NIEDERSÄCHSISCHE STAATS- UND UNIVERSITÄTSBIBLIOTHEK GÖTTINGEN

Werk

Jahr: 1974
Kollektion: fid.geo
Signatur: 8 Z NAT 2148:40
Digitalisiert: Niedersächsische Staats- und Universitätsbibliothek Göttingen
Werk Id: PPN1015067948_0040
PURL: http://resolver.sub.uni-goettingen.de/purl?PPN1015067948_0040

LOG Id: LOG_0022
LOG Titel: A field evaluation of Caner's broad-band geomagnetic induction instrumentation
LOG Typ: article

Übergeordnetes Werk

Werk Id: PPN1015067948
PURL: http://resolver.sub.uni-goettingen.de/purl?PPN1015067948
OPAC: http://opac.sub.uni-goettingen.de/DB=1/PPN?PPN=1015067948

Terms and Conditions

The Goettingen State and University Library provides access to digitized documents strictly for noncommercial educational, research and private purposes and makes no warranty with regard to their use for other purposes. Some of our collections are protected by copyright. Publication and/or broadcast in any form (including electronic) requires prior written permission from the Goettingen State- and University Library.
Each copy of any part of this document must contain there Terms and Conditions. With the usage of the library's online system to access or download a digitized document you accept the Terms and Conditions.
Reproductions of material on the web site may not be made for or donated to other repositories, nor may be further reproduced without written permission from the Goettingen State- and University Library.

For reproduction requests and permissions, please contact us. If citing materials, please give proper attribution of the source.

Contact

Niedersächsische Staats- und Universitätsbibliothek Göttingen
Georg-August-Universität Göttingen
Platz der Göttinger Sieben 1
37073 Göttingen
Germany
Email: gdz@sub.uni-goettingen.de

J. Geophys. 40, 121–129, 1974

A Field Evaluation of Caner's Broad-Band Geomagnetic Induction Instrumentation

H. Dragert

Department of Geophysics and Astronomy
University of British Columbia, Vancouver

Received September 17, 1973

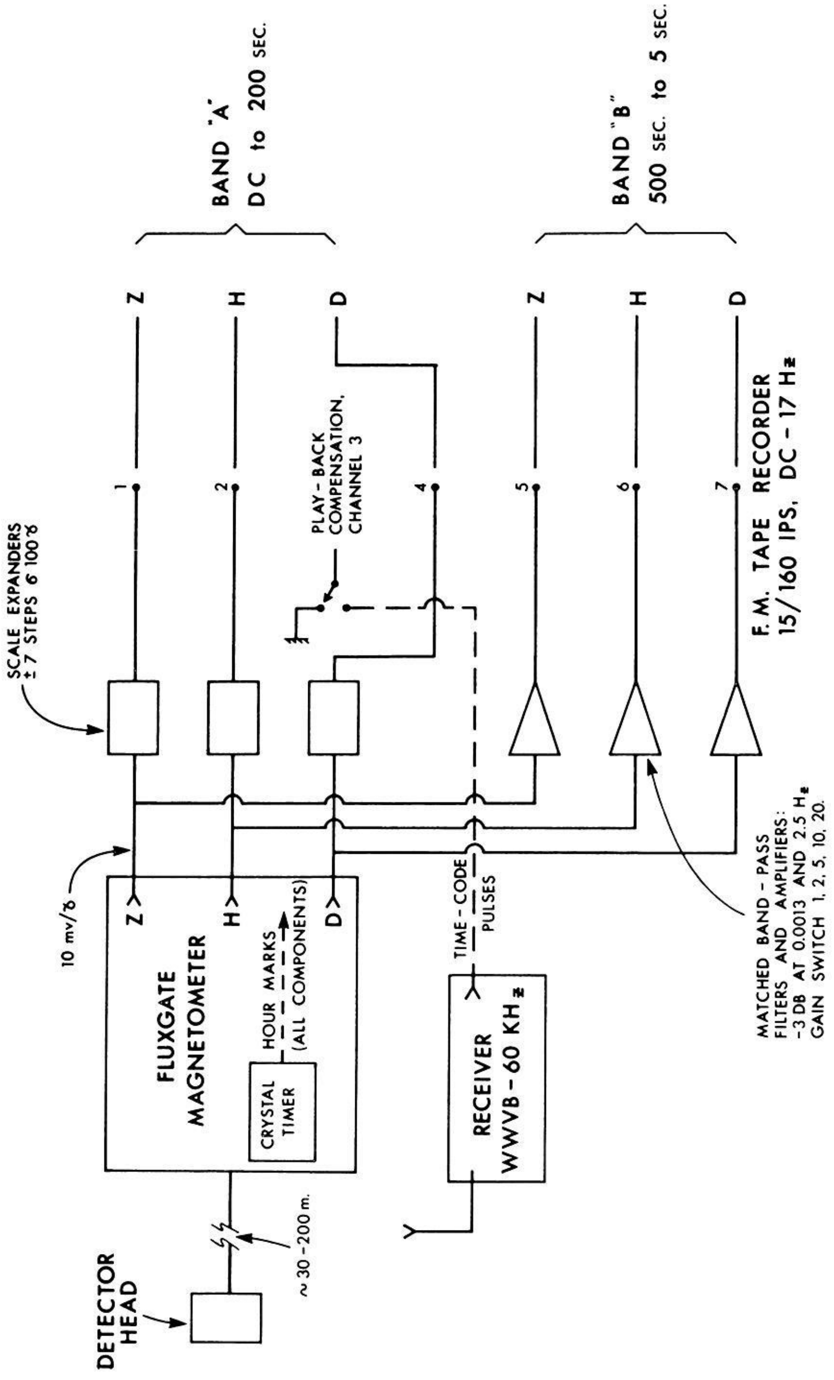
Abstract. Instrumentation for broad-band geomagnetic induction work developed by Caner and Dragert (1972) is briefly evaluated on the basis of a two-month field project employing four of these instrument systems in the geomagnetic depth-sounding (GDS) mode. The results may be summarized as follows: No instrumental difficulties were encountered in the operation of the fluxgate sensors modified by the filter-amplifier interface modules, and only the 7-channel FM tape recorders used with these dual-band systems actually required the constant attention of the five-day service cycle employed in this project. The two overlapping frequency bands performed almost to specification. The system dynamic range was generally 78 db, with the short-period band resolution limited to 0.2 γ. The proposed frequency range of 0.01 to 100 millihertz was limited in practice to about 0.05 to 100 millihertz because of instrumental sensitivity to daily temperature variations. It is concluded that with minor logical modifications, a more compact, more flexible version of this system can easily be built which would prove invaluable for field research in broad-band geomagnetic variation studies.

Key words: Geomagnetic Induction Instruments — Registration of Geomagnetic Variations — Geomagnetic Depth-Sounding.

1. *Introduction*

Regions such as western North America, geomagnetically characterized by a strong attenuation of the vertical field fluctuations (ΔZ), present the stringent requirements of a high sensitivity combined with a large dynamic range for any geomagnetic induction instrumentation. To improve the recording of magnetic variations particularly in such areas, a broad-band geomagnetic depth-sounding system was developed by Caner and Dragert (1972). Basically, by recording data in two overlapping frequency ranges with variable sensitivities, this instrumentation system was designed to record over a frequency band of 0.01 to 100 mHz with a dynamic range of about 80 db.

Although this system can be used for both geomagnetic and magnetotelluric induction work, this report deals only with the first extensive field testing of the GDS mode of operation. With reference to the block diagram


DETECTOR HEAD
~30-200 m.
FLUXGATE MAGNETOMETER
CRYSTAL TIMER
HOUR MARKS
(ALL COMPONENTS)
Z
H
D
10 mv/γ
SCALE EXPANDERS
± 7 STEPS 6 100γ
RECEIVER
WWVB-60 KHz
TIME-CODE
PULSES
PLAY-BACK
COMPENSATION,
CHANNEL 3
1
2
4
5
6
7
Z
H
D
Z
H
D
BAND "A"
DC to 200 SEC.
BAND "B"
500 SEC. to 5 SEC.
F. M. TAPE RECORDER
15/160 IPS, DC - 17 Hz
MATCHED BAND-PASS
FILTERS AND AMPLIFIERS:
-3 DB AT 0.0013 AND 2.5 Hz
GAIN SWITCH 1, 2, 5, 10, 20.

of Fig. 1, the aspects of this mode may be summarized as follows. The detector head, a transistorized saturable-core magnetometer (Trigg, Serson, and Camfield, 1971), senses H, D, and Z variations, providing signals at a sensitivity of 10 mv/γ. The three components are then split into two bands. In Band A (DC to 200 s periods), the signals are passed through automatic zero-suppression circuits (Trigg, 1970) which step the voltage back by 1 v when the amplitude of the input signal exceeds 1 v. With seven steps in both positive and negative directions, a total dynamic range of 1600 γ is achieved. In Band B (500 s to 5 s periods), the signals are passed through matched active band-pass filters which remove low frequencies and amplify higher frequencies to a sensitivity step-wise variable between 20 and 200 mv/γ. These two bands, along with superimposed internally generated hour marks, are recorded on 7-channel FM tape recorders (Geotech type 17373, or Precision Instruments type PI-5100) at a recording speed of 15/160 ips and within a recording band of DC to 17 Hz. Time-code pulses from a WWVB signal for absolute time reference, or, the FM centre frequency for playback compensation are recorded on the remaining channel.

2. *Field Performance of the System*

During a period of two months, beginning mid-September 1971, four complete broad-band GDS systems were operated as part of a short-spaced profile in the Rocky Mountain Trench area near Golden, British Columbia. The location of these four systems is illustrated in Fig. 2 and summarized in Table 1. All sites were easily accessible by road and had facilities of either line or diesel-generated electric power. Consequently, the systems, which have optional AC or DC power modes, all used AC power for operation.

Table 1. Location of the four broad-band GDS systems during the pilot project

Station		Longitude	Latitude	Geomagnetic latitude
Downie Creek	(DOW)	118.2° W	51.3° N	58.0° N
Rogers Pass	(ROG)	117.6° W	51.2° N	58.1° N
Nicholson	(NIC)	117.0° W	51.3° N	58.3° N
Banff	(BAN)	115.6° W	51.2° N	58.6° N

←

Fig. 1. Block diagram of system circuitry for GDS application. (After Caner and Dragert, 1972)

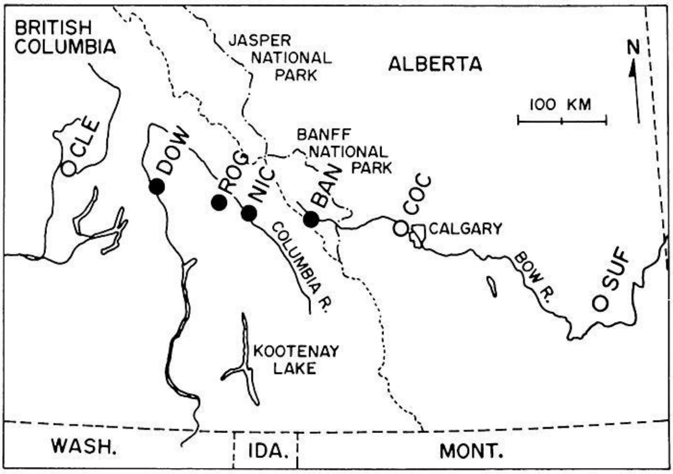


Fig. 2. Station locations for the field testing of Caner's broad-band GDS systems. (Solid circles are broad-band sites, open circles are Askania variograph sites)

However, batteries were still connected in a stand-by configuration to ensure continuous recording during power failures or diesel-generator shutdowns. Indoor sheltering, required by the temperature and humidity sensitive tape recorders only, was available at all sites except ROG where an insulated, weatherproof, wooden shelter was used to house the recorder. All recording was done using 10.5-inch precision reels holding 3600 feet of magnetic tape, thus permitting a five-day service cycle. The relatively short spacing of stations and their ease of accessibility allowed efficient servicing by a single operator within this cycle, even during adverse weather conditions. Completed data tapes were shipped in magnetically shielded, insulated transit boxes to the University of British Columbia where a brief playback of tapes would reveal any required instrument adjustments which were subsequently communicated to the field operator.

All four systems were operated simultaneously for a period of 55 days, each recording 6 channels of data and thus giving 330 'channel-days' of possible records at each site, a possible 1320 channel-days for the entire project. The data loss due to instrument failure was approximately 200 channel-days, giving a better than 80% relative data return. Tape recorder failure was the primary cause of system breakdown, and would probably have caused greater loss but for the constant attention of the five-day service cycle. At the outdoor site (ROG) low temperatures and wet weather necessitated the eventual addition of a drying agent and an 8-W heating bulb within the recorder housing to ensure a dry, above-freezing environment required for a more reliable operation of this recorder. Aside from some initial excessive heat generation within the insulated transit cases housing the control instrumentation, no major problems were presented by the combined systems of the fluxgate control unit and the filter-amplifier modules. Over the first 15 days of operation, ample simultaneous short-period data had been recorded for a thorough Band B analysis. It was expected to collect sufficient long-period data for Band A analysis within 30 days; however, the infrequent occurrence of magnetic storms and the interruption of continuous, simultaneous records by successive servicing of tape stations prolonged data collection.

3. Evaluation of the System

a) Calibration

Calibrations of the broad-band systems were carried out at the beginning and end of each five-day tape by applying an accurate ±1.00 volt pulse from an internal battery as an input signal to each of the six data channels (This does not provide an absolute calibration of the fluxgate unit, but merely a calibration of recorder sensitivity.) During the 55-day project, the two sites (NIC and BAN) which were subject to small temperature variations showed less than 2% variation in sensitivity over each five-day period. The other two systems displayed slightly larger variations, with the tape recorder at ROG showing calibration changes as large as 5% on playback. It should be noted, however, that when only 'end-of-tape' calibrations are considered in which the temperature equilibrium of the tape recorder is left undisturbed, five-day sensitivity variations were smaller than 2% even at these latter sites.

b) Timing Marks

The hourly time marks generated by the fluxgate control unit were calibrated against a standard WWVB signal at the beginning and end of each tape. During the field project, the maximum deviation observed over a five-day period was two seconds, indicating an absolute timing stability of better than 1 part in 2×10^5. Furthermore, these timing drifts were generally linear and simultaneous playback of timing marks and the WWVB signal indicated that relative time could be recovered to within 0.1 s.

Unfortunately, the fluxgate sensing systems containing the timing circuits were borrowed from the Victoria Earth Physics Branch as complete units, and hence could not be altered easily to introduce time marks after the band-pass filters of Band B. Hence, to avoid large, slowly-decaying, filter-convolved step-functions in the short-period data, the time-mark relays were by-passed for the three Band B channels. However, power or line-impedance fluctuations due to relay closures still generated small (2 to 5 mv) characteristic, filter-convolved time pulses. At the higher Band B amplifications, these slowly decaying signals interfered with actual magnetic variations having periods of the order of the decay time (~ 3 min). However these pulses were well-defined and could be removed digitally before data analysis.

c) Record Quality

The quality of the recovered data depends not only on the sensing system and the actual recorder, but also on tape-playback and analogue-to-digital (A/D) conversion, since these latter operations are an integral part of data reduction. For this project, the FM data were played back using a Sanborn Model 3900 tape recorder employing a flutter compensation mode which kept absolute playback noise below 30 mv. Before digitizing, these analogue signals were low-pass filtered to further reduce playback noise (to ≤ 5 mv) and to reduce aliasing. An Interdata A/D Converter was then employed to digitize the filtered signals over a range of ± 10.00 v with a resolution of 10 mv.

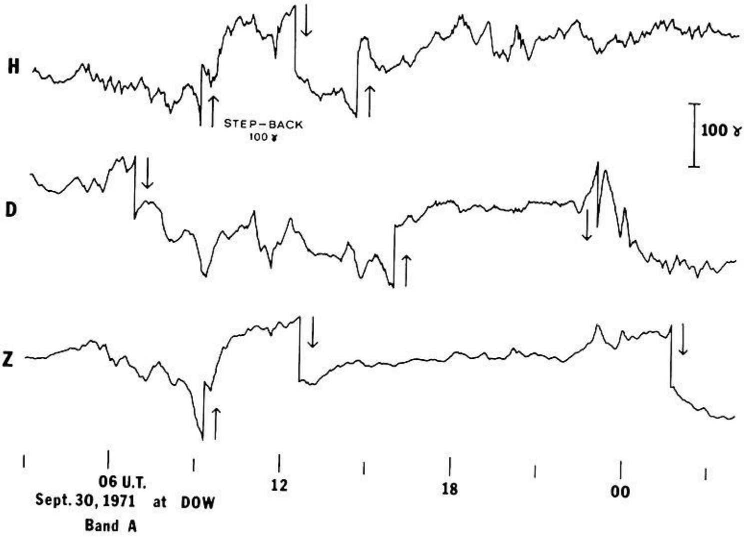


Fig. 3. Example of the broad-band system recording of long-period variations (Band A). Arrows indicate step-backs of 100 γ provided by the automatic zero-suppression circuit of Trigg (1970)

Fig. 3 shows a sample of long-period data (Band A) recorded at DOW. 'Step-backs' of the automatic zero-suppression circuit (shown by arrows) illustrate the extension of the dynamic range. Each step is recorded as an instantaneous change of 100γ and was generally found to be clearly recognizable even during intense magnetic disturbances. Peak-to-peak noise in this band was found to average from 1 to 2γ. An example of short-

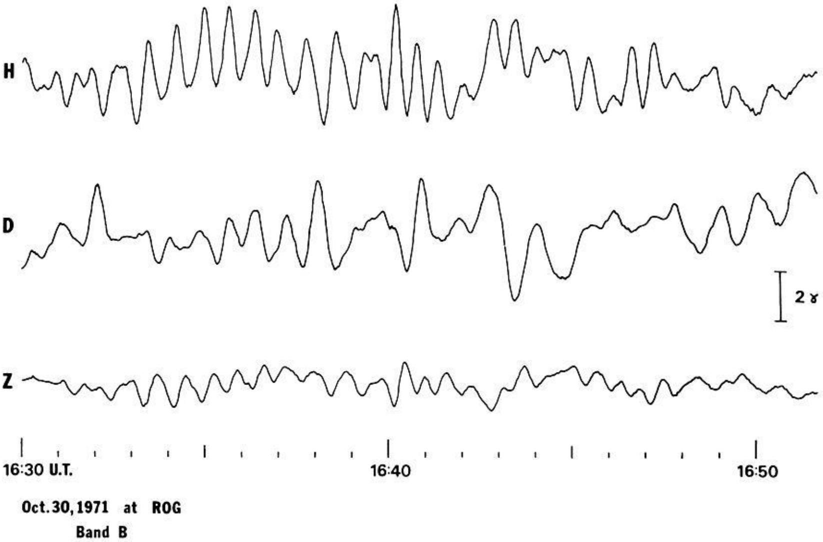


Fig. 4. Example of the broad-band system recording of short-period variations (Band B)

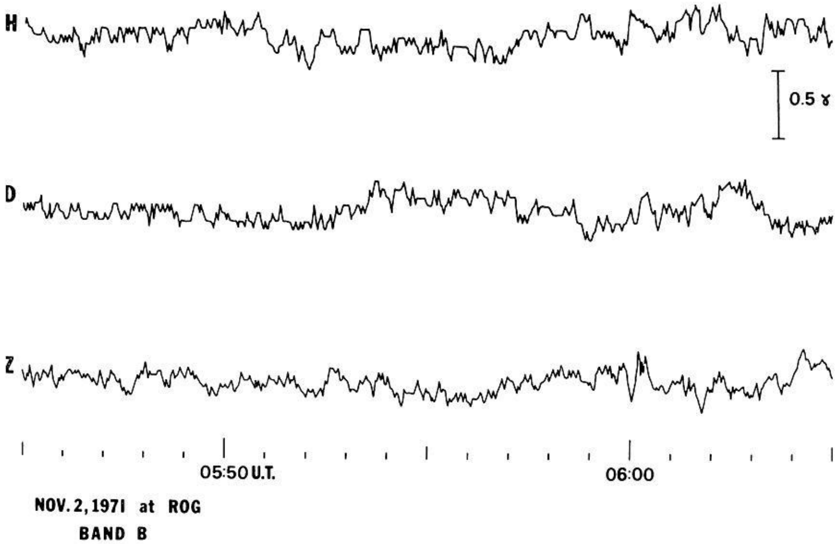


Fig. 5. Example of Band B total noise (recorded, playback, and digitizing noise) at a magnetically quiet period

period data (Band B) recorded at ROG is given in Fig. 4, which shows a section of record dominated by a 43 s period pulsation. The components illustrated here were all recorded at a gain of five and show a noise level between 0.1 and 0.2γ at this amplification. To clearly indicate the total operational noise inherent in the recording and the reduction of Band B data, a magnetically undisturbed period is shown in Fig. 5 at an expanded scale. Again, all components were recorded at a gain of five and a peak-to-peak noise level of $\sim 0.2\gamma$ is apparent. A large part of the noise appears to be digital, implying that further amplification of Band B signals could be carried out, but would, of course, be accompanied by a corresponding sacrifice in dynamic range.

4. Conclusions and Recommendations

In terms of total data return for this pilot project, instrumental reliability can be judged as good. (An improved recording system alone would have increased relative data return from 80% to 95%). Both Band A and Band B exhibited satisfactory record quality, showing average resolutions of 2γ and 0.2γ respectively, and a combined dynamic range of about 78 db. Variations with periods down to 5 s were resolved, but this large gain of information achieved on the short-period side was found to be slightly at the expense of the long-period (diurnal) data. The fluxgate sensing head presently used with the system lacks the temperature stability of the standard Askania variograph. Consequently, extreme daily temperature variations can limit the reliability of the long-period data. Furthermore, the slow-speed FM tape recorders appear to be too sensitive to temperature and humidity, and hence are ill-suited to an environment of extremes.

Most operational difficulties stemmed from the method of recording. The relative complexity of the FM tape recorders demand servicing by an experienced operator, mainly since a direct visual evaluation of the quality of the recorded data is not possible. Also, the five-day cycle imposed by the length of the data tapes makes it extremely difficult to record uninterrupted long-period events simultaneously at several stations. An obvious solution is to use longer data tapes (14-inch reels holding 7200 feet of tape), or better, to record long-period data on digital tapes having a 25 to 30-day cycle capability.

In general, it can be concluded that the pilot project has shown the instrumentation developed to be a valuable and practical new tool for field research in geomagnetic variation studies. The extended frequency range and the wide dynamic range make this instrument particularly well suited to areas where short-period vertical field variations are strongly attenuated. The full potential of this moderate-cost, dual-band system is yet to be realized. By a straightforward reorganization and streamlining of its component parts, a more compact and versatile system version can easily be built. For instance, the fluxgate control unit and the filter-amplifier unit could be integrated into one compact unit providing not only variable sensitivity but also variable band-pass capabilities. Furthermore, by introducing separate recording systems for each band, uninterrupted data lengths appropriate for the analysis of each frequency range could be recorded more easily and more efficiently. (Such system changes are presently being implemented by the Earth Physics Branch at Victoria under the direction of Dr. L. K. Law).

The application of this system should by no means be limited to simply the improved monitoring of geomagnetic (and magnetotelluric) variations. Because of the increased sensitivity and expanded frequency range, immediate system applications include the study of long-period micropulsations as well as the location of upper-crustal conductivity anomalies such as geothermal areas with power-source potential.

Acknowledgements. This work was supported by Grant No. 66-9521 (G.K.C. Clarke) from the Defence Research Board of Canada. Personal financial support provided by the National Research Council of Canada is also gratefully acknowledged.

References

Caner, B., Dragert, H.: Instrumentation for wide-frequency-band (0.01—100 millihertz) geomagnetic induction work. Z. Geophys. *38*, 121—132, 1972

Trigg, D. F.: An automatic zero suppression circuit. Rev. Sci. Instr. *41*, 1298—1302, 1970

Trigg, D. F., Serson, P. H., Camfield, P. A.: A solid-state electrical recording magnetometer. Publ. Earth Physics Branch, Ottawa *41*, 5, 67—80, 1971

Dr. H. Dragert
Institut für Geophysik
D-3400 Göttingen
Herzberger Landstraße 180
Federal Republic of Germany