DATA PROCESSING

The mix of instruments posed several unique recording problems. The SCR and PRS1 instruments have nearly matched instrument responses designed for lower-frequency refraction recording (2-30 Hz), whereas the SGR and Ref Tek recorders are matched and were equipped with industry geophones designed for higher-frequency reflection recording (≥ 10 Hz). Although all four playback systems produce SEGY data tapes, the header files and sample rates are different for each system. Record sections and normal-moveout (NMO) corrected shot gathers were produced in the field within 48 hours of shooting because each seismic instrument system had its own data playback facility. However, merging the data required extensive processing.

Processing of the data was undertaken at Rice University on a SUN SPARC 4/390 computer using the Cogniseis DISCO processing system. Geometry for recording sites was defined for each of the five deployments (Figures 3 and 5) and shotpoints were defined by distance to the nearest recording site. No geometry was defined for shots 62 and 63. Processing proceeded deployment by deployment in 3 stages (Figure 11). In the first stage, major trace header variables were established for each instrument type including shot and receiver parameters. Timing corrections associated with instrument recording and geometry corrections were applied in the first phase along with a reducing velocity of 8 km/sec. In the second stage, data belonging to each of the different instrument types were merged and sorted into shot order. Additional trace header variables were assigned and all shots were plotted and tables for the trace headers were compiled. Finally, in stage III, the shot ordered data were written in SEGY format to tape.

Stage I

Each of the different instrument systems produced raw SEGY formatted data tapes with different predefined trace headers. Certain key variables, namely the field file identification, FFID, trace sequence number, SEQNO, and the receiver station location, XSTA, were used to define a consistent set of major trace headers; SHOT (bytes 9-12), SP (bytes 17-20), and CHAN (bytes 13-16). To identify the different instrument types, a BOXTYPE (bytes 211-212) trace header was defined; 1= SCR, 2 = SGR, 3 = PRS1, and 4 = Ref Tek.

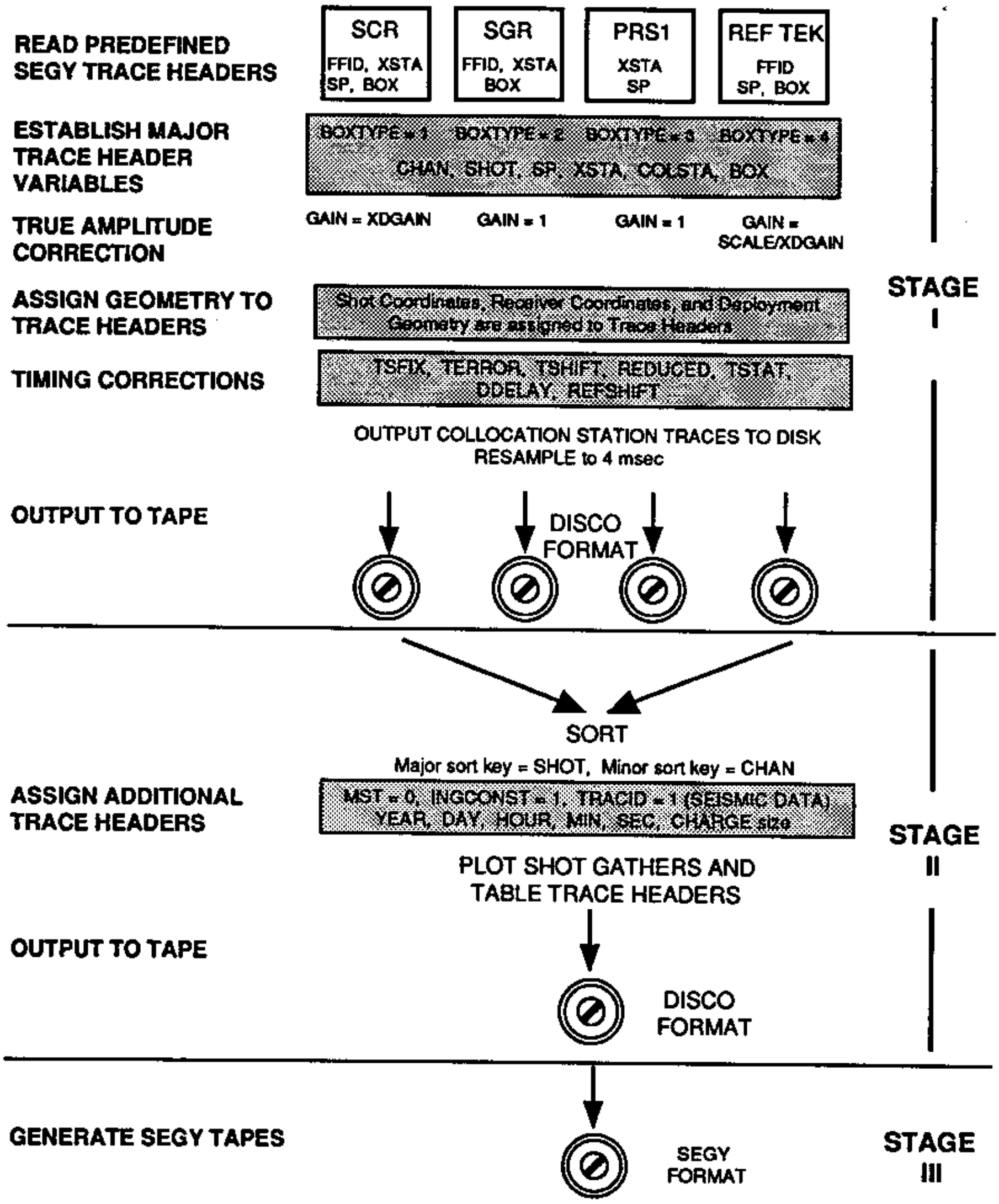

Figure 11. Schematic diagram showing the steps used to process the Brooks Range data.

During each deployment, one site was chosen to collocate all instrument types. The trace header COLSTA (bytes 235-236) was defined to indicate which traces are from collocation sites. COLSTA is set to 1 for collocation sites; otherwise it is 0. Table 4 lists station locations used for collocation sites. Collocation traces were used to check timing corrections and trace polarity. The amplitude of these traces can be used to obtain absolute amplitude corrections.

TABLE 4

Deployment	Collocation Station	Box type
1	1679	2,3,4
2	2100	1,2,3,4
3	3055	1,3,4
4	3480	3,4
5	2515	2,4

Amplitude corrections or scaling ratios of one instrument type to another have been calculated in two ways. The first (Table 5, A), a more approximate method, compared maximum and average amplitudes for collocated box-types 1, 2, and 4 for only deployment 2. In a second more thorough evaluation (Table 5,B), collocation amplitudes for all Brooks Range deployments were calculated by averaging both positive and negative amplitudes over a time window. A 'mean' or average scale factor for each box type was then calculated. These two estimates provide scale factors within a factor of 2 of each other (Table 5)

TABLE 5

Box Type	Instrument	Scaling Factor A / B
1	SCR	1.0 / 1.0
2	SGR	4.5×10^6 / 6.79×10^6
3	PRS1	-- / 0.641
4	Ref Tek	7.5×10^7 / 9.73×10^7

The timing corrections applied to the Brooks Range data include: a correction due to shot errors, instrument drift corrections, and a reduction time correction. To ensure that the original data can be recovered or that the timing errors can be recomputed, the major timing variables are placed in the extended SEGY trace header space (user defined space). The following is a definition of those headers:

TSFIX — digitizing start time in msec.

DRIFT — instrument drift in msec.

TERROR — shot time correction in msec (due to master clock error).

MST — MST is set equal to 0.
Timing correction so that digitized traces start on the second. For SGR data, this correction is done in the transcribing process by adding MST to the DRIFT term. In the SCR and PRS1 data, the correction is done in the digitizing process.

TSHIFT — Shifts the beginning of the trace to shot time. TSHIFT is defined for each instrument type as follows:

SCR	XOFFSET/8.0* + TSFIX + TERROR - DRIFT
PRS1	XOFFSET/8.0* + TSFIX + TERROR - DRIFT
SGR	TSFIX + TERROR + DRIFT
Ref Tek	TSFIX + TERROR + DRIFT

* - reduction time applied to data in the field.

REDUCED — reduction time applied to the data (- OFFSET/8.0 (km/s)).

TSTAT — Sum of all time shifts applied to the original data.
(TSHIFT + REDUCED).

DDELAY — If DDELAY is removed the trace is returned to the state that we received it. DDELAY is defined for each instrument type as follows:

SCR	TSTAT - MST*/1000
PRS1	TSTAT - MST*/1000
SGR	TSTAT + 0
Ref Tek	TSTAT - MST*

* - MST from original field tapes.

REFSHIFT — Empirical static shift applied to the Ref Tek's which experienced large clock drifts. This was calculated using cross correlation's on adjacent SGR traces.

Based on analysis of first arrival time picks, it is likely that an additional -0.12 sec shift for shot 15 and a -0.1 sec shift for shot 29 is required to satisfy reciprocity constraints. These shifts (travel-time advances) are approximate. To

correct for a missed shot window on the first deployment, traces from shot 63 (sp 126) were merged with shot 10 (sp 126). Data from shot 62 (sp 127) did not fit the defined geometry and therefore, are not presented here. At this stage, the data were resampled to 4 msec and temporary tapes were written for each instrument system.

Stage II

During the second stage, data from the temporary tapes for each instrument system were merged and sorted into shot ensembles and the data were plotted. In addition, trace headers were tabled and checked. At this stage, trace headers related to the date and time of shots (see extended SEGY trace header space of table 6) and shot charge size (CHARGE; bytes 187-188) were added, TRACEID (bytes 29-30) was set to 1 (seismic data), MST (bytes 181-184) was set to 0, and the instrument gain constant, INGCONT (bytes 185-186), was set to 1.

Stage III

In the third and final stage of processing, SEGY-formated data was written to tape at 6250 bpi and trace header information was written to the EBCDIC reel header (Figure 12). The data were written as shot gathers in deployment order with a sample rate of 4 msec and a trace length of 60 seconds (see appendix B for actual tracelength). A description of the trace headers is given in Table 6.

Several headers were specially set to ensure compatibility with U.S. Geological Survey record-section plotting programs and software at the Canadian Geological Survey (Luetgert, 1988). Headers MST (bytes 181-184) and COR (bytes 185-186) were set to zero. In addition, the trace start time (bytes 157 through 166) was set to the shot time (bytes 189 through 202). The instrument gain correction (bytes 121-122) was set to one.

```
*************************************
* SEG-Y BINARY HEADER INFORMATION *
*************************************

MAXNTR.......          800
SAMPLE RATE..         4000  (MICROSECONDS)
LENGTH.......        15000  (SAMPLES)
DATA FORMAT..            1  (IBM FLPT)


**********************
* EBCDIC REEL HEADER *
**********************

C1      BROOKS RANGE EXPERIMENT 1990  : RICE UNIVERSITY PROCESSING
C2      GSC, SGR, PRS1 AND  SCR MERGED DATA FOR DEPLOYMENT 2.
C3
C4      SAMPLE RATE = 4 MS / 60 SECS DATA / 32 BYTE IBM FLOAT FORMAT
C5      DATA IS REDUCED (VRED = +8.0KM/SEC)
C6      DATA IS DRIFT CORRECTED, AND CORRECTED FOR ALL OTHER TIMING ERROR
C7              AND TIMING SHIFTS.
C8      HEADERS ARE DESCRIBED AS NAME (XXX,N) WHERE XXX IS THE BYTE LOCATION
C9                                                    N   IS THE NUMBER OF BYTES
C10      SHOT     (  9,4) = SHOT SEQUENCE NUMBER
C11      CHAN     ( 13,4) = CHANNEL NUMBER
C12      ESPNUM   ( 17,4) = SHOTPOINT NUMBER, EQUIVALENT TO SP
C13      INGCONST(121,2) = TRUE AMPLITUDE FACTOR =1 INSTRUMENT GROUPS ARE TRUE
C14                        AMPLITUDE WRT THEMSELVES NOT WRT EACH OTHER
C15     MST      (181,4) = 0 MICROSECONDS OF TRACE START TIME
C16     COR      (185,2) = 0 MS TIMING CORRECTION (MST AND COR HEADERS USED TO
C17                         MAINTAIN COMPATABILITY WITH LUETGERT'S PROGRAMS)
C18     CHARGE   (187,2) = CHARGE SIZE IN LBS
C19     SYEAP    (189,2) = SHOT TIME:(YEAR,HOUR,DAY,MIN,SEC)EACH IN 2 BYTE HEADER
C20     SSMIC    (199,4) = SHOT TIME: MICROSECONDS
C21     TSFIX    (203,2) = MSEC TIME BEFORE SHOT = INITIAL DIGITIZING TIME
C22     DRIFT    (205,2) = MSEC INSTRUMENT DRIFT
C23     TERROR   (207,2) = MSEC CORRECTION TO SHOT TIME
C24     BOX      (209,2) = SERIAL NO. OF THE BOX!  PRS1 VALUE SHOULD HAVE 'A' PRE
C25     BOXTYPE  (211,2) = 1 FOR SCR / 2 FOR SGR / 3 FOR PRS1 / 4 FOR REFTEK
C26     REC-STAT(213,4) = RECEIVER STATION
C27     TSHIFT   (217,4) = TSFIX + TERROR - DRIFT + XOFFSET/8.0 (TSHIFT CORRECTS
C28                        TO SHOT TIME; -XOFFSET/8.0 IS FAKE REDUCTION APPLIED IN
C29     REDUCED (221,4) = -OFFSET/8.0 (OFFSET IS TRUE <R-S< OFFSET)
C30     TSTAT    (225,4) = TSHIFT + REDUCED (WHAT WE APPLIED TO DATA)
C31     DDELAY   (229,4) = TSHIFT + REDUCED - MST/1000.
C32                        (MST IS A MICROSECOND ERROR ASSOCIATED WITH TURNON TIME
C33                        OF SCR AND PRS1 INSTRUMENTS) IF DDELAY IS REMOVED THE
C34                        TRACE IS RETURNED TO THE STATE IN WHICH WE RECEIVED IT
C35     GAIN     (233,2) = GAIN THAT APPLIED TO TRACES TO PROVIDE TRUE AMP
C36     COLSTA   (235,2) = 1 COLLOCATION STATION : ONE TYPE OF EACH INSTRUMENT
C37                      = 0 OTHERWISE
C38     REFSHIFT (237,2) = EMPIRICAL STATIC SHIFT APPLIED TO REFTEKS(CLOCK DRIFT)
C39     CONTACT A.R. LEVANDER OR S.A. HENRYS FOR ADDITIONAL INFORMATION
C40     PROCESSED BY S.A. HENRYS, A.R. LEVANDER, AND W. LUTTER.END REEL HEADER.
```

Figure 12. EBCDIC reel header.

TABLE 6

ARCHIVE DATA TAPE FORMAT

Archive data tapes are written in standard SEG-Y 32-bit IBM floating point format (Barry et al., 1975). The tape recording density is 6250 bpi and each tape has the standard SEG-Y EBCDIC reel header. Minor modifications to the trace headers allow refraction data to be archived in this format. A list of the header fields used for this data is shown below.

Trace Identification Header (total of 240 bytes)	
1-4	Cumulative sequence number within deployment
5-8	Trace number within reel
9-12	Shot
13-16	Channel (recorder location number)
17-20	Shot point location number
21-24	CDP
25-28	Trace sequence number within shot ensemble
29-30	Trace identification code (1 = seismic data)
31-32	Not used
33-34	Not used
35-36	Not used
37-40	Distance from source to receiver
41-44	Receiver group elevation (m)
45-48	Surface elevation of source (m)
49-52	Shot depth
53-56	Not used
57-60	Not used
61-64	Not used
65-68	Not used
69-70	Not used
71-72	Not used
73-76	Source X coordinate (meters east of Shot point 154)
77-80	Source Y coordinate (meters north of Shot point 154)
81-84	Group X coordinate (meters east of Shot point 154)
85-88	Group Y coordinate (meters north of Shot point 154)

TABLE 6 (continued)

89-90	Not used
91-92	Not used
93-94	Not used
95-96	Not used
97-98	Not used
99-100	Not used
101-102	Not used
103-104	Not used
105-106	Not used
107-108	Not used
109-110	Not used
111-112	Not used
113-114	Not used
115-116	No of samples in this trace
117-118	Sampling interval in microseconds
119-120	Not used
121-122	Gain constant
123-124	Not used
125-126	Not used
127-128	Not used
129-130	Not used
131-132	Not used
133-134	Not used
135-136	Not used
137-138	Not used
139-140	Not used
141-142	Not used
143-144	Not used
145-146	Not used
147-148	Not used
149-150	Not used
151-152	Not used
153-154	Not used
155-156	Not used
157-158	Year of trace start time
159-160	Day of trace start time
161-162	Hour of trace start time
163-164	Minute of trace start time

TABLE 6 (continued)

165-166	Second of trace start time
167-168	Not used
169-170	Not used
171-172	Not used
173-174	Not used
175-176	Not used
177-178	Not used
179-180	Not used
181-184	Microseconds of trace start time
185-186	Millisecond of timing correction
187-188	Amount of explosives (lbs)
189-190	Shot time - Year
191-192	Shot time - Day
193-194	Shot time - Hour
195-196	Shot time - Minute
197-198	Shot time - Second
199-202	Shot time - Microsecond
203-204	Initial digitizing time
205-206	Clock drift rate
207-208	Correction to shot time in microseconds
209-210	Instrument number
211-214	Instrument type (1= SCR, 2= SGR, 3= PRS1, 4 = Ref Tek)
213-216	Reciever location number
217-220	Corrects trace to shot time (see comments in EBCDIC reel header)
221-224	Reduction (- offset / 8.0)
225-228	correction applied to data (see comments in EBCDIC reel header)
229-232	error in turn on time of SCR and PRS1 (in microseconds)
233-234	Gain
235-236	Collocation site for each type instrument (1=yes, 2=no)
237-238	Static shift applied to Ref Teks (clock drift)

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