FIELD PROCEDURE MANUAL FOR SELF-POTENTIAL SURVEYS

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PREFACE

The self-potential (SP) method has a long history of successful exploration for minerals. However, the technique has fallen into disuse, partly for reasons of fashion, but primarily because of problems with repeatability and reproducibility of the data. A very high degree of data reproducibility and repeatability can be obtained using the techniques and procedures given in this manual. Careful attention to the field techniques stated here should allow any reasonably careful field crew to obtain low cost, reliable SP data with minimum difficulty. Conversely, carelessness on the part of the field crew and lack of proper supervision by the responsible geophysicist can lead to the same old problems of poor repeatability and reproducibility. We hope that this manual will be of some use in obtaining high quality self-potential data, and help rekindle interest in the self-potential method.

This manual defines the field procedures and data presentation to be used by self-potential field crews in mineral surveys. With few modifications, it should also be useful in other types of SP surveys (e.g., geothermal, hydrocarbon, geologic, environmental contaminants, etc.) as well. Section 1 is a short overview of SP and the method used to acquire the data. Section 2 discusses some of the difficulties encountered. Section 3 consists of the step-by-step procedure used to acquire SP data. Section 4 discusses the data reduction procedures. At the end of the manual are a series of appendices which discuss in detail: (A) the symbols to be used on the field map for recording the locations of the measurement or anything else of interest; (B) troubleshooting wire breakage; (C) the equipment used and its maintenance; (D) walking line radio procedure; and (E) maximum tolerances for SP surveys.

An attempt has been made to present a fairly detailed picture of SP data acquisition, although many problems encountered by the crew will almost certainly not be covered by this manual. Of these, many can be corrected easily by the crew. Other difficulties and any occasion that the crew is in doubt concerning the appropriate course of action are to be reported to the responsible geophysicist at once.

It is expected that the field crew will read and understand this manual before going into the field. It is also the responsibility of the field crews to insure that the tolerances specified in this manual and its appendices are met. If for any reason the tolerances specified cannot be met, the field crew must contact the responsible geophysicist as soon as practical.

ACKNOWLEDGEMENT

This manual was originally written while the authors were employed by the Climax Molybdenum division of AMAX. Inc., Golden. Colorado. We would like to thank AMAX for permission to publish this revision of the original manual.

1 SELF-POTENTIAL, AN OVERVIEW

1.1 What is self-potential (SP)?

Self-potential (SP) is the naturally occurring electrical potential of the earth resulting from geologic, geochemical, and hydrologic interactions which cause electric potentials to exist in the earth in the vicinity of the measurement point. Since 1830 the SP method has been employed in the search for minerals. Anomalous surface potentials are commonly measured in the vicinity of pyrite (marcasite), chalcopyrite, pyrrhotite, sphalerite, and graphite. These potentials are measured in millivolts (mV) relative to a "survey base", where the potential is arbitrarily assigned to be zero volts. Amplitudes of SP anomalies in mineralized areas range from a few millivolts to one volt or more. The potentials of interest are always negative above a mineralized body relative to a point outside the mineralization. The observed potentials are the result of oxidation, or valence electron stripping, of sulfides; hence, the negative potential.

1.2 Basic equipment required

The basic equipment required is simple, consisting of a pair of electrodes connected by wire to a digital multimeter (DVM) with a high input impedance capable of a reading accuracy of +/- 0.0001 volts. There are, however, two restrictions on the electrodes and voltmeter which are most important. They are: (1) no spurious potentials can be introduced by the measurement technique, and (2) the reference or base electrode must be placed outside the system, above the water table, and not in a reducing environment such as a bog or swamp. The avoidance of these errors is the primary reason for this manual.

1.3 Data acquisition

Figure 1 shows schematically the method of conventional SP data acquisition. The operator attaches one end of the wire to the base station electrode. The wire is unreeled to station 1 where the roving electrode is placed in a shallow hole in the ground. The voltage between the base station electrode and the roving electrode is recorded with the defined sign convention. The base pot is <u>always</u> attached to the <u>negative</u> lead of the voltmeter. After making the voltage measurement the roving electrode is picked up and more wire is unreeled to station 2. The roving electrode is again placed in the earth, and another voltage measurement is made. This procedure is repeated until the end of the wire is reached, at which point the wire is rewound, and the base station is moved to the end of the completed line, where a secondary base station is established. This process is repeated until the survey is complete.

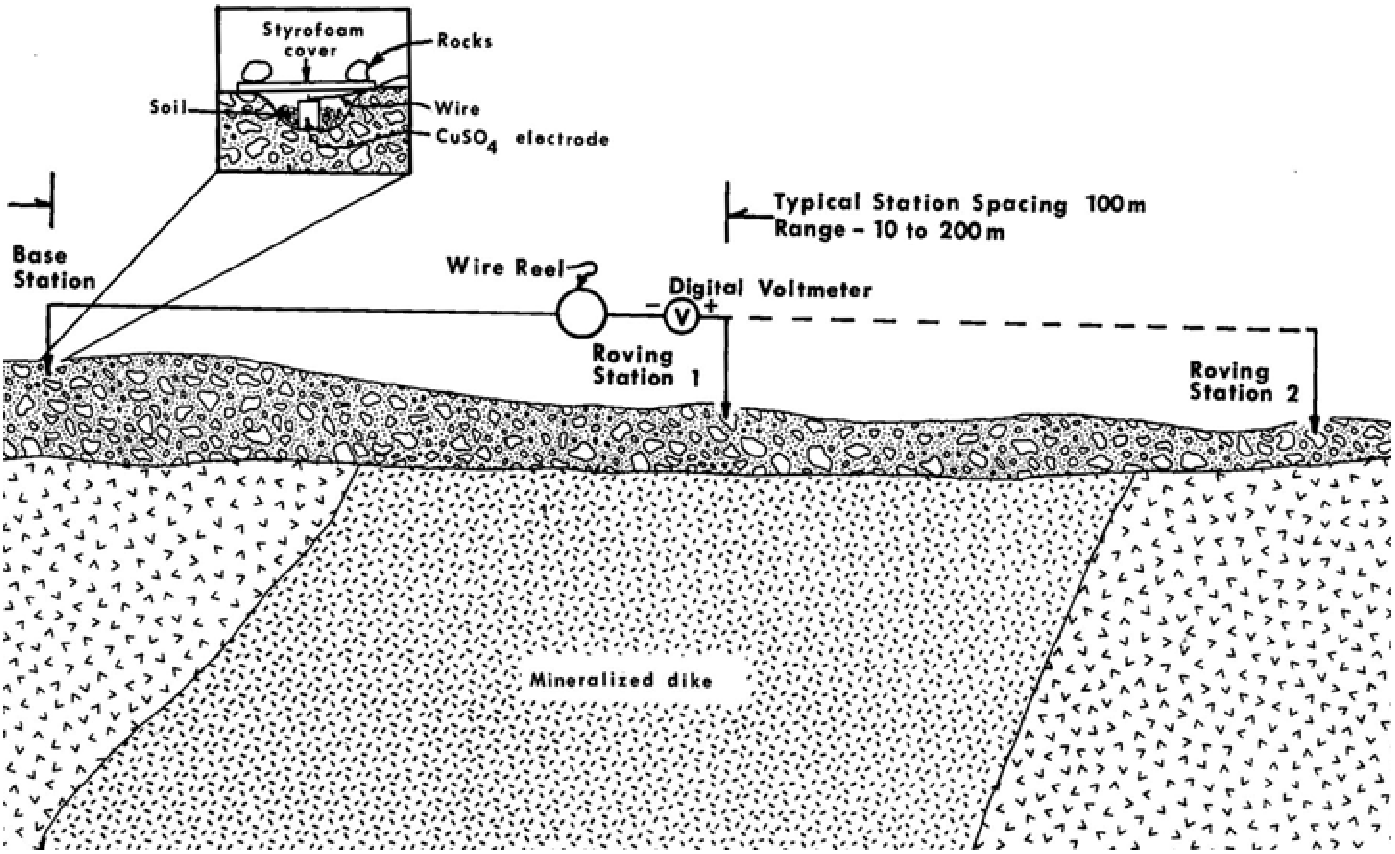


Figure 1 Schematic of the procedure used to collect SP data.

1.4 One day's coverage

The distance which can be covered in one day will vary depending on terrain and frequency of unexpected problems. Try to cover a minimum of 12 km per day on driving lines, and at least 5 km per day on walking lines. An average of at least 7 km per day is expected.

1.5 Data set for a completed survey

The data set for a completed survey consists of an accurate map (Plate I) showing the location of the measurement stations and the topography in the area and the voltage relative to the base station, a set of data records, self-potential profiles covering the anomalous areas within the survey and the field topographic maps used during the survey. The data and maps must be of sufficient detail and clarity that the entire survey can be reconstructed by a geophysicist using the field notes and maps independent of the field crew. The procedures outlined in the following sections are intended to insure reproducibility without hindering production rates.

2 DIFFICULTIES IN OBTAINING RELIABLE DATA

The potential of a point on the earth's surface results from the superposition of several different electric fields. The direct current (DC) field contains the SP field and possibly cultural noise. The time-varying field consists of telluric currents and cultural noise. In SP surveys, only the DC field is of interest; all other electric potentials are regarded as "noise" and are to be avoided.

2.1 Telluric Currents

2.1.1 Definition

Telluric currents are time-varying electric fields originating with magnetospheric fluctuations resulting from the interaction of the solar wind with the earth's magnetic field. They can be observed by monitoring the potential difference between two arbitrarily placed electrodes on the ground (Figure 2). The amplitude of the telluric field, in part, depends on the resistivity of the material through which it is flowing. Ten mV/km of AC voltage fluctuation may be considered common in mid-latitudes.

Telluric current activity is by no means constant; it varies with the time of day, latitude, and solar activity. There are times when it is almost nonexistent e.g. at night; other times it may exceed 250 mV/km.

2.1.2 Frequency Range

Telluric currents commonly contain high energy components in a frequency range from 0.001 Hz to 100 Hz. Frequencies lower than 1 Hz are difficult, if not impossible, to observe in the few seconds required to take an SP reading. However, the potential of a point on the ground may be slowly raised and lowered with respect to the survey base in response to the tellurics, thereby introducing an undesirable component in the self-potential being measured.

2.1.3 Telluric Monitor

Since the field crew must have a way to detect telluric activity, a telluric monitor is deployed to observe the long period (greater than one second) telluric currents. Section 3.5.2 describes in detail the deployment of this monitor. The Use of this instrument can help decide whether or not the potential variations observed during measurements of SP might be due to telluric activity. It also provides a method for monitoring a solar storm so that the crew will know when it is possible to continue a line. Do <u>not</u> record SP data when the telluric monitor shows telluric activity exceeding +/- 2.5 mV/100m without consulting the responsible geophysicist.

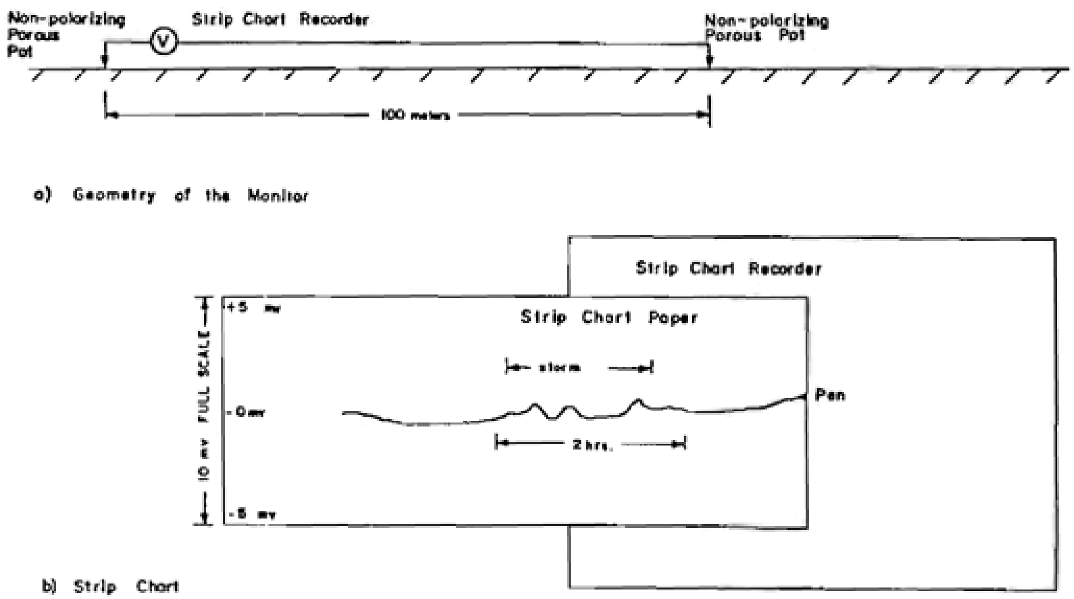


Figure 2 Measurement of telluric currents and what they look like. The electrode separation is normally 100 m. The strip chart drive speed is set to 10 cm/hr. A sensitivity of 10 mV full scale can be used in normal conditions.

2.2 Cultural Noise

Changes in the "natural" SP field can result from power lines, radio (mainly ULF) communications, buildings, fences, pipelines, etc. Noise from such sources may be common in many SP survey areas. Care should be taken to avoid measurements suspected of significant cultural noise. The following is a list of the more common noise sources.

2.2.1 Power lines

Sixty hertz alternating current (AC) is used for power transmission in the United States. Near high tension lines or generating stations, this signal may be strong enough to saturate the voltmeter and cause major fluctuations in the voltage readings.

Power lines are often grounded on every, or every other pole. The ground wires alter the ground potential for several meters. No measurement should be made within 10m of a ground wire to avoid any cultural DC offset. Base stations should not be located within 500m of any power 1ines.

If it proves impossible to avoid cultural noise due to power transmission, it is sometimes possible to filter out the 60 Hz with a suitable notch or low pass filter.

2.2.2 Telephone lines

Telephone lines are grounded at regular intervals. No measurement should be made within 10m of a ground wire to avoid any cultural DC offset. Base stations should not be located within 500m of any telephone line.

2.2.3 Metal pipes, gas lines, cased drill holes, railroad tracks, fences. etc.

These objects alter the electrical potential field of the earth wherever they are in contact with the ground. They either "short out" the potential or interfere with the earth's natural state with cathodic protection devices as are commonly found on pipelines. If possible, measurements should not be made within 20m of any metal object. Pipelines are often electrically charged in order to prevent corrosion. Measurements should not be made within 500m of an electrically-protected pipeline. This includes all gas lines and most other metal pipe lines. When a measurement must be taken near such objects, the distance to the object and description of the object should be recorded on the data sheet. A note should be made stating that cultural interference is suspected. Use as much space on the data sheet as necessary for a satisfactory description. Obviously, a base station must not be located within 500m of any of these objects. Field studies also indicate that old drill casing will affect the SP, and thus should be avoided if possible as far as 500 meters away.

2.2.4 Industry

Mines, mills, power plants, substations, and factories all produce or use large amounts of electricity. The potential of the ground may be affected for tens of kilometers around them. The data quality surrounding these objects is uncertain. Large scale power producers and consumers should be documented by the SP crew on the map and in their notes so the area can be critically reviewed. Areas where the data are obviously affected should be avoided. In the event the survey must be done near such sources, consult the responsible geophysicist before proceeding. In some cases, such as near large operating mines, it may be impossible to run an SP survey because of the extreme interference unless the mine operations are shut down.

2.3 Mistakes in Polarity

SP measurements are made and recorded with both possible polarities as an aid to minimizing errors. The normal polarity is the first potential measurement taken. It consists of the base pot connected to the negative terminal of the voltmeter and the roving pot to the positive. The normal voltage is used in preparing the SP map (Plate 1). Accidently reversing the polarity recorded in the normal column of the data sheet can have devastating effects on the SP survey. Take the utmost care to insure proper polarity. The instrumentation is normally designed so that this mistake is not possible; however, field modifications and repairs may negate the fail-safe design. After field repair or modification of the equipment, check the polarity by measuring the voltage of a known source such as a car or transistor battery.

2.4 Electrode Problems

Copper-copper sulfate, non-polarizing electrodes are used to make contact with the ground. They consist of a plastic container filled with a saturated solution of copper sulfate. Immersed in this solution is a copper rod to which the DVM lead is attached. The base of the container is porous and allows the solution to leak slowly into the ground. The porous pot itself can affect the SP readings made by the crew in a variety of ways as detailed below.

2.4.1 Chemical Differences

Chemical differences in the copper sulfate solution between the porous pots can result in a potential difference of several millivolts, independent of the earth. It can be measured with the DVM when both are placed in the copper sulfate bath. If necessary, this voltage may be reduced to less than 1 mV by mixing the solutions together or changing the solutions. Cleaning the ceramic surface on the bottom of the pots after each station will also help in this respect.

2.4.2 Sunlight

Ultraviolet radiation on the copper sulfate solution will change its electrical potential. This effect can be as high as 50 mV, though it is generally less. For this reason, keep the pots out of sunlight.

2.4.3 Temperature

Temperature can also have an effect on the potential of one pot relative to another. This effect is generally less than 10 mV, but an attempt must be made to shield the pots from radical temperature changes. Keep the base pot insulated after it is emplaced. Keep the roving pot out of the sunlight when making a reading, and in the constant temperature bath when not making a reading.

2.4.4 Pot drift

During the course of measuring an SP line, the potential between the base pot and roving pot will change due to chemical and temperature variations. These variations result in pot drift. The drift can be reduced by keeping the pots in the shade, and in the constant temperature bath when not in use.

Since the drift error is additive it must be removed each time the base pot is moved to a new location. Suppose the drift correction is not made for a drift voltage of +10 mV. The absolute voltage at the end point of the first line is then 10 mV too high. The end point of the first line is the base for the second line.

At the end of the second line the drift voltage is again +10 mV. The potential of the end point is again 10 mV high relative to its base. That means the absolute voltage assigned to the end point of the second line is 20 mV high. The same error will then propagate along all subsequent lines run off this new base, and will result in a bad tie when this line is in any loop.

2.4.5 High Contact Resistance

The current resistance (R contact) between the porous electrodes and the earth may affect the SP measurement by loading the circuit, and hence, reduce the measured voltage if the contact resistance approaches within two orders of magnitude of the input impedance (R input) of the DVM (i.e. R contact must be much less than R input (R contact « R input)).

In order to keep the contact resistance as small as possible, the pot should be placed in the most conductive ground available within 10 meters of the distance mark on the cable. To minimize contact resistance, dig a small hole to reach moist soil and plant the pot firmly in it. This procedure generally results in less than 50 kilohms resistance between the base and roving pots. If the contact resistance is greater than 50 kilohms, re-position the pot in another hole. Occasionally, it will not be possible to obtain a contact resistance less than 50 kilohms due to frozen ground, very dry ground, high resistivity country rock, etc. When this is the case, and if the voltage is stable, take the voltage reading and continue the survey. Be sure to enter the contact resistance on the data sheet. <u>Do NOT under any circumstances water the pot holes to reduce the resistance</u> because this will affect the potential reading. In highly resistive or dry ground, contact resistance between 100 and 200 kilohm can be expected. In frozen ground the contact resistance may easily exceed 1 megohm.

2.4.6 Soil Moisture

The SP survey should not continue under conditions where soil moisture may be changing during a line. The onset of heavy or persistent rain, or for a period of 12 hours after such a rainstorm stops, precludes continuation of the survey. However, a brief shower which does not penetrate more than 1 cm into the soil need not stop the survey. Since changes in soil moisture always cause changes in the measured potential, a prime responsibility of the field crews is to avoid conditions in which the soil moisture is changing while a line is being run.

It is critical that at all base stations the base electrode be located above the water table and out of any area where reducing conditions (low Eh-high pH) might exist such as peat bogs, swamps, willow bogs, alongside streams, etc. The base pot is best located on a hillside in previously undisturbed ground away from road fill, but locating it in road fill would be preferable to marshy ground at the side of the road.

2.5 Wire Shorted to Ground

2.5.1 Bare Spots

Bare spots on wires which short to the ground between the base pot and the DVM produce large positive contact potentials (50 to 600 mV) which may be relatively steady with time. Usually the bare spots will only ground in muddy or very damp earth. Unfortunately, grounded wires are difficult to diagnose since planting a base in an area of negative potential and measuring in an area of higher SP also produces these large positive potentials. For this reason, among others, it is not a good idea to put a base station within an area of large (<-100 mV) negative potential. To deal with the problem, put base stations in areas of high amplitude negative potential only as a last resort and immediately question any large positive voltage measurements. Repair any bare spots on wires where the insulation has broken through, and always keep the wire out of water or mud. This means when driving lines through muddy areas and stream crossings, the driver must periodically stop and hang the line in trees and on rocks to prevent the wire from lying in the mud or water. The same precaution must also be taken on walking lines.

2.5.2 Shorts to the Reel Housing

A similar situation results when a wire shorts to the reel housing. After the reel housing is placed on the ground, the short circuit is completed. All reels must be checked daily to make sure there is infinite resistance between the wire and reel housing.

3 FIELD PROCEDURES

The following is a detailed, step-by-step procedure used to collect SP data. The field procedure is to be strictly followed by the field crews and contractors. If there are any questions about the method, please ask the responsible geophysicist. It is assumed the procedure is understood at the beginning of the survey and will be followed throughout.

3.1 Office Preparation

3.1.1 Field Equipment

Check and make sure that the field equipment is complete and serviceable. A list of this equipment is found in Appendix C. The wire reels should always be checked for open circuits in the wire. A reasonable resistance is a few hundred ohms or less per km of wire. To avoid spurious contact potentials between the reel housing and the earth, the wire must be electrically isolated from the reel and the resistance reading between the wire and the reel housing must be infinite. Check that the distance marks on the wire are marked clearly and located properly, and that they are not slipping on the wire. Tape flags should be located every 100 m and marked in km (0.5, 0.6, …, 1.3, etc.)

3.1.2 Topographic Maps

Locate at least two copies of the topographic maps covering the survey area. One of these is to be used for the field and one is to be used as a clean, "hotel room" copy. Data are to be transferred from the field map to the hotel copy on a daily basis. The proposed lines are marked with a "Hi-Liter" on the field copy and are subject to change as the survey progresses. For this reason the hotel map is labeled only with the actual data points as the survey progresses. Also, it is probable that not all proposed lines will actually be run. If the proposed SP lines have not been marked on the field copy of the map, contact the responsible geophysicist. The clean hotel maps should be rolled and placed in a map tube for protection.

3.1.3 Last Minute Check

Before leaving for the field, do a small survey in the vicinity of the office to insure that all equipment is present and working.

3.1.4 Programmable Calculator

If a programmable calculator is going to be used it is advisable at this time to obtain or develop the program for obtaining the drift correction, tie-in voltage, and absolute voltage for each station (See Section 4).

3.2 Explanation of the Data Sheet

The data sheet (Figure 4) is used to record all numbers and remarks relevant to the survey. New data sheets should be started at the beginning of each day, or at the beginning of each new line designation. All field data are to be entered in black ball point pen on the data sheets (assume the data sheet will get wet). If an error is made, cross it out with a single line, and rewrite the data above the error or on the next line of the data sheet. Illegible field notes can make the entire survey useless. The methods to be used for acquiring the recorded data are discussed in the following section. A completed data sheet is shown in Figure 3.

3.2.1 Date

Record the month, date, and year (e.g., 7/24/80) when that particular form is being filled out. The beginning of each day should start on a new data sheet.

3.2.2 Area

Record the name designated for the survey and the name of the map quadrangle on which the survey is currently being run. When assessment work is being done on two or more claim blocks, the field crew must also designate which claim blocks are being worked on each day so that the work done for the benefit of each set of claims may be legally determined.

3.2.3 Line

Record the reference points used to designate the beginning and end of the survey line. The reference point at the beginning of the line must be recorded at the beginning of each line. Enter the reference for the end of the line when you reach it. The line designation will have the Form G-H or AC-AD (see "Use of Reference Points", Section 3.3).

3.2.4 Personnel

Record the names of the persons on the crew for that particular line.

3.2.5 Time

Record the time at which the measurement was made in 24 hour local time, i.e., 0000 to 2359 hours.

3.2.6 Distance From Line Base

Record the distance from the base pot to the roving pot in meters, i.e., 100, 200, 300, etc., <u>not</u> 1, 2, 3 or some other private code.

3.2.7 Normal Voltage

This is the voltage reading between the base pot and roving pot in millivolts. The <u>normal</u> polarity is the base pot connected to the <u>negative</u> input of the DVM and the <u>roving</u> pot to the <u>positive</u> input of the DVM. The <u>sign</u> of the voltage reading, whether positive or negative, is to be stated explicitly on the data sheet, i.e., +150. not just 150.

3.2.8 Reversed Voltage

Record the voltage reading between the base pot and roving pot with reverse polarity, i.e., the base pot connected to the positive DVM input, and the roving pot to the negative input. The sign of the voltage is again recorded explicitly. The reversed voltage should be equal in magnitude (within +/- 5 mV) and of opposite polarity from the normal voltage. If it is not, then telluric activity should be suspected or other problems (such as a loose connection) may exist.

3.2.9 Resistance

Record the resistance in kilohms between the base pot and the roving pot, measured with the DVM. In areas of extreme SP, i.e., the areas of interest, the resistance may be negative. In these areas, check the resistance with polarity reversed, and record both values, normal polarity written <u>above</u> the reversed polarity.

3.2.10 Base-to-Roving Pot Drift Voltage

Record the voltage between the base and roving pots while placed in the copper sulfate bath. The measurement is made at the beginning of each line, and every time the base pot is picked up at the end of a line. The measurement is made with the normal polarity convention: the base pot connected to the negative DVM terminal and the roving pot to the positive terminal of the DVM.

3.2.11 Drift Correction

This is a number which must be added to the normal voltage to compensate for drift in the electrodes. To obtain the drift correction, reverse the sign of the drift voltage measurements which are taken at the beginning and the end of the line. Put these values in the drift correction column, then interpolate between the beginning and the end of the line as a function of time to obtain the drift correction for the new base station, i.e., the last station on the line.

3.2.12 Base Tie-in Correction

The base tie-in correction is the absolute voltage of the base from which a line is run. This value must be added to the entire line in order to refer the voltage to the survey base. The procedure for obtaining this value is given in Section 4.

3.2.13 Absolute Voltage

This is the station voltage relative to the Survey Base in millivolts. It is calculated by adding the normal voltage to the drift and base tie-in corrections.

3.2.14 Map Reference Point

The entries in this column consist of letters of the alphabet and refer to similarly labeled points on the topographic map used for the survey and associated profiles. See the following section on "Use of Reference Points" for a detailed description of these labels.

3.2.15 Remarks

Any topographic or cultural point which shows on the map should be noted here. Also, any nearby culture which might affect the survey, e.g., culverts, powerlines, etc., should be noted here. Many comments will be short (i.e., base station, end of line, pipeline 100m north, etc.) and will fit in this section. Do not try to "squeeze" the information in; if more room is needed, write across the form as in Figure 3. While the crew's life story is not required, in general, there cannot be too many comments. Most crews err on the side of too few and cryptic comments. Be sure this does not apply to you. Imagine yourself trying to make sense of another crew's comments a year hence, and write for that crew. Remember that it is frequently necessary to relocate the survey stations at some later time. Be sure your descriptions are adequate to allow subsequent crews to relocate these points.

Always note any stations which are flagged in the remarks, e.g. kilometer stations. Be sure to describe the location of every base station exactly and concisely so that follow-up surveys can locate that same point.

SELF-POTENTIAL SURVEY DATE: 6/24/78

AREA: Elk Park LINE: B→C

PERSONNEL: A. Mazzella, S. McCorkhill TELLURIC MONITOR: Voltage scale: 10 mV full scale Chart speed: 10 cm/hour

TIME	Distance from Line Base (m)	Normal Voltage (mV)	Reversed Voltage (mV)	Resistance (Kilohms)	Base-Roving Pot Drift Voltage (mV)	Drift Corr.	Base Tie-in Correction	Absolute Voltage (mV)	Map Reference Point	Pots in use: Base pot – C Rover #2 Remarks
0745	0				-2.0	+2	-30	-30	B	BASE STATION on
NORTHEAST CORNER of APEX-CENTRAL CITY Road jcn DRIFT CHECK										
0810	200	-10.4	+10.2	30		+2		-38		
0825	400	-5.3	+5.8	28		+2		-33		
0835	600	-2.1	+1.7	43		+2		-30		Bend in the road
0845	800	+1.5	-1.0	28		+2		-26		
0900	1000	+1.8	-3.0	32		+1		-27		FLAGGED
0915	1200	+3.5	-5.5	22		+1		-25		
0925	1400	+12.4	-10.9	15		+1		-17		
0938	1600	+27.8	-26.9	18		+1		-1		CULVERT 10m NE
0940	1800	-50.1	+52.3	40		0		-80		
0955	2000	-80.2	+81.5	38		0		-100		FLAGGED
1000	2100	-100	+102	35		0		-130		REDUCED STA. SPACING
1015	2200	-120	+123	32		0		-150		
1020	2300	-136	+134	36		0		-166		Road Junction.
1025	2400	-180	+176	38		0		-210		
1030	2500	-110	+108	46		-1		-141		Saddle
1040	2600	-50.9	+52.3	28		-1		-83		
1045	2700	-20.3	+22.1	15		-1		-51		
1050	2800	-10.6	+12.1	18		-1		-42		INCREASE STA. SPACING
1055	3000	+15.1	-16.2	12		-1		-16		FLAGGED near fence.
1105	3200	+5.3	-4.8	14		-1		-26		
1115	3400	-10.2	+11.3	18		-2		-42		
1125	3600	+15.6	-16.1	22		-2		-16		Cabin - W side of road
1135	3800	+5.1	-6.6	26		-2		-27		
1140	4000	+1.8	-2.1	30		-2		-30	C	FLAGGED: Located
15 meters W of road, just below saddle on ridge										NO SIGNIF. VOLT. DRIFT.
1150	3000	+18.4	-16.8	14		-2		-14		REOC -
1203	2000	-83.4	+80.1	36		-2		-115		Reoc
1215	1000	+2.5	-2.9	32		-2		-29		Reoc
1225	0				+2.1	-2.0			B	Drift check
										at Base B

Figure 3 Example of Completed Data Sheet.

SELF POTENTIAL-SURVEY DATE: ____________

AREA: LINE: ____________

PERSONNEL: TELLURIC MONITOR: Voltage scale: ________ mV full scale

Chart speed ________ cm / hour

TIME	Distance from Line Base (m)	Normal Voltage (mV)	Reversed Voltage (mV)	Resistance (Kilohms)	Base-Roving Pot Drift Voltage (mV)	Drift Corr.	Base Tie-in Correction	Absolute Voltage (mV)	Map Reference Point	Remarks

Figure 4 A Blank Data Sheet (reduction)
(a full-sized sheet is on last page)

3.3 Use of Reference Points

3.3.1 Reference Points

Reference points, indicated by the symbols given in Appendix A. are used to relate the map, raw data sheets, and profiles together. Without these it is difficult, if not impossible, to cross reference these documents. Reference points are useful in answering the following types of questions:

1. What data points were taken on a particular day? Where is this on which map? On the profiles?
2. A particular section of data looks interesting in profile. Where is this located on the map?
3. The geology of an area shows one particular region of interest. What lines cross this area, and what do the profiles look like?
4. The data on a profile look suspicious. Where on the map is this section located? Where in the field notes is the description of telluric problems or data noise located?
5. Given any profile, where on the raw data sheets are the original measurements recorded?

3.3.2 Standardized Use of Reference Points

The use of reference points has been standardized so that a good data sheet can be constructed without an undue expenditure of time either by the field crew, the analyst interpreting the survey after it is complete, or a survey crew extending the survey the next field season.

3.3.3 Mandatory Reference Points

The following reference points are mandatory and are designed to facilitate the interpretation and drafting of the final report. They must be noted and described in the field notes, and clearly marked on the field map.

1. The start of the day as month, date, and year, e.g., 7/24/80.
2. The end of the day.
3. The intersection of two SP lines.
4. The beginning of a new line.
5. The end of a line.
6. The meeting of any person of interest. If property boundaries are involved, sketch or have the property owner sketch the property boundaries on the field map.

3.3.4 Designation of Reference Points

All reference points are designated by letters of the alphabet. They are labeled in sequence beginning with A. If more than 26 letters are required, the 27th through 52nd are designated AA-AZ, the 53rd through 78th are BA-BZ, etc. Each point so labeled is placed on four documents:

1 On the field map next to the reference symbol described in Appendix A while in the field.

2 On the raw data sheet in the column marked "Map Reference Point" while in the field.

3. On the hotel map next to the reference symbol described in Appendix A.

4. On the profile at the appropriate location.

3.3.5 Recording of Reference Points

The explanation of a reference point is written on the data sheet in the section labeled "Remarks". Do not try to fit all the comments in just this column. If more than a word or two is necessary, use the horizontal lines of the data sheet as a "notebook". Make all comments legible, and include all pertinent information. Illegible and uninterpretable field notes are the principal problem with many surveys. Do not let your survey be ruined by bad field notes. The time used to adequately document the survey is well spent. An undocumented survey is of no value to anyone.

3.4 Reconnaissance

Spend a morning or afternoon (four or five hours should be sufficient) driving around the survey area to learn the "lay of the land". The most direct way to do this is to drive to the best vantage point available, orient and study the map for awhile. Look for roads, vegetated areas, houses, mine dump s, etc. (anything that might affect the survey). If major producers of cultural noise are not already on the map, draw them in. This might include power substations, high tension lines, new mines, etc. Look at the terrain with the highlighted SP lines in mind. Look for alternate routes when the ones marked appear exceptionally difficult. While at your vantage point, prepare a quick plan of attack as to which lines are to be done first, and which last. As a general rule, the easier lines should be done first. This will help to establish a reasonable pace early in the survey, and help define areas of most interest. When you have a good feeling for the area, drive around to locate some of the roads and alternate routes. As was previously mentioned, four or five hours is sufficient for this kind of reconnaissance. Do not get wanderlust and spend more time than this. As the survey progresses, much more will be learned about the area.

3.5 Acquiring the Data

3.5.1 Survey Base Location

Move to the location of the proposed survey base. The survey base is the location to which all measurements refer and will normally be located by the responsible geophysicist. The base may be marked on the field map, given to the crew, or chosen during the reconnaissance of the prospect at the beginning of the survey by the geophysicist. The survey base is chosen to:

1. Lie outside any area of known or suspected mineralization.
2. Be away from areas of cultural disturbances.
3. Be in an area not unduly subject to disturbance by animals or humans.
4. Be above the water table and away from areas where reducing (low Eh - high pH) conditions, e.g. swamps, marshes, bogs, etc. might prevail.

Investigate the survey base location for obvious difficulties at this time. High tension lines within 500 m, a buried gas pipeline with 500 m, and housing developments with associated pipelines within 500 m are all examples of problems which may necessitate moving the survey base location. The survey base may only be relocated with the prior knowledge and consent of the responsible geophysicist. Once a suitable survey base has been found, the telluric monitor should be deployed in the immediate vicinity.

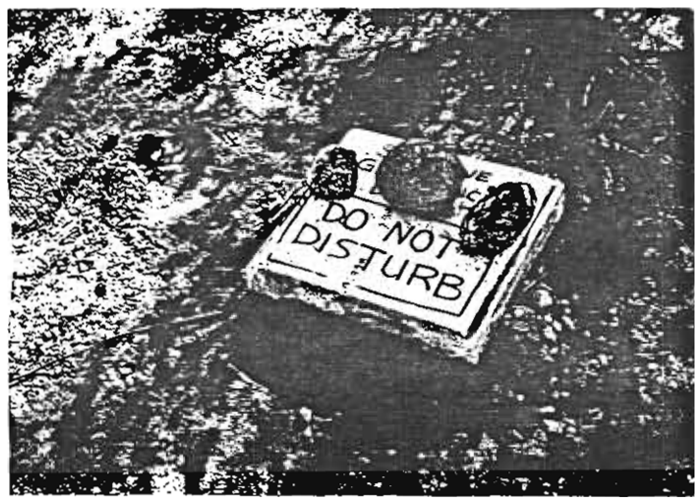
3.5.2 Deploying the Telluric Monitor

Deploy the telluric monitor (Figure 2) by laying out a 100 m wire as parallel as possible to the general direction of the SP line being measured. One end of the monitor is to be within 10 m of the survey base. Dig a hole deep enough to reach moist soil (generally about 10-15 cm) at the far end of the wire. Place a porous pot firmly in the hole and connect it to the wire. Tap dirt around the base of the pot and cover the hole completely with a styrofoam sheet to keep it out of the sun and prevent the soil from drying out {See Figure 5). At the end of the wire closest to the survey base location, prepare another porous pot in a hole as described above. Connect the end of the 100 m wire which leads out to the far pot to the positive terminal of the strip chart recorder. Using a short length of wire, connect the porous pot closest to the survey base to the negative terminal of the strip chart recorder. The monitor is now ready for operation.

Dig a hole deeper than the length of the pot.

Cover the sides of the pot with dirt (but not the top), and DO NOT WATER IT!

Pack dirt around the edges of an insulating sun shield to prevent air circulation.



Weight the shield with rocks and tie the wire to a tree or bush.

Figure 5 Preparing a base pot or telluric monitor pot.

3.5.3 Starting the Telluric Monitor

With the pen cap left on, set the strip chart speed to 10 cm per hour. Using the zero adjust, set the pen to the midpoint of the chart. Set the sensitivity to 10 mV full scale. When monitoring telluric currents caused by a solar storm or severe cultural effects, a higher sensitivity (usually 100 mV full scale) may be required. Do not record SP data during solar storms.

Write the name of the survey, date, chart speed, bearing of the positive (far) pot, and voltage scale directly on the strip chart paper (Figure 6). Write the date, area, and personnel at the top of the data sheet. Mark the full scale voltage and the drive speed of the telluric monitor at the top of the data sheet as illustrated in Figure 3. Errors on the data sheet should be crossed out with a single line only. Always use black ball point pen to write on the data sheet (assume the data sheet will get wet). Sketch the location and orientation of the telluric monitor line on the field map using the symbols described in Appendix A. On the field map also give the month, date, and year of the station occupation. Begin monitoring by removing the pen cap. Make sure the drive is operating and the paper is smoothly engaged in the chart drive cogs and that the pen is marking the paper correctly.

Mark the time directly on the strip chart paper (see Figure 6). A tick mark for the time is made by deflecting the voltage-"zero" switch on the front of the recorder. Whenever you return to the monitor, put another time mark and the voltage information on the strip chart as just described. When a line is completed, mark the time again. Remember, the records are useless if the data are not properly recorded.

It may become necessary to change voltage scales during the course of the day. All changes must be carefully annotated directly on the chart record at the time they are made. Problems with the recorder such as a stuck drive, pen out of ink, etc., should be recorded both on the strip chart and the data sheet. Mark a reference point on the strip chart paper (Figure 6) and in the "Map Reference" column of the data sheet (Figure 3 and Appendix A). Refer to Section 3.3 for the "Use of Reference Points."

Watch the telluric monitor for five minutes. If the voltage on the chart record is steady, the location of the survey base is good and the survey may begin. Proceed to measure the pot drift voltage.

If the voltage is not steady, with greater than +/- 2 mV of drift, there may be a cultural source of time-varying currents in the area necessitating the relocation of the survey base. If cultural interference is encountered, the responsible geophysicist should be requested to pick an alternate location for the survey base, preferably as far away as practicable from the area of the suspected cultural disturbance. Re-deploy the telluric monitor at the new base. If the voltage is steady at the alternate location, proceed to measure the pot drift voltage.

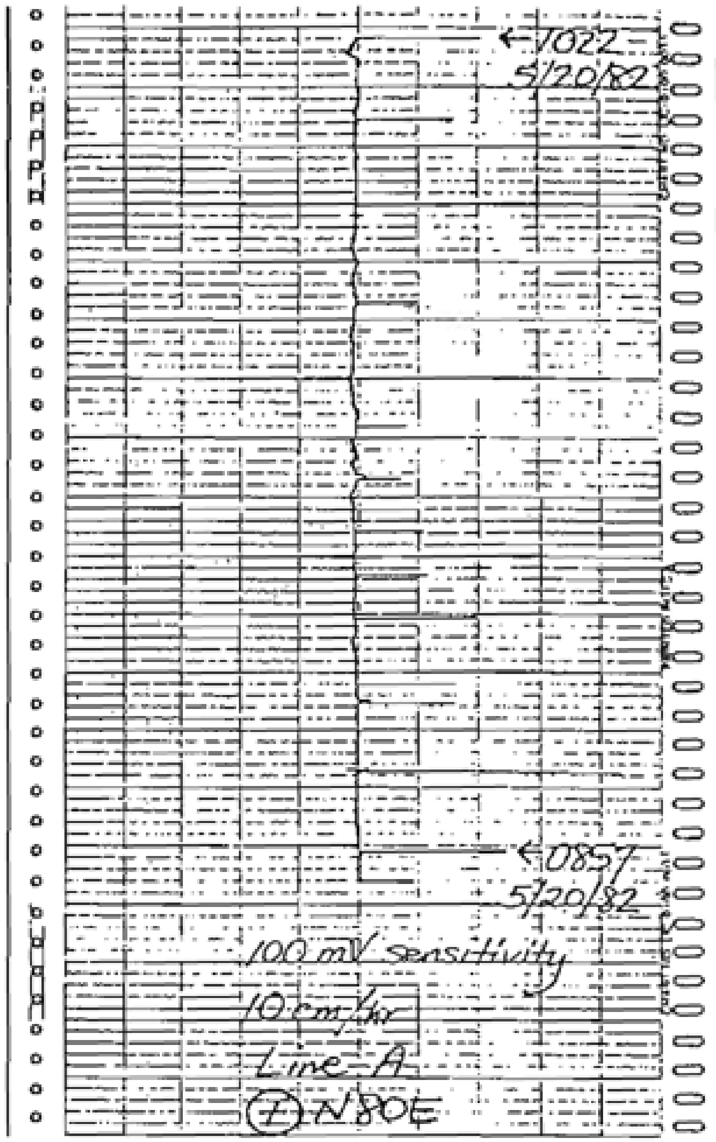


Figure 6 The telluric monitor strip chart. This is an illustration of what a typical strip chart record should look like. The base designation given to a strip chart record is the same as that given to the nearest base station.

Occasionally the telluric monitor indicates electrical noise throughout the survey area. The noise may be caused by a very large cultural power producer or user in the area, or by natural telluric currents. If a source of cultural noise is not immediately evident, it is often useful to leave the telluric monitor out overnight. If the noise persists overnight, the source is cultural. If the noise declines or dies out during the night, it is due to solar activity and will most probably disappear within a few days. If the noise source proves to be cultural in origin, contact the responsible geophysicist immediately. If the noise is telluric in origin, continue to deploy the telluric monitor on a daily basis until quieter conditions prevail. Continue to deploy the monitor with every line for at least one day following the cessation of telluric activity. The maximum telluric noise which can be tolerated is specified in Appendix E.

After establishing the survey base, the telluric monitor need only be deployed when cultural or telluric activity is encountered. Electrical interference during a survey line will be evident by an unstable voltage reading at a station.

3.5.4 Measure the Drift Voltage

Immediately before and after each line, check the drift voltage between the roving pot and the base pot. To do this, place both pots in the porous pot bath. While keeping the pot and the interior of the bath out of the sun, connect the base pot to the negative terminal of the digital voltmeter (DVM), and the roving pot to the positive terminal. Measure the voltage that exists between the pots. This voltage is called the drift voltage and should be less than +/-5 mV. If greater than +/- 5 mV is measured, use a different pair of pots which have been filled with copper sulfate crystals and water and left in the bath for at least 12 hours. If this procedure does not reduce the drift voltage to less than 5 mV, mix the copper sulfate solutions of the roving and base pots together and clean the ceramic bases. The pots and the bath used for the survey must contain undissolved copper sulfate crystals to insure the solution is saturated.

3.5.5 Plant the Base Pot

While keeping the bath shaded, remove the base pot (the pot with the large base) and dry the terminal post. Place the base pot in a hole sufficiently deep that moist soil is reached and the entire pot is below ground level, but well above the water table, i.e., no water should trickle into the hole. Push dirt around the sides of the pot to hold it securely in the bottom of the hole. Do not allow the copper post on the top of the pot to contact dirt from the side of the hole, and be sure the copper sulfate bath solution has been dried off from the contact post as it may cause spurious contact potentials. Do not expose the pot to sunlight at any time. Connect the free end of the wire from the wire reel to the base pot. Cover the pot with a styrofoam sheet. Weight the styrofoam sheet with a rock and cover the edge with dirt to prevent air circulation. In this fashion, the base pot is reasonably isolated from temperature changes, photoelectric effects, and drying of the ground around the base pot while the line is being run (see Figure 5).

Record the base pot location and reference point on the map using the appropriate symbol (Appendix A), and in the "Map Reference" column of the data sheet (Figure 4) together with the month, date, and year on the field map. Be specific, complete, and accurate in your location description.

Tie the wire around a tree or large rock to prevent the base pot from being pulled loose by cars, animals, or as the wire is being unreeled.

After tying the wire, weight it down so that it lies as flat on the ground as possible. This is to minimize the possibility of automobiles or animals catching the wire and breaking it.

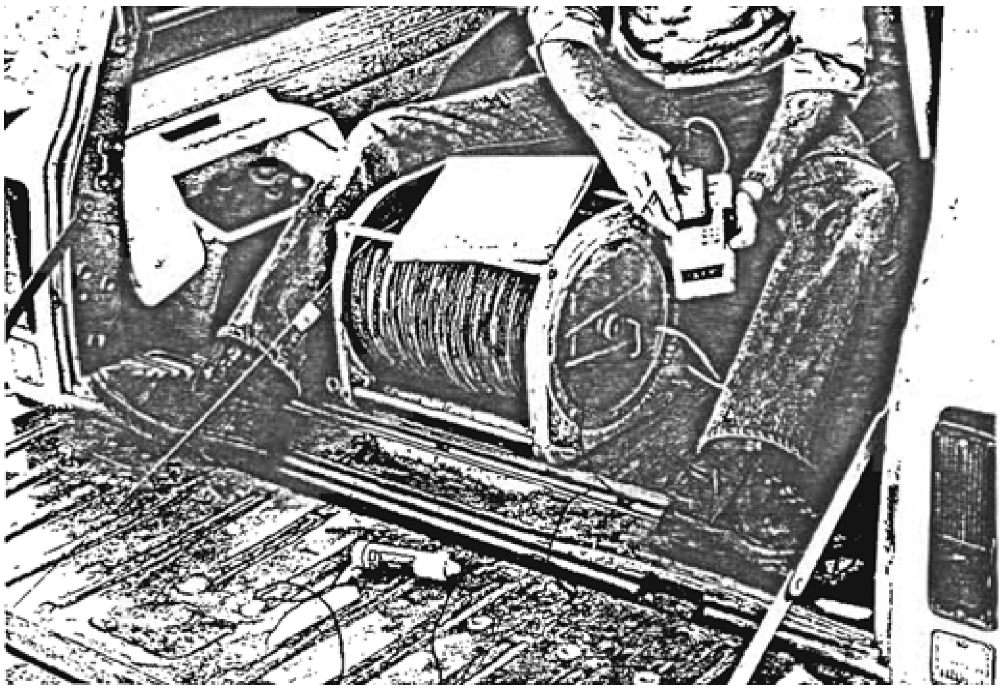


Figure 7 Equipment set-up in vehicle for driving lines.

On driving lines, mount the wire reel in the back of the vehicle so that it may be unreeled as the vehicle drives down the road (Figure 7). The reel should be placed so that it is securely fastened and need not be moved for the duration of the survey. For walking lines, the breast reel should be carried in the most comfortable and convenient manner (see Figure 14). Make sure sufficient spares are taken at this time; i.e., extra banana plugs, voltmeter lead wires, shrink tubing, matches or lighter, electrical tape, flagging tape, spare pen, etc., so that the survey may be continued in spite of Murphy.

3.5.6 Measurement Station Locations

Begin unreeling the wire by driving or walking to the first measurement station. The operator monitors the wire as it is being unreeled and watches for the distance marks. Stations are normally taken every 200 m when exploring for porphyry sulfides. However, in areas where the potential relative to the survey base is lower than -100 mV, stations must be occupied every 100 m.

The minimum sampling interval for any survey can be determined using the Nyquist sampling theorem. If the expected target is one kilometer across, then stations must be taken at least every 0.5 km to define the anomaly, i.e. the maximum station interval is equal to one-half the target width. In theory, if the target is a 10 m wide dike, then the station interval should be 5 m. In practice, however, the SP anomaly will be larger than the causative body so that for a 10 m mineralized dike the SP anomaly will probably be approximately 20 m across. In this case, a station interval of 10 m would suffice for reconnaissance, though a smaller sampling interval would be desirable when doing a detailed survey of the anomaly. The time, and hence the cost, of any SP survey is critically dependent on the station interval. Use the largest practical station interval as indicated by prior experience even though this station interval may violate the Nyquist sampling theorem. On the other extreme, it is seldom practical to use a station interval greater than 200 m due to risks of broken wire, target size, and other operational problems which usually make it advisable to stop every 200 m and take a reading.

At the measurement station, place the roving pot in the most conductive ground within 10 m of the distance mark on the wire. Dry off the terminal post when the roving pot is removed from the bath. Dig a hole sufficiently deep to reach moist soil. Insert the pot by pressing it downward and twisting. Make sure it is <u>kept in the shade at all times</u> (Figure 8). Do <u>not</u> water the pots at any time. Do <u>not</u> touch the copper post on the top of the electrode with the hand while making a voltage reading since this changes the impedance of the circuit and affects the voltage reading on the DVM by producing spurious potentials.

3.5.7 Resistance Measurement

Measure the resistance between the base and roving pots with the DVM. The resistance should be less than 50 kilohms. If it is not, deepen the roving pot hole, replant the pot, and measure the resistance again. If that fails to reduce the resistance to below 50 kilohms, relocate the hole and try again. Place the pot in the most conductive of the holes tried. Record the resistance value on the data sheet. Do not make lengthy resistance measurements because they may polarize the two electrodes. In areas of very high negative SP, the resistance measured with normal polarity will commonly be negative. If this is the case, read the resistance both with normal polarity <u>and</u> reversed polarity and record both values with the normal polarity value above the reversed.

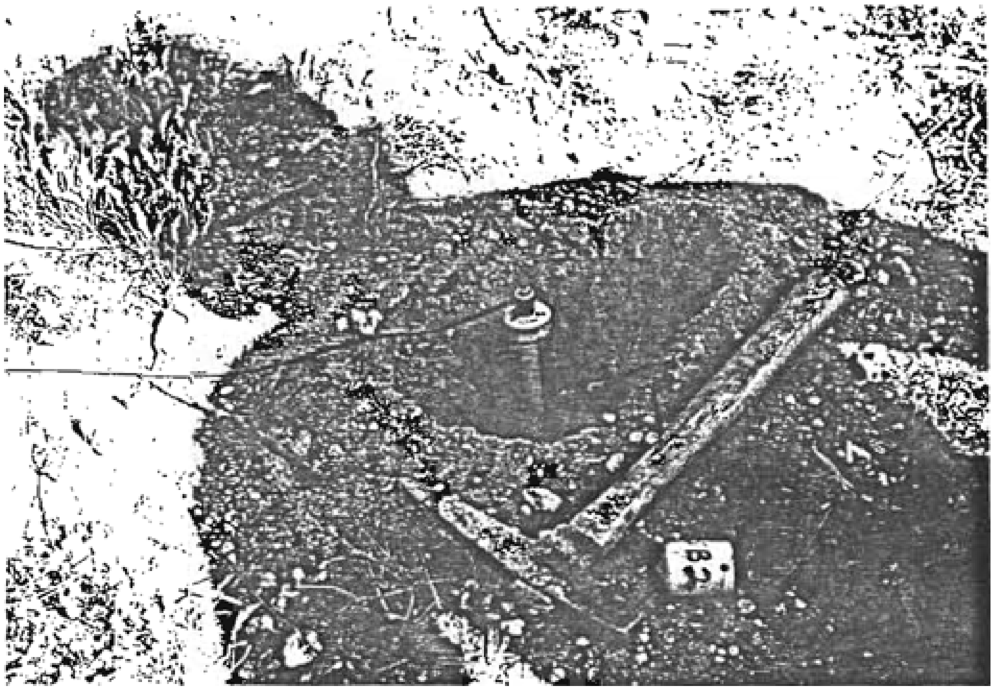


Figure 8 Keep the roving pot in the shade. This avoids photochemical potentials and helps to minimize temperature variations.

3.5.8 Normal Polarity Voltage Measurement

NORMAL VOLTAGE. Measure the voltage between the base and roving pots with normal polarity. The normal polarity is defined to be the base pot wire attached to the negative terminal of the DVM, and the roving pot connected to the positive terminal. Record this measurement in the "Normal Voltage" column with the sign explicitly given, i.e., +150, not just 150.

TIME. Record the time of the normal polarity measurement in Column 1 of the data sheet. Use 24 hour local time (e.g., 0000 to 2359 hours).

3.5.9 Reverse Polarity Voltage Measurement

Reverse the polarity of the input leads at the DVM (i.e., base pot to positive lead, roving pot to negative lead) and take another measurement. Record the reverse polarity measurement in the proper column on the data sheet. If the normal and reverse polarities do not agree to within 5 mV, something is wrong and must be corrected. The most likely cause is a broken wire. Recheck the resistance with the polarity reversed. Check the wire connections to make sure they are secure. If it is suspected that the wire is broken, follow the procedure given in Appendix B. If a broken wire is not the problem, try the other DVM. If one DVM is bad, continue the survey with the good instrument and have the bad one repaired or replaced as soon as possible.

Another cause of non-repeatability is telluric activity, and such activity will be evident on the telluric monitor if it is deployed. If it is not deployed, telluric activity may manifest itself as a varying voltage on the DVM, although caution should be exercised since a broken wire or leaky insulation may give the same sort of drift.

REMARKS. Record pertinent remarks and mark a reference point where necessary. Always record any topographic or cultural features observed, i.e., saddles, stream crossings, culverts, power lines, etc. On driving lines, the driver should be especially alert for such features and point them out to the operator, whose field of vision is somewhat limited within the vehicle. See Section 3.3 for the "Use of Reference Points." An explanation for a reference point is mandatory. When noisy data must be recorded, include under "Remarks" an estimate of the total variation in voltage (for example. +/- 20 mV). It is impossible to make too many remarks. The first time you try to locate a point used by a previous survey crew, you will find out why.

Record the estimated station location on the field map. Mark the reference point designation on the map if one is used. If the location coincides with, or is close to a topographic expression visible on the map, be sure to note it in the "Remarks" column.

3.5.10 Clean the Roving Pot

After the voltage reading is completed, remove the porous pot from the shaded hole, fill the hole with dirt, clean the pot base with a stiff bristled brush while keeping it in the shade, and place it in the porous pot bath. This keeps the copper sulfate bath clean, reduces the drift, and minimizes electrochemical reactions between different soil types as the survey moves along. Cover the ceramic tips with a plastic cap if the pot bath is inaccessible (as on walking lines) to protect it and keep it clean.

3.5.11 Move to the Next Station

Drive or walk to the next station, repeat the measurement station procedure, then move to the next station until the line is completed. Flag at least every 1,000 meter station, or every 10th station, with line number, distance, and date. These stations are to be re-occupied when picking up the wire. Flagged holes should be annotated as flagged on the data sheet, and should be filled in with dirt after completing the measurement to prevent the hole from drying out.

3.5.12 Establish a New Base

When the end of the wire is reached, and a line is to be continued, a new base should normally be established in the same hole as the last measurement station on a line; however, a base can be established in a flagged hole other than the last measurement station if conditions, such as steep SP gradients, warrant. A hole where a new base is to be established should be farther away from the road shoulder and in less rocky ground that the average roving pot hole, and should be made deep enough to accommodate a base pot. It must also be above the water table and away from marshy or swampy ground, bogs, old beaver dams, peat, streams, or any other areas where reducing (low Eh - high pH) conditions might exist. A location on a hillside in sandy loam is an ideal site, but may seldom be found. Do not put the base pot in road fill material, mine tailings or dumps, earth dams, or other disturbed areas.

Since the error resulting from the establishment of new base stations is additive, the number of base stations must be kept to an absolute minimum. Also, the accuracy of the normal voltage is much more critical. For a hole in which a new base is eventually to be established, watch the drift of the normal voltage measurement for at least two minutes. Write down the average voltage under "Normal Voltage" on the data sheet. Follow the same procedure for the reversed polarity reading. Estimate the amount of drift, if any, in the voltage measurement (+/-10 mV, for example) and put this in the "Remarks" column. After the reading, fill in the hole to prevent it from drying out and flag the hole so it will be easy to find later. In some areas, it is often advisable to hide a flag behind a tree, or away from the trail to minimize removal by passers-by.

Base stations must not be established in areas of steep potential gradient, i.e., greater than 100 mV change per 100 meters, or in areas with noticeable time-varying fields due to cultural activity. Ideally, each new base station should be in an area where the SP is close to background, usually 0 +/- 50 mV. Occasionally, this will mean that the crew must back up several stations, or splice on a second reel and continue forward, if telluric activity permits, to establish the best location for the next base station. As stated before, the number of base stations must be kept to a minimum since the errors inherent in establishing bases are additive. For this reason, the crew should make each line a minimum of 4 to 5 km long and move the base pot only when absolutely necessary. Often lines in several directions can be run from a single base. This should be done even when it means spooling off a kilometer or more of wire before beginning the new line.

If a second reel of wire is available, it is often desirable to splice onto the first reel and continue a line without establishing a new base. Do this if the telluric activity over a two minute period at the last station of the line is less than +/- 25 mV. This tolerance should be rechecked every kilometer as the line lengthens. When telluric conditions are quiet, lines as long as 10 km or more may be run off the same base.

If cultural noise is present at the last station of a line, it is frequently possible to splice on the second reel and move out of the area of cultural interference to establish the next base station. Of course, if the continuation of the line moves toward the source of cultural interference instead of away from it, such action may simply make the problem worse. However, this may serve to pinpoint the source of cultural interference, if it is not obvious, and allow the crew to work around the noise source on future lines. The field notes should contain liberal comments on what happened, and what steps were taken to remedy the situation. If the area of cultural interference proves to be so large that it interferes with the survey objectives, such as in the vicinity of a large operating mine or power station, the responsible geophysicist should be consulted. Under no circumstances should a base station be established in an area of known cultural interference.

3.5.13 Reel in the Wire and Re-occupy Stations

For driving lines, reel up the wire and re-occupy the stations at the one kilometer intervals which were flagged on the way out. The roving pot for the re-occupation is placed in the same hole used for the first potential reading at that location. After completing the reading, fill in the hole with dirt again since the same hole may be used later when tying lines together.

Record the re-occupation resistance, time, and voltage exactly like any measurement station.

Write the word "re-occupation" (or "reoc") in the "Remarks" column of the data sheet. A lack of agreement between measurements (+/- 10 mV) is an indication that something is wrong. The most likely causes for a station to drift are: 1) telluric activity; 2) cultural activity; 3) a broken wire; or 4) possibly electrode drift if the pots are exposed to sunlight or large temperature changes.

Telluric and cultural noise is usually AC and will appear as a voltage drift on the voltmeter. When telluric or cultural activity is suspected, leave the wire reel at the last station, return to the present base station, and deploy the telluric monitor, if it has not been deployed already. If long period tellurics beyond the limits specified in Appendix E are indicated on the telluric monitor, delay the survey until the telluric activity diminishes or ends. Continue to deploy the monitor with every line for at least one day following the end of telluric activity in case of any unexpected renewal of solar activity. Forecasts of solar activity are broadcast on WWV short wave radio stations.

If a wire break is suspected, follow the procedure given in Appendix B.

To reel in the wire for walking lines the procedure stated above for re-occupation is normally used; however, a second procedure may be preferred in steep terrain when reeling wire up steep slopes can be avoided. The alternate method is to establish a base at the end of the line with the highest elevation. The line is then run predominantly down-slope to the lower elevation. When the line is completed and tied to an existing line, install the roving pot in the same manner as a base pot at the last station. Return to the base pot location. The base pot is then pulled out and the line is reeled in down-slope as well as using the original base pot to do the 1 km re-occupations. Generally, this alternate method should only be used in the steepest terrain.

Logistics for the alternate method involve letting the operator off as near as possible to the top of the mountain and driving around for the pickup at the bottom. The operator is then shuttled back up to the top where the drift measurement is performed and the reeling in of the wire is begun. The driver goes back to the bottom for the final pick up.

If a third person is available and the crew is equipped with at least two walkie-talkies, the shuttle trip is not required. The second person waits at the top while the operator goes down the mountain. At the bottom the operator sets up the roving pot at the last station or a new base station and then tells the second person by radio to remove the base pot and begin reeling in the wire. The third person drives the vehicle down for the final pick up (See Appendix D, Walking Line Radio Procedures).

3.5.14 Drift Voltage

After the last re-occupation, usually at 1 km, reel up the remaining wire, remove and clean the base electrode, and measure the drift voltage in the manner previously described (see section 3.5.4).

Record the drift voltage in Column 6. Record the time, and in the "Remarks" column, note the base where the drift measurement was made. Use a new line of the data sheet.

Electrode drift is another possible cause for a lack of agreement between measurements. If an electrode is exposed to the sun, the incident ultraviolet rays and the increase in temperature will cause a DC offset in the measurement. If pot drift exceeds the specifications in Appendix E, the responsible geophysicist must be notified. Excessive pot drift is virtually always the result of exposure to sunlight and large temperature changes. It is a prime responsibility of the field crew to guard against this by keeping the pot in the shade at all times, and in the bath when not in use.

3.5.15 Field Data Reduction

Reverse the sign of the drift voltage measurements which were taken at the beginning and the end of the line. Put this value in the "Drift Correction" column. Interpolate the drift correction as a function of time between the beginning and the end of the line (see Figure 3. page 20 for an example).

The absolute voltage of the base station used for the line is the base tie-in correction for the line. Thus, for lines using the survey base where the absolute voltage is zero, the base tie-in correction is zero.

For lines done using other bases, the base tie-in correction is the absolute voltage of the appropriate base, which will be the absolute voltage of the last station on the previous line.

Compute the absolute voltage for any hole in which a new base is to be established by adding the normal polarity voltage measurement for that hole to the base tie-in correction and drift correction for that hole. The absolute voltage of the new base becomes the base tie-in correction for any line using the new base.

3.5.16 Beginning a New Line

Repeat the procedure used to do the initial line given above. Make sure that the base pot is placed in exactly the same hole as used for the final measurement station on the previous line. By knowing the base tie-in correction for the new line, the operator will know when absolute voltages are below -100 mV, requiring a change from 200 to 100 m station spacings.

At the end of each line, mark the last station recorded with a reference point on the map and in the "Map Reference Point" column. Complete the data sheet by marking the line, e.g., line A-B, at the top of the data sheet.

3.6 Replacing the Copper Sulfate Solution

3.6.1 When to Change Solution

This chore is necessary when greater than 5 mV of drift between pots is observed in the field. While the porous pots themselves will rarely require cleaning, it will be necessary to clean out the bath about once a month due to dirt buildup.

3.6.2 Cleaning

To clean the porous pots, pour out the solution and wash the pots with water. Distilled water is preferred, but not essential except in areas where the water is foul to the taste, or is excessively chlorinated. Clean the ceramic bases thoroughly with a stiff bristled brush and rinse thoroughly and replace the tips if they are excessively worn. Remove any corrosion from the copper rods with emery paper. Fill the pot about one-third full with copper sulfate crystals and fill the remainder with water, leaving approximately a 1/2 inch air gap between the cover and the top of the solution. When replacing the porous pot solution, always change the porous pot bath solution at the same time.

After cleaning out accumulated dirt from the pot bath, pour about two inches of water into the bottom of the bath and add enough copper sulfate crystals to saturate the solution. It is important that this chore be performed in the afternoon as soon as the crew returns from the field. The solution must be allowed to stabilize as long as possible (minimum 12 hours) before data acquisition begins. After the solution has stabilized, the bottom of the bath must still have undissolved crystals to insure the solution is saturated. If more copper sulfate crystals must be added, wait an additional 12 hours for the solution to stabilize. Spending the effort to prepare the bath right the first time will save considerably more time later.

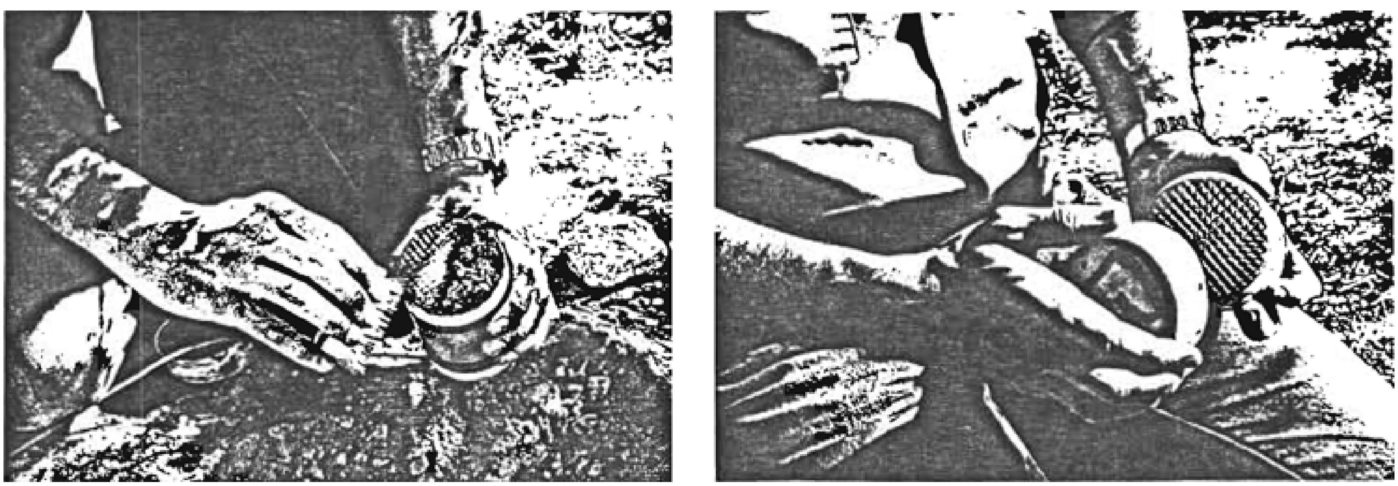


Figure 9 Always clean the ceramic base of a pot whenever vou pull it from the ground. Keep pots covered if they are not returned to the pot bath promptly.

4 DATA REDUCTION

4.1 Absolute Voltage Relative to the Survey Base

To obtain the absolute voltage of a station relative to the survey base there are two corrections: the drift correction, and the base tie-in correction.

4.1.1 Drift correction

To determine the drift correction, reverse the sign of the drift voltage measurements which were taken at the beginning and the end of the line. Put these values in the "Drift Correction" column, then interpolate as a function of time between the beginning and the end of the line. Most scientific calculators make such interpolation a simple matter.

4.1.2 Base tie-in correction

The base tie-in correction is the absolute voltage of the base from which a line is run. This is the value that must be added to the entire line to refer the voltage to the survey base. The base tie-in correction for lines run off the survey base is, by definition, zero. All other lines will most likely have a non-zero tie-in correction. The tie-in correction is determined by finding the drift-corrected absolute voltage of the last station of the previous line. Since this station is normally used as the base station of the current line the absolute voltage of the new base station is known.

Absolute voltage (V_{abs}) for any other station on a line is determined by adding the normal voltage (V_{norm}) at that station to the appropriate drift (C_{drift}) and tie-in corrections (C_{base}). A completed data sheet on which these corrections have been made is shown on Figure 3 ($V_{abs} = V_{norm} + C_{drift} + C_{base}$).

4.2 Absolute Voltage From A Floating Base

4.2.1 Logistical Problems

Because of logistical problems, it may be necessary to plant a new base in a location for which the absolute voltage is not known. However, somewhere the line must tie to a flagged hole in which the absolute voltage has previously been determined. If the survey is to be extended farther from the currently floating base, then the tie point on the existing line must be a previous base station. In the event that no further lines are to be run from the floating base, then a tie to one of the flagged 1 km re-occupation points on a previous survey line will suffice. Since it will not generally be known in advance whether or not the line will be extended, it is good field practice to always tie the line to a previous base station.

4.2.2 Conversion

To convert the normal polarity measurements to absolute voltages for this case, a "floating" base calculation is used. The principle is the same, but the procedure is slightly different. First, obtain the interpolated drift correction the same way as before. Second, for the tie point where the absolute voltage has previously been determined, put this value in the "Absolute Voltage (mV)" column. The base tie-in correction (C_{base}) for the line is now determined algebraically by subtracting the normal voltage (V_{norm}) and the interpolated drift correction (C_{drift}) from the previously determined absolute voltage at the known base station (V_{base}) ($C_{base} = V_{base} - V_{norm} - C_{drift}$). The base tie-in correction calculated in this manner applies to the entire line and is also by definition the absolute voltage of the "floating" base. Absolute voltages (V_{abs}) for the entire line are calculated as before, by adding the normal voltages (V_{norm}) to the base tie-in (C_{base}) and the drift corrections. A complete data sheet in which this correction has been performed is shown on Figure 10. (C_{drift}) ($V_{abs} = V_{norm} + C_{base} + C_{drift}$).

4.2.3 When To Use

A floating base should be used only as a last resort since it is impossible to know if the floating base is in a region of steep gradients, or when the absolute voltage goes below -100 mV (which requires going from 200 to 100 m spacings along the lines). Generally, if a floating base is required, the first 500 m, at least, should be run at 100 m spacing for these reasons. The tie point to a previous line must be outside an area of steep gradients, and the other precautions for establishing a base station should be carefully observed when using a floating base.

4.3 Loops

4.3.1 Test of Measurement Error

As a test of measurement error caused from using several bases along a long line, it is desirable to create a loop of SP lines to check the voltage error around the loop. When closing a loop by occupying a point from two or more different bases that are already tied together along the back side of the loop, the absolute voltage at the point should be the same referenced to all base stations in the loop. Voltage errors when tying loops should be less than 50 mV. When small anomalies are encountered closure of loops is especially important as a check that an anomaly actually exists.

SELF-POTENTIAL SURVEY DATE: 10/15/80

AREA: Mount Mantero LINE: AZ — BA

PERSONNEL: G. DeMoully, S. Clement

TELLURIC MONITOR: Voltage scale: N/A mV full scale; Chart speed: N/A cm/hour

TIME	Distance from Line Base (m)	Normal Voltage (mV)	Reversed Voltage (mV)	Resistance (Kilohms)	Base-Roving Pot Drift Voltage (mV)	Drift Corr.	Base Tie-in Correction	Absolute Voltage (mV)	Map Reference Point	Base pot at BA: #4 Roving pot: #2 BASE (BA) is "floating" Remarks
1100					-2.1	+2				DRIFT CHECK
1145	0						-48		BA	Base located adjacent
to Benchmark on Mt Mantero Peak								DeMoully heading downhill to AZ		
1200	100	-50.2	+51.0	15		+2		-96		
1215	200	-100	+102	16		+2		-146		
1225	300	-223	+226	8				-269		Nose on ridge
1235	400	-408	+410	2				-454		Base of cirque headwall
1245	500	-600	+603	-15 / +10				-646		Stream crossing
1255	600	-786	+782	-18 / +8				-832		
1305	700	-653	+660	-15 / +20				-701		
1315	800	-523	+526	-5 / +25				-569		
1325	900	-381	+376	4				-427		
1340	1000	-189	+195	10				-235		FLAGGED by tree
1350	1100	-121	+119	15				-167		
1400	1200	-80.1	+76.8	20				-126		
1410	1300	-53.1	+55.6	23				-99		Stream crossing
1420	1400	-20.6	+22.1	25				-67		
1435	1600	+15.1	-16.8	27				-31		Increase sta. spacing
1450	1800	-12.6	+13.7	28				-59		
1500	2000	-50.8	+52.1	30				-97		FLAGGED
1515	2200	+30.1	-32.0	26				-16		
1525	2400	+20.8	-22.3	30				-25		
1535	2600	-1.3	+2.1	31				-47		
1545	2800	-5.7	+6.2	35				-52		
1555	3000	-7.2	+8.6	32				-53		On road now
1610	3150	-10.1	+10.8	28		+2	-48	-56	AZ	Tie to exist. base AZ=-56
ROVING POT NOW PLANTED					AT BASE AZ / Clement					recs + rewind downhill.
1705	1000	-181	+183	20		+2	-56	-235		REOC
1735	2000	-44.1	+42.8	13		+2	-56	-98		REOC
1807	3000	-1.1	+1.6	8		+2	-56	-55		REOC
1820					-2.4	+2				DRIFT CHECK

Figure 10 *A completed data sheet using a "floating" base. Note the different base tie-in corrections used for the data stations and the re-occupation points.*

4.3.2 Large Surveys

For large surveys with a large number of loops it may be necessary to distribute the errors along some lines. The techniques for doing this, while beyond the scope of this procedure, are the same as those used for airborne magnetic surveys, and are the responsibility of the geophysicist, not the field crew. Usually no elaborate adjustment is needed, and a simple DC offset of a line or two within the survey will provide ties within specifications for the entire network. If a simple DC offset will not correct the loop ties, then the responsible geophysicist should be consulted, and if necessary, questionable lines should be rerun.

4.4 Nightly Data Reduction

It is a primary responsibility of the field crew to keep the data reduction up to date since the future course of the survey will depend on the anomalies found as the survey proceeds.

4.4.1 Computing Absolute Voltages

Compute the absolute voltage for all stations by adding the normal voltage to the base tie-in and drift corrections ($V_{abs} = V_{norm} + C_{base} + C_{drift}$). Record the absolute voltage of each station in the designated column.

4.4.2 Plotting Profiles

If anomalies with amplitudes of -100 mV or more were encountered during the day, plot the absolute voltages for the day's work in profile. These profiles will allow the field crew and the geophysicist to evaluate the data quickly, and to design follow-up survey lines. The profiles are to be marked with the survey name, date, line designations, and reference marks. The scale on the profiles for mineral surveys should be 100 mV/inch extending from +100 to -1,000 mV vertically, and 1 km/inch horizontally. The future design of the survey is critically dependent on delineating the anomalies encountered as soon as possible. This is best done on the plotted profiles. The field crew must keep the profiles of any anomalous areas up to date.

4.4.3 Plot Stations on the Hotel Map

Record each day's station locations carefully on the rolled map in the hotel. This is to be done using the map symbols discussed in Section 3.3. Make sure that all mandatory reference points listed in Appendix A are included.

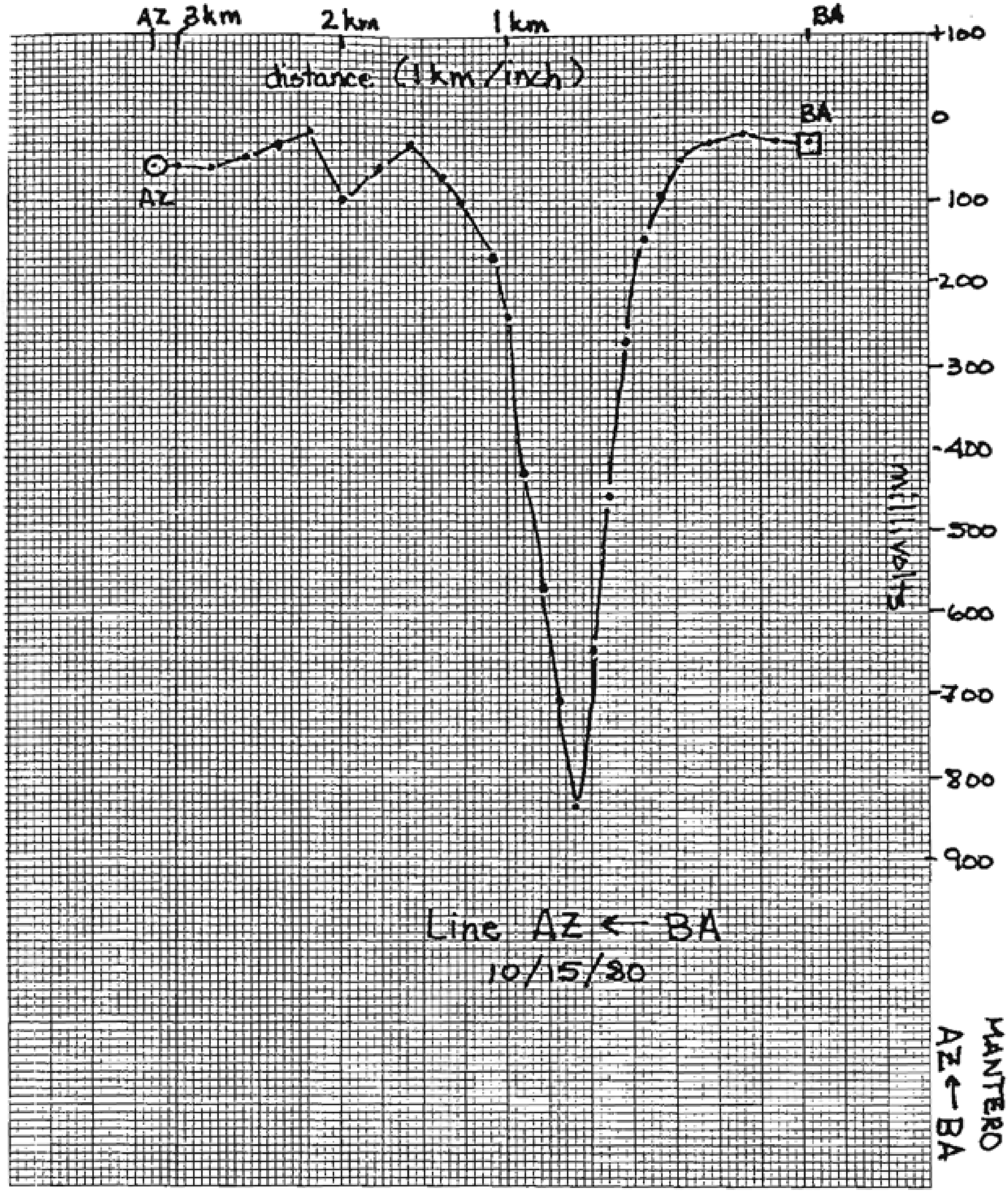


Figure 11 Example of an SP line profile.

APPENDIX A

SYMBOLS TO BE USED ON THE FIELD MAP

(⊗) Survey Base - This is the site chosen to be the reference voltage for the entire survey. All voltages are measured relative to this location, and the voltage is arbitrarily taken to be zero volts.

(⊡) Base Pot Location - Designates base pot locations other than the survey base.

(•) Roving Pot - Locations of the roving pot.

(⊙) Previous Survey - Points from a previous survey (if applicable). Occasionally one survey is to be connected to another and the previous survey base or several lines are to be re-occupied. These points are designated with this symbol. Voltage from both surveys will be plotted on the final map, which shows the absolute voltages.

(◬) General Reference Point - This point is mentioned in the notes, and on the profiles. It refers to any location of interest such as interesting rock types, intersection of SP lines, meeting with irate landowners, etc.

(T M ├──┤) Telluric Monitor Line - with polarity shown. This marks the position of the telluric monitoring station on the map. The proper polarity of the recorder is noted by "+" and "-" symbols. Give month, date, and year of occupation on field map.

APPENDIX B

TROUBLESHOOTING WIRE BREAKAGE

Wire breakage is a common mechanical problem associated with SP surveys. Wire breaks are generally discovered when the voltage readings are unstable, and when an infinite or very high resistance is measured between the base and roving pot. However, a number of other problems cause symptoms similar to a broken wire, and these should be tested first. When an infinite or very high resistance reading is observed which cannot be corrected by relocating the roving pot, first check that the banana plug is securely in the reel. Often this is the only problem. If the plug is in, check the leads from the voltmeter. Sometimes the connection between the banana plug and the voltmeter lead wire will open circuit. Sometimes the problem is in the polarity-reversing switchbox. These problems may be quickly diagnosed by measuring the resistance of the meter leads with the tip of the banana plug shorted to the copper post of the roving electrode. Infinite resistance in this circuit is an indication that the problem is in the meter leads, and not in the wire.

If the problem is not in the meter leads, then some other part of the circuit is open. Infinite resistance may mean a separation of the wire from its connection with the female banana plug on the inside of the reel, although this is rare. To diagnose this problem, slit the insulation in the wire just where it comes off the reel and measure the resistance of the circuit between the female banana plug on the inside of the reel and the wire where it has been slit (Figure 13). Infinite resistance for this circuit means that the wire has probably separated from its connection to the female banana plug on the inside of the reel. Solving this problem necessitates reeling the wire back up while making voltage measurements, to the point where the break was diagnosed.

If the circuit on the inside of the reel is all right, and the meter leads test all right, then the break must have occurred somewhere between where the wire comes off the reel and the base pot location. Take the reel out of the vehicle, and drive back to the base pot, checking for breaks along the way. If the base pot has been disturbed, or there is a simple break in the wire, it is often possible to fix the circuit without having to reel in the wire. Sometimes the wire may be missing a section (as much as 100 m or more). Every time the wire is broken by a vehicle, it must be checked to ensure a segment is not missing. Missing segments must be replaced before the survey can continue. This usually requires reeling the wire up to the point of the break, replacing the missing segment, unreeling the wire back out to the last station, and continuing the survey.

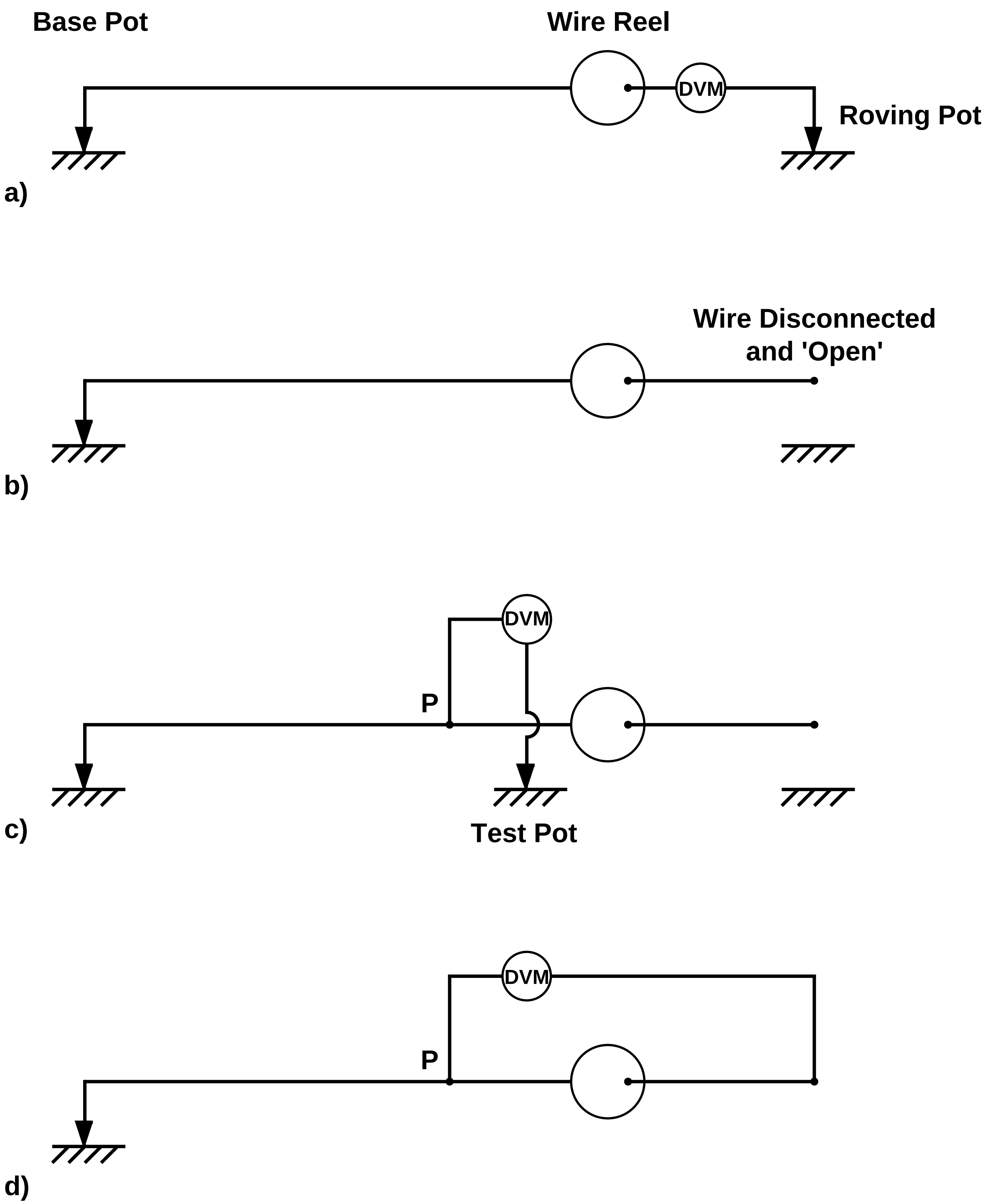


Figure 12 Troubleshooting procedure for finding a break somewhere along the wire.

If visual inspection of the wire and base pot fails to diagnose the problem, and if the problem is not in the leads, nor the inside of the reel, the problem is probably due to a stress fracture within the insulation. Generally, intermittent opens will have been observed before this occurs. This type of open is extremely difficult to find since there is usually no obvious break in the line. Fixing this kind of break involves locating the section to within 100 m, then replacing that entire section. This is easiest to do with the wire laid completely on the ground and one end grounded to a porous pot. The procedure is shown schematically in Figure 12. Another porous pot and the DVM are carried to different locations on the wire (labeled P in Figures 12 and 13). At location P, a slice is made in the insulation sufficient to insert the probe of the multimeter. The resistance between the base pot and location P is measured. An infinite resistance reading indicates the open is between the point P and the base pot. A finite resistance indicates the break occurred between the point P and the open end of the wire. Repair the insulation slice at point P. The distance between P and the end of the wire toward the break is again bisected. This procedure is continued until the break has been located. A maximum of 7 checkpoints are necessary to locate the break to within 100 m for an 8 Km wire. Once the 100 m segment has been isolated, it is replaced with a fresh segment. Fortunately, this type of break is rare.

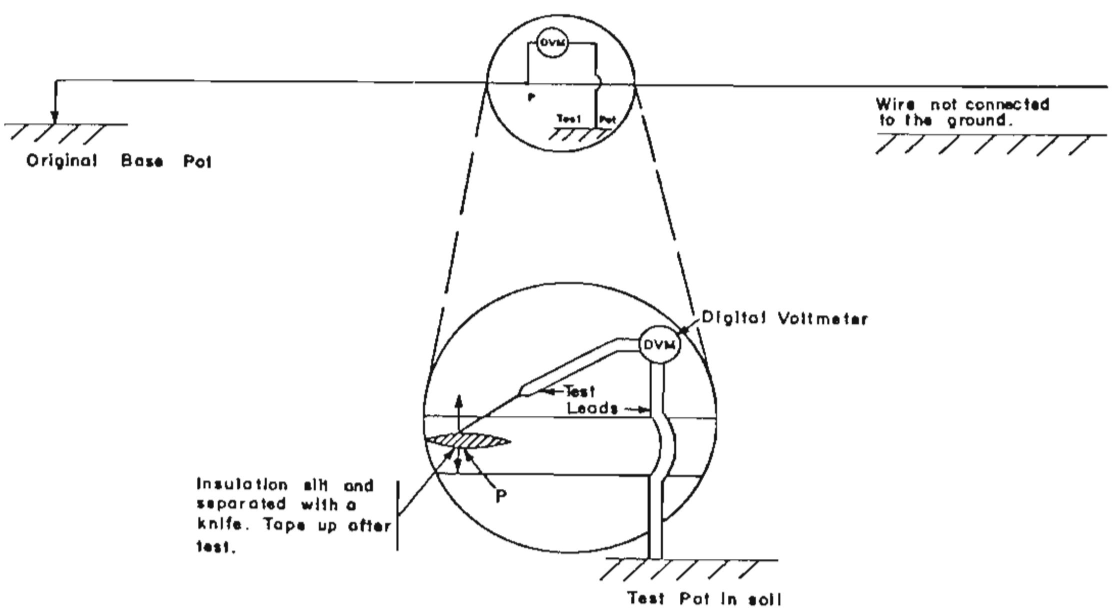


Figure 13 The method used to find the location of an internal stress fracture in the wire. The entire wire is laid out with one end grounded to a porous pot, and a resistance measurement is made at some point P.

APPENDIX C

EQUIPMENT AND EQUIPMENT MAINTENANCE

The equipment needed for an SP survey consists of SP data acquisition equipment, vehicle and vehicle maintenance tools, and field equipment.

The accompanying list is assembled from experience, and is thought to represent the best and most practicable equipment available at the present time. No doubt improvements on equipment will be made in the future, and after proving their worth in the field the equipment list should be updated. To the person new to self-potential surveys the list may seem unnecessarily detailed and the equipment costs excessive for so simple a survey. However, with costs for a two man SP crew being approximately $700 per day, the omission of a spare part could easily cost a day or more lost time. Since it is a corollary of Murphy's Law that the spare you have omitted will be for the part that breaks on the remotest leg of the survey, it is wiser to spend the time and money providing for the unexpected insofar as possible in advance. While there is undoubtedly room for debate as to what has been included and what has been left out, the equipment shown below has served well over several field seasons. The total lists are intended to be used as a check list each time <u>before</u> going in the field.

SP MEASUREMENT EQUIPMENT

Porous Pot Electrodes

Two styles of porous pots are commonly used: Tinker and Rasor, Models 3A and 6B. The 3A "fatboy" is short and fat with a flat, corrugated bottom and this style is normally used as a base pot. The Model 68 is long and slender with a pointed tip and is used for a roving pot. Either of these may be used for the telluric monitor, however, the Model 3A is preferred. The Model 3A and 6B electrodes may be ordered directly from Tinker and Rasor, 417 Agostino Road, San Gabriel, California 91778. (213) 287-5259.

These pots are both copper-copper sulfate half-cell non-polarizing electrodes, and consist of a copper rod inserted into a saturated solution of copper sulfate and water. In order to insure saturation, copper sulfate crystals should be visible in the pot at all times. It is preferred that distilled water be used, but tap water is acceptable if the water has no foul taste and is not excessively chlorinated. After filling, the pots should sit in the bath for 24 hours (12 hours minimum) before use to insure they are in stable equilibrium.

Regular maintenance of the pots consists of brushing off the ceramic bases with a stiff nylon bristled brush and changing the solution. The bases are to be brushed off whenever the pots are pulled out of the ground. The copper sulfate solution is replaced whenever it appears cloudy or is causing drift problems (>5 mV). The tips need to be replaced whenever they begin to leak, are broken. or become excessively worn, and the copper rods should be kept free of corrosion. It is good practice to have one or two spare tips submersed in the bath in order to minimize stabilization time for a replacement tip.

Copper sulfate crystals, a stiff non-metallic brush, extra tips for both pot styles, and a container with the bottom filled with copper sulfate solution for pot storage should all be carried with the crew in the field. As the pot tips become worn, another set of pots should be prepared in advance to replace the ones in use.

Porous Pot Bath

This is an insulated container with the bottom filled with open-cell foam saturated with copper sulfate solution. It serves two functions: 1) to store the pots so that the ceramic bottom is immersed and the copper sulfate will not crystallize out, and 2) as a temperature insulator for the roving pot between data stations. A small cooler ("Playmate") works quite well. This is the bath in which drift voltage is measured and all pots are stored when not being used. A wooden rack to hold the electrodes upright in the bath should be constructed to fit the insulated container. A one-inch thick foam padding immersed in the copper sulfate solution at the bottom of the bath will minimize tip wear.

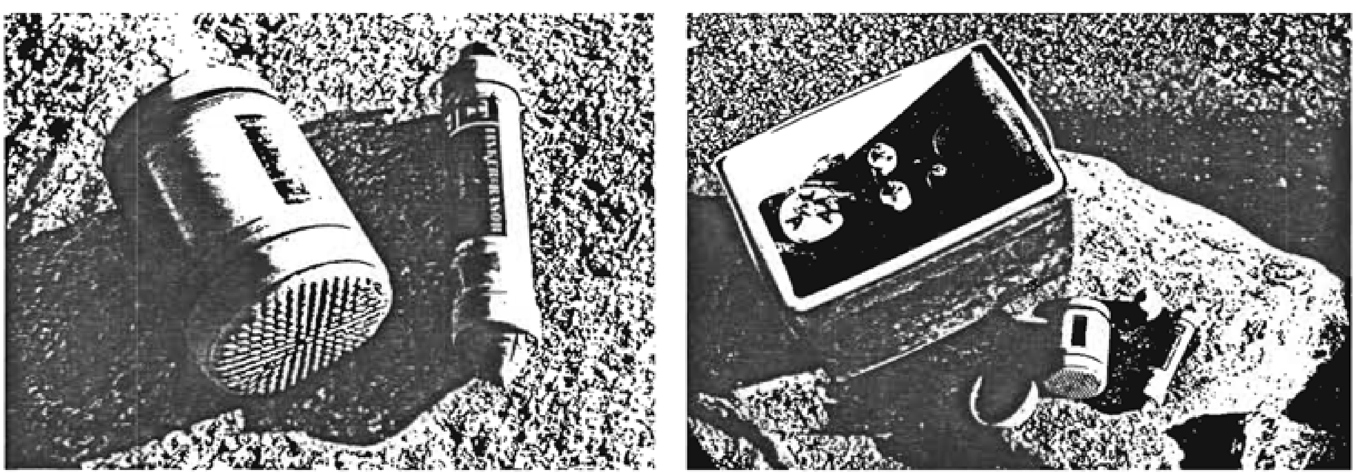


Figure 14 Porous pot electrodes and an insulated pot bath with wood rack in bottom to hold electrodes. Foam padding placed under rack.

Porous Pot Tips

The ceramic bottoms of the porous pots are rugged and wear out infrequently, but extra tips for both the base and roving pots are easy to carry and could save a lot of time in the event of breakage. A couple of spare tips are normally kept in the copper sulfate bath to minimize the time required for the pots to stabilize after changing tips. Spare tips can be ordered directly from Tinker and Rasor.

Stiff Bristled Brush

The brush is used to clean the bottom of the porous pots before putting the pots back in the copper sulfate bath. The bristles should not be made of metal which can rub off on the ceramic bottom of the pot. A variety of these are sold at most supermarkets, usually for cleaning vegetables.

Copper Sulfate Crystals

The copper sulfate solution of the porous pot bath needs to be replaced regularly. Low grade copper sulfate is often sold in hardware stores as septic system root killer. Use this type only when higher grades are unavailable and only for the porous pot bath. Ten pounds of crystals (technical grade or better) should be sufficient to last a summer.

Wire

The wire commonly used for SP surveys may be obtained from Mark Products, 10507 Kinghurst Drive, Houston, Texas 77009, (713) 498-0600 or Zonge Engineering. For walking lines, 15 kilometers of #26 gauge stranded, single conductor, cadmium-bronze wire is required. The wire should be marked in 100 m lengths on four of the Sharpe reels (3 kilometers each). The remaining 3 kilometers should be kept as a reserve. For driving lines 12 kilometers of #20 gauge, 7x6x36 stranded, single conductor, copper clad steel wire is required. Eight of the 12 kilometers is to be marked every 100 m on two Zonge reels in 4 kilometer lengths, and the rest held in reserve.

The wire is marked every 100 m with cloth bookbinding tape ("Mystic" tape) folded over the wire onto itself. Distances are marked directly on the tape in kilometers (1, 1.1, 1.2, etc.) with indelible ink. Occasionally the tape will slip and markers should be repaired as soon as slippage is noticed. Mystic bookbinding tape is widely available in supermarkets and drug stores.

Wire breaks are spliced using a wireman's splice and insulated with shrink tubing. All abrasions through the insulation must be repaired with electrical tape as soon as noticed.

Wire Reels for Driving Lines

Three large wire reels with a minimum capacity of 4 km of #20 gauge wire are required for the driving lines. The Zonge Engineering Portable Reel BR/12 which may be purchased from 3322 East Fort Lowell Road, Tucson, Arizona 85716, (520) 327-5501, serves the purpose quite well, and is readily available.

Wire Reels for Walking Lines

Three small wire reels are required for walking lines. These reels should have detachable spools. The Model GR-1000 reel is lightweight, rugged, and reliable. They may be purchased from Edgar Sharpe and Associates. Ltd., 1983 Kipling Avenue North, Rexdale, Toronto, Ontario, Canada, (416) 743-8144. In addition to the spools supplied when one orders the "GR-1000, complete", two additional spools per reel are required.

Digital Voltmeter

Two Fluke 8020B DVM are required. They may be purchased from John Fluke Manufacturing Company, P.O. Box 43210, Mount Lake, Terrance, Washington, 98043, (800) 426-0361 or their local distributor. This meter has a high input impedance (10 Megohms), and will read from 0.1 mV to 1,000 volts. This DVM runs for approximately 200 hours on a single 9 volt alkaline transistor battery. There is a low voltage indicator incorporated into the display to give sufficient warning to replace the battery. The only maintenance required is battery replacement. An extra battery should be carried for each DVM.

Scientific Calculator

A handheld calculator which includes most scientific functions and is quasi-programmable is required. One of the more inexpensive, yet adequate models is the Texas Instruments TI-35 calculator. Many crews prefer the more expensive, though more flexible TI-59 programmable calculator.

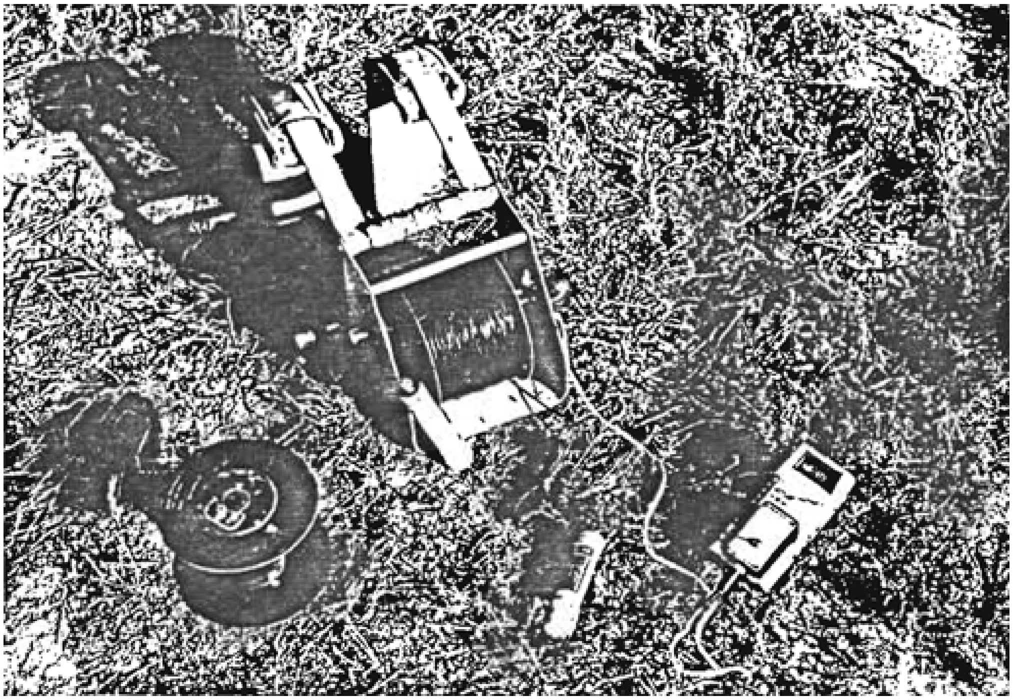


Figure 15 A walking reel, DVM, roving pots, and a spare spool.

Strip Chart Recorder

This battery-operated recorder is used as a telluric monitor. It must have the capability to record 10 and 100 mV full scale, and have a drive speed of about 10 cm/hr. A paper catch or automatic roll-up is desirable. One such recorder is the Linear Systems, Inc. Model 142, battery powered strip chart voltage recorder which may be obtained from Linear Systems, Inc., 17282 Eastman Avenue, Irvine, California 92714, or their local distributor. Be certain when charging this recorder that the power switch is on.

Rock Hammer

This is used to dig the small pit into which the roving and base pots are placed. The ground in mountainous terrain tends to be rocky and a device such as this is necessary. In areas with well-developed soil, a sedimentary rock hammer will work better. Normally, both types are carried in the field truck.

Tools

The crew should have a basic set of tools for field repairs. A suggested list follows. Crews should have a separate list of tools and spare parts located in the glove box of the vehicle. The tools are to be checked by the crew before departing for the field.

Whenever an item needs replacement in the field, whether from the spares provided or otherwise, a replacement should be ordered at once. If the breakage of equipment will hinder or slow production, the responsible geophysicist should be notified at once. Be certain that the truck spares are for the truck you are taking into the field, and that nuts and bolts for the vehicle are in the same units (English or metric) as the field vehicle which will be used. If metric nuts and bolts are used, add a set of metric tools to the following list.

SP FIELD EQUIPMENT (Minimum)

1	4-wheel drive heavy duty vehicle rigged to spool out and recover wire from the tail gate and equipped with a two-way radio.
4	Copper-copper sulfate half-cell electrodes (Tinker and Rasor, Model 3A)
5	Copper-copper sulfate half cell electrodes (Tinker and Rasor, Model 6B)
2 extra	Ceramic tips for 3A electrodes
2 extra	Ceramic tips for 6B electrodes
2 extra	Nuts for electrodes
10 lbs	Copper sulfate crystals (technical grade)
2	Digital Multimeters (Fluke. Model 8020A DVM)
2 extra	Batteries for the Digital Multimeter
2 extra	Fuses for the Digital Multimeter
15 km	26-gauge stranded cadmium bronze wire. single conductor, insulated
3	Walking line reels, complete (Edgar Sharpe Model GR-1000)
6 extra	Spools for walking line reels (3 km marked wire per spool on 4 spools, 2 empty)
12 km	20-gauge 7x6x36 stranded copper clad steel wire, single conductor, insulated 4 km marked wired per spool
3	Driving line reels, Zonge Engineering Portable Reel BR/12 (4 km marked wire per spool on 2 reels, 1 empty)
2	"Playmate" coolers for the strip chart recorder and porous pot bath
3	Stiff bristled brushes, non-metallic
2	Ordinary rock hammers

2	Sedimentary rock hammers
3 rolls	Electrical tape
15 rolls	Flagging (various colors)
3 rolls	Book binding tape (white Mystic)
3	Fine tip markers, black (Marksalot), permanent ink
5	Broad tip markers. black (Marksalot). permanent ink
20 ft	Shrink tubing, for 26-gauge wire
20 ft	Shrink tubing, for 20-gauge wire
3	Butane cigarette lighters, adjustable flame
1	Soldering iron, battery powered
1 roll	Solder, #26-gauge Rosin core
3 pr	Wire cutters or strippers
1	Pocket knife
1 pr	Needle nose pliers
1	Small screwdriver
4 pr	Gloves, heavy duty leather
2 copies	Survey area topographic maps
1	Brunton compass
40 male	Banana plugs for the wire ends
5 female	Banana plugs for the inside of reels
40 ft	Test lead wire, for multimeter leads
2	Switch boxes for Digital Multimeter - to allow polarity reversal of meter input by means of a spring-loaded switch) Available from Zonge Engineering
4 extra	Switches for switchbox
2 extra	Switch box plugs, male and female
8 pcs	Styrofoam, 15" square, minimum I" thick
1 roll	Duct tape. 2" x 60 yds.
1	Strip chart voltage recorder (Linear Systems Inc., Model 142). Recharge with power switch <u>on</u>
1	Three to two prong 120 volt adapter, for strip chart voltage recorder so that it can be plugged into motel outlet
5 extra	Rolls strip chart paper
5 extra	Strip chart pens
1	100 meter telluric monitor wire
1	Extension cord spool, for telluric monitor wire

10	Fine-tip black ballpoint pens for recording data
500	Data acquisition sheets (see Figure 4, p.21)
1	100 meter steel measuring tape for flagging wire
2	Canteens, military, with belt attachment
1	Canteen, 1 gallon for vehicle (2 if desert operations)
2	Leather tool belts with large pockets for carrying DVM and roving pot on walking lines
2	Clip boards, modified for walking lines
2	Daypacks
3	Walkie talkies
3	Radio battery chargers
2 extra	Battery sets, for walkie talkies
1 sheet	foam padding
1 tube	Superglue

Toolbox

1	Screwdriver, stubby
1	5 pc. Punch & Chisel set
1 pr	Ignition Pliers
1	12 oz. Ball peen Hammer
1	Feeler Gauge (0.001 – 0.025 inches)
3	Screwdrivers, Phillips head, #1, #2, #3
1	3/16” x 4 Screwdriver
1	1/4” x 6 Screwdriver
1	5/16” x 8 Screwdriver
1	3/8” x 12 Screwdriver
1	3/16” x 9 Screwdriver
1	1/8” x 4 Screwdriver
1	1/8" x 2 Screwdriver
1 10 pc	Midget Combination Wrench Set
1 14 pc	Hex Key Set
1	Hacksaw
10	Hacksaw Blades
1	3/8 x 7/16 Short Box Wrench
1	1/2 x 9/16 Short Box Wrench

1	5/8 x 3/4 Short Box Wrench
1 set	Combination Wrenches 1/4" to 1" in 1/16" steps (14 total)
1	1/4" Drive Ratchet
1	6" flex, T handle, 1/4" drive
1	6" extension bar, 1/4" drive
1	3" extension bar, 1/4" drive
9	1/4" drive standard Sockets, 3/16, 7/32, 1/4, 9/32, 5/16, 11/32, 3/8, 7/16, 1/2 (inches)
1	Permanex box for 1/4" drive Sockets
9	1/4" drive deep Sockets, 3/16, 7/32, 1/4, 9/32, 5/16, 11/32, 3/8, 7/16, 1/2 (inches)
1	3/8" drive Ratchet
1	5/8" Spark Plug Socket, 3/8" drive
1	6" Extension Bar, 3/8" drive
1	10" Extension Bar, 3/8" drive
1	3” Extension Bar, 3/8" drive
7	3/8" drive Standard Sockets, 3/8, 7/16, 1/2, 9/16, 5/8, 11/16, 3/4 (inches)
8	3/8" drive deep well Sockets, 3/8, 7/16, 1/2, 9/16, 5/8, 11/16, 3/4, 13/16 (inches)
1	1/2" Drive Ratchet
1	Universal Joint, 1/2" drive
1	6" Extension Bar, 1/2" drive
1	3" Extension Bar, 1/2" drive
1	10" Extension Bar, 1/2" drive
1	15" Flex T Handle, 1/2" drive
1	13/16" Spark Plug Socket
12	1/2" drive Standard Sockets, 7/16, 1/2, 9/16, 5/8, 11/16, 3/4, 13/16, 7/8, 15/16, 1, 1-1/16, 1-1/8 (inches)
11	1/2" drive Deep Sockets, 1/2, 9/16, 5/8, 11/16, 3/4, 13/16, 7/8, 15/16, 1, 1-1/16, 1-1/8 (inches)
1	Tire pressure gauge 5# to 40# in 1# increments
1	10’ Steel Measuring Tape, retractable
1	Battery Terminal Post Cleaner
5 pc	Screw Extractor Set
1	12” adjustable wrench, Crescent
1	10” adjustable wrench, Crescent
1	8” adjustable wrench, Crescent

1 pr	Vice Grip Pliers
1 pr	Channel Lock Pliers
1 pr	Slip joint or common gas pliers
1 pr	Heavy duty Cutters, TL Pliers
16 pc	Drill Set – Carbon steel 1/16” to 9/16” with 3/8” shanks on larger drills.
1	3/8” chuck reversible and/or variable speed drill motor, 12 VDC operation if available
1	Come Along, large, Rigid model 584
25 ft	Chain with hooks each end
3	30’ Nylon snatch-em tow straps 30,000# rating
1	Hydraulic jack, low profile, 5 ton
1	Hi-lift jack
1	Lug wrench
1	Flashlight with alkaline batteries
1	Complete set of fan belts
1	Set of radiator hoses, complete
8 ft	Heater hose, 5/8”
1	Large Crowbar
2	Shovels
1	Small tarp or sand mat (desert operations)
1	3# to 5# Sledge hammer
1	5# Fire extinguisher, mounted on bracket in truck
1	MSHA First aid kit
1	Sven folding saw (Eddie Bauer)
1	Grease gun and cartridge of grease in plastic bag
Asstd	Rags
1 roll	Toilet paper
1 roll	Paper towels
1	Container, hand cleaner
1 can	Heavy duty brake fluid
2 cans	Fix a flat
1 roll	16 Gauge wire
6	Assorted bungee cords with hooks at each end
1 pr	Battery Jumper cables
1	Tire pump (electrical or spark plug)

1 set	Engine mounts, front and rear
1	Distributor cap
1	Ignition coil
1	Pipe wrench, 14"
1 pr	Tin snips
1	Chain saw, self sharpening
1 gal	Chain saw oil
1	Spare chain for chain saw
2	Spare sharpening stones for chain saw
1	Gas can for chain saw, gas-oil mixture
4 cans	2-cycle oil for chain saw
1	1/4" x 8" chain saw file
1 can	Power steering fluid
2	Air filters, heavy duty
2	P.C.V. valves
1	Smog pump filter assy. (if required)
1	Crankcase inlet filter (if required)
1 can	WD-40
1 tube	Locktite

NOTE: ALL TRUCK SPARES SHOULD BE CHECKED TO INSURE THAT THEY ACTUALLY FIT THE VEHICLE IN WHICH THEY ARE CARRIED.

APPENDIX D

WALKING LINE RADIO PROCEDURE

Base man

1. Help set up base station.
2. Conduct a radio check before roving man departs.
3. Climb to high point overlooking proposed line.
4. Set up radio away from trees or other vegetation.
5. Listen for 1 km radio checks. Time interval between 1 km checks.
6. If a radio check is not heard within the normal time interval plus 10 minutes, walk down the line with the radio on to another vantage point (but not past the 2 km mark on the line). Wait at this point for next radio (or visual) contact.
7. When roving man indicates he is at end of line, return to base station, pick up base pot and cover, then reel up wire to next base station, re-occupying 1 km points flagged by roving man.
8. Begin next line.

Roving man

1. Help set up base station.
2. Conduct a radio check before departing.
3. Begin spooling out wire and taking stations.
4. At every 1 km. make a radio check. Do this even if last radio check was negative, as the base man may have occupied new vantage point. When doing radio check move away from any vegetation and out from under any trees as much as possible.
5. When last station on line is completed, set roving pot in ground and cover for use as new base. Call base man and have him begin reeling in wire.
6. If base man cannot be reached by radio, leave all equipment (except radio) at last station and walk back up line until contact is established with base man. Attempt radio contact from any clearings encountered if working in timber, and climb any small hills or other vantage points if you think they may enhance radio communication.
7. When communication is established with base man, and he understands you have finished the line, return to last station and await the arrival of the base man.
8. Begin next line.

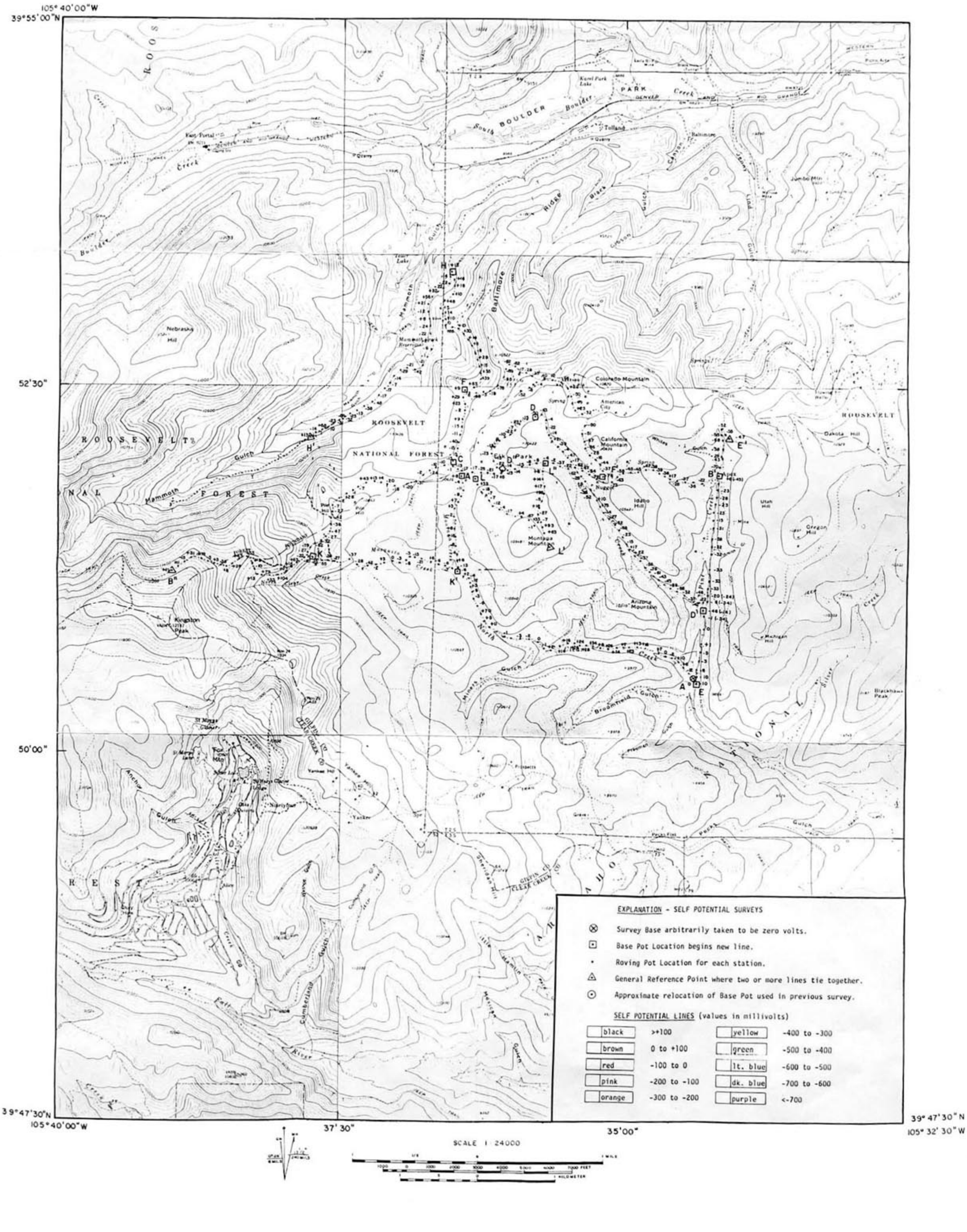
APPENDIX E

MAXIMUM TOLERANCES FOR SP SURVEYS

Difference between Normal and Reversed voltage of any station	≤ 5 mV
Repeat voltage at any station re-occupied while picking up the wire	≤ l0 mV
Pot drift – voltage between base and roving pots in bath:	
beginning of line	≤ 5 mV
end of line	≤ 10 mV
Ties around loops using different base stations:	
difference between voltages at the same point	≤ 50 mV
Long Period Tellurics (<5 second period):	
On 100m telluric monitor	< ± 2mV / 100m
During survey on DVM	< ± 25mV / km
Voltage drift at last station on line	
(where a new base will be) over two minute period	< ± 25mV
Horizontal voltage gradients at base stations	< 100mV / 100m

Station Spacing:

Reduce station spacing to 100 m when absolute voltage drops below -100 mV, otherwise use 200 m station spacing. For SP surveys other than the porphyry sulfides determine station spacing by dividing expected target width by 1/2, e.g., the station spacing for a target 100 m wide would be 50 m. It will also be necessary to re-mark wire when using other than standard station spacings. The time and cost of the survey are critically dependent on station spacing. The estimate of target width should therefore be liberal. Remember that small targets are seldom of economic size or grade, and that a 100 m station spacing will detect virtually every anomaly likely to be of economic importance.


105° 40'00"W
39°55'00"N
52'30"
50'00"
37'30"
35'00"
39°47'30"N
105°40'00"W
39°47'30"N
105° 32' 30"W
SCALE 1:24000
ROOSEVELT
NATIONAL FOREST
Nebraska Hill
Colorado Mountain
American City
California Mountain
Idaho Hill
Montana Mountain
Arizona Mountain
Utah Hill
Oregon Hill
Dakota Hill
Michigan Hill
Blackhawk Peak
Kingston Peak
Jumbo Mtn
Tolland
Baltimore
Mammoth Gulch
Baltimore Gulch
Gamble Gulch
North Clear Creek
Broomfield Gulch
Cumberland Gulch
South Boulder Creek
Fall River
Yankee Hill
St Marys Lake
EXPLANATION - SELF POTENTIAL SURVEYS
Survey Base arbitrarily taken to be zero volts.
Base Pot Location begins new line.
Roving Pot Location for each station.
General Reference Point where two or more lines tie together.
Approximate relocation of Base Pot used in previous survey.
SELF POTENTIAL LINES (values in millivolts)
black >+100
brown 0 to +100
red -100 to 0
pink -200 to -100
orange -300 to -200
yellow -400 to -300
green -500 to -400
lt. blue -600 to -500
dk. blue -700 to -600
purple <-700

SELF POTENTIAL-SURVEY

DATE: ____________________

AREA:

LINE: ____________________

PERSONNEL:

TELLURIC MONITOR:

Voltage scale: ________ mV full scale

Chart speed ________ cm / hour

TIME	Distance from Line Base (m)	Normal Voltage (mV)	Reversed Voltage (mV)	Resistance (Kilohms)	Base-Roving Pot Drift Voltage (mV)	Drift Corr.	Base Tie-in Correction	Absolute Voltage (mV)	Map Reference Point	Remarks