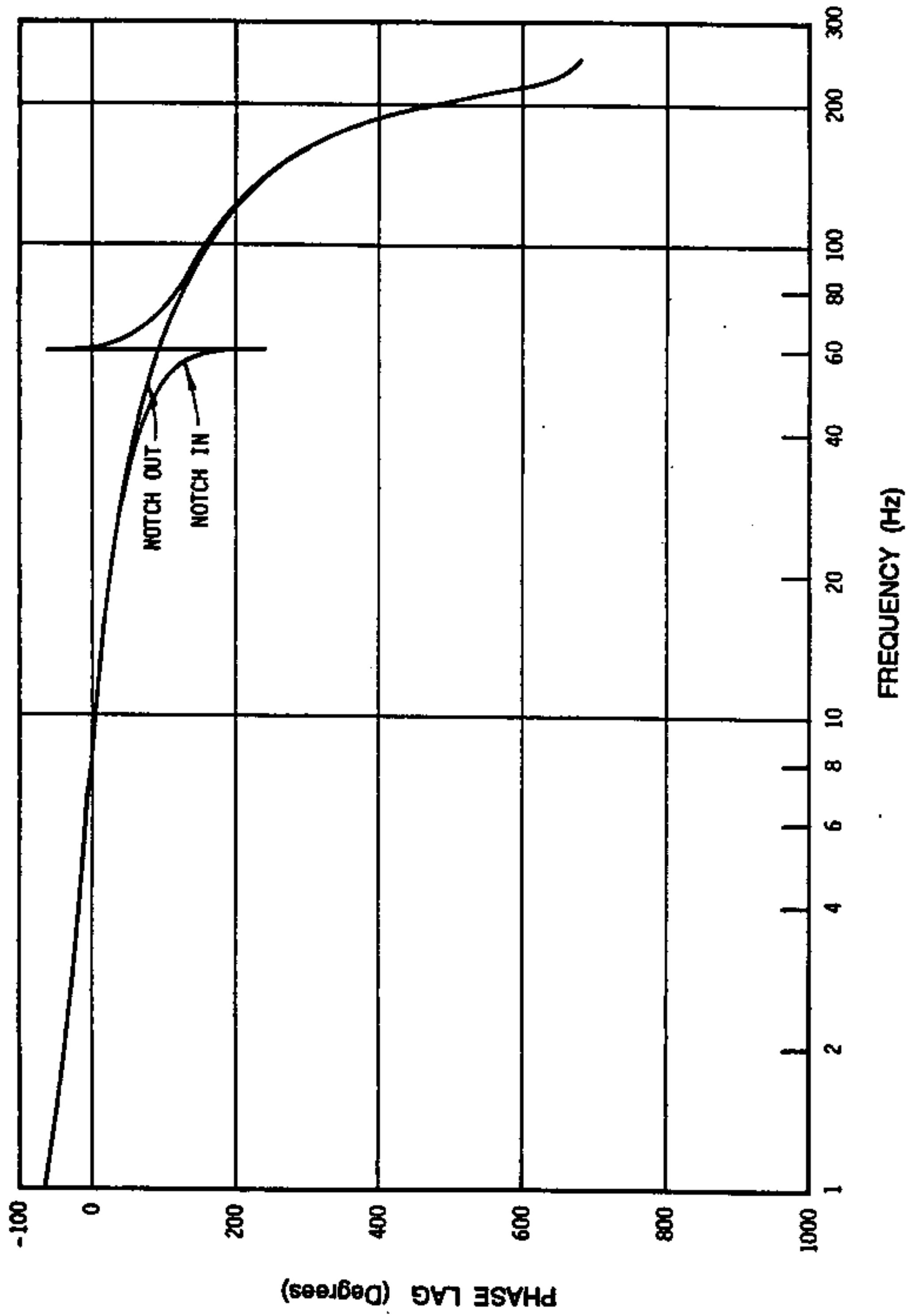


Figure 9a. The phase characteristics of the SGR III's with filters as described in the text (the geophone is not included here).

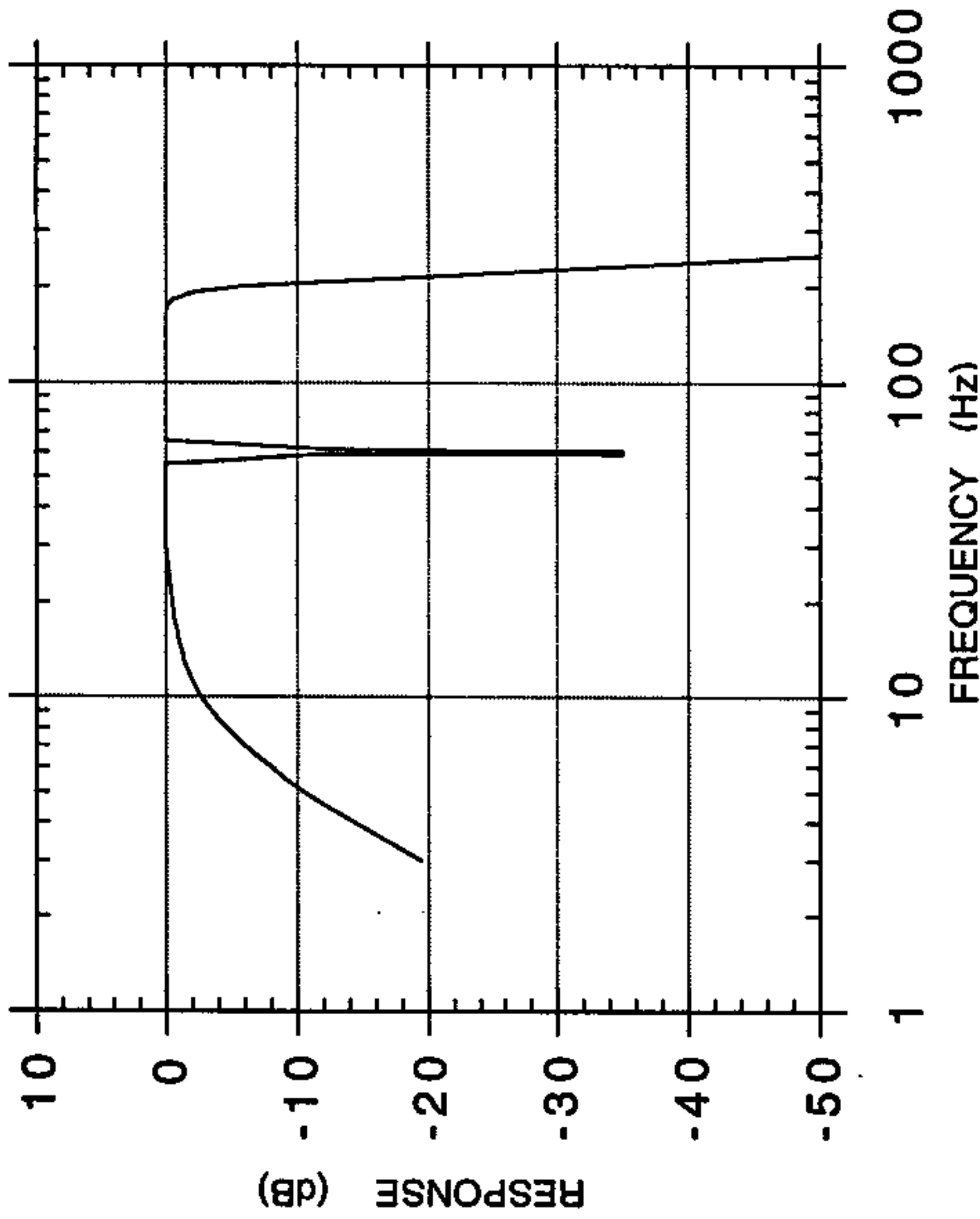


Figure 9b. The amplitude response for the SGR III with the modified Mark Products L10-B geophone string.

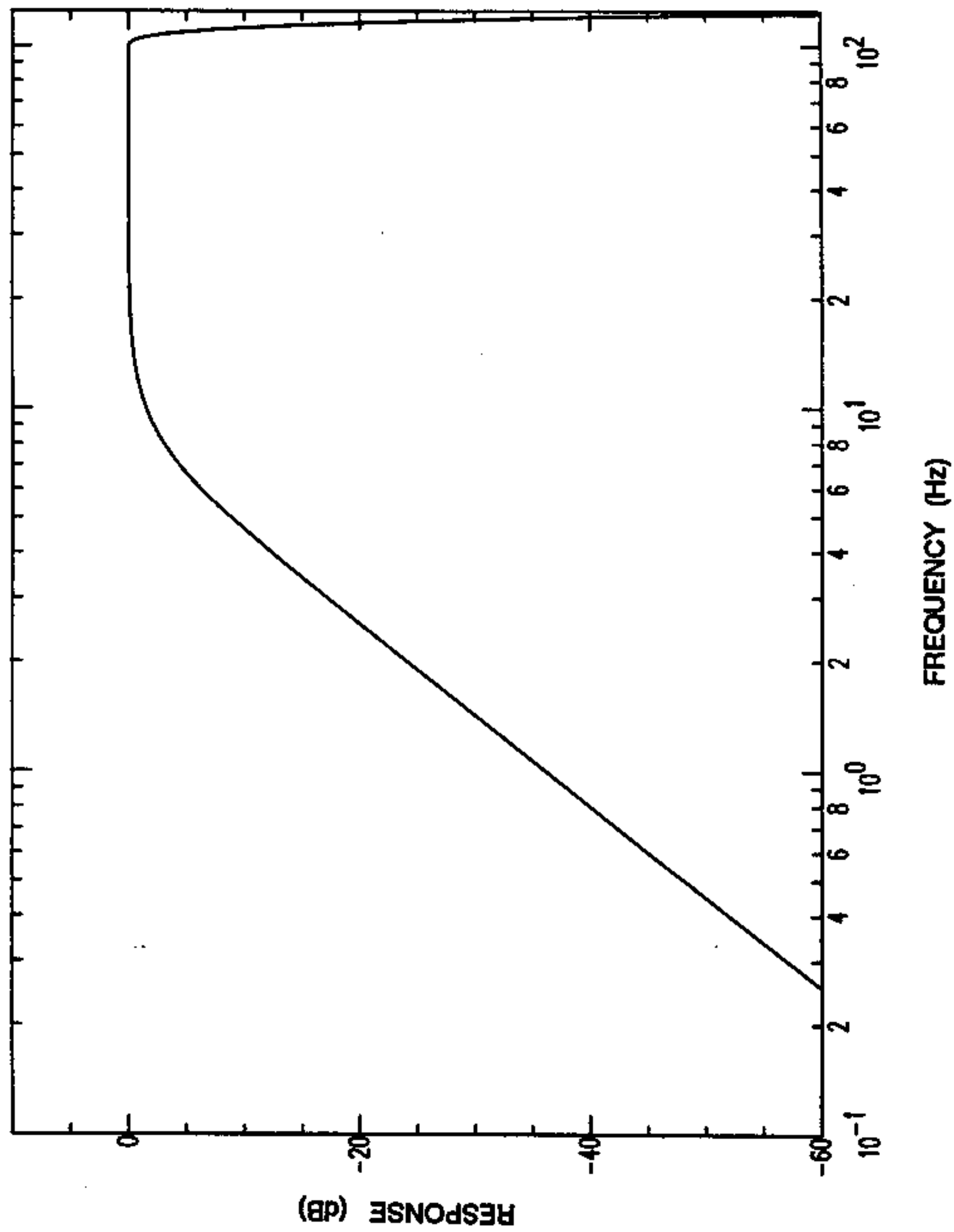


Figure 10. The amplitude response for the REF TEK 72A-02 seismic recorder with the Mark Products L10-B geophone string.