Instruction Manual

FLUXGATE GRADIOMETER

FM256

Instruction Manual Version 1.6

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Chapter 1

INTRODUCTION

About This Documentation

This Instruction Manual provides guidance on how to operate and survey with the FM256 Fluxgate Gradiometer System. The software used is Geoplot 3.0 for Windows, also produced by Geoscan Research. The manual includes assembly instructions, batteries and charging information, operating instructions, care and maintenance, field procedure for both single and dual gradiometers, data processing, presentation and interpretation, troubleshooting and a number of appendices. A full description and specification of the FM256 system are given in Appendix A. Geoplot 3.0 software is described in Appendix B.

FM18/36 users who have upgraded their instruments to FM256 specifications should follow instructions as for a new FM256 instrument. However, if the sensor housing has the old style soft outer coating, and not a solid tube, then differences in alignment technique will be highlighted in the text. Some very recent FM18/36 instruments may have been *partially* upgraded with some functionality limitations – see data sheet in Appendix A for details. For p*artially* upgraded instruments alternative instructions are given in the manual where necessary.

Brief Introduction to the FM256

The FM256 Fluxgate Gradiometer System is designed as a one man rapid location, mapping and identification system for a wide range of targets, which can be archaeological, environmental, utility services, geological or military in origin. Archaeological targets include fired structures such as kilns, furnaces, hearths and ovens, and structures with an enhanced magnetic susceptibility such as pits, ditches, enclosures, field systems, barrows etc. Other targets include environmental waste, oil drums, pipelines, cables, unexploded ordnance and geological formations.

The FM256 can be operated as a single stand alone gradiometer or in dual gradiometer mode. The dual mode uses two instruments carried together in a CF6 Carrying Frame to double the survey speed or, by using interleaving, to provide increased survey density (double or quad). Integration with Geoplot 3.0 software provides excellent data capture, processing, analysis, graphics, interpretation and presentation facilities, allowing you to realise the full potential of your gradiometer data.

Single FM256 Gradiometer

The FM256 instrument can be used in either scanning mode to search rapidly for disturbed areas, or in logging mode, to collect detailed data in parallel or zig-zag traverses. The data-logging facilities, with integral sample trigger, provide powerful functions for fast and efficient surveying, keeping track of survey position, and giving both audible and visual indication of current survey position. Data can be collected at up to 16 samples/m and stored in a 256000 reading memory.

Dual Gradiometer System

The dual gradiometer system uses two instruments carried together, 1m apart, either to double the speed at which a survey can be made or to increase the sampling density of a survey. Basing the system on two individual gradiometers gives optimum flexibility since they can also be used separately at different sites when required.

A three-sided CF6 Carrying Frame supports the two gradiometers. An FM256 acts as a master sample trigger that controls a second slave gradiometer - this can be either another FM256, an FM18/36 or a *partially* upgraded instrument. Note that a *partially* upgraded instrument cannot be used as a master sample trigger. Once data sets have been collected in the two gradiometers they are downloaded, and assembled into two individual composites (data sets) as normal. The two data sets are then easily merged together to form the final composite data set – Geoplot 3.0 provides for this in one operation.

The system can be used in either parallel or zig-zag survey mode. When used in zig-zag mode the operator, not the frame, turns around at the end of a traverse, thereby avoiding the introduction of direction dependent heading errors. Since there is no need for restrictive harnesses, turnaround is very rapid.

Supplied Accessories and Optional Accessories

The FM256 comes complete with robust padded carry case for transportation, instruction manual, data dump lead, universal charger and adapter pins sets, balance alignment tools, screwdriver and battery holder for alkaline batteries. The carrying case cut-out has compartments designed for the standard items provided and also compartments for other accessories.

An optional external hand-log key, with a 1.2m lead, is available for manual logging or for controlling the integral sample trigger if preferred. Spare rechargeable NiMH battery packs are also available.

Technical Support

Full technical support, via telephone, fax or email, is provided free of charge. If you have a query, then please consult this manual first. The main text of the manual has various hints and tips and the Trouble-Shooting chapter covers frequently asked questions. If you cannot find the answer to your query then please consult our website www.geoscan-research.co.uk for technical support or contact Geoscan Research or Geoscan Research USA (see below), whichever is most convenient.

When you call, fax or email please could you supply the following information:

- Your name, organisation, contact details and instrument serial number– please note it here:
- Details of the enquiry – please be as specific as possible.
- If it is a download / or software problem: (a) operating system in use, (b) operating system version number, (c) service packs applied, (d) the exact error number and location reported if one occurred.
- Your actions taken to resolve the query.

UK / Worldwide Technical Support

Geoscan Research is based in the UK and can be contacted by telephone on: +44 (0) 1274-880568 or fax on: +44 (0) 1274-818253. Our email address is: techsupport@geoscan-research.co.uk

USA & Canada Technical Support

In the USA & Canada technical support is available from Geoscan Research USA on Tel/Fax: 510-841-5141. The email address is : somers@frontier.net. You may fax, telephone or email with specific technical support requirements, assistance with data processing, interpretation and survey design issues.

How to Use the Documentation

FM256 documentation comprises seven main chapters and a number of appendices providing further background information and reference sections. The manual is organised as follows:

Chapter 1, Introduction

Introduces the FM256 system and this instruction manual. Typographic conventions used in the rest of this manual are described.

Chapter 2, Assembly Instructions

Provides a packing list of items supplied with the FM256, describes the physical layout of the FM256 and gives instructions for assembling a single or dual gradiometer system.

Chapter 3, Batteries and Charging

Describes the power system used (rechargeable and primary), memory backup battery, battery installation and replacement, fast charging of the rechargeable battery pack, battery voltage and low battery monitoring.

Chapter 4, Operating Instructions

This section introduces the user to the main display and operating modes. This is followed by a more detailed look at keyboard functions, logging and data download procedures, instructions on how to align the fluxgate sensors and how to take care of the gradiometer. Instructions and advice on how best to use the gradiometer in the field are given in Chapter 5. It is advisable to read Chapter 2, which describes the physical layout, before reading this section.

Chapter 5, Field Procedure

This chapter gives practical instructions on how to plan and perform efficient surveys in the field. The first section concerns scanning techniques whilst subsequent sections are devoted to detailed area surveys. ‘Planning a Detailed Area Survey’ at the start of the detailed area sections provides important background information about survey procedures and some of the terminology used in Chapter 4, – this will be of particular relevance to those new to geophysical survey techniques but it also provides essential advice to experienced practitioners. Subsequent sections give specific technical advice on survey techniques. To fully appreciate these later sections you should be already familiar with Chapter 4, ‘Operating Instructions’. The order in which the sections are described below is a good guide to the recommended sequence of field procedures that you should adopt.

Chapter 6, Data Handling

This chapter provides brief guidance on data output to a computer, describes merging of dual gradiometer data sets and provides guidelines on how to process gradiometer data. Detailed examples of processing single and dual gradiometer data sets are provided, along with an introduction to statistical analysis. This chapter is based on use of Geoplot 3 software but other software can be used.

Chapter 7, Trouble-Shooting

This chapter answers a number of frequently asked questions concerning the use of the FM256 and suggests suitable action to take should any difficulties arise.

Appendix A, FM256 Data Sheet

Appendix B, Geoplot 3.0 Data Sheet

Appendix C, Interface Connector

Appendix D, Interference

Document Conventions

Warnings

Warnings of potential problems are displayed in a grey box with a ‘Stop’ sign. Pay particular attention to the message to avoid problems occurring.

WARNING

Warnings of potential problems are represented in this way, in a grey box with outline.

Information Panels

Important information is displayed in information panels consisting of text within grey shadow boxes. These panels may summarise information discussed in the text or may introduce very important concepts which you should read and understand whilst following the main text.

Information

Important information is displayed in this format, in a grey shadow box.

Front Panel Keys

Whenever the text refers to one of the front panel keys, the name of the key is shown in a different font, for example reference to the Delete Line key. When the name is first introduced or discussed a heavier font is used, for example **Delete Line**.

ASSEMBLY INSTRUCTIONS

Unpacking

As you unpack the gradiometer, check that the parts shown in figure 2-1 are present, and that nothing has been damaged during transportation. The external hand-log key and spare NiMH battery pack shown are optional extra accessories that may have been ordered at the same time as the instrument. Note that replacement keys *cannot* be provided as they are individual to the carry cases.

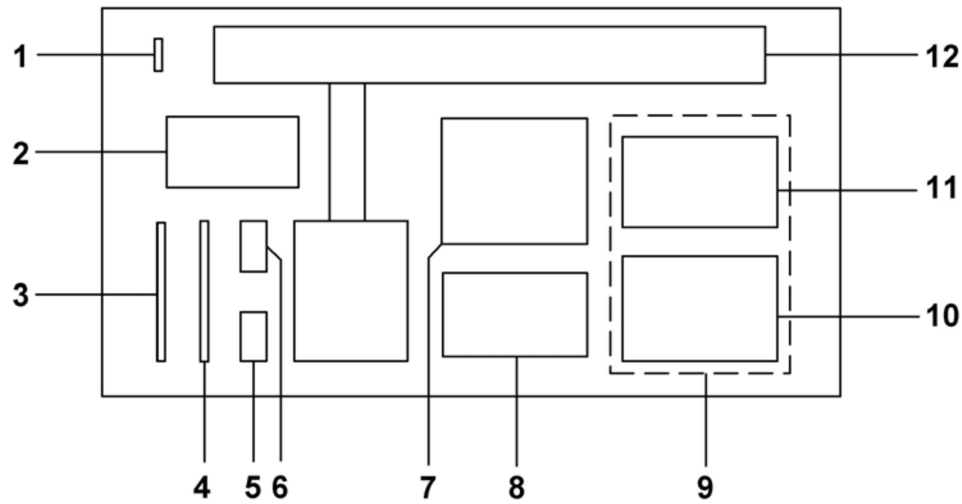


Figure 2-1. Carrying Case Contents

1	Carrying case keys	7	Data dump lead
2	International pin adapters for battery charger	8	Battery charger
3	Screwdriver	9	Instruction manual
4	Three balance alignment tools	10	External hand-log key (if ordered)
5	Battery holder for alkaline batteries	11	Spare compartment for accessories
6	Spare NiMH battery pack (if ordered)	12	FM256 Gradiometer

The gradiometers are supplied with NiMH rechargeable batteries already fitted. They will have been charged for testing prior to shipment but may have lost some of their charge in storage. If the FM256 is not powered up soon after delivery, it is advisable to fully charge the batteries, as described in Chapter 3, page 3-6, before switching on the gradiometer for the first time to avoid any damage.

FULLY CHARGE BATTERY BEFORE SWITCHING ON

To avoid damage to the FM256 fully charge the NiMH battery pack before switching on for the first time. See Chapter 3, page 3-6, for charging instructions.

Physical layout of the Gradiometer

The names of the parts of the gradiometer are shown in figure 2-2. A brief guide to their function follows below and more detail is given in subsequent sections of the Instruction Manual. Do not adjust any controls, or couple connectors until you have read the detailed sections thoroughly.

1 and 9 East/West and North/South sensor alignment controls

These two controls are used to accurately align the axes of two fluxgate sensors contained within the sensor housing tube 8. Accurate alignment of the fluxgate sensors is critical for good performance and correct adjustment of these controls will mean that, no matter which direction the gradiometer is facing with respect to the earth's magnetic field, the display will show a similar reading. Although these controls are designed to be adjustable do not attempt to do this until you have read Chapter 4 thoroughly. They have been adjusted before shipment to their correct setting and tampering with the controls at this stage will mean that subsequent alignment of the fluxgate sensors may take longer to achieve.

2 Charging LED

This dual colour LED or light emitting diode is used to indicate whether fast charging is in progress (orange colour) or whether fast charging has finished and trickle charging is now taking place (red colour). If you try to charge alkaline cells in the battery holder the LED will not be illuminated. (This LED is not present on a *partially* upgraded instrument)

3 Interface connector for charger input, serial data output, external triggering and expansion

This is a six-way connector that has four functions. Firstly it is used to output stored data to a computer using an RS232 interface. Secondly, the optional external hand-log key plugs into this connector. Thirdly it may be used for the synchronisation of two gradiometers when operated in dual gradiometer mode, acting as either trigger source or destination. Fourthly, the battery charger plugs into this connector. (Functionality is reduced on a *partially* upgraded instrument). See Appendix C for pin connections.

4 On/Off/Charge switch

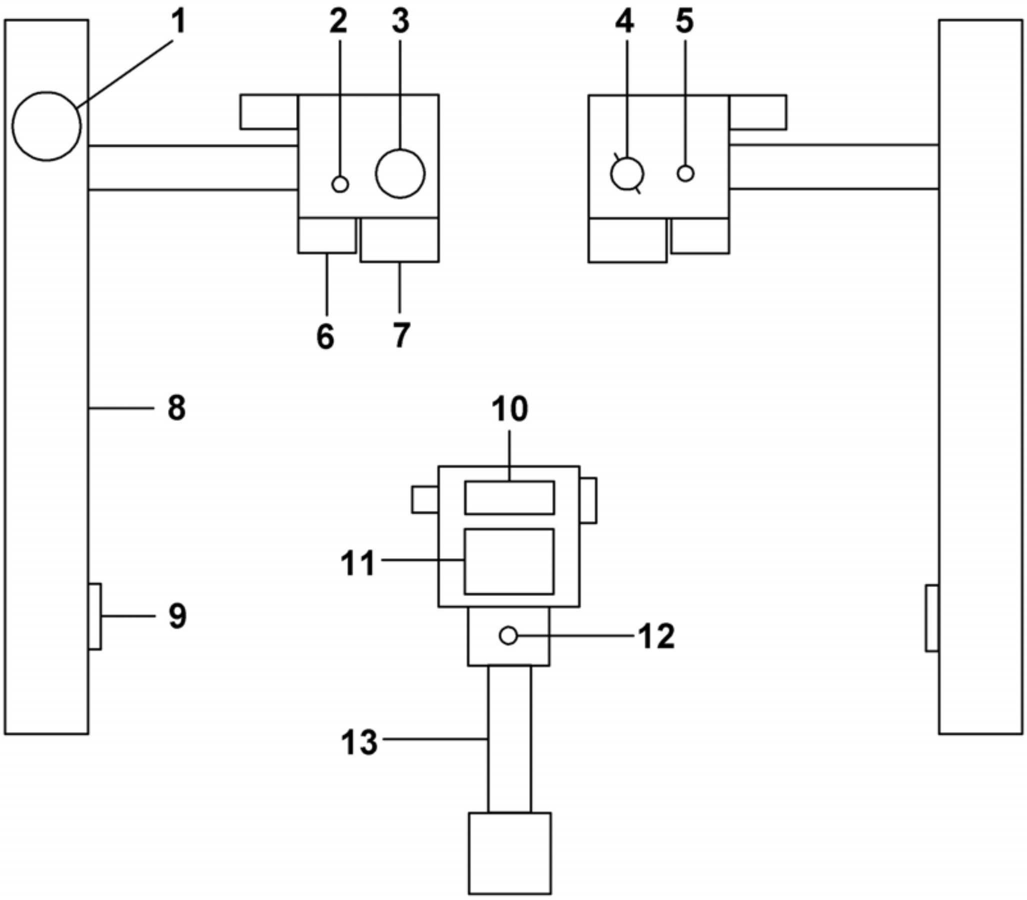
This switch is used to turn power on or off to the instrument. When in the Off position the battery pack is disconnected from the internal electronics but connected to connector 3 for recharging. If the battery holder with alkaline cells is installed instead of the NiMH battery pack, then there will be no connection to the charger to prevent accidental charging.

5 Balance control

The balance control is used to precisely match the sensitivities of the two fluxgate sensors. It is adjusted in conjunction with the fluxgate alignment controls 1 and 9. This control is necessary for the alignment to be correctly adjusted.

6 Memory backup battery compartment

This compartment contains the FM256 memory backup battery. The battery is a CR2450, DL2450, ECR2450 or equivalent 3V lithium cell. The FM256 checks this battery every time it is switched on and will indicate if the battery needs changing – it should last for up to 10 years at 25 degrees C. (This compartment is not present on a *partially* upgraded instrument)



1	East/West sensor alignment control	7	Main battery pack compartment
2	Charging LED	8	Sensor housing tube
3	Interface connector for charger, data o/p, ext. trigger	9	North/South alignment control
4	On/Off/Charge switch	10	LCD display
5	Sensor balance control	11	Membrane keyboard
6	Memory backup battery compartment	12	Start/Stop switch
		13	Carrying handle

Figure 2-2. Component parts of the FM256 Fluxgate Gradiometer.

7 Main battery pack compartment

This compartment contains the main power supply for the FM256. It is normally fitted with a special rechargeable 3500mAH 2.4V NiMH battery pack that contains a 10K thermistor temperature sensor. Alternatively a battery holder that takes two C size alkaline batteries can be fitted. There is a small vent to release any out-gassing should a problem arise during charging. (This compartment is not present on a *partially* upgraded instrument)

8 Sensor housing tube

The sensor housing tube provides protection for the sensors. With the alignment control sealing caps in place it provides a waterproof housing for two sensors that are positioned at the top and bottom of the tube.

10 LCD display

The liquid crystal display is used to indicate the instrument reading, status, logging position and menu options. A backlight can be turned on and viewing contrast adjusted via the setup menu. (A backlight is not present on a *partially* upgraded instrument)

11 Membrane keyboard

The waterproof membrane keyboard is used to control various instrument functions including mapping mode, range setting, instrument set-up and status, communications, zeroing, display mode and logging facilities.

12 Start/Stop key

The Start/Stop key is used to initiate or stop sample trigger logging. It can also be used for manual logging or for holding the readings during initial alignment.

13 Carrying handle

The carrying handle may be grasped in the hand or placed in the bracket of the dual gradiometer CF6 carrying frame.

Assembling the FM256 System for Field Use

Instructions on how to assemble and interconnect the FM256 for use in Single or Dual gradiometer mode are given below. Details of how to set up the systems are given in Chapter 4. Details of how to use the systems in the field are given in Chapter 5.

Bulgin Connectors

The FM256 system uses Bulgin connectors which are sealed to IP67 - these have waterproof sealing caps on both the instrument and cables. Instrument sealing caps may be undone by gripping the retaining strap with one hand while the ‘turret’ extension of the cap is turned with the other hand. Cable sealing caps may be undone by gripping the connector with one hand, gripping the ‘turret’ extension of the cap with the other hand and then turning the retaining collar with fingers of the first hand. Whe inserting connectors of a cable into the FM256 connector note that there is a small locating lug inside to ensure correct orientation and mating. Once inserted, screw the outer retaining collar into place.

Single FM256

Although in general there is no assembly required, if the external hand-log key is to be used, then its lead should be plugged into the connector labelled 3 in figure 2-2. It is often better to align the fluxgate sensors before attaching the hand-log key – see Chapter 4, ‘Fluxgate Sensor Alignment and Balancing’, page 4-15 for details.

Dual Gradiometer System

System assembly consists of the following stages: assemble the CF6 carrying frame, set the DIP switch on carrying frame, align the gradiometers and mount them on the carrying frame, and finally connect cables. These stages are described in turn.

CF6 Carrying Frame

Figure 2-3 shows a dual gradiometer CF6 carrying frame assembled, together with an FM256 and FM36 mounted in place. Assembly consists of attaching four legs in the mounting holes provided in the four corners of the frame. Ensure there is a nylon washer top and bottom of the frame and the nylon wing nut is securely tightened – see figure 2-4. Place the assembled frame on the ground.

DIP Switch Setting

There are two Start/Stop switches on the carrying frame. The central Start/Stop switch box has a small DIP switch inside – see figure 2-3 for its location. The DIP switch setting must be set according to the type of slave gradiometer. If it is necessary to alter the DIP switch then the Start/Stop switch box must first be opened by undoing the two screws. There are two settings marked on the pcb: FM256 Slave and FM18/36 Slave. The factory default setting is for using with an FM18/36 – use this setting also for a *partially* upgraded instrument. If a second full FM256 is used as a slave the DIP switch setting will need altering to FM256 slave.

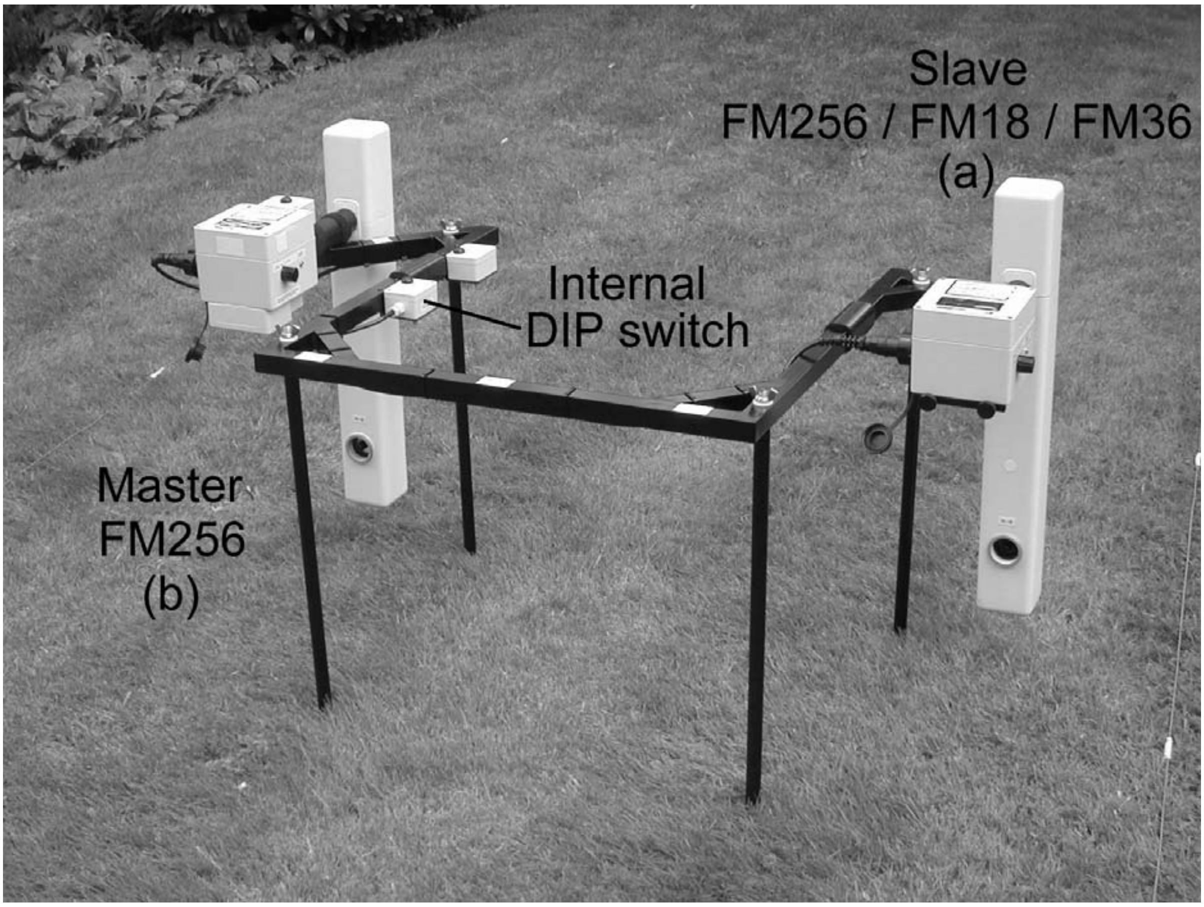


Figure 2-3. Dual gradiometer carrying frame, with gradiometers mounted. Note that the DIP switch (see text) is mounted in the central Start/Stop switch box.

Figure 2-4. Leg mounted on carrying frame.

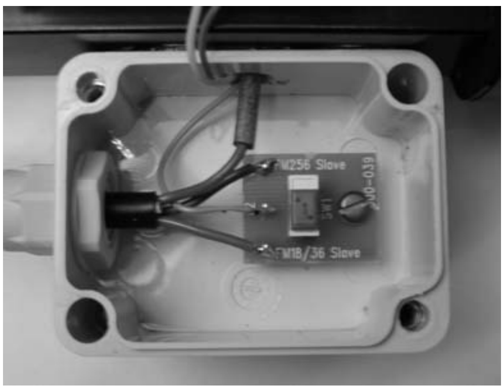


Figure 2-5. Dip switch located in the central Start/Stop switch box (set here to FM18/36).

Mounting the Gradiometers on the Frame

Before mounting the two gradiometers on the frame they should be individually aligned and zeroed – see Chapter 4, 'Fluxgate Sensor Alignment and Balancing', page 4-15 for details. The frame is designed to be stable even when supporting only one gradiometer at a time such as during alignment or assembly, but it is advisable to take care where ground is uneven. Mount the master FM256 on the side nearest the Start-Stop buttons and the slave gradiometer on the other side, see figure 2-3 – the slave can be an FM18, FM36, *partially* upgraded instrument or FM256. Labels on the frame, next to the mounting bracket, indicate the positions and function: on one side the label reads 'FM256 Master (b)' and on the other side the label reads 'FM18 / FM36 / FM256 Slave (a)'. The 'a' and 'b' are to remind you of the data file suffix that should be used when merging the two gradiometer data sets – see Chapters 4 and 6 for details.

The gradiometer handle should be centrally placed in the bracket and Velcro fastening used to fix the handles in position, figure 2-6. Start with the Velcro fastening on the inner edge of the bracket, at the end nearest the gradiometer front panel. Wrap around as shown in the photos of figure 2-6.

Figure 2-6. Gradiometer mounting bracket, handle position and Velcro fastening.

Cable Connections

After mounting the instruments in the carrying frame, the frame cables can be connected to the six pin connectors on each instrument: the position of the connector is identified as item 3 in figure 2-2. When you attach the cable to the slave gradiometer, feed the cable over the frame first before attaching – see figure 2-3.

The dual system is now assembled ready for use.

Chapter 3

BATTERIES AND CHARGING

Introduction

There are two battery types to consider in the FM256: the memory backup battery and the main power supply battery. These are housed under the instrument housing in two separate sealed compartments with external access, making battery changes simple. The external access preserves environmental seals and isolates any alkaline battery leakage. Figure 3-1 and figure 2-2 in the previous chapter show their locations.

If the instrument has been *partially* upgraded from an FM18/36 then the memory backup battery is located inside the electronics housing, on the microprocessor pcb, and is reached by removing the electronics housing lid.

The battery types are discussed in turn below, followed by charging instructions for the main battery pack.

Figure 3-1. Locations of the memory backup battery and the main battery pack.

Memory Backup Battery – FM256

The memory backup battery is situated in the smaller compartment under the instrument, figure 3-2. The battery is a CR2450, DL2450, ECR2450 or equivalent 3V Lithium cell that should retain data for up to 10 years at 25 ºC, less under elevated temperatures. Its function is to preserve data and instrument settings in memory when the main power is switched off. See Chapter 4, 'Switching On for the First Time', page 4-1, for details about when the battery needs changing. See Chapter 7, 'Troubleshooting' for emergency action if you cannot obtain the correct size battery.

> **BEFORE CHANGING THE MEMORY BACKUP BATTERY:**
>
> Download data prior to changing the backup battery to avoid possible data loss. Then switch off the gradiometer before changing the battery.

When you replace the battery, an internal capacitor will retain existing data and instrument settings for about 2 minutes. However, if you do not replace the battery within this period, when you next switch the instrument on a message will state that memory is corrupted and that defaults have been set. Any data and instrument settings previously made will have been lost. In this case go through the menu settings and ensure the instrument is set up according to your requirements.

To change the battery, first remove the outer lid by unscrewing the two retaining screws. Then, lift the retaining clip with your thumbnail, slide the screwdriver supplied with the FM256 underneath the battery and use the forefinger and screwdriver to grip and slide out the battery. To insert a new battery again lift the clip with your thumbnail and slide in the new battery with your other hand – the positive terminal should be uppermost and visible as in the photo. Try and avoid contact with the upper and lower surfaces of the battery to avoid contamination with grease from the fingers.

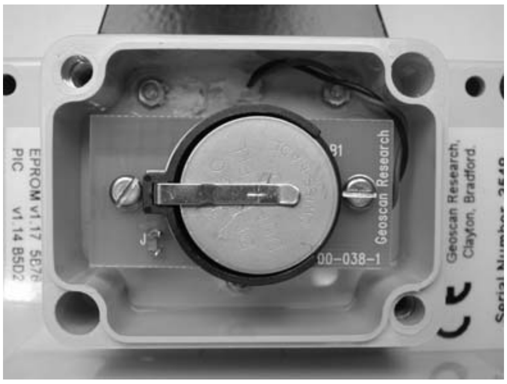


Figure 3-2. Full FM256 Memory backup battery

Memory Backup Battery – *Partially* Upgraded FM256

The memory backup battery for a *partially* upgraded FM256 is located inside the electronics housing, on the microprocessor pcb, and is reached by removing the electronics housing lid. The battery is a CR2025, DL2025, ECR2025 or equivalent 3V Lithium cell that should retain data for up to 2.5 years at 25 ºC, less under elevated temperatures. Its function is to preserve data and instrument settings in memory when the main power is switched off. See Chapter 4, 'Switching On for the First Time', page 4-1, for details about when batteries need changing.

> **BEFORE CHANGING THE MEMORY BACKUP BATTERY :**
>
> Download data prior to changing the backup battery to avoid possible data loss. Then switch off the gradiometer before changing the battery.

When you replace the battery, an internal capacitor will retain existing data and instrument settings for about 2 minutes. However, if you do not replace the battery within this period, when you next switch the instrument on a message will state that memory is corrupted and that defaults have been set. Any data and instrument settings previously made will have been lost. In this case go through the menu settings and ensure the instrument is set up according to your requirements.

Gaining access to and changing the memory backup battery is similar to the procedure used for gaining access to the main batteries in the original FM18/36, except that the exact battery location is different:

1 Switch the gradiometer off.

2 Undo the four screws on the instrument front panel - there is no need to remove these entirely.

3 Carefully lift the lid about two inches away from the main box and then very gently twist and flip the lid over towards the On/Off switch. Take great care not to strain the wire connections between the lid and main case - loosen the wires gently with your fingers if they become caught.

4 The memory backup battery is located on the microprocessor board. This is the pcb nearest the main battery pack. Looking at the front of the pcb, figure 3-3, the memory backup battery is located at the top, right hand side. Use a balance alignment tool to gently push the old battery out of the holder. Do *not* use a screwdriver since you may create a short between the positive and negative terminals with the result that you will definitely lose any data and settings. Slide a new battery back between the terminals – the positive terminal should be uppermost and visible as in the photo. Try and avoid contact with the upper and lower surfaces of the battery to avoid contamination with grease from the fingers.

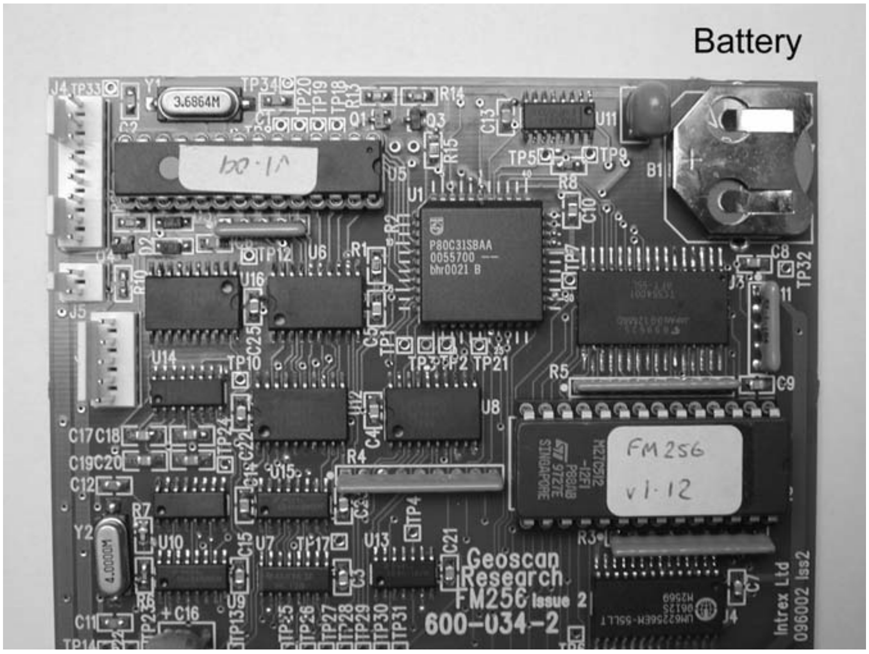


Figure 3-3. Memory backup battery is located at the top, right hand corner of the microprocessor pcb.

5 When replacing the lid great care must be taken to feed the connecting wires between the lid and main case back into their original positions. Although the wire harness is assembled such that the wire bundles have a natural position lying between the main battery compartment and adjacent printed circuit board, a little help is required to get them back into position. In particular note that the transparent connector strip from the lid that has seven silver strips embedded in it, should lie straight and vertical. It will need guiding into place otherwise it may be bent and trapped between the pcb nearest it and the lid.

6 Before tightening up the four screws on the instrument front panel, gently push the lid closed with your hand. This will enable you to verify that there are no wires trapped.

Main Power Supply Battery Types

Rechargeable NiMH Battery Pack

The FM256 is supplied fitted with a special 3500mAH 2.4V NiMH battery pack (which includes a 10K thermister temperature sensor) but can also be used with a pair of 1.5V alkaline batteries fitted in the holder provided (see next section). These instructions DO NOT apply to the *partially* upgraded instrument as the original battery pack of the FM18/36 will have been retained and should be charged in the original manner. The FM256 main battery pack is situated in the larger compartment underneath the instrument. The instrument operating period with a fully charged NiMH battery pack is 21 hours without LCD backlight, 15 hours with LCD backlight. The NiMH cells can be fast charged in 3-3½ hours from the universal voltage power supply which is supplied with worldwide pin adapters (the charging circuit prevents accidental charging of alkaline cells). Charging status (fast or trickle) is shown by a dual colour LED. *You should only use Geoscan Research battery packs which have been designed to match the fast charging system.*

Figure 3-3. Rechargeable NiMH battery pack.

To change the battery first remove the outer lid by unscrewing the four retaining screws.The battery pack is connected via an eight way gold Molex connector. It can be disconnected by first standing the battery pack on end to get access to the Molex connector. Next use your thumb nail to gently lever each of the pair of white tabs in turn away from the connector housing and use the forefinger nail to pull the connector out by engaging with the very small lugs at the side of the housing, figure 3-4. *Avoid pulling on the wires to avoid breakages.* Reconnecton is simply a matter of reinserting the connector housing into the pinned plug, observing correct orientation. Gently ease the wires into place before replacing the lid and ensure no wires are trapped when you replace the lid.

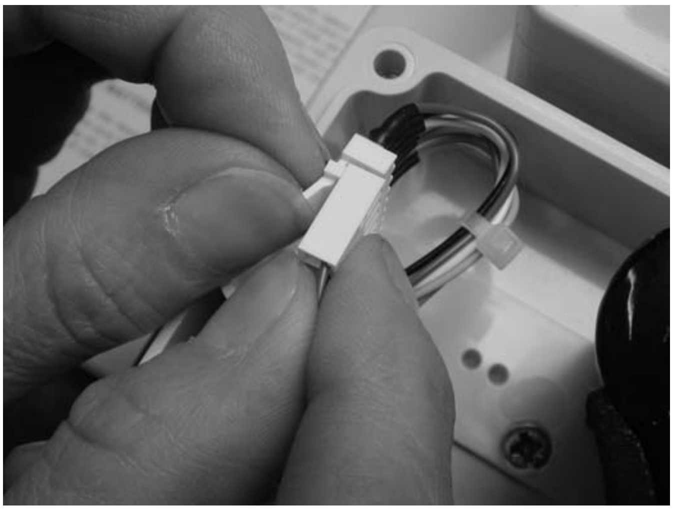


Figure 3-4. Disconnecting the battery pack.

AVOID SWITCHING ON WITH FLAT BATTERIES

Switching on the instrument with the battery voltage below the recommended minimum may cause damage to both instrument and batteries so make sure the batteries are given a full charge after long periods of non-use before switching on. Rechargeable batteries may be left in the instrument for long periods, in any state of charge, without permanent deterioration.

Primary Batteries and Pre-charged NiMH/NiCad Batteries

It is strongly recommended that the normal NiMH rechargeable battery pack is used at all times if possible. This is to avoid dirt and moisture getting into the battery compartment if frequently opened. However, if it becomes imperative to fit primary cells, because of low charge during a survey or because operation is in a remote location with no charging facilities, then you can use the battery holder provided to fit standard primary batteries or even pre-charged NiMH / NiCad batteries. *Note that the FM256 charging system will not recharge these cells – you must use an external charger for NiMH / NiCad batteries loaded in the battery holder.* Two standard alkaline ‘C’ cells, international designation LR14, such as Duracell MN1400, will power the instrument for 44 hours (31 hours with backlight). Standard rechargeable NiMH ‘C’ cells with a capacity of 2000mAh will power the instrument for 12 hours (8.5 hours with backlight).

Figure 3-5. Battery holder with alkaline cells.

To fit the battery holder first remove the outer lid by unscrewing the four retaining screws. The normal battery pack is connected via an eight way gold Molex connector. It can be disconnected by first standing the battery pack on end to get access to the Molex connector. Next use your thumb nail to gently lever each of the pair of white tabs in turn away from the connector housing and use the forefinger nail to pull the connector out by engaging with the very small lugs at the side of the housing, figure 3-4. *Avoid pulling on the wires to avoid breakages.* Insert the battery holder in the place of the normal battery pack and insert the connector housing into the pinned plug, observing correct orientation. Gently ease the wires into place before replacing the lid and ensure no wires are trapped when you replace the lid.

REGULAR USE OF ALKALINE BATTERIES

If you regularly use alkaline batteries avoid unplugging the 8 way Molex connector – instead unplug the PP3 connector to the holder or simply just replace the batteries without unplugging anything.

Charging the NiMH Battery Pack

Battery Low Warning

When the battery voltage drops below 2.3V, a flashing ‘B’ will appear in the top right hand corner of the LCD display. As soon as you see this you have only a short time before the voltage drops to a dangerous level. If you are using the NiMH battery pack there is probably between 1 and 2 hours of operating time left – if temperatures are low and the batteries were not fully charged before use then there may be much less than 1 hour of operating time left. If you are using primary cells there is probably about 4 hours operating time left. You are advised to stop surveying as soon as possible after this warning, since the battery voltage will drop rapidly after this point and it if it is allowed to drop below 2V the instrument and batteries may be damaged.

You can check the battery voltage by choosing ‘Battery Voltage’ in the Status menu option – see Chapter 4, ‘General Keys’, page 4-4, for further details (you cannot check the voltage in a *partially* upgraded instrument). Immediately after charging the battery, the voltage will read approximately 2.9V but will fall to about 2.6V after a short time, even with the instrument switched off. During normal operation the voltage will lie in a band between 2.6V and 2.4V. When the voltage falls below 2.4V the capacity of the battery is starting to become low.

LOW VOLTAGE WARNING AND DIM DISPLAY

If you continue to use the instrument after the low voltage warning and the display starts to go dim switch off immediately to avoid damage !

The FM256 Battery Charger

The battery charger is supplied with worldwide pin adapters (UK, Euro, USA, Japan, Australia) and will operate with an input of 100V-240V, 47-63Hz. It fast charges the battery in 3-3½ hours and supplies 7.5V at 700mA whilst fast charging, 7.5V at 100mA whilst trickle charging – *no other Geoscan Research charger can be used.* Unlike the FM256, the battery charger is not waterproof so must *no*t be exposed to wet or damp conditions such as those encountered in the field. The pin adapters on the charger may be changed by sliding off and replacing with another set – take care not to push on the pins otherwise these may be damaged.

USE THE CORRECT BATTERY CHARGER

You MUST use the FM256 battery charger to charge the FM256.

Partially upgraded instruments should be charged with the original FM18/36 charger.

Do not attempt to use an RM4, DL10, FM18/36 or RM15 charger with the FM256. If you attempt to do so you will damage the charger, battery and instrument.

Charging Instructions for FM256

Position the charger in a cool position if possible and plug into the mains supply – the temperature of the FM256 should ideally be in the range 10-45ºC for charging. To charge the NiMH battery pack, switch the ON/OFF/CHARGE switch of the FM256 to the OFF/CHARGE position, insert the six way flying socket of the battery charger into the six-way chassis plug of the FM256, labelled 3 in figure 2-2. Insert the charger into a mains socket and switch on power to the mains socket. *Only use the FM256 charger adapter that supplies 7.5V at 700mA*

– no other Geoscan Research charging adapter can be used. The charging LED marked 2 in figure 2-2 will glow orange during the charging period and turn red when the battery pack is fully charged – at this time it will swop from fast to trickle charge and can be left on overnight if required, but this is best avoided if at all possible to prolong the battery life. If you try to charge with the instrument switched on the LED will glow red and no charging will take place. If you try to charge alkaline batteries fitted in the holder supplied no charging will take place and the LED will not be illuminated. Time to fast charge a battery from its uncharged state will be approximately 3-3½ hours after which time the charger will revert to trickle charge. If the battery is partially charged then it is safe to add a top-up charge but the charge time will be reduced proportionately, down to a minimum of about 15 minutes.

The NiMH battery pack can be recharged up to approximately 600 times. After this number of recharges it will start to lose its ability to retain charge and will need replacing at this stage.

General Battery Safety Information

Nickel Metal Hydride cells are broadly similar to Nickel Cadmium cells in many ways but are less tolerant of abuse. Particular hazards are electrolyte leakage and gassing. The electrolyte used is potassium hydroxide. Under certain conditions NiMH cells may vent hydrogen. Remove electrolyte with water. If electrolyte comes into contact with skin or clothing, wash off with plenty of water. If a skin reaction occurs, contact a physician. If electrolyte enters the eye, flush immediately with copious amounts of water, holding the eyelids open and rolling the eye. Seek immediate medical help. Hydrogen gas may form an explosive mixture with air. If venting is suspected, ventilate immediately. Avoid sparks or naked flame.

Precautions

Do NOT short the battery pack terminals even when discharged.

Do NOT apply any mechanical shock or drop the battery pack.

Do NOT expose the battery pack to water or moisture.

Do NOT attempt to open the battery pack.

Do NOT incinerate when disposing of the battery pack.

Always store the battery pack in a cool dry place.

Keep the battery pack away from fire and extreme heat.

The battery pack has a limited service life. Replace when the operating time of a completely charged unit has become noticeably shortened.

Chapter 4

OPERATING INSTRUCTIONS

Introduction

This section introduces the user to the main display and operating modes. This is followed by a more detailed look at keyboard functions, logging and data download procedures, instructions on how to align the fluxgate sensors and how to take care of the gradiometer. Instructions and advice on how best to use the gradiometer in the field are given in Chapter 5. It is advisable to read Chapter 2, which describes the physical layout, before reading this section.

Switching on for the first time

Before switching on for the first time make sure the battery pack has been given a full charge - see Chapter 3, page 3-6 for charging instructions. To switch the gradiometer on, rotate the ON/OFF/CHARGE switch clockwise to the ON position. *If at any time you switch the gradiometer off then on again wait about 5s before switching on.* A double beep of about 0.5 second duration will be heard and, after a brief display of a row of blocks on the top line, the LCD will display the message ‘Geoscan Research’ on the top line with ‘FM256’ and a version number on the bottom line for about 1.5s. This is followed by a report of the Firmware version on the bottom line for about 1s. This will be replaced by a report of the memory backup voltage, with ‘Memory battery’ appearing on the top line and the voltage on the bottom line for about 1s.

The memory backup battery nominal voltage is 3.0V but you may see a voltage reported in the range 3.1V to 2.8V. Should the voltage fall below 2.5V then the message ‘Replace’ is flashed on the display and 4 beeps are heard. If the memory battery is low then the letter ‘M’ will also flash in the top right hand corner of the digital display mode (see below). You should replace the memory backup battery as soon as possible at this stage (see Chapter 3, page 3-2 for details) to avoid potential loss of any data or instrument settings. It is advisable to replace the memory backup battery before the ‘Replace’ message appears, when the voltage starts to drop below 2.8V.

After this intial reporting the LCD will then look something like the following (you may observe a +ve instead of a negative sign and a smaller, fluctuating reading, depending on how magnetic your environment is):

```
   -204.7   nT
             0.1  nT
```

This is known as the Digital Display mode and the gradiometer will always start up in this mode. There are three basic display modes: Digital, Analogue and Logging Display modes. These are introduced below, with more detail given in the following sections.

Digital Display Mode

Apart from displaying the gradiometer reading in digital form, this mode also indicates the current display resolution in the bottom right hand corner. The reading is displayed towards the left hand side of the top line and may be either positive or negative, with a maximum value of 204.7 nT, 2047 nT or 20470 nT depending on whether 0.1 nT, 1 nT, or 10 nT range resolution is selected in the Range menu. The current resolution is shown in the bottom right hand corner as 0.1 nT, 1 nT, or 10 nT.

The Digital Display also indicates the status of a number of instrument settings, battery levels and current instrument mode. All the possible status messages, in the form of capital letters, are shown below though it is very unlikely you will see them all at the same time:

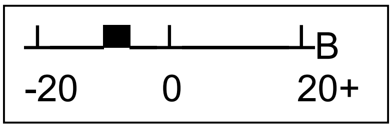
```
H  -204.7  nT   MB
DL  Held      0.1 nT
```

(Note that you may see a V in the H position, depending on instrument mode)

An 'H' will be displayed in the top left hand corner if the instrument is in Hold mode – this mode is designed to freeze the readings when the instrument is held inverted during alignment and the message 'Held' will also appear on the bottom line when the reading is frozen. If the memory backup battery is low a flashing 'M' will appear in the top right hand corner. A low main battery is indicated, as in all the display modes, by a flashing 'B' in the top right hand corner. If this is showing you should refer to Chapter 3, page 3-6, for charging instructions and advice on the operational time left. Log Zero Drift status is indicated in the bottom left hand corner - the presence of a 'D' indicates that it has been selected, an absence of character indicates it has not been selected. If the LCD backlight is turned on then an 'L' is displayed in the bottom left hand corner as a reminder that the main battery will have a shorter life in this mode.

Analogue Display Mode

Press the **Display Mode** key situated at the bottom left hand side of the keyboard once to show the Analogue Display Mode This mode uses a moving black bar to indicate the signal and magnitude of a reading, rather like the needle indicator of a conventional moving coil meter; the black bar can move over a total of 16 positions. The particular range selected is shown on the scale at the bottom of the display.



If the reading is too strong for the range selected the bar will be replaced by an arrow at the end of the scale, pointing either left or right, depending on whether the reading was positive or negative. The analogue mode is useful for preliminary scanning over an area to locate areas of interest before the logging mode is used for a more detailed survey. Press the **Display Mode** key again to return to the digital display

Logging Display Mode

Press the **Enable Log** key on the bottom right hand corner of the keyboard to bring up the Logging Display mode. (If you cannot show the Logging Display Mode make sure you have changed the previous Analogue Display mode back to the Digital Display mode first). In this mode the resolution and status information on the bottom line is replaced by a sequence of letters and numbers that are used to indicate the position reached on a survey. The letters G, L, and P and the numbers to the right of each letter indicate, respectively, the current grid, the current survey line in a grid, and the next reading position to be logged.

```
   -204.7  nT
G  1  L  1  P  1
```

As the readings are logged into memory P, L and G will increment to help you keep track of survey position. They will also change if some of the other logging function keys such as **Delete, Finish Line, Dummy Log** etc. are pressed. Readings can only be logged or data memory altered whilst the Logging Display mode is selected. Press the **Enable Log** key once again to return to the Digital Display mode.

The function and operation of these display modes and the remainder of the key positions are described in greater detail in the following sections, whilst advice on their use in the field is given in Chapter 5.

Keyboard Operation

The keyboard layout of the FM256 is shown in figure 4-1. A reasonable amount of pressure is required to activate a key. Press with the pad of your finger rather than the tip since this will give a larger pressure area and you are more likely to locate the centre of the key. Remember that logging functions will only operate when the Logging Display is selected, so there will be no response at other times.

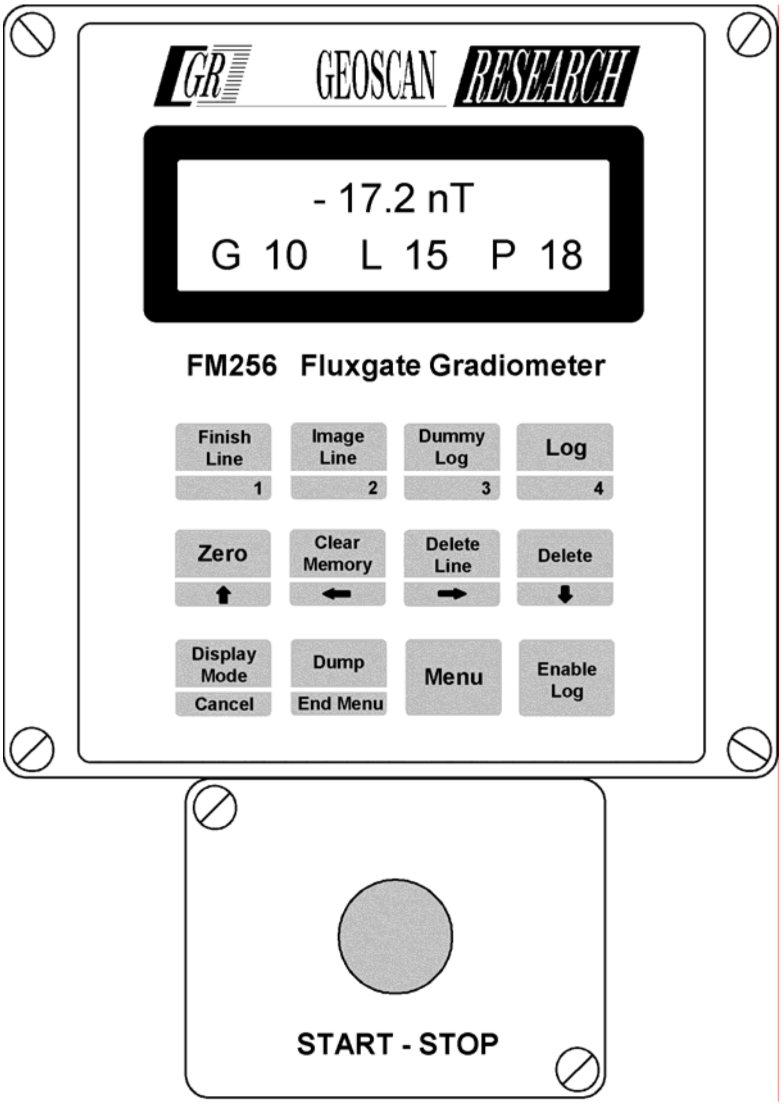


Figure 4-1. Keyboard layout.

Each key press is accompanied by a sound from the buzzer for feedback. A range of sounds are used, ranging from a simple 'beep' observed when the **Display Mode** key is pressed to a 'warble' sound which only occurs when the **Log, Dummy Log** or optional hand-log key is pressed. There are also other sequences of 'beeps' and 'clicks' used for various key functions and status indications. The type of sound associated with each key function is fully described at each appropriate point.

The key functions may be split into two groups: general keys and logging keys. There follows a detailed description of each of the keys, starting with the general keys, followed by the logging keys. You will observe from figure 4-1 that some keys have duplicate functions and these are described later.

General Keys

Menu and End Menu Keys

The **Menu** key, in association with **End Menu** and the arrow keys, is used to configure the gradiometer for field use and report on the status of the instrument. The menu sequence may be entered from any of the three display modes. Pressing the Menu key will display the main menu screen :

```
1 Map-m  2 Range
3 Setup  4 Status
```

You can press the End Menu key to return to the digital or analogue display mode, whichever was last used, or enter one of the numbers between 1 and 4 (on the top line of the keypad) to select one of the sub-menus. Once in a sub-menu the first parameter and its current value or status will be shown, as shown in Table 4-1.

Map-M

[Possible Warning Message]

Grid Length	10, <u>20</u>, 30, 40, 50, 100 m
Sample Interval	0.0625, 0.125, <u>0.25</u>, 0.5, 1 m
Grid Width	10, <u>20</u>, 30, 40, 50, 100 m
Traverse Interval	0.0625, 0.125, 0.25, 0.5, <u>1,</u> 2 m
Traverse Mode	<u>Zig-Zag</u>, Parallel
Adj. Trig. Rate	<u>Off</u>, On (then adjust between 0.40s – 3.00s, default value <u>1.00s</u>)

Range

[Digital Display]

Resolution	<u>0.1</u>, 1, 10 nT

[Analogue Display]

Range	5, <u>10</u>, 20, 40, 80, 160, 320, 640 nT

Setup

Hold Reading	<u>Off</u>, On
Remove Zeroing	<u>Off</u>, On
Averaging	<u>Off</u>, On
Average Cycles	2, <u>4</u>, 8, 16, 32
Backlight	<u>Off</u>, On
LCD Contrast	Low, <u>Medium</u>, High
Log Zero Drift	<u>Off</u>, On
Trigger Type	<u>Internal</u>, External, Hand-log
Baud Rate	600, 1200, 2400, 4800, 9600, 14400, <u>19200</u>
Data Format	ASC+SPCS, ASC, Fast ASC, <u>Hex D+R</u>, Hex D
Scan Sound	Off, <u>On</u>
Navigation	Off, <u>On</u>
Battery Status	<u>Measured</u>, Low Batt
Set Time/Date	<u>No</u>, Yes
Noise Test	<u>Off</u>, On
Reset FM256?	<u>N</u>, Y *[Dump Data First !]*

Status

Battery Voltage	Displays voltage eg 2.56 V
Time and Date	Displays time and date eg 11:35 05/10/02
Max. # Grids	Displays number of grids eg <u>163</u>
View Readings	<u>No</u>, Yes
Memory Size	256000 readings

Table 4-1. Sub-menu parameters and choices. Some sub-menus may start with a warning message if the memory is not empty. If the FM256 is reset, factory default values, shown underlined, will be set.

For example if you pressed the top left hand key, **1**, to select Map-M, then the first parameter displayed would be Grid Length and the current setting (10 m, 20m, 30 m, 40 m, 50 m, or 100 m) would be shown. Table 4-1 shows the factory default values (underlined) that are obtained when the FM256 is reset as described under Setup below.

The Up and Down arrow keys are used to step through the list of parameters. The setting of each parameter may be changed by using either the left arrow or right arrow key to decrease or increase respectively the current value or toggle between Off and On. Navigation symbols in the form of up, down, left right arrows are displayed at the four corners of the LCD to indicate possible directional choices – if you prefer not to display these symbols you can turn them off by setting Navigation in the Setup menu to ‘Off’.

Once you have inspected or changed the parameters press End Menu to return to the main menu screen – the new parameter settings are then implemented. You can then choose another sub-menu, by entering the appropriate number, or you can press End Menu once again to return to the digital or analogue display mode, whichever was last used.

Note that some parameters associated with logging may give a double beep and display a warning message when you try to change the parameter: ‘Dump and clear mem before changing!’. This is to remind the user that correct operation of the FM256, especially data storage and data dumping will depend on these parameters not being changed during a logging session. These messages will not appear if you have cleared the memory so if you wish to change such a parameter, press End Menu twice, dump the data (see later for details), press Enable Log and clear the memory (see ‘Clear Memory Key’, 4-9, for details) before returning to change the parameter.

Each sub-menu is now discussed in turn with reference to where more details may be found.

1 Map-M

Map-M is short for mapping menu and is used to set the surveying details. See Chapter 4, ‘Dual Gradiometer System’, page 4-23 and Chapter 5, ‘Planning a Detailed survey’, page 5-2, for selection advice and terminology. Typically Grid Length = Grid Width = 20m, Sample Interval = 0.25m and Traverse Interval = 1m. You cannot change the mapping parameters mid-way through logging readings, with the exception of ‘Traverse Mode’ and ‘Adj. Trig. Rate’, since this would confuse the survey tracking. If you try to change any of the first four parameters you will see the warning message : *‘Dump and clear mem before changing!’*. To adjust any of these four parameters you must first dump existing data and then clear the memory.

Traverse Mode can be set to either Zig-Zag or Parallel but is reserved for future use and is non-operational at present.

Adj. Trig. Rate (Adjust Trigger Rate) is used to set the rate of the 1m marker ‘beeps’ which are sounded when the FM256 is used with the integral sample trigger. Set the parameter to ‘On’ and then press End Menu twice as though you were going to return to the normal display. However, the display will now show the current marker time on the top line, together with left and right arrows on the bottom line. ‘Beeps’ will be sounded at the current rate too.

```
1m  Marker   1.00s
         ←  →
```

Use the left or right arrow keys to move the time down or up in 0.02s increments over the range 0.40s to 3.00s. If you keep either the left or right arrow keys depressed for more than 5 changes then the rate of adjustment becomes much faster, enabling you to move from one extreme of the range to the other more rapidly. Once you are satisfied with the rate press the Cancel key to escape to the normal digital display.

2 Range

The Range menu is used to set either (a) the instrument resolution, if in digital display mode, or (b) the instrument range, if in analogue display mode. See Chapter 5, ‘Scanning’, page 5-1 and ‘Display resolution’ page 5-7, for selection advice.

3 Setup

The Setup menu is used to define various instrument parameters. Table 4-2 over the page shows the chapters and sections where guidance on some of these parameters may be found. The remainder are discussed below.

If light conditions are poor, the LCD backlight may be turned on, by setting Backlight to ‘On’. Bear in mind that instrument operating time will decrease (for NiMH battery pack) from 21 hours down to 15 hours or decrease (for alkaline cells) from 44 hours down to 31 hours.

LCD contrast can be set to Low, Medium or High and is used to optimise the visibility and response time of the LCD display as it changes over temperature extremes.

Setup Parameter	Chapter	Section
Hold Reading, Remove Zeroing	Chapter 4	Fluxgate Sensor Alignment and Balancing, page 4-15.
Baud Rate, Data Format	Chapter 4	Data Output to a Computer, page 4-26.
Trigger Type	Chapter 4	Logging Keys: Log Key; Data Logging, page 4-19.
Averaging, Average Cycles	Chapter 4	Digital Averaging, page 4-13.
	Chapter 5	Planning a Detailed Survey: Samp./Trav. Intv., page 5-4.
Log Zero Drift	Chapter 4	Logging Keys: Log Key; Data Logging, page 4-21.
	Chapter 5	Planning a Detailed Survey: Log Zero Drift, page 5-13.
Scan Sound	Chapter 5	Scanning, page 5-1.

Table 4-2. Location of further guidance on some Setup sub-menu parameters.

Use Navigation to turn 'On' and 'Off' the navigation arrows that appear in the four corners of the LCD display as you step through the menu structure.

Battery Status will be set to 'Measured' for an FM256, but if you have a *partially* upgraded instrument then this will be set to 'Low Batt' as the instrument is not able to measure the main battery voltage. Instead, a *partially* upgraded instrument will only be able to indicate a low battery by a flashing 'B' in the top right hand corner. The default 'reset' setting, however, will be 'Measured'. Therefore, although all *partially* upgraded instruments will be supplied with the correct setting at the time of shipment, if the instrument is 'reset' for any reason then you will need to change Battery Status from the default setting of 'Measured' to 'Low Batt' to ensure correct operation.

Time and Date can be adjusted by changing the setting from 'Off' to 'On' and then pressing End Menu twice as though you were going to return to the normal display. The display will now show 'Hours' on the top line and the current setting of Time and Date on the bottom line:

```
    Hours
10:05   13/05/02
```

'Hours' indicates that this is the first item to be changed. Use the left or right arrow keys to change the hour down or up respectively. To move to the 'Minutes' setting, press the down key – the top line will now show 'Minutes' and you can use the left or right arrow keys to change the number of minutes. Use the down key to move to the other settings: 'Date', 'Month' and 'Year' and set these in turn – you can use the 'up' key to move back a setting. When the correct time and date settings are made you can escape from this mode by pressing the Cancel key and return to the normal display.

Noise Test should be left set at 'Off' – it is for factory use only.

The Reset FM256 option allows you to apply the factory default menu parameter settings, as indicated in Table 4-1, should the instrument unexpectedly lose its parameter settings or, if you are new to the instrument and you are unsure of a good starting point. Normally the top line displays: 'Reset FM256? N' and the bottom line is blank. Should there be data in memory the bottom line will display: 'Dump Data First!'. Normally the parameter should be left at 'N' for 'No' but, if you do want to reset the FM256, then change the 'N' to 'Y' for 'Yes' using the right arrow key, and the bottom line will then display the message: 'Reset in 10 secs'. The number will count down 1s at a time until 0s is reached at which point the FM256 will reset. If you decide you do not want to reset the FM256 after all, then press the left arrow key to show 'N' on the top line again before the 10s count has elapsed. Once a reset has been performed the bottom line displays the message: 'Defaults Set'.

4 Status

The Status menu is only used to examine settings and data within the FM256 – you cannot make any parameter changes in this menu. The first parameter to be reported is Battery Voltage – see Chapter 3, 'Charging the NiMH Battery Pack', page 3-6, for details regarding the voltage displayed. The second parameter is Time and Date, discussed above. The third parameter is the maximum number of grids that can be surveyed using the current mapping parameters: grid length, grid width, sample interval and traverse interval. The value reported in 'Max. # Grids' will change if any of the mapping parameters are changed.

The fourth parameter, View Readings, allows you to view the readings currently stored in memory. To view, change 'No' to 'Yes' using the right arrow key and then press End Menu twice as though you were going to return to the normal display. However, the display will now show a display very similar to the logging display except that the letter 'V' is shown in the top left hand corner:

```
V      7  nT
G  1  L  1  P  1
```

You can step through the readings one at a time using the right key and as you do so the tracking parameters will change accordingly. Press the left arrow key to move back one reading at a time. Use the down arrow key to step forwards through the data one line at a time and the up arrow key to move backwards through the data one line at a time. Use the Log key to step forwards through the data one grid at a time and the Finish Line key to move backwards through the data one grid at a time – there may be a short time delay before the new grid is shown. When you get to the end of the current data the FM256 will 'beep' and show the message 'END OF DATA !!!' briefly. You can continue to move through the memory beyond this point if you wish, though the data you are looking at will be previously 'cleared' data - in fact Clear Memory does not erase the memory but simply resets the survey tracking pointers – see Logging Keys for more details. When you have finished looking through the data you can escape from the view data mode by pressing the Cancel key and return to the normal display.

The fifth report is the size of the FM256 memory in terms of number of readings that can be stored.

Dump Key

The **Dump** key is used to start the transfer of the memory contents to another device such as a portable computer, via the RS232 link. See section 'Data output to a Computer' later in this chapter for more complete instructions and advice on data format, baud rate settings, setting up receiving software etc. The Dump key may be used in any display mode. When Dump is pressed the buzzer sounds a single 'beep', the LCD display is cleared and the message 'Dumping Data' is displayed on the top line. Once the FM256 has dumped all the logged survey data transmission will stop and a single 'beep' will be sounded. The display will then return to the normal digital display mode. If you wish to terminate the data transfer at any time press the Cancel key. Before dumping data ensure you are not in an electrically noisy environment to avoid data corruption during transmission – see Appendix G for further details.

Note that the FM256 will normally only dump memory contents that contain recently logged data and then stop transmission – it will not attempt to dump the entire memory. However, if the survey tracking position has been reset using Clear Memory, pressing Dump will then cause the entire memory contents to be output. This can be useful in retrieving data should the Clear Memory key be accidentally used.

If the last grid is only partly surveyed and the rest of the grid is not completely filled up with dummy readings using Finish Line then when you press Dump you will see the message 'Preparing Data'. There will then be a pause whilst the FM256 completes the last grid with dummy readings – this may take some time if sample interval is very small. You may prefer to fill in the remainder of a grid using Finish Line yourself. It is good practice to fill partly surveyed grids with dummy readings so that processing software knows which are dummy readings and ignores these when calculating grid statistics.

If handshaking lines CTS and RTS are not set up correctly, e.g. the data transfer cable is not plugged in, or a user-made data dump cable is incorrectly wired up (see Appendix C for further details) then transmission will almost immediately stop and the LCD display will show the message: 'CTS Low'. This message may also appear momentarily when CTS is toggled by the PC.

Cancel Key

The **Cancel** key acts as an escape key to four modes of operation, returning the FM256 to the normal digital display:

- Terminates data dumping via the RS232 interface – see Dump Key, page 4-7, for details.
- Escapes from setting 'Trigger Rate' in the Map-M – see Menu and End Keys, 1 Map-M, page 4-4.
- Sets 'Hold Reading' to 'Off' - see Fluxgate Sensor Alignment in this chapter, page 4-15.
- Sets 'Remove Zeroing' to 'Off' – see Fluxgate Sensor Alignment, page 44-15, and Zero Key over page.

Zero Key

The **Zero** key is used to set the reading to zero when the gradiometer is held over a survey Zero Reference station and is pointing in the traverse direction. Zero is typically used just before starting to survey each grid so that all grids in a survey have matching background levels. The key must be kept depressed for four 'beeps' during which time the LCD will display a status message:

7 nT
Setting Zero

After the four 'beeps' there will be a pause of 12 seconds during which time the gradiometer nulls the reading. It does this by calculating the internal offset and applying a correction of opposite polarity. This calculation automatically uses averaging for greatest accuracy – there is no need to turn averaging on in the Status menu for this to be used. The offset correction is stored in the non-volatile memory for recall at power-up. The Zero key will operate in all the display modes but note that the value of the internal offset changes when the *resolution* of the digital display is changed, whereas the internal offset associated with the analogue display remains the same, no matter which *range* is selected. Furthermore, the internal gain of the analogue display is the same as that used for 1 nT resolution on the digital display. Therefore, when swapping between the two modes, there will be a discrepancy in the zeroed readings displayed if any resolution other than 1 nT is used. You will need to press Zero again, if you swap between modes or change resolution in the digital mode.

If the Zero key is not kept depressed continually for four 'beeps' the zeroing operation will be aborted and the display and internal offset will revert to its former value, thereby preventing any accidental shift of the zero. The gradiometer Zero key can provide null adjustment of up to +/-90 nT with 0.1 nT resolution, +/-900 nT with 1 nT resolution and +/-9000 with 10 nT resolution on the digital display, and +/-900 nT for the analogue display, regardless of the range selected. If the reading is outside these limits then the gradiometer will try its best to zero the display but quickly gives the warning:

7 nT
Balance

This situation will only occur if, either the balance control has been set well off its correct position, or very magnetic alkaline batteries have been installed. The latter is very rare in practice but can be remedied by changing the batteries.

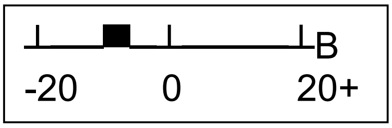
The effect of the Zero key can be removed or temporarily deactivated by setting 'Remove Zeroing' to 'On' in the Setup menu. This can assist when aligning and balancing the sensors – see 'Fluxgate Sensor Alignment and Balancing' page 4-15 for details. To reactivate it set 'Remove Zeroing' back to 'Off'. Whenever you press the Zero key this automatically sets 'Remove Zeroing' to 'Off'.

Display Mode Key

The **Display Mode** key is used to switch between the digital and analogue display modes. Each press of the key switches the gradiometer into the other display mode and is accompanied by a single 'beep'. These modes have already been introduced but are shown again below, digital display on the left, analogue display on the right.

-8 nT
1 nT

↔



The reading will be updated three times a second for the digital display mode, and nine times a second for the analogue display mode, providing 'Averaging' is not set to 'On'. If 'Averaging' is set to 'On' then the update rate, for both analogue and digital display, will depend on the number of average cycles - see 'Digital Averaging', page 4-13, later in this chapter for further details.

Note that the internal offset of the gradiometer is changed when the *resolution* of the digital display is changed, whereas the internal offset associated with the analogue display remains the same, no matter which *range* is selected - see the Menu key for details of changing resolution and range. The internal offset value of the analogue display is the same as that for 1 nT resolution on the digital display. Therefore when swapping between the two modes there will be a discrepancy in the readings displayed, if any resolution other than 1 nT is used – see Zero key for more details.

Logging Keys

Enable Log Key

The **Enable Log** key can only be used in the Digital Display Mode and is used to enter the Logging Display mode. This is the only display mode that allows readings to be logged or the data memory to be altered. The Enable Log key has no effect if the gradiometer is in the Analogue Display Mode. The display shows a sequence of letters and numbers that are used to indicate the position reached on a survey. The letters G, L and P and the numbers to the right of each letter indicate, respectively, the current grid, the current survey line in a grid, and the *next* reading position to be logged.

```
        7  nT
G  1  L  12  P 15
```

For example, the above survey tracking position indicates that the user is currently surveying grid 1, is on line 12, has logged the 14^{th} reading and is about to log reading 15. As the readings are logged into memory P, L and G will increment to enable you keep track of survey position. They will also change if the other logging function keys such as Delete, Finish Line, Dummy Log etc. are pressed. The Enable Log key itself does not log a reading but rather is a mode change key - pressing Enable Log whilst in the Logging Display Mode will cause the display to return back to the Digital Display Mode. A single 'beep' is sounded whenever this key is pressed.

Clear Memory Key

The **Clear Memory** key is used to initialise the survey tracking function when a new set of grids is to be started. The Clear Memory key only operates in the Logging Display Mode and must be kept depressed for four 'beeps' during which time the LCD will display the message: 'Clearing Memory' on the bottom line:

```
        7  nT
Clearing Memory
```

After the four 'beeps' there will be a short pause of four seconds during which time the survey position will be initialised. G, L and P will all be reset to 1:

```
       7  nT
G  1  L  1  P  1
```

If the key is not kept depressed continually for four "beeps" the erasing operation will be cancelled and the reading and survey position will revert to their former value, thereby preventing accidental loss of data or position.

Since survey tracking is reset, the user will no longer have direct access to old grids of data. Subsequent logging will overwrite old data at the same tracking position. However, the old data still exists in memory and can still be dumped via the RS232 interface – see Dump key, page 4-7, for details.

Log Key

The **Log** key is pressed to store the current display reading in the data memory. You must set Trigger Type in the Setup menu to ‘Hand-log’ to be able to log single readings in this way - if Trigger Type is not set to ‘Hand-log’ you will see the message ‘Trigger type is not hand-log’ when you press the key and you will not be able to log the reading. This mode of operation is known as manual logging – see ‘Data Logging’, page 4-19, later in this chapter for details of other logging modes.

The following discussion principally revolves around manual logging but, since much of the detail applies to other logging modes, users should read the following text even if they plan to use sample trigger logging.

The optional external hand-log key and Start/Stop switch (item 12 in figure 2-2) have the same function as the Log key when logging manually but may be more convenient to use. Details on how to physically connect the external hand-log key are given in Chapter 2, ‘Assembling the FM256 System for Field Use’, page 2-4.

Survey Tracking

Readings may be logged only in the Logging Display Mode. As well as the reading, this display shows a sequence of letters and numbers indicating the position reached on a survey. The letters G, L and P and the numbers to the right of each letter indicate, respectively, the *current* grid, the *current* survey line in a grid, and the *next* reading position to be logged. With the memory cleared G, L and P will all equal 1. Each time Log is pressed the buzzer will give a ‘warble’ sound to indicate that the reading has been stored and P will increment by one.

Note that P indicates where the *next* reading is to be logged and not the current position**.** Thus on a 20m grid, with sample interval of 1m, P=20 when there is only one more reading to go before the end of the line. The equivalent display for other logging intervals is P=40 for a 0.5m sample interval, and P=80 for a 0.25m sample interval.

When the last reading of a line is logged the buzzer will sound a single ‘beep’ instead of a ‘warble’ and L will increment by one whilst P will be reset to one. When the last reading of a grid is logged the buzzer will sound two ‘beeps’ instead of a ‘warble’ and G will increment by one whilst L and P will both be reset to one. Once the memory is full with complete grids, the usual two ‘beeps’ will be replaced by three ‘beeps’ after the last reading to signify a full memory. Attempts to log any more readings will result in the three ‘beeps’ being repeated. You will however be prompted to log the zero drift at the end of that grid if that mode is enabled – see next. The current survey position and data will be remembered by the gradiometer even if it is switched off. Therefore incomplete grids can be resumed after a break.

Operation if Log Zero Drift is On

The sequence at the end of a grid is slightly different if Log Zero Drift is set to ‘On’ in the Setup menu (indicated by the letter ‘D’ in the bottom left hand corner of the Digital Display:

```
        7  nT
D            0.1  nT
```

Zeroing is typically used just before starting to survey each grid so that all grids in a survey have matching background levels. Using Log Zero Drift just at the end of each grid survey allows you to record any change in the background level that has occured. This value is downloaded with the data and used to make an automatic correction for the drift. If Log Zero Drift is enabled, two ‘beeps’ will be given at the end of the grid as before but, before the display shows the position ready for the next grid i.e. G incremented by one and L and P reset to 1, the display will show :

```
        7  nT
  Log  Zero  Drift
```

This is a prompt to take the gradiometer over to the survey Zero Reference station and to take a reading at that point with the Log key, or the external hand-log key if being used. A ‘warble’ will be sounded when this reading is logged – the full procedure is described in Chapter 5, page 5-13. The display will then show the position ready for surveying the next grid, with L and P reset to 1. While at the Zero Reference station, the Zero Key should be used to reset the instrument reading to zero before resuming the survey.

Using Dummy Log, Finish Line, Image Line, Delete, Delete Line, Clear Memory

You can perform any of the other logging functions listed above at any time whilst in the Logging Display and using manual logging.

Over-range, Dummy Readings and Storage Resolution

If the display goes over-range it shows the maximum possible reading at the chosen resolution i.e.: +/-204.7, +/-2047, or +/-20470. Pressing Log will cause a reading to be stored equivalent to one unit *less* than the maximum possible reading but with the correct +/- sign. In contrast, pressing Dummy Log (see next page) in these same circumstances will always cause a positive reading to be stored equivalent to the maximum possible reading. The result is that you will be able to differentiate between (a) regions containing obstacles that were not surveyed, which will show as a special dummy reading in a Geoplot 3.0 graphics plot, and (b), regions with over-range signals, which will show as the maximum possible positive or negative reading possible, not as a dummy symbol.

Although the readings are only displayed with a resolution of 0.1 nT, 1nT and 10 nT to avoid flickering on the display, they are in fact stored with a resolution of 0.05 nT, 0.5 nT and 5 nT .

Data Capture Rates

When in the hand-log mode, readings can be stored at a maximum rate of one every 0.5s (much faster rates are achieved when using the internal sample trigger) although, in practice, storage rate is not as fast as that since time must also be added for movement between reading positions.

Digital Averaging

If the gradiometer is in the Digital Averaging mode the Log key and the survey position tracking operates in exactly the same way but the sequence of sounds differs – see 'Digital Averaging', 4-13, later in this chapter.

Delete Key

The **Delete** key is used to delete the last reading logged. When the key is pressed the buzzer will sound a single 'beep' and P will be decremented by 1. If the survey position is at the beginning of a new line or grid, then Delete will delete the last reading of the previous line or grid (or delete the Log Zero Drift reading if enabled). The key may be pressed as many times as required.

Delete Line Key

The **Delete Line** key is used to delete the current line of readings. The key must be kept depressed for four 'beeps' during which time the LCD will display a warning message:

```
    7   nT
Deleting Line
```

After the four "beeps" there will be a pause of about one second (longer if sample interval is very small) during which time the current line of data will be erased, the survey line position L will decrement by 1 and P will be reset to one. If the key is not kept depressed continually for four 'beeps' the deleting operation will not be started and the reading and survey position will revert to their former value, thereby preventing accidental loss of data or position.

If a line of readings has just been completed, but the first reading of the next line has not been logged then Delete Line will delete the *previous* line of readings. In this case L will be decremented by one and, as before, P reset to one.

If a line of readings has already been started then only those readings will be deleted. If the survey is at the start of a grid Delete Line will have no effect. In order to delete the previous line Delete must first be pressed to delete the last reading of the previous grid (and an extra press of Delete to delete the Log Zero Drift reading if enabled) and then press Delete Line.

Dummy Log Key

The **Dummy Log** key is used to enter a dummy reading in situations where a reading cannot be taken. For example there may be a physical obstruction in the way at the reading station. In this case a positive dummy reading equivalent to the maximum possible reading for the chosen resolution is displayed and stored as: +204.75 nT, +2047.5 nT or +20475 nT for resolutions of 0.1 nT, 1 nT or 10 nT respectively.

Each time Dummy Log is pressed the buzzer will give a 'warble' sound to indicate that the reading is being stored, the display will show the maximum positive reading momentarily on the top line, and P will increment by one, just as for the Log key.

Note that there is an important difference between the behaviour of Dummy Log and that of Log or the internal sample trigger operation if the display is over-range. In the latter case the display shows the maximum possible reading at the chosen resolution i.e. +/-204.7, +/-2047, or +/-20470. Pressing Log (see earlier) or using the internal sample trigger (see later) will cause a reading to be stored equivalent to one unit *less* than the maximum possible reading but with the correct +/- sign. In contrast, pressing Dummy Log in these same circumstances will always cause a positive reading to be stored equivalent to the maximum possible reading. The result is that you will be able to differentiate between (a) regions containing obstacles that were not surveyed, which will show as a special dummy reading in a Geoplot 3.0 graphics plot, and (b), regions with over-range signals, which will show as the maximum possible positive or negative reading possible, not as a dummy symbol.

Finish Line Key

The **Finish Line** key is used to complete the rest of a survey line with dummy readings, either for dealing with large obstacles or for completion of a grid with dummy readings. When Finish Line is pressed the display will show the dummy reading appropriate to the resolution - see Dummy Log above - and the buzzer will give a single 'beep'. L will be incremented by 1 and P reset to 1. The gradiometer will keep track of survey position in just the same way as for the Log key. For example if the last line of the grid is completed with Finish Line the buzzer will sound two 'beeps' and G will increment by one whilst L and P will both be reset to one. See Chapter 5 for further applications of the Finish Line key.

Image Line Key

The **Image Line** key may be used, after a Finish Line instruction, to create a mirror image of dummy readings at the start of the next survey line. The same number of dummy readings is inserted at the beginning of the next line as at the end of the previous Finish Line. It is *only* used for zig-zag surveying - see Chapter 5, page 5-14 - and should only be used after the previous line has been completed with a Finish Line instruction.

When Image Line is pressed the display will show the dummy reading appropriate to the resolution - see Dummy Log above - and the buzzer will give a 'warble' sound. L will be incremented by one and P set to the number of dummy readings inserted by Finish Line plus one. For example, on a 10m grid with logging at 1m sample and traverse intervals, if after the first three readings have been logged (P=4), Finish Line is pressed then L increments by one, P=1, and seven dummy readings will have been inserted. If Image Line is pressed then seven dummy readings will also be inserted and, since the gradiometer will be waiting for the eighth reading (P=8), there will be three more readings required to complete the survey line.

Digital Averaging

Introduction

The FM256 automatically integrates the readings at all times so as to minimise system noise. Digital averaging can be selected to improve further the signal to noise ratio. This is useful on sites where anomaly strength is comparable with system noise. A wide range of averaging cycles (2 to 32) allows the user to optimise the trade off between significant noise reduction and optimum speed. Digital averaging is automatically used when Zeroing and using Log Zero Drift for improved accuracy. Digital averaging may be used with the digital display mode only and with either manual or sample trigger logging.

To activate digital averaging set ‘Averaging’ in the Setup sub-menu to ‘On’. The degree of averaging is controlled by the setting for ‘Average Cycles’ in the Setup sub-menu. The number of cycles, shown on the bottom line of the display, may be set to 2, 4, 8, 16 or 32 cycles, with 2 cycles being the fastest averaging period and 32 cycles being the longest averaging period; the default number of cycles is 4.

Press End menu to return to the digital display mode. The readings displayed will be accompanied by a sequence of short ‘clicks’, with each click coinciding with the end of each averaging period – the clicking will pause should you enter the menu or dump data but will resume once you return to the digital display mode. Whilst the FM256 is calculating the average of each period, the reading displayed will not change until the end of the averaging period, at which point the reading will be updated.

The gradiometer will continue to cycle in this way until ‘Averaging’ is set to ‘Off’ in the Setup submenu - when you switch off the FM256 the status of ‘Averaging’ will be remembered for future use.

Digital averaging reduces system noise by approximately the square root of the number of cycles - see Table 4-3.

Average Cycles	Approximate Noise Reduction	Time for Average Period
2	x 1.4	0.1s – 0.2s
4	x 2	0.2s – 0.4s
8	x 2.8	0.4s – 0.8s
16	x 4	0.8s – 1.6s
32	x 5.7	1.6s – 3.2s

Table 4-3. Approximate noise reduction with digital averaging and corresponding average period. The default FM256 setting is 4 cycles.

Manual Logging

If ‘Averaging’ is selected when the gradiometer is in the Logging Display mode and manual logging is in operation i.e. Trigger Type = ‘Hand-log’ in the Setup submenu, then each press of the Log key will cause the buzzer to give a ‘beep’ instead of the usual ‘warble’ sound, and it will over-ride the current averaging period and start a new one. Only on completion of the averaging period will a ‘warble’ sound be made and the averaged reading will be stored. A new averaging period can then be started using the Log key or the gradiometer will continue to cycle through as before, sounding a ‘click’ at the end of each period.

If you are using manual logging then, providing you can accept longer surveying times, there is no restriction on the number of average cycles used with any chosen sample interval.

Sample Trigger Logging

If the gradiometer is in the Logging Display mode and sample trigger logging is in operation i.e. Trigger Type = ‘Internal’ or ‘External’ in the Setup submenu, then pushing the Start/Stop switch, or sending an external trigger pulse to the FM256 via connector 3 - see figure 2-2, will start the sample trigger logging sequence – see ‘Data Logging’, page 4-19, later in this chapter. The normal sequence of events for sample trigger logging will occur: a sequence of ‘beeps’ sounds every metre whilst internally the gradiometer logs readings at the set sample interval. However, with digital averaging selected, the logged readings will be averaged readings.

If you see an occasional negative full scale reading on the display, carry on as normal – the averaged reading will have been correctly logged, but this indicates that there is only just sufficient time to measure the average period between logging data. However, should there be insufficient time to measure the average period, and keep up with the speed of data logging at the chosen sample interval, the message ‘Reduce Rate’ will appear on the top line. If you see ‘Reduce Rate’ then you *must* stop and either reduce the number of average cycles, increase the sample interval or increase the 1m marker time with the trigger rate – any readings logged with the ‘Reduce Rate’ message displayed will have been recorded as a negative full scale readings.

It can be seen from Table 4-3 that there is a considerable difference in the time it takes for an averaged reading, depending on the number of average cycles. It ranges from typically 0.1s to 1.6s, although these times will increase or double if there is a strong anomaly present since the FM256 will take longer to convert the reading. The choice of number of cycles is determined by the trade off between desired noise reduction, survey time and sample interval and is discussed below.

Many users want to complete a survey as fast as possible and so use internal sample trigger logging and fast walking rates, typically between 0.6s and 1s per m. Additionally, sample intervals of at least 0.5m, and often 0.25m or 0.125m are used. Looking at Table 4-3, it is clearly not possible to walk at 1.0s/m, have a sample interval of 0.25m (i.e. 0.25s per reading) and have 8 average cycles, since there is not sufficient time to complete the averaging (0.4s x 4 = 1.6s). At this speed of walking and traverse interval it is just possible to use 4 average cycles (0.2s x 4 = 0.8s i.e. < 1s), providing there are not extensive strong anomalies which push the averaging period over 1s.

You can use the FM256 to guide you to a safe sample trigger rate as follows. Set up the desired number of average cycles and sample interval first and then select ‘Adj. Trig. Rate’ in the Map-M sub-menu. As you adjust the ‘1m Marker’ time, if you try to set a time that is too fast, the message ‘Unsafe Rate’ will appear briefly on the bottom line. If you see this message increase the ‘1m Marker’ time until you no longer see the message. If possible, increase the time even more to be sure of correct operation over extensive strong anomalies.

Fluxgate Sensor Alignment and Balancing

Introduction

Setting the gradiometer up for good sensor alignment and balancing is vital to getting the best possible results. When you tilt or twist a gradiometer a small change in reading will occur, introducing a small amount of 'noise' to the observed or logged readings. This may be observed as a general increase in noise, periodic errors perpendicular to the traverse direction or banding in the traverse direction. Maintaining good alignment keeps this error to a minimum but good results are still achievable with a small amount of misalignment. The FM256 will almost always be used with 0.1 nT resolution so the alignment procedure described below is based on this, with any differences when used with 1 nT and 10 nT resolutions indicated afterwards. If the gradiometer sensors were always perfectly aligned then, no matter which direction the gradiometer was facing or tilted with respect to the earth's magnetic field, the reading would always be the same. In practice it is possible to approach this ideal state for moderate periods of time, providing the sensor alignment and balance control is trimmed at the start of each day and checked periodically.

The sensor housings of early models of FM18 / FM36 gradiometers had a soft outer coating and different alignment controls. If your FM256 has been upgraded from an early model then you should still follow the instructions given below but bear in mind that the earlier, coarser edge adjustment wheel is much more sensitive – 0.5 degree of rotation of the edge wheel will change the reading by 1nT. In contrast, the geared sensor alignment control system used in later FM18/36 models (which have a solid tube) and the new FM256, provide a much smoother adjustment – one rotation of the control knob will change the reading by 1nT. The apertures for access to the sensor adjustment controls are sealed against dust and dirt ingress, whilst the outer sealing caps maintain full waterproofing.

Although the procedure described below sounds complicated at first, it is in fact very quick in practice, usually 2-3 minutes to set up alignment at the start of the day, and less than 1 minute to check alignment every few grids. Bear in mind that, since you are trying to maintain alignment of the sensors to 0.0015 degrees just to keep errors below 1 nT, the gradiometer should be treated with care and banging or jarring should be avoided.

Precautions

It is vital that you have no magnetic items in, or on your clothing. Items to avoid are watches, keys, belt buckles, coins, wallets with credit cards, spectacles, zips and studs in trousers, studs in waterproof nylon anoraks, bras with under-wiring or metal clips, studs in boots, or even eyelets in lace up shoes, etc. If you have absolutely no choice but to wear clothes with a magnetic effect then this may be minimised to some extent by holding the gradiometer at a constant distance and orientation to your clothes. However this is not really recommended and should only be attempted by experienced operators who know when this is acceptable.

> **CLOTHING MUST BE NON-MAGNETIC**
>
> It cannot be stressed too strongly that clothing MUST be non-magnetic and you must not have magnetic objects in your pockets or on your person – otherwise you will have great difficulty aligning the sensors and may obtain poor results.

As well as the gradiometer you will require a balance alignment tool (three are supplied as standard accessories) and a compass, if you do not know precisely in which direction magnetic north lies. The balance alignment tool itself is very slightly magnetic and when not being used should be placed on the ground about 1m away from the reference point and instrument – *do not carry it in your back pocket*. The compass on the other hand will, by its very nature, be magnetic so once you have located magnetic north and marked the direction with pegs etc store the compass well away before attempting to align the sensors.

Figure 4-2. Balance alignment tool – do NOT use an ordinary screwdriver as this is magnetic.

Alignment and Balance Procedure

1 Select the Digital Display mode and 0.1 nT resolution. In Setup submenu set both ‘Hold Reading’ and ‘Remove Zeroing’ to ‘On’ - the letter ‘H’ will appear in the top left hand corner and any previous effect of the Zero key will be removed so the display will now show a positive or negative reading offset some way from zero. It is usual to turn ‘Averaging’ to ‘Off’ although some users may prefer to use, for example, 4 cycle averaging when assessing the readings. Remove the sealing caps that protect the alignment controls (1 and 9 in figure 2-2) and keep them in a safe place.

2 The next step is to set up an Alignment and Balance station in a magnetically ‘uniform’ area on the site i.e. a region where there are no localised changes observable. The Alignment and Balance station will also form the Zero Reference station. *Selection of a high quality alignment and balance station is VITAL for good survey results.* To find such an area, select a convenient central location and scan over the ground +/-2m in all directions noting any data changes – *you must take care to hold the gradiometer vertical and at a constant orientation with respect to magnetic north to minimise tilt and orientation errors, since the sensors may not be properly not aligned at this stage.* If data variations are less than 1 nT a uniform magnetic area has been found and the location should be marked with a non-magnetic peg; aim to hold the sensor tube within +/- 5cm of this position when aligning. If the changes are much greater then it is likely that there is a magnetic object buried nearby and you should try another location. Note, however, that some soils, which are uneven and have a high magnetic susceptibility, may give larger changes than 1 nT as the gradiometer is scanned even though there is no buried magnetic object, and due allowance should be made for this. An alternative approach is to stand on a wood or plastic box, or other pedestal that is at least 1m tall. Experience shows that when the bottom sensor is at least 2m above the ground a relatively uniform magnetic location has been found (providing there are no strongly magnetic objects buried underneath). Always choose a location at least 40m away from any parked survey vehicles, preferably much further to avoid magnetic non-uniformity due to the vehicles.

> STOP
>
> **HIGH QUALITY ALIGNMENT AND BALANCE STATION**
>
> Selection of a high quality alignment and balance station is VITAL for good survey results. Choice of a poor station can lead to such problems as mismatch between grids, striping errors, periodic errors and tilt errors.

3 At the Alignment and Balance station use a compass to accurately locate *magnetic* north and mark with pegs the four magnetic directions N, S, E, and W around this point – aim for an accuracy of +/-5 degrees. When aligning it is *very* important that you are pointing in the correct magnetic direction otherwise you will have difficulty aligning the instrument correctly. In fact if you are 90 degrees out from the correct direction (not unknown, even for experienced users!) then any adjustments will actually make alignment worse and eventually the instrument will become unusable.

> STOP
>
> **ACCURATE MAGNETIC NORTH, SOUTH, EAST, WEST**
>
> It is VITAL that you are pointing in accurate magnetic directions N, S, E, W when aligning the instrument.

4 The sensor alignment is adjusted first, followed by balance adjustment. Hold the instrument vertically against your body as depicted in figure 4-3, making sure that you are facing towards magnetic North. Position the gradiometer so that you have access to both the upper and lower alignment openings and can also see the LCD display.

5 Note the reading and its polarity. Rotate through 180 degrees to point South and note the reading again. If it is different by more than +/- 1 nT then rotate the control knob of the N-S alignment control, located at the bottom of the sensor tube, so that the reading lies midway between that observed for the two orientations. For example if the north reading was -24nT and the south reading -14nT then, whilst still facing southwards, adjust the reading

to show -19nT. One rotation of the control knob will adjust the reading by about 1nT. However, you will observe a "dead" zone of about half a revolution in which rotation of the control knob will produce no change in reading - this is the backlash zone associated with the teeth of the gears. It is advisable, when using the control knob, to rotate the required number of turns then rotate back slightly about one third of a turn until the control knob is back into the dead zone. You should not press against the tube as you make adjustments, especially when aligning North-South, since this will bend the tube and can produce a change in reading of up to 5nT. Instead, make sure your hand just turns the control knob, ensuring you do not push it at the same time, whilst taking care not to rest your hand on the tube. *Make sure you do not alter the E-W alignment control when making N-S adjustments.*

6 Rotate the gradiometer through 90 degrees so that it is now facing towards the East and repeat procedure 4, except that adjustments are now carried out on an E-W alignment and using the E-W alignment control situated at the top of the sensor tube, figure 4-4. Make sure you do not alter the N-S alignment control when making E-W adjustments.

7 Repeat steps 3, 4 and 5 again so that any differences when pointing N-S or E-W are of the order of +/- 1 nT.

8 The next step is to adjust sensor balance control. Orientate yourself so that the gradiometer handle is aligned N-S and you are facing East, figure 4-5. Hold the gradiometer as shown and note the reading and its polarity. Take care to hold the tube vertically.

9 Invert the gradiometer as shown in figure 4-6. The gradiometer is pivoted about its handle by the right hand swinging the sensor support tube into a vertical position. This method of inversion ensures that the gradiometer is always facing the same direction, a requirement if the balance control is to be properly adjusted. Again, take care to hold the sensor tube vertical. Use the right hand to press the Start/Stop switch or the Log key – this holds or freezes the display reading when it is upside down, figure 4-7.

10 Return the gradiometer to its non-inverted position. The display now shows the reading that was held or frozen when the gradiometer was inverted – the bottom line of the display will show ‘Held’ in the centre to signify this. Observe the held or frozen reading and its polarity and press the Start/Stop switch or Log key again to release the held reading. If the reading is different for the normal or inverted positions, to within +/- 1 nT, insert the balance alignment tool into the sensor balance control aperture ensuring the tool has engaged in the slot (item 5 in figure 2-2) and adjust the balance control with the balance alignment tool by turning the tool until the reading lies midway between that observed for the inverted and non inverted positions, figure 4-8. For example if the two readings were –25 nT and –15 nT then adjust the reading to –20 nT. Check that the gradiometer now produces the same reading for both the inverted and non-inverted position, and if not make any necessary slight adjustments to the balance control to achieve this.

11 The whole process is now repeated. First the N-S and E-W alignments are adjusted as described in procedures 3, 4 and 5 and this is then followed by the balance adjustment as described in procedures 7, 8 and 9. The processes are repeated until changes of +/- 1nT or less are observed for any of the above procedures.

12 Hold the gradiometer in the same orientation with respect to the traverse direction that it will be held in whilst surveying. The instrument can now be zeroed at the Balance and Alignment station using the Zero key – this will automatically set ‘Remove Zeroing’ back to Off. When you subsequently press Enable Log to start data capture this will automatically set ‘Hold Reading’ back to Off so there is no need to formally do that beforehand.

You should now find that you can point the gradiometer in any direction and there will be changes of +/- 1 nT or less. Depending on the site characteristics and precision required changes of +/- 2 nT may be acceptable for more routine or evaluation surveys. You should also find now that the gradiometer can be tilted from the vertical with little change in reading. This means if you maintain the gradiometer to within +/- 2.5 degrees of vertical any tilt errors you introduce should be much less than 1 nT, depending on the terrain and technique used – see Chapter 5 for more advice on field procedures.

If, when trying to align the instrument, it seems to be a very long way out of adjustment or you are experiencing large variations in readings as the instrument is tilted, you may find it beneficial to select less resolution such as 1 nT or even 10 nT in severe cases, until the instrument is better aligned and balanced. Once alignment and balance is more under control increase the resolution to the level you propose to do the survey with and make a final alignment and balance at that level. You should *always* make final alignment and balance adjustments on the range you intend to use for a survey, rather than, for example, aligning on the 1nT range then switching to the 0.1nT range for the survey.

If you are using a dual gradiometer system, you can zero each instrument separately, as described above. However, much better matching of the data will be achieved if if you zero the instruments *after* loading onto the frame – see ‘Using the Zero Reference Station’, Chapter 5, Field Procedure, page 5-10, for further details.

Figure 4-3. N-S alignment.

Figure 4-4. E-W alignment.

Figure 4-5. Balance – normal position.

Figure 4-6. Balance – inverted position.

Figure 4-7. Freeze (hold) reading.

Figure 4-8. Balance adjustment.

Data Logging

Introduction

Data logging can be performed in three ways:

- Rapid data collection under control of an *internal* sample trigger system
- Rapid data collection under control of an *external* sample trigger system
- Manually, one reading at a time.

All three methods can operate in the digital averaging mode for improved data quality. Sample Trigger logging provides increased data sampling, enhancing data quality and interpretation, without any increase in survey time compared to manual logging.

- Internal sample trigger logging operates as follows. Pressing the Start/Stop switch (item 12 in fig. 2-2) initiates a sequence of ‘beeps’ according to the ‘1m marker rate’ set in the ‘Adj. Trig. Rate’ (see Map-M submenu, page 4-5), whilst internally the gradiometer logs readings at the set sample interval. The operator walks along the survey line at a pace that ensures the ‘beeps’ coincide with 1m marks along the tape - with practice the tape can be dispensed with for even faster surveys. The ‘beep’ rate can be varied between 0.4s and 4.0s, in 0.02s steps. Data can be logged at between 1 and 16 samples/m (set as sample intervals of between 1m and 0.0625m). If preferred, an optional external hand-log key can be used instead of the Start/Stop switch to initiate logging.

- External sample trigger Logging operates in a very similar way to (a) except that an external sample trigger system, coupled to connector in figure 2-2, controls the rate of data collection. A gradiometer to be used as a slave in a dual gradiometer system would be set up in this way and is controlled by the master gradiometer (which operates with an *internal* sample trigger) – see Dual Gradiometer System section which follows, page 4-23. The external trigger system could be user-designed if required – interface details available if required.

- Hand-Log or Manual logging is usually performed using an external hand-log key, though the Start/Stop switch and Log key can be used instead. Operation of this method is described in detail in Chapter 4 under the entry for Log key, page 4-10. Connection of the hand-log key is described in Chapter 2, page 2-4

Selection of Logging Method

You can specify how the FM256 logs data by setting ‘Trigger Type’ in the Setup submenu. There are three choices: ‘Internal’, ‘External’ and ‘Hand-log’. These choices relate to the three methods introduced above.

Internal Sample Trigger Logging

Preparing the Gradiometer

1 Press Enable Log and Clear Memory to clear the data logger memory – dump any required data beforehand.

2 Select the Map-M sub-menu and set the required grid length, width, sample interval and traverse interval – see ‘Planning a Detailed Survey’, Chapter 5, page 5-2, and ‘Dual Gradiometer System’, Chapter 4, page 4-23, for guidance.

3 If required, Set ‘Averaging’ to ‘On’ and set the number of cycles – see ‘Digital Averaging’, Chapter 4, page 4-13 for details.

4 Select the Map-M sub-menu and set ‘Adj. Trig. Rate’ to ‘On’ to alter the ‘1m Marker ’ rate at which ‘beeps’ are sounded. Adjustment of trigger rate is described under Map-M in section ‘Menu and End Menu Keys’ page 4-5. As you adjust the ‘1m Marker’ time (or ‘beep’ rate), if you try and set a time that is too fast, the message ‘Unsafe Rate’ will briefly appear on the bottom line. If you see this message increase the ‘1m Marker’ time until you no longer see the message. If possible increase the time even more to be sure of correct operation over extensive strong anomalies. If the increased time is unacceptable consider reducing the number of average cycles, turning averaging off or increasing the sample interval until an acceptable rate is found.

5 Select the Setup sub-menu and set Trigger Type to ‘Internal’.

6 If required, set Log Zero Drift to ‘On’ in the Setup sub-menu.

Doing a Traverse

1 Press Enable Log to show the Logging Display (it should show G=1, L=1, P=1).

2 Press the Start/Stop switch as you step over the ‘start’ position (edge of the grid) to initiate a logging sequence – see ‘Field Procedure’, Chapter 5, page 5-13, for exact details.

The FM256 will then start to issue a sequence of 1m marker ‘beeps’, including a ‘beep’ when the switch is first pressed over the start position (figure 4-10) and also a longer ‘beep’ at the very end of the line. Thus, for example, on a 10m traverse the FM256 will beep 11 times – see figure 4-9. In between the 1m Marker ‘beeps’ the gradiometer sounds a short ‘click’ every time a reading is logged. The various sampling patterns and their relationship to the 1m Markers are shown in figure 4-10. The FM256 will automatically stop recording at the end of a traverse. Press the Start/Stop switch to start recording the next traverse and proceed as before until grid is completed

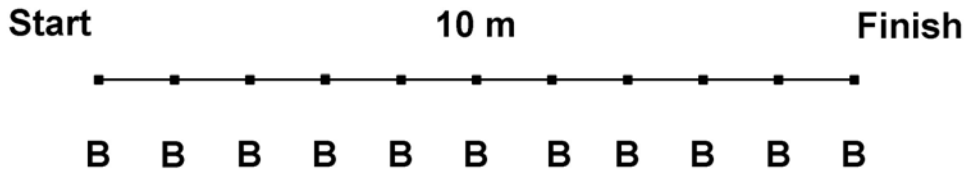


Figure 4-9. FM256 1m ‘beep’ markers, represented by a ‘B’, on a 10m traverse.

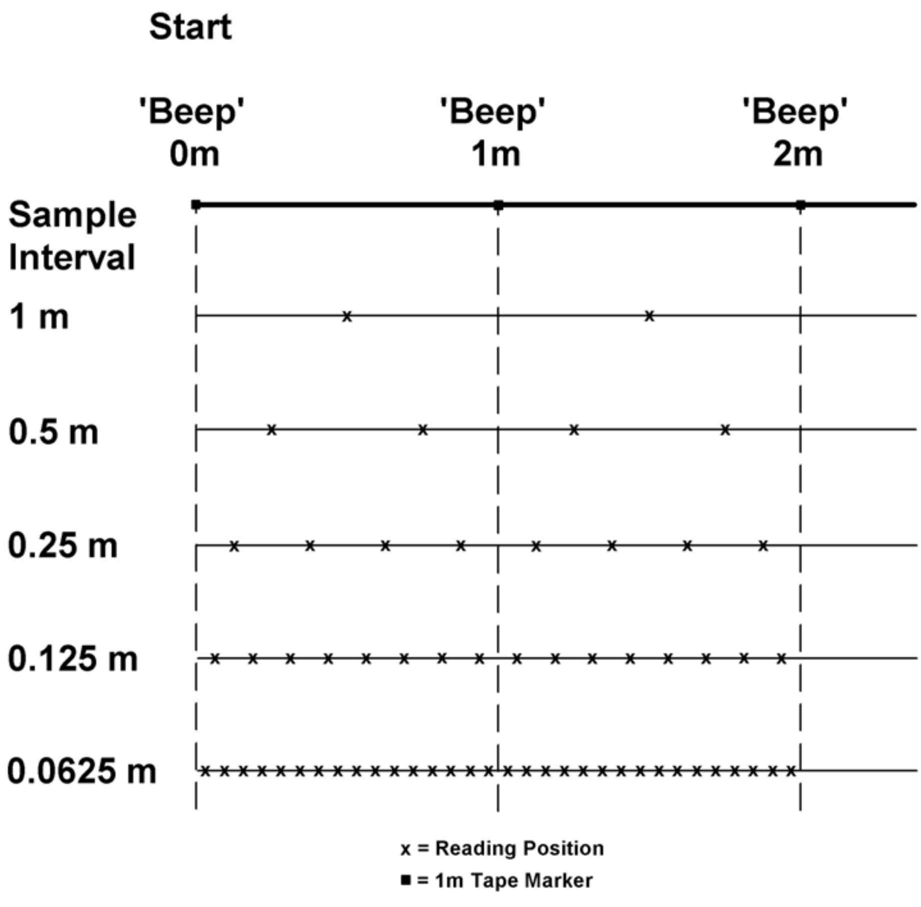


Figure 4-10. FM256 sampling patterns relative to the 1m marker positions on a tape.

Survey Tracking

Survey tracking operates in just the same manner as described under Log Key in the General Keys section: the letters G, L and P and the numbers to the right of each letter indicate, respectively, the *current* grid, the *current* survey line in a grid, and the *next* reading position to be logged. With the memory cleared G, L and P will all equal 1, the start position. P will increment as readings are logged until the last reading of a line is reached when the buzzer will sound a longer ‘beep’ and L will increment by one whilst P will be reset to 1. When the last reading of a grid is logged the buzzer will sound two ‘beeps’ and G will increment by one whilst L and P will both be reset to 1. Once the memory is full with complete grids, the usual two ‘beeps’ will be replaced by three ‘beeps’ after the last reading to signify a full memory. Attempts to log any more readings will result in the three ‘beeps’ being repeated. You will however be prompted to ‘Log Zero Drift’ at the end of that grid if that mode is enabled – see next section. The current survey position and data will be remembered by the gradiometer even if it is switched off.

Operation if Log Zero Drift is On

If ‘Log Zero Drif’t is enabled, two ‘beeps’ will be given at the end of the grid as before but, before the display shows G incremented by one and L and P reset to 1, the display will show :

```
      7   nT
 Log  Zero  Drift
```

This is a prompt to take the gradiometer over to the survey Zero Reference station and to take a reading at that point with the Log key, or the external hand-log key if being used. A ‘warble’ will be sounded when this reading is logged – the full procedure is described in Chapter 5, page 5-13. The display will then show the position ready for surveying the next grid, with G incremented by one and L and P reset to 1. While at the Zero Reference station, the Zero Key should be used to reset the instrument reading to zero before resuming the survey – see Log Key in the General Keys section for more background detail.

Using Dummy Log, Finish Line, Image Line, Delete, Delete Line, Clear Memory

Once a traverse has been completed you can use any of the other logging functions listed above. If you wish to stop the automatic logging during a traverse then press the Start/Stop switch or external hand-log key. You may need to do this, for example, when you want to insert dummy readings where a physical obstacle prevents you from continuing along the survey line. Insert the required number of dummy readings, move to a new position and then press the Start/Stop switch or external hand-log key to resume the traverse – the FM256 will automatically stop at the end of the traverse. Alternatively you can use any of the other logging keys at this point such as Finish Line to complete the line with dummy readings.

Over-range, Dummy Readings and Storage Resolution

If the display goes over-range during a traverse and shows the maximum possible reading at the chosen resolution i.e. +/-204.7, +/-2047, or +/-20470, then the reading will be stored equivalent to one unit *less* than the maximum possible reading but with the correct +/- sign. In contrast, pressing Dummy Log in these same circumstances will always cause a positive reading to be stored equivalent to the maximum possible reading. The result is that you will be able to differentiate between (a) regions containing obstacles that were not surveyed, which will show as a special dummy reading in a Geoplot 3.0 graphics plot, and (b), regions with over-range signals, which will show as the maximum possible positive or negative reading possible, not as a dummy symbol.

Although the readings are only displayed with a resolution of 0.1 nT, 1nT and 10 nT to prevent flickering on the display, they are in fact stored with a resolution of 0.05 nT, 0.5 nT and 5 nT.

Data Capture Rates

When using internal sample trigger logging, readings can be stored much faster than with manual logging, but there is a limit to how fast the trigger rate can be set when you choose a small sample interval. Should there be insufficient time to log a reading at the chosen sample interval, the message ‘Reduce Rate’ will appear on the top line. If you see ‘Reduce Rate’ then you *must* stop and either increase the sample interval or increase the 1m marker time with the trigger rate – any readings logged with the ‘Reduce Rate’ message displayed will have been recorded as a negative full scale readings. The *line* should be surveyed again if only the 1m marker rate is adjusted, but the *grid* must be surveyed again if a new sample interval is set.

Table 4-4 shows the maximum 1m marker times you can use for different sample intervals with Digital Averaging set to ‘Off’.

Sample Interval	Samples / m	Minimum 1m Marker Time
1, 0.5, 0.25 m	1, 2, 4	0.4 s
0.125 m	8	0.64 s
0.0625 m	16	1.28 s

Table 4-4. Minimum 1m marker times for different sample intervals (Digital Averaging Off).

Digital Averaging

If the gradiometer is in the Digital Averaging Mode the survey position tracking and sounds operate as described above, though of course the FM256 will be idling in Digital Averaging Mode before the Start/Stop key is pressed. Using Digital Averaging with sample trigger logging may mean the 1m Marker times shown in Table 4-4 will have to be increased, depending on the combination of number of cycles and sample interval. See ‘Digital Averaging’, page 4-13, earlier in this chapter for more details with regards to the trade off between number of average cycles, sample interval and trigger rate.

External Sample Trigger Logging

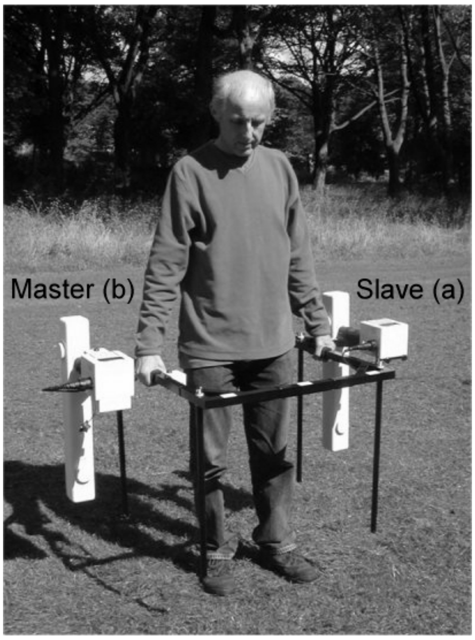
External sample trigger logging operation (slave gradiometer mode) is identical to that described for *internal* sample trigger logging, apart from step 5 in ‘Preparing the Gradiometer’ above, where Trigger Type should now be set to ‘External’. Initiation of a traverse and pausing during a traverse will be under control of the master FM256. See the ‘Dual Gradiometer System’ section which follows for more details.

Manual Logging

Operation of this method is described in detail in Chapter 4 under the entry for Log key in the Logging Keys section, page 4-10.

Dual Gradiometer System

Introduction



The dual gradiometer system uses two instruments carried on a CF6 Carrying Frame, 1m apart, either to double the speed at which a survey can be made or to increase the sampling density of a survey – see opposite. One FM256 acts as a master sample trigger that controls a second slave gradiometer - this can be either another FM256 or an FM18/36 or a *partially* upgraded instrument. Once data sets have been collected in the two gradiometers they are downloaded, and assembled into two individual composites (data sets) as normal. The two data sets are then merged together to form the final composite data set – Geoplot 3.0 provides for this in one simple operation. The convention used for merging data is that the master gradiometer is called 'b' and the slave gradiometer is called 'a'. This convention is also marked on the CF6 carrying frame and used below when discussing traverse patterns.

Assembly of the Dual Gradiometer System for field use is described in Chapter 2, including a DIP-switch setting on the CF6 carrying frame, which may need to be adjusted depending on the slave type, page 2-4. The individual instruments are aligned at an Alignment and Balance station (Survey Zero Reference point) as described earlier in this chapter, page 4-16, before being mounted on the CF6 carrying frame. The Start/Stop switch on the FM256 (item 12 in figure 2-2) is replicated twice on the carrying frame for ease of use, depending on the direction in which the surveyor is walking.

Operating instructions for dual systems based on: (a) two FM256's, (b) an FM256 plus *partially* upgraded instrument or (c) FM256 plus FM18/36, are all very similar, but there are restrictions to bear in mind when using an FM18/36 because of the instruments more restricted survey tracking capabilities. First choose one of the three possible survey modes.

Dual Gradiometer Survey Modes

The dual gradiometer system can be operated in three different survey modes and these determine the required instrument traverse interval settings - see Table 4-5:

- Double Speed Mode – each traverse covers a 2m wide 'corridor' in 1 traverse.
- Double Density Mode– each *pair* of traverses interleave to cover a 2m wide corridor in 2 traverses.
- Quad Density Mode – each *quad* of traverses interleave to cover a 2m wide corridor in 4 traverses.

More complete details of the interleaving patterns are given in Chapter 5, Field Procedure, 'Planning a Detailed Survey', page 5-16. The survey patterns shown in Table 4-5 indicate the traverses the master and slave gradiometers make relative to one another.

Since two gradiometers rather than one are used to cover a given area of ground, the traverse interval setting on the master gradiometer (or master and slave if 2 FM256's are used) should be half of the final merged traverse interval. The table below shows the allowable traverse interval settings if you are using Geoplot 3.0 software to merge the data sets - note that you cannot use Traverse Interval settings greater than 2m or less than 0.5m. *You MUST make sure you enter the Traverse Interval Setting and not the final Merged Traverse Interval in Geoplot 3.0 Acquisition Details – see Data Handling, Chapter 6 for more details.*

Mode	Traverse Intv. Setting	Merged Traverse Intv.	Survey Pattern
Double speed	2 m	1 m	ab
Double density	1 m	0.5 m	aabb
Quad density	0.5 m	0.25 m	aaaabbbb

Table 4-5. Traverse Interval settings for different dual gradiometer modes.

Double FM256 System or FM256 +*partially* upgraded instrument

Use of a double FM256 system is almost as straightforward as using a single FM256. In the following instructions the instrument on the right hand side of the operator is designated the master instrument (b), whilst the instrument on the left is designated the slave (a). The slave can be a full FM256 or a *partially* upgraded instrument.

Preparing the Gradiometers

1 Both gradiometers: align, balance and zero at the same reference station, before loading onto the carrying frame. Alternatively, much better matching of the data will be achieved if you zero the instruments *after* loading onto the frame – see 'Using the Zero Reference Station', Chapter 5, Field Procedure, page 5-10, for further details.

2 Both gradiometers: dump any required data then press Enable Log and Clear Memory to clear the data logger memory.

3 Both gradiometers: select the Map-M sub-menu and set the required grid length, width, sample interval and traverse interval – see table 4-5 above, and 'Planning a Detailed Survey', Chapter 5, for further guidance. For example, if you are doing a double speed survey, traverse interval will be set to 2m on both gradiometers, even though the final, merged traverse interval will be 1m.

4 Both gradiometers: if required, Set 'Averaging' to 'On' and set the number of cycles – see 'Digital Averaging', Chapter 4 for details.

5 Master gradiometer only: select the Map-M sub-menu and set 'Adj. Trig. Rate' to 'On' to alter the rate at which the marker 'beeps' are sounded every metre. Adjustment is described earlier in the entry for 'Menu and End Menu Key', in the General Keys section. As you adjust the '1m Marker' time, if you try and set a time that is too fast, the message 'Unsafe Rate' will briefly appear on the bottom line. If you see this message increase the '1m Marker' time until you no longer see the message. If possible increase the time even more to be sure of correct operation over extensive strong anomalies. If the increased time is unacceptable consider reducing the number of average cycles, turning averaging off (both gradiometers) or increasing the sample interval (both gradiometers) until an acceptable rate is found.

6 Master gradiometer: select the Setup sub-menu and set Trigger Type to Internal.

7 Slave gradiometer: select the Setup sub-menu and set Trigger Type to External.

8 Both gradiometers: if required, set Log Zero Drift to On in the Setup sub-menu.

Doing a Traverse

1 Both gradiometers: press Enable Log to show the Logging Display (it should show G=1, L=1, P=1).

2 Support the carrying frame in both hands.

3 Use the right thumb to press the Start/Stop switch *on the carrying frame* as you step over the 'start' position (edge of the grid) to initiate a logging sequence – see Chapter 5, Field Procedure for exact details.

The master FM256 will then start to issue a sequence of 1m marker 'beeps', including a 'beep' when the Start/Stop switch is first pressed over the start position (figure 4-10) and also a longer 'beep' at the very end of the line, just as we saw for a single gradiometer. In between the 1m Marker 'beeps' the master *and* slave gradiometer both sound a short 'click' every time a reading is logged. The master FM256 will automatically stop at the end of a traverse and since it controls the slave gradiometer so will that instrument. The tracking on both instruments will match.

Depending on whether zig-zag or parallel traverses are being used the same procedure is followed for the next traverse, with the most convenient Start/Stop switch on the frame being pressed to start the next traverse.

Survey tracking, Log Zero Drift, use of Dummy Log and other logging keys, etc is the same as for a single gradiometer, except that any operation on one instrument must be duplicated on the other, e.g. Delete Line must be applied to both instruments if required. Over-range, storage of dummy readings, data capture rates, and digital averaging are also identical to that described for a single gradiometer.

FM256 + FM18/36 System

Use of dual FM256 system based on one FM256 (master) and an FM18/36 (slave) needs to take account of the differences in survey tracking capabilities of the two instruments. In the following instructions the instrument on the right hand side of the operator is the master FM256 (b) whilst the instrument on the left is the slave FM18/36 (a).

Preparing the Gradiometers

1 Both gradiometers: align, balance and zero at the same reference station, before loading on to the carrying frame. Alternatively, much better matching of the data will be achieved if you zero the instruments *after* loading onto the frame – see 'Using the Zero Reference Station', Chapter 5, Field Procedure, page 5-10, for further details.

2 Both gradiometers: dump any required data then press Enable Log and Clear Memory to clear the data logger memory.

3 Master FM256 gradiometer: select the Map-M sub-menu and set the required grid length, width, sample interval and traverse interval – see 'Planning a Detailed Survey', Chapter 5, for further guidance. For example, if you are doing a double speed survey, traverse interval will be set to 2m on the FM256, even though the final, merged traverse interval will be 1m. Always choose 10, 20 or 30m grid sizes so that they match the FM18/36.

4 Slave FM18/36 gradiometer: use the Menu key to step through and set the required grid size and sample interval. These settings should match those of the FM256. However, you cannot change the traverse interval as this is always 1m. This is correct for double density surveys but not for double speed or quad density surveys – in these two cases either one FM18/36 grid is logged for every two FM256 grid or two FM18/36 grids are logged for every one FM256 grid. However, data is downloaded as though it were FM256 data. *It is very important that you see 'Planning a Detailed Survey', Chapter 5, for further guidance.*

5 Both gradiometers: It is not possible to use Digital Averaging in logging mode on an FM18 / 36 so this *MUST be set to 'Off' on the FM256.*

6 Master FM256 gradiometer only: select the Map-M sub-menu and set 'Adj. Trig. Rate' to 'On' to alter the rate at which the marker 'beeps' are sounded every metre. Adjustment is described earlier in the entry for 'Menu and End Menu Key', in the General Keys section, page 4-4. Remember that the FM18/36 will not be able to respond to the triggering system as fast as the FM256, so that the FM18/36 will set the maximum trigger rate that can be used – the 'Unsafe Rate' guidance in the FM256 is not safe to use in this case. It is advisable to log a few test traverses over typical anomalies to see whether the FM18 / 36 'drops' any readings over a line – if it does then reduce the rate or increase the sample interval. As a general guide you can use a 0.25m sample interval on both instruments whilst using a 1m Marker time of 0.7s which offers good compromise performance.

7 Master FM256 gradiometer: select the Setup sub-menu and set Trigger Type to Internal.

8 Slave FM18 / 36 gradiometer: use the Menu key to step through and set External Trigger Type to Encoder.

9 Both gradiometers: you can only easily use Log Zero Drift on the FM18 / 36 if using Double Density coverage. It is not possible to use Log Zero Drift if using Double Speed coverage and only possible if using Quad Density coverage if you are prepared to break off half way through each FM256 grid and record FM18 /36 drift. If Log Zero Drift is required, and possible, set Log Zero Drift to 'On' in the FM256 Setup sub-menu and Log Zero Drift to 'On' in the FM18 / 36 Menu. *See 'Planning a Detailed Survey', Chapter 5, page 5-2, for further guidance.*

Doing a Traverse

1 Both gradiometers: press Enable Log to show the Logging Display (it should show G=1, L=1, P=1).

2 Support the carrying frame in both hands.

3 Use the right thumb to press the Start/Stop switch *on the carrying frame* as you step over the 'start' position (edge of the grid) to initiate a logging sequence – see Chapter 5, Field Procedure for exact details.

The master FM256 will then start to issue a sequence of 1m marker 'beeps', including a 'beep' when the Start/Stop switch is first pressed over the start position (figure 4-10) and also a longer 'beep' at the very end of the line, just as we saw for a single gradiometer. In between the 1m Marker 'beeps' the master *and* slave FM18/36 gradiometer both sound a short 'click' every time a reading is logged. The master FM256 will automatically stop at the end of a traverse and since it controls the slave gradiometer so will that instrument. As we have seen above, the tracking on both instruments may not necessarily match in terms of grid count – if Double Density coverage is being used tracking will match, but if Double Speed coverage or Quad Density coverage is being used grid and position tracking will not match - s*ee 'Planning a Detailed Survey', Chapter 5, page 5-2, for further guidance.*

Depending on whether zig-zag or parallel traverses are being used the same procedure is followed for the next traverse, with the most convenient Start/Stop switch on the frame being pressed to start the next traverse.

Survey tracking, Log Zero Drift, use of Dummy Log and other logging keys, etc is the same as for a single gradiometer, except that any operation on one instrument must be duplicated on the other, e.g. Delete Line must be applied to both instruments if required. Remember that there is a slight difference in the way Delete Line operates for the FM256 and the FM18/36 if a grid has just been completed. If you want to delete the last line of the previous grid then with the FM256 you must first use the Delete key first to get back into the previous grid and then use Delete Line, whereas with the FM18/36 you can press Delete Line straight away.

Over-range and dummy readings are stored differently for the FM256 and FM18/36: as we have already seen in the previous Data Logging section, the FM256 stores dummy readings and over-range readings in distinguishable ways whereas the FM18/36 stores over-range and dummy readings in the same way; this should be taken into account when merging and processing data.

Data Output to a Computer

Once the survey has been completed the stored data may be output, via the RS232 link to another device such as a portable computer. The FM256 is supplied with a cable suitable for connecting the gradiometer to an IBM compatible computer. *It is important to note that the FM256 has different pin connections to a partially upgraded instrument and so requires a different data dump cable.* The data dump cable for each instrument is labelled appropriately: 'FM256 Data Dump Cable' and 'Partial FM256 Data Dump Cable'.

Should you be in the field and only have an older FM18/36 data dump lead available then this may be used in an emergency – however it should only be used for smaller data dumps and/or slower baud rates since handshaking is not implemented in this cable.

You will require suitable software for receiving the downloaded data in the computer. Program Geoplot 3.0 for Windows has provision for handling FM256 and dual gradiometer data.

The procedure for transferring the data to a computer is as follows:

1 Choose a convenient location for the gradiometer and computer. Though you may successfully transfer data from the FM256 to a computer in most environments, we strongly recommend you avoid doing this inside, or adjacent to a motor vehicle which has its engine running (or similar noisy environments). If the vehicle electrical system is badly suppressed the inteference may corrupt the data transferred – see Appendix G for further details.

2 Connect the data dump cable to the gradiometer connector labelled as (3) in figure 2-2. Instructions for mating the connectors are given in Chapter 2, page 2-4.

USE THE CORRECT DATA DUMP CABLE

Full FM256's and *fully* upgraded FM256's use a different data dump cable to *partially* upgraded FM256's, identified by a labels on their sides.

3 Insert the 9 way 'D' connector into the serial socket of the computer.

4 Switch both the gradiometer and computer on.

5 Select the gradiometer Setup sub-menu and check that both the Data Format and Baud Rate settings are correct. There are five data dump formats available which are listed here in increasing order of efficiency and speed: ASC+SPCS, ASC, Fast ASC, Hex D+R and Hex D. The first three formats could be used to dump to software that only has provision for receiving older FM18/36 data, with Fast ASC being the fastest. The two Hex formats can only be used with newer Windows software that has provision for them. Hex D+R is the default setting for the FM256, though Hex D is potentially twice as fast as Hex D+R and can be used providing all data was collected using the same range. Details of these formats are given in Appendix C. Baud Rate is typically set to the fastest speed i.e. 19200, which is also the default FM256 setting.

6 Make sure the software has Baud Rate, Data Format and Log Zero Drift settings that match those on the FM256 - *ensuring the Log Zero Drift settings match is critical for avoiding scrambled data*.. Run the computer program to the point where it is awaiting transfer of the data from the gradiometer. This must be done before the Dump key is pressed otherwise some of the data output from the gradiometer may be lost or corrupted. If program Geoplot 3.0 for Windows is being used full details of the dumping sequence is given in the manual, and the program itself will prompt the user. The software will usually require you to pre-enter the names of the grids to be downloaded – if using a Dual Gradiometer System please consult Chapter 6, Data Handling, page 6-2, for guidance on suitable names.

7 Press the Dump key on the gradiometer to start transmission of the data - see earlier section in General Keys for details on using the Dump key. If data format is Hex D and baud rate is 19200 baud it will take about 15

minutes to download all 256000 readings. Download times will be reduced for smaller numbers of readings. At the end of transmission a ‘beep’ will be sounded and the normal display will return. If at any point you wish to terminate transmission press the Cancel key or simply turn the gradiometer off.

Geoplot 3.0 for Windows will take care of all data handling and storage automatically for you. If you require it, details of how readings may be reconstructed from the downloaded data is given in Appendix D. Details of the RS232 link and pin connections are given in Appendix C.

Note that the FM256 will normally only dump memory contents that contain recently logged data and then stop transmission – it will not attempt to dump the entire memory. However, if the survey tracking position has been reset using Clear Memory, pressing Dump will then cause the entire memory contents to be output. This can be useful in retrieving data should the Clear Memory key be accidentally used.

Care and Maintenance for Optimum Reliability

This section provides important suggestions for the care and maintenance of the FM256 – following this advice will help to prolong the lifetime of the instrument, maintain reliability and avoid problems in the field.

1. Although the gradiometer and accessories have been designed to be waterproof and robust, they should still be treated as carefully as possible to maintain reliability.
2. Environmental sealing is to IP65 standard but working in extremely heavy or driving rain should be avoided if at all possible.
3. Since the sensors must be aligned and maintained to 0.0015 degrees, the instrument should not be subjected to banging or jolting. You should at all times transport the gradiometer in the case provided.
4. If the front panel becomes dirty it should be cleaned gently with a very wet tissue soaked in tapwater – *never* dry wipe since this may scratch the display area or, in dry atmospheric conditions, may create static electricity that could cause a malfunction or damage the LCD display. Wipe the panel in one direction only and leave to air dry. If you rub hard, and fine sharp particles of grit are present, they will scratch the LCD display area.
5. Always replace the sealing caps on the instrument interface connector and data dump cable. If the sealing cap will not easily screw back on, it is likely that small particles of dirt are trapped in the threads. They may be dislodged by using a sharp point and then blown clear - do not try to force the cap on otherwise you may strip the thread.
6. Always replace the sealing caps on the alignment control apertures. Should you lose one of the caps, obtain a replacement as soon as possible since this is required to keep moisture from entering the sensor mounting and adjustment system. The dust seals under the control knobs will only prevent dirt entering when caps are lost.
7. Avoid exposing the charger to damp conditions on survey sites – seal the charger in a plastic bag if it is taken into the field, even if it is stored in the carrying case.
8. Always carry a spare memory backup battery with you.
9. Always carry spare balance alignment tools with you – they are easily mislaid in the field. You must *not* use the screwdriver instead since it is too magnetic.
10. Always follow the advice given at the end of Chapter 3 regarding batteries.

Chapter 5

FIELD PROCEDURE

Introduction

This chapter gives practical instructions on how to plan and perform efficient surveys in the field. The first section concerns scanning techniques whilst subsequent sections are devoted to detailed area surveys. ‘Planning a Detailed Area Survey’ at the start of the detailed area sections provides important background information about survey procedures and some of the terminology used in Chapter 4, – this will be of particular relevance to those new to geophysical survey techniques but it also provides essential advice to experienced practitioners. Subsequent sections give specific technical advice on survey techniques. To fully appreciate these later sections you should be already familiar with Chapter 4, ‘Operating Instructions’. The order in which the sections are described below is a good guide to the recommended sequence of field procedures that you should adopt.

Scanning

Rapid assessments of large areas may be made using scanning techniques. Scanning requires an experienced operator who can assess the background level response and compare this with any anomalous responses. Traverses are made by walking forwards and backwards over the **site**, as shown in the pattern of figure 5-1. The traverses are usually spaced 10-15m apart. The site is shown here partitioned into a number of smaller units, called **grids** so that the traverse pattern can be illustrated. However, a formal grid system would usually only be set up on a detailed survey, *no*t during scanning. Figure 5-1 shows 10m square grids and normally the site would be much more extensive.

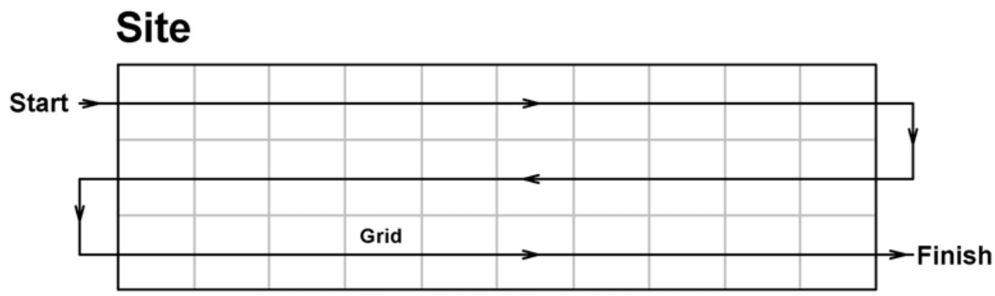


Figure 5-1. Scanning typically uses traverses separated by 10-15m.

A single gradiometer is held in the same orientation at all times, usually in front of the operator, so that heading errors do not cause a shift the background level. The operator alternates his grip of the handle from left to right as he changes direction. Any anomalies above a given threshold, which is typically +/-2 nT are noted. Markers are placed at these points and/or on a map. Detailed surveys can then be made over specific areas or sample blocks as a second stage.

Usually the Analogue Display Mode will be selected for scanning, although the standard Digital Display Mode may also be used if preferred. The Analogue Display Mode has eight display ranges, the most sensitive being +/-5 nT and the least sensitive being +/-640nT; the black bar on the display can move through a total of 16 positions. On archaeological sites for general use select the 10nT range, where each display segment represents

2 nT. The default setting for the Analogue Display Mode provides an audio as well as visual feedback as the site is scanned, indicating to the operator that readings are significant. As the bar graph position changes, the buzzer emits a series of clicks proportional to the magnitude of the response. There is a dead band in the centre equal to +/- one segment when no clicks will be heard. The dead band covers +/- 2nT within the 10nT range but only +/- 1nT within the 5nT range. Therefore the threshold at which the buzzer sounds can be adjusted by switching to a different range. The 5nT range may be required if the site is magnetically quiet. In this case each segment will represent 1 nT. A higher range may be selected if looking for features that are expected to have a strong anomaly, such as a pottery kiln. However, the range should not be set too high if wide search strips are being used, since even a strong feature will give much a much smaller response at, or beyond, its edges. Use of sound also opens up the possibility of using a dual gradiometer system to cover a slightly wider 'corridor' with less chance of missing features. The sound can be turned 'On' or 'Off' by setting 'Scan Sound' in the Setup submenu.

Scanning Procedure

1 Switch on the gradiometer as soon as you arrive on site to allow it time to warm up and stabilise with the environment.

2 Locate the scanning area and place markers at the ends of the traverses to act as visual guides whilst walking.

3 Remove all magnetic items from your person - *double check you are non magnetic.*

4 Locate a magnetically uniform area that can be used as both an Alignment and Balance Station and as a Zero Reference Station.

5 Align and Balance the gradiometer at the Alignment and Balance Station – see page 4-16.

6 Zero the gradiometer at the Zero Reference Station, ensuring that the gradiometer is pointing in the same orientation that it will be held in whilst scanning – see page 4-8 and 4-17.

7 Select Analogue or Digital Display Mode and set Scan Sound to 'On' if required.

8 At the start position, orientate the gradiometer appropriately and start walking in the traverse direction.

9 Traverse the site at a medium walking pace, observing the reading and/or sound for anomalies whilst ensuring the gradiometer is kept in the same orientation.

10 Mark anomalies above the threshold with canes or other non-metallic markers, or plot on a map.

11 Continue to traverse the site until all the area has been scanned.

Planning a Detailed Area Survey

Introduction

Detailed surveys may be initiated following identification of areas of interest by the previous scanning procedure or may have been requested because there is known archaeology or a detailed investigation is necessary for some other reason. The rest of this chapter is devoted to providing guidance for this approach.

Single or Dual Gradiometer Survey

If you have access to a dual gradiometer system then this can be used to either double the speed or increase the sampling density of the survey - see 'Dual Gradiometer System', page 4-23 in Chapter 4 for more details. However, on small sites, extremely rough or steep terrain or if vegetation is extremely dense a single gradiometer may be more appropriate. Whichever system is used the same basic survey methods are applicable.

Grid System

In a detailed area survey the site is partitioned into a number of grids, typically 20m or 30m squares, which are in turn subdivided into a mesh of smaller squares, typically 1m square. One or more instrument readings are taken within each 1m square, giving a detailed and systematic coverage of a site. Figure 5-2 shows a site subdivided into 10m squares and illustrates several grid parameters that are used when setting up the FM256. **Readings** are taken by walking along a **traverse**. The separation between readings along a traverse is known as the **sample interval**. The separation between traverses is known as the **traverse interval**. The length of the traverse specifies the **grid length**. The number of traverses and the traverse interval define the **grid width**. All these measurements are specified in terms of metres. The corners of grids are usually marked with plastic or wooden pegs.

Usually, where there are no other constraints, grids are aligned so that the axes are N/S and E/W, allowing a graphics North symbol to be parallel or perpendicular with the grid coordinate system. However the grids can be aligned in any direction where it is necessary to fit in with any boundaries or physical constrictions. Where necessary some grids can be defined as dummy grids or parts that cannot be surveyed can be filled in with dummy readings. See ‘Traverse Direction’ for further comments.

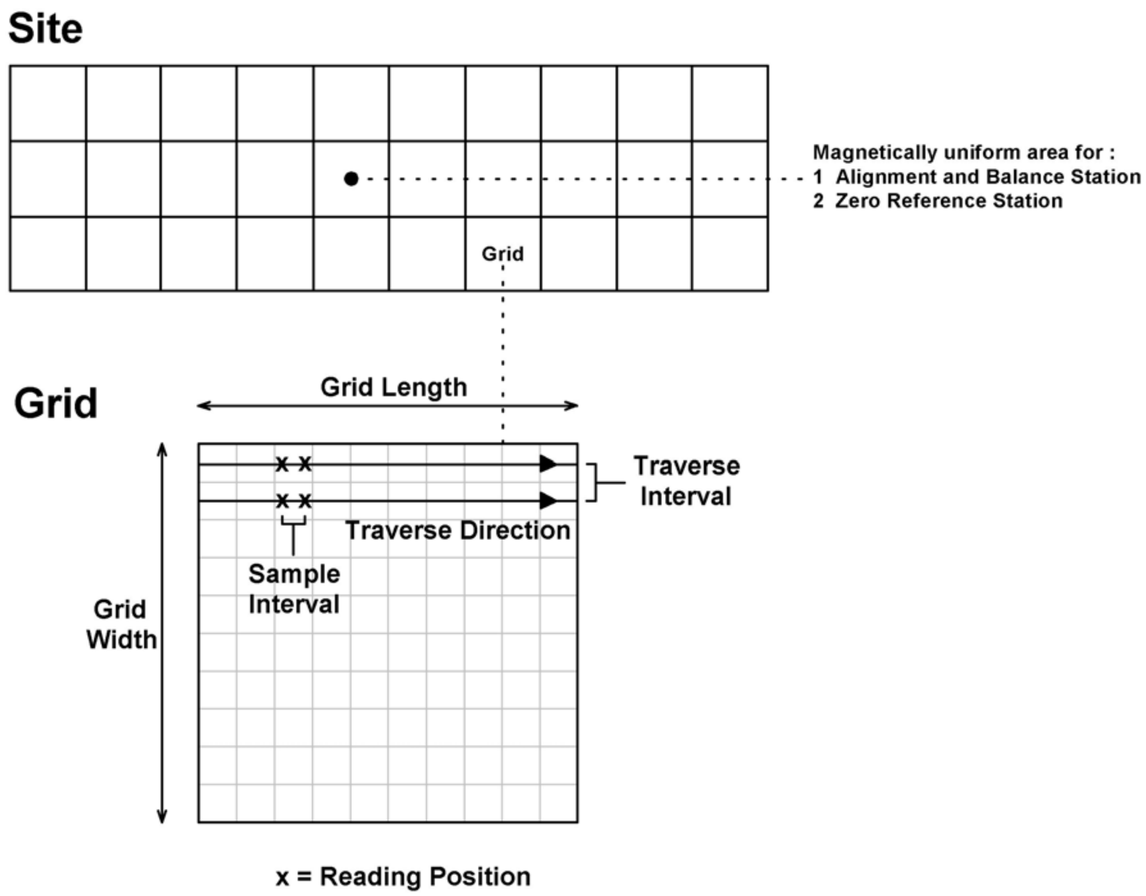


Figure 5-2. Diagram to illustrate the relation ship between Site and Grid, and introduce grid and survey measurements. In the above example a grid size of 10m x 10m is partitioned into smaller 1m squares. Sample interval is 0.5m and traverse interval is 1m. A typical position for the Alignment and Balance Station and Zero Reference Station is also shown on the site map.

Grid Size

Grids may be square or rectangular with dimensions of 10m, 20m, 30m, 40m, 50m or 100m although typically these are 20m or 30m squares. The wide range of grid sizes allows you to tailor logging to your survey requirements or allows you to minimise or avoid subsequent data processing difficulties.

Although the 20m square grid is a commonly used and relatively efficient size, a 30m square grid may be more efficient as it will require fewer corner pegs when laying out and fewer movements of survey guide lines if used. Grids of 10m square are *not* usually recommended since they involve many more grid corner pegs to be set up, much more movement of survey guidelines and ‘Zero Mean Traverse’ may not perform as well as on other larger grid sizes. A dual system based on an FM256 + FM18/36 can only use grid lengths of 10, 20 or 30m because of survey tracking limitations, but there are no such limitations with a double FM256 system.

If there are known to be extensive strong anomalies or ferrous responses and Geoplot’s ‘Zero Mean Traverse’ process function is to be used, choosing a longer grid length, eg 30 to 40m, may enable that function to perform better since it is will have more undisturbed length over which to estimate the true background response.

If environmental conditions are such that drift is noticeable, using very large grid sizes, for example 50m x 50m, is probably best avoided since this may lead to insufficient alignment checks at the end of grids for optimum survey results – see ‘Alignment Stability’, page 5-9 for further guidance. However, if environmental conditions are at an optimum, then use of long traverses and medium sized widths, for example 50m by 20m, can be beneficial in dual gradiometer surveys since the time taken in turning around for the next traverse will be proportionately less.

Choice of grid size is dependent on whether survey guide lines or sighting pegs or canes are used, since grid lengths larger than 20-30m may make these methods more difficult to use – see 'Survey Guides', page 5-11, for further information.

Sample and Traverse Interval

The choice of sample interval and traverse interval is often a compromise influenced by the following factors:

- Site evaluation or research objectives
- Required sampling density
- Speed of operation
- Anticipated signal to noise ratio
- Use of Digital Averaging
- Availability of a single or dual system
- Whether a dual system is totally FM256 based or includes an FM18/36 as part of it

Figure 5-3 shows some possible sample and traverse patterns that can be used, though smaller sample and traverse intervals are not shown to preserve clarity.

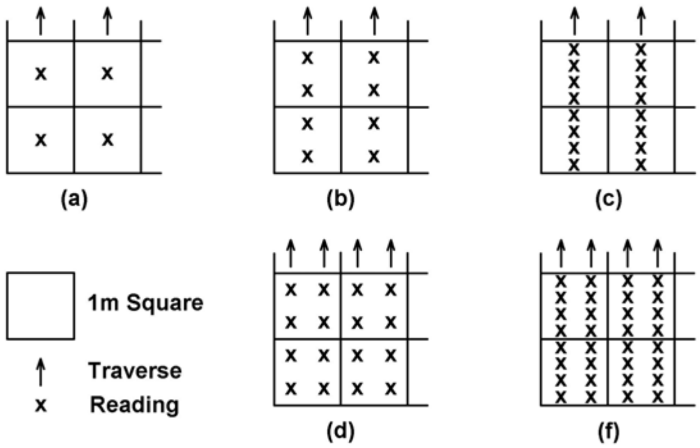


Figure 5-3. Some possible data sampling patterns – higher sample and traverse intervals are not shown to preserve clarity.

In principle you should try and collect data at as high a data sampling density as possible so as to achieve the best signal to noise ratio and maximise spatial resolution. However, this is not always possible in practice due to a variety of constraints.

For general evaluation purposes traverse intervals of 1m are normally used. This, combined with sampling of 4 to 8 samples per metre (pattern 'c', figure 5-3), provides good overall performance with the higher sampling densities giving coherence to any weak signals thus enabling them to be more easily detected.

For research purposes or in evaluation situations where targets are relatively small and weak, such as grave pits, then traverse intervals of 0.5m should be considered, combined with sampling of 4 to 8 samples per metre, (pattern 'f', figure 5-3) though this will double the survey time unless a dual system is used. If targets are less than 1m in width then they could be missed entirely or prove difficult to interpret if a general traverse interval of 1m is used. Using a dual gradiometer system makes it more attractive to use a traverse interval of 0.25m, which, combined with a sample interval of 0.0625m, would provide 4 x 16 = 64 readings per metre giving extremely good resolution, improved signal to noise ratio and much greater signal coherence.

For a single FM256 gradiometer the large memory size and fast response means sample intervals as small as 0.125m, i.e. 8 samples per metre, can be used whilst still maintaining a walking pace as fast as 0.64s/m (see Table 4-4, page 4-22). Since evaluation surveys are usually made at speeds of 0.6 – 0.8 s/m, sampling of up to 8 samples per metre can be selected. However, increasing sampling to 16 samples per metre will require walking pace to be slowed to 1.28 s/m resulting in an increased survey time that may be unacceptable.

If Digital Averaging is used (see page 4-13 for details) then this will also introduce speed limits since, for example using 4 average cycles and a sample interval of 0.25m speed will limited to1s/m. Research surveys may be able to trade off increased survey time for the benefits of increased sampling and may make more extensive use of digital averaging so sampling of 16 samples per metre is then possible. Digital averaging will be of greatest use on sites where anomaly strength is comparable with system noise.

If a dual gradiometer system is based on a pair of FM256's then system memory and speed will be large enough to not impose any compromises on sample and traverse intervals and survey speed. However, if the dual system uses an FM18/36 in one half then compromises will usually have to be made:

- Digital Averaging cannot be used.
- Using a sample interval of 0125m with an FM18/36 will require a slow trigger rate, typically 1.5s/m., reducing survey speed, whereas a sample interval of 0.25m will allow fast trigger rates.
- The limited memory size of an FM36 (16000 readings) or an FM18 (4000 readings) will limit the sampling strategy if frequent data downloads are to be avoided.

When using a dual system for general evaluation purposes a good compromise is to use an overall sample interval of 0.25m, traverse interval of 1m and trigger rate of 0.7s/m, (pattern 'c', figure 5-3). This will allow up to 20 x 20m x 20m grids to be surveyed before downloading, typically one half day of survey time if using zig-zag traverses (see later). For detailed evaluation or research purposes consider decreasing traverse interval to 0.5m, (pattern 'f', figure 5-3) which allows up to 10 x 20m x 20m grids to be surveyed before downloading. Note that you can only have merged traverse intervals of 1m, 0.5m or 0.25m in dual gradiometer surveys.

Where there is a known archaeological structure it may be desirable to survey an area greater than that occupied by the structure because this can assist greatly in the interpretation of a site. This is especially appropriate where it is anticipated that complicating factors such as geology, terrain, field drains, ridge and furrow etc. will also produce a response, usually fairly extensive. Indeed, once a survey is started it often becomes apparent that the archaeology also extends further than at first anticipated. Clearly the balance between resolution and time available to survey the larger area must be carefully considered before embarking on too detailed a survey.

Traverse Mode

In a detailed area survey the ground is covered by a sequence of traverses adjacent to one another. The traverses may be either in the same direction all the time, referred to as **Parallel traverses**, or may reverse direction for each alternate traverse referred to as **Zig-Zag traverses**, figure 5-4.

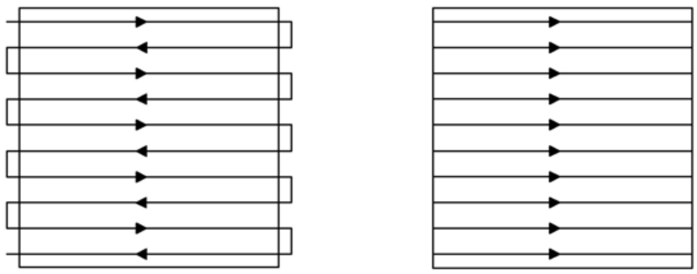


Figure 5-4. Zig-zag traverses (left) and Parallel traverses (right).

Whichever mode is chosen, the gradiometer should always be held in the same orientation so that heading errors do not cause a shift in the background level. For a single gradiometer with parallel traverse surveys the operator holds the instrument by their side. For a single gradiometer with zig-zag traverse surveys the instrument is usually held in front of the operator who alternates his grip on the handle from left to right as *the operator* changes direction whilst the instrument does not. If a dual gradiometer system is used for zig-zag traverse surveys the operator normally turns around whilst the frame does not. An exception occurs if the carrying frame is being used without legs because then there is no opportunity to rest the frame on the ground while the operator turns around. In these circumstances the gradiometers do change orientation so heading errors may occur.

The choice of traverse method is a compromise between the faster survey speed from using zig-zag traverses and the slightly higher quality data from parallel traverses. Use of zig-zag traverses eliminates the return walk back to the beginning of the next traverse thus making much more efficient use of time. Therefore, in general, most evaluation surveys use zig-zag traverses since speed is of the essence and usually any errors can be corrected for in software. For research surveys, where survey time may be less critical, either mode can be adopted, with parallel traverses usually resulting in slightly better quality data. There are three main reasons why zig-zag traverses slightly degraded performance compared to parallel traverses:

- If clothing, glasses etc. are slightly magnetic, then the position of the gradiometer sensor tube relative to the body, and hence relative to the clothing, will change for successive traverses potentially causing a slight shift in reading which can be seen as striping in the data – this may typically be of the order of 0.5-1 nT. The effect can usually be corrected for using Geoplot's 'Zero Mean Traverse' process function.
- Alignment or tilt errors are also more apparent for zig-zag traverses. This is because it is difficult to hold the gradiometer exactly vertical all the time, and any tilt error will reverse for successive traverses causing a double shift in background reading. This too will be seen as striping in the data, again typically of the order of 0.5-1 nT. The effect can usually be corrected for using Geoplot's 'Zero Mean Traverse' process function.
- Care must be taken to ensure that the sensor tube is always opposite the survey guide markers (see 'Survey Guides', page 5-11) or at the correct position the instant the data is logged, otherwise data will be slewed or displaced forwards and backwards for successive traverses. It can be difficult for operators to achieve this precisely. The effect is to appear to displace data on successive traverses and is most noticeable when using high sampling rates, fast walking speeds and traverses are perpendicular to linear features. The effect can usually be corrected for using Geoplot's 'Destagger' process function.

Parallel traverses can reduce these potential problems slightly since it is easier to maintain a constant, repeatable gradiometer position and tilt angle, and any slew errors are all in the same direction, causing no relative error. The dual gradiometer system tends to provide better performance than a single gradiometer when comparing use in zig-zag mode since, even if the operator is slightly magnetic he is substantially further away from each gradiometer, and the carrying frame allows the user to control angular variations better.

Traverse Direction

Choice of traverse direction is influenced by three factors:

- The software used to download, store and process the data may have specific requirements. If you imagine looking at a plan of a grid, the first reading could be in any of the four corners shown in figure 5-5. Geoplot expects the first traverse of downloaded data to always be in a clockwise direction from the first reading. If your first traverse is in the opposite direction the data will be interpreted incorrectly, resulting in a mirror image. Although you can correct for this in Geoplot, it is time consuming and inefficient and best avoided unless there is no alternative because of the constraints of the survey site. Therefore to make data processing easier you should always try to ensure that all grids are surveyed with the start position in the same relative corner.

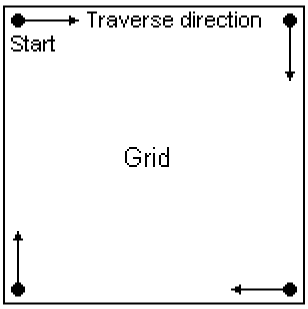


Figure 5-5. Acceptable traverse start points and directions (clockwise) for compatibility with Geoplot.

- If you know in advance the shape and form of the survey targets, it may be advantageous to orientate the traverse direction (which is usually the direction of highest sampling density) so as to ensure that the maximum the number of data points crosses a feature in a particular direction. For example, if you are investigating narrow targets that run NS along their length, then setting the traverse direction EW will ensure best resolution, and reduce the chance of missing the target. You will obtain more information on the magnetic profiles of features that are crossed at right angles.
- If the survey is to be made over linear or rectangular features it can be very advantageous to set the traverse direction, and hence grid pattern, at 45 degrees to the target. This is because traverse dependent process functions like 'Zero Mean Traverse' will calculate the true background response more accurately if the process function direction is not parallel to the linear feature and therefore will be less likely to remove the linear feature in error.

Display Resolution

For most applications a display resolution of 0.1 nT should be used. In the logging mode this will allow a reading to be stored with a resolution of 0.05 nT and the maximum reading, before being logged as over-range, will be 204.7 nT. If the targets of interest have signal strengths over 204.7 nT and you wish to examine the magnetic profile at the higher strengths then you should choose a resolution of 1nT or even 10nT resolution in extreme cases. For example, if you wish to look at the magnetic profiles and structure within a pottery kiln you should consider using 1 nT resolution, which can display readings up to 2047 nT before they are logged as over-range. Over a tile kiln or some industrial sites, you may require a resolution of 10 nT, depending on the maximum signal response and detail required.

Consistent Grid Size, Survey Pattern and Orientation

For each site, *always* use grids that have the same size, sample and traverse interval, traverse direction and orientation. This will make subsequent data assembly and processing much easier and faster to achieve.

CONSISTENT GRID SYSTEM AND ORIENTATION

Always use grids that have the same size, sample and traverse interval, traverse direction and orientation to ensure ease of subsequent data processing and to retain the possibility of being able to apply all process functions.

Whilst software can be used to rotate grids, to correct for inconsistent traverse directions, if some of the grids are not symmetrical in terms of sampling intervals and physical size, you will not be able to directly assemble the grids into one complete data set, or composite. You would instead have to create individual composites from each grid and then use process functions to interpolate and reassemble the survey, piece by piece. This will be time consuming to do. More importantly, if you cannot create a composite directly from same sized grids you will not be able to use many of the grid or traverse based process functions that software packages provide for removing data collection defects; in Geoplot 3, for example, you would not be able to use process functions such as ‘Zero Mean Traverse’, ‘Zero Mean Grid’, ‘Destagger’, ‘Edge Match’, etc. This will greatly limit what you can do subsequently with the data.

Alignment and Balance Station / Zero Reference Station

A magnetically uniform area must be selected on each survey site for two very important procedures:

- Alignment of the fluxgate sensors at the Alignment and Balance Station
- Zeroing and optional logging of zero drift at the Zero Reference Station

Setting the gradiometer up for good sensor alignment and balance is *vital* to getting the best possible results – this process will minimise measurement tilt or twisting errors which can result in a general increase in noise, periodic errors perpendicular to the traverse direction or striping in the traverse direction. The Zero Reference station is used to ensure that all grids in a survey have matching background levels and is also optionally used to monitor and log any drift occurring during the survey of each grid.

The same point or station will normally be used for both alignment and zero control and usually a central location should be selected for easy access from all parts of the survey area. S*election of a high quality Alignment and Balance / Zero Reference station is VITAL for good survey result* - see ‘Alignment and Balance Procedure’ instructions given on page 4-16 for guidance on how to select an appropriate station. Always choose a location at least 40m away from any parked survey vehicles, preferably much further, to avoid magnetic non-uniformity due to the vehicles.

The station may need to be relocated on a very large site, but avoid this if possible. If the station must be moved then make sure the new station is equally magnetically uniform and check that the reading is zero at both the old and new stations.

Outline Field Procedure for Detailed Surveys

An outline of the recommended field procedure is listed below. Preparations for the survey should already have been planned as discussed in the previous section. The topics listed below are then discussed in more detail in the sections following.

1. Switch on the gradiometer as soon as you arrive on site to allow it time to warm up and stabilise with the environment. Clear the memory and adjust the survey settings for grid length and width, sample interval, traverse interval, trigger type, sample trigger rate, display resolution, Digital Averaging status and number of average cycles if used, Log Zero Drift status.
2. Lay out the corners of all the grids. Set out survey guide lines at the first grid to be surveyed or, if using guide pegs or canes, set these out in advance for a number of grids.
3. Make a sketch map of the survey area with the grid pattern superimposed. Record survey details such as instrument settings, traverse direction, compass North, location of physical obstacles and fixed ferrous features such as iron fences, pylons etc. This information will be used when interpreting the survey later on.
4. Where feasible remove any surface iron that is visible in the survey area.
5. Remove all magnetic items from your person - *double check that you are non magnetic.*
6. Locate a magnetically uniform area that can be used as both an Alignment and Balance Station and as a Zero Reference Station.
7. Align and Balance the gradiometer(s) at the Alignment and Balance Station – see page 4-16.
8. Zero the gradiometer(s) at the Zero Reference Station – see page 4-8 and 4-17.
9. Survey the site, checking and readjusting alignment, balance and zero periodically. Use the Zero Reference Station to Log Zero Drift and re-zero at the end of surveying each grid if that facility is being used. More than one survey session may be required to cover a site, depending on the size of site and memory limitations. Keep the gradiometer powered up between sessions to optimise stability.
10. Download the data to a computer, examine the results graphically and decide if the survey area needs extending or parts need resurveying.
11. Complete the survey.

Gradiometer Alignment and Stability

Warm-up Time

As soon as you arrive on site take the gradiometer out into the field and switch it on – place it in full sunlight *not* shade. This will allow the electronics to stabilise and the fluxgate sensor alignment system to achieve thermal equilibrium with the field environment.

Allow a stabilisation time of as long as possible, but a minimum of 15 minutes, before a detailed survey is started. Typically the reading will change by about 1-2nT over the first 3 minutes and settle down but the fluxgate sensor alignment will not have properly stabilised by this time, as it is a mechanical arrangement. Although usually this will not contribute to reading drift, the sensor alignment will not yet be optimised for minimum tilt errors. Attempts to adjust alignment at this stage are pointless since it will have drifted away from optimum by the time the detailed survey is started.

During this warm-up period preparations can be made for the detailed survey, marking out corner pegs, laying out survey guidelines etc. If only scanning is required, this can commence after only 5-10 minutes since generally tilt errors at this stage will not be large, providing the instrument was correctly set up from the previous survey. It may be prudent to check this, and adjust accordingly, especially if it is a very quiet site magnetically.

Removal of Magnetic Items from your Person

As has already been emphasised in ‘Fluxgate Sensor Alignment and Balancing’ page 4-15, it is *vital* that you have no magnetic items in, or on your clothing when using the gradiometer. Items to avoid or remove before starting are watches, keys, belt buckles, wallets and credit cards, coins, spectacles, zips and studs in trousers, studs in waterproof nylon anoraks, bras with under-wiring and metal clips, studs in boots or even eyelets in lace up shoes, etc. You can check items of clothing for suitability by bringing them close to the stationary gradiometer and look for any reading changes. Anomalies from these objects can range from between 5 and 200 nT, which is very significant compared to the 0.1 nT survey resolution typically required.

If you wear spectacles then you may find that plastic frames fitted with screws that are non-magnetic are best. Footwear can cause a particular problem since your feet will always be moving relative to the gradiometer. In wet weather moulded Wellington Boots are recommended (but make sure there are no metal studs in the sole) and for dry weather plimsolls or trainers are recommended, since the eyelets and lace and caps are usually made from aluminium which is non magnetic – *but always check first*.

CLOTHING MUST BE NON-MAGNETIC

It cannot be stressed too strongly that clothing MUST be non-magnetic and you must not have magnetic objects in your pockets or on your person – otherwise you will have great difficulty aligning the sensors and may obtain poor results. Make it standard practice to check for and remove magnetic items before each survey session.

Sensor Alignment

Once the gradiometer has had time to achieve thermal equilibrium with the field environment then the fluxgate sensors should be aligned, following the ‘Alignment and Balance Procedure’ instructions given on page 4-16. The Alignment and Balance / Zero Reference station is usually a convenient point central to the survey so as to minimise walking distances involved when checking alignment or zeroing the instrument.

It is vital that a good quality Alignment and Balance station is chosen for correct alignment of the instrument.

HIGH QUALITY ALIGNMENT AND BALANCE STATION

Selection of a high quality alignment and balance station is VITAL for good survey results. Choice of a poor station can lead to such problems as mismatch between grids, striping errors, periodic errors and tilt errors.

It is advisable to check your data after one or two grids, either by observing the readings as they are collected, by using the View Data submenu on the FM256 or by dumping the data. If the majority of readings are not centred around zero then this indicates that the Alignment and Balance / Zero Reference station is not as magnetically uniform as it should be. You should then try and locate a better station.

Alignment Stability

In order to maintain high data quality you should check the alignment periodically throughout the day, with the frequency of checking depending very much on the weather conditions and the magnetic quietness of the site. Steady ambient temperatures of between 5 and 25 degrees C with no winds, or only moderate winds, usually cause little change. Typically operators check alignment every 2-4 grids.

However, temperatures can change fairly rapidly at the beginning and end of the day so at these times it may be prudent to check alignment more regularly, say every 1-2 grids. Obviously, if weather conditions do change markedly during the day, check the alignment more often. On days of extreme weather, very hot, very cold or very windy, check the alignment more frequently.

Optimum alignment stability will be achieved if the instrument is kept powered up as continuously as possible, with minimal switching on and off. Stability can also be improved if the instrument is supported vertically during breaks in a survey, such as during a lunch break. This may be achieved by leaving gradiometers on the CF6 carrying frame or by the construction of a simple wooden stand.

Stability is maximised if you survey as many grids as possible without a break (checking alignment and balance as required). However, inexperienced users may find it beneficial to dump data every one or two grids to ensure that the survey is proceeding correctly and that survey technique or instrument settings do not need modifying.

Using the Zero Reference Station

The Zero Reference station is used to ensure that all grids in a survey have matching background levels – zeroing of the instrument at this station, using the Zero key, is done usually just before starting to survey each grid or every time alignment is checked – see ‘Alignment Stability’ above for guidance on the frequency with which the zero reference station should be used. If ‘Log Zero Drift’ is ‘On’ the Zero Reference station is also used to monitor and log any drift occurring during the survey of each grid – in this case the station will be used at the end of each grid. Like the selection of the Alignment and Balance station, s*election of a high quality Zero Reference station is VITAL for good survey result*

To use the Zero Reference station the gradiometer is held in the same orientation with respect to the traverse direction as used whilst surveying – *this is most important*. Use a point on the horizon or a feature some distance away or use a marker peg as a sighting point to make sure you and the instrument are always aligned with the traverse direction each time the zero reference point is used. Position the fluxgate sensor tube directly over the reference point, to within +/-5cm of the centre, and position your body and the instrument in exactly the same way as they would be when surveying. The instrument can now be zeroed using the Zero key – see page 4-8 and 4-17 – or you can log zero drift using the Log key – see page 4-10 and 4-21.

If you are using a dual gradiometer system, you can zero each instrument separately, as described above. However, much better matching of the data will be achieved if you follow the procedure described next. Move the frame over to your reference point and place it on the ground facing your traverse direction, but with the first instrument tube placed directly over the reference point. Zero the instrument. Position the other instrument tube over the reference point, still pointing in the traverse direction and zero that instrument. This technique will only work if you keep the frame pointing in the same traverse direction all the time. You can adopt a similar procedure if you use the log zero drift facility.

Laying Out Grids

The corners of grids are usually marked with plastic or wooden tent pegs. Use an EDM, plane table or measuring tapes to locate the corners – often a central baseline is used to work from. If you are using tapes, table 5-1 gives diagonal measurements for a range of different grid sizes. It is very important to make sure that there are no nails left in wooden stakes otherwise these will appear as anomalies at the corner of each grid. If you use measurement tapes and subsequently leave them lying on the ground make sure the tape end and winding mechanism are at least 3m away from the survey area otherwise these too can appear as anomalies on the survey. Be aware that some nylon tapes have a ferrous strengthening core that also can show up as an anomaly if left too near the survey area.

Survey Grid Dimensions	Diagonal
10 x 10	14.14 m
20 x 20	28.28 m
30 x 30	42.43 m
40 x 40	56.57 m
50 x 50	70.71 m
10 x 20	22.36 m
10 x 30	31.62 m
10 x 40	41.23 m
10 x 50	50.99 m
20 x 30	36.06 m
20 x 40	44.72 m
20 x 50	53.85 m
30 x 40	50.00 m
30 x 50	58.30 m
40 x 50	64.03 m

Table 5-1. Useful diagonal dimensions for various grid sizes.

Single Gradiometer Surveys

Introduction

Step by step instructions for a single gradiometer survey are provided in this section, although they can be modified to suit individual circumstances and preferences. It is assumed you have already made choices with regards to mapping parameters, such as grid size, sample interval etc, which are discussed in the earlier section 'Planning a Detailed Survey'. Detailed information on how to use the instrument is given in Chapter 4, 'Operating Instructions'. You should read this section in conjunction with the final section in this chapter, 'Minimising Data Collection Defects' to obtain the best data quality.

Survey Guides

Guide systems are employed to ensure traverses are made on a correct line and readings along the traverse are made in the correct position. Many variations are possible but two typical systems are described below, both are intended for use with sample trigger logging – if manual logging is being used the same ideas can be modified. The first system, using guide lines, gives good positional accuracy as required for traverse intervals of less than 1m or for high sampling densities. The second system, using sighting pegs, gives minimal positional guidance but is ideal for fast and efficient evaluation surveys at 1m traverse intervals.

Guide Lines

The guide line system provides the accurate positioning information required for 0.5m or 0.25m traverse intervals and small sample intervals such as 0.125m or 0.0625m. It requires the operator to walk each traverse alongside a guide line whilst ensuring the *sensor tube* and 1m marker 'beeps' coincide with special marks made on the guide line. Figure 5-6 shows a typical layout – a 10m grid is shown for clarity although more often a 20m or 30m grid will be used in the field.

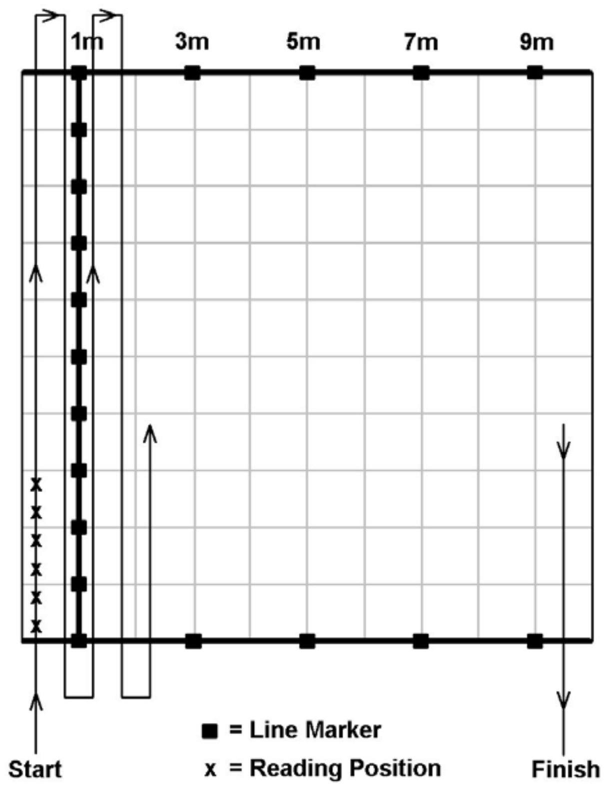


Figure 5-6. Survey guide system using guide lines – traverse interval 0.5m, sample interval 0.5m

This system consists of three lines marked at appropriate intervals - two fixed parallel lines (shown horizontal in figure 5-6) and one that is moved perpendicular to the other two. The parallel lines have markers starting at 1m and subsequently every 2m. On a 20m square grid the markers would be at 1m, 3m, 5m, 7m 9m, 11m, 13m, 15m, 17m and 19m. The perpendicular line has markers every 1m. In the example shown in figure 5-6, where traverse interval is 0.5m, each position of the perpendicular line is used as a guide for four traverses, two either side. The first two traverses are made at a distance of 0.75m and 0.25m from the guide line. The second two traverses are made at a distance of 0.25m and 0.75m on the other side of the line. The gradiometer is carried so that the *sensor tube* and 1m marker 'beeps' coincide with the 1m marks on the perpendicular line. The perpendicular line is then moved on two line intervals, to the 3m mark, for the next set of traverses and so on (5m, 7m, and 9m marks) until the whole grid is completed. Trigger rate is typically 1s/m or slower to allow accurate positioning. Traverses may be parallel or zig-zag and usually a sample interval of 0.25m or smaller is used – for highest data quality parallel traverses are recommended. The system can also be used for 0.25m or 1m traverse intervals.

You should *not* use standard measuring tapes as guide lines since the tape ends and winding mechanisms will be too magnetic Instead make the guide lines from plastic washing lines, nylon rope or copper wire, marked either with brightly coloured bands of adhesive tape or heatshrink sleeving. Put loops at each end so that the line may be fixed in position. Using a set of perpendicular lines will avoid having to move one single central line frequently.

Sighting Pegs

The sighting peg system provides efficient but minimal positioning information suitable for rapid evaluation surveys at a traverse interval of 1 m. It requires the surveyor to be able to walk a traverse at an accurate and repeatable pace so that the 1m marker 'beeps' always stop at the correct position at the end of a traverse – there is no central guide line in this case. This is not difficult to master in practice. Figure 5-7 shows a typical layout – a 10m grid is shown for clarity though more often a 20m or 30m grid will be used.

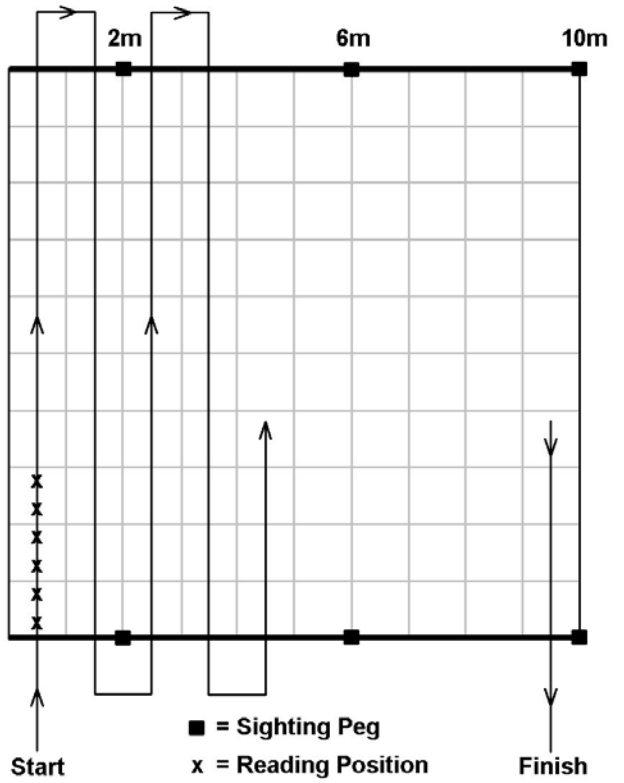


Figure 5-7. Survey guide system using sighting pegs – traverse interval 1m, sample interval 0.5m.

This system employs sighting pegs positioned on two parallel lines. The first pegs are located 2m from the grid edge whilst subsequent pegs are at 4m intervals. On a 20m square grid the pegs would be at 2m, 6m, 10m 14m and 18m. In the above example of a 1m traverse interval, each pair of sighting pegs is used as a guide for four traverses, a pair either side. Trigger rate is typically 0.6 to 0.8 s/m. Traverses may be parallel or zig-zag and usually a sample interval of 0.5m to 0.25m is used. Experienced operators may be able to reduce the sample interval down to 0.125m, if traverses are parallel, although zig-zag traverses at that sample interval and trigger rate are likely to generate traverse stagger problems. The system is generally accurate enough for a 1m traverse interval but the previous guide system should be used for a 0.5m traverse interval.

Survey Procedure

The following instructions follow on from steps 1-8 given previously in 'Outline Field Procedure for Detailed Surveys', page 5-8, so the instrument should already be aligned and balanced and has been zeroed at the Zero Reference station. The instructions are based upon sample trigger logging and zig-zag traverses – if manual logging is being used refer to the comments at the end of the steps. Refer to figures 5-5, 5-6 and 5-7 when following the instructions.

1 Take the gradiometer to a start position about 1m outside the grid, in line with the first traverse direction.

2 Press Enable Log so the Logging Display is shown.

3 Set off walking at a constant pace and as the *sensor tube* passes over the edge of the grid press the Start/Stop switch. This will initiate sample trigger logging. Take great care not to tilt the instrument or change your body posture when pressing the switch.

4 Continue to walk at a constant pace, and if you are using guide lines ensure the 1m marker 'beeps' coincide with the 1m marks on the perpendicular guide line.

5 At the end of the line you should find that the *sensor tube* passes over the edge of the grid at the instant the last, longer 'beep' is sounded. If there is a significant discrepancy in terms of sample interval then consider deleting the line and resurveying it. Either change your walking speed or the trigger rate so that timing is improved.

6 For the next traverse, again position the gradiometer at a start position which should be about 1m outside the grid

7 Repeat steps 3 – 5 until the whole grid is surveyed.

8 If you have set the gradiometer up to log zero drift the message 'Log Zero Drift' will be displayed. If this message appears then:

- Go to the Zero Reference Station and press the Log key to record the drift – see pages 4-10 and 4-21 for details. The logging display will then show the normal G, L and P positions.
- Re-zero the gradiometer using the Zero key.
- Press the Enable Log key to restore the Logging Display; the next grid number will be shown and L and P will both be set to 1 ready for the next grid.

9 If the instrument is *not* set up to log zero drift the logging display will simply show the next grid number and L and P will both be set to 1 ready for the next grid.

10 At this point you can either start surveying the next grid or go to the Alignment and Balance / Zero Reference station to check sensor alignment or re-zero the instrument. If you do either of the latter procedures you will need to Press the Enable Log key to restore the Logging Display.

11 Carry on surveying the site using the same procedure, checking and readjusting alignment, balance and zero periodically. More than one survey session may be required to cover a site, depending on the size of site and memory limitations. Keep the gradiometer powered up between sessions to optimise stability.

12 Download the data to a computer, examine the results graphically and decide if the survey area needs extending or parts need resurveying.

13 Complete the survey.

If you are using manual logging then you will be using guide lines that have the reading positions marked on them instead of the 1m markers described in the previous section. For example, if collecting data at a 1m sample interval the guide line marks would be at 0.5m, 1.5m, 2.5m etc. The procedure described above should be modified to take into account that the operator, not the sample trigger system, controls the timing, and start position. The operator moves to the first reading position, logs the reading by pressing Log or the start/stop switch, and moves along the traverse logging a reading at each sample interval position according the sample interval chosen. Procedures for logging zero drift, checking alignment and re-zeroing remain the same.

Data Quality

Walking style can have a noticeable influence on the quality of the data. A good walking style will use the body as a stabilising system that maintains the gradiometer at a constant height above ground, keeps the sensor tube positioned vertically and in the same heading all the time. Additionally, you should ensure that the sensor tube is adjacent to guide marks at the instant the 1m marker 'beeps' are sounded. Poor walking styles, postures and timing errors can lead to a number of data defects such as traverse striping, banding, stagger errors and periodic errors – these are discussed further in Chapter 7, 'Trouble-shooting'. These errors can generally be corrected by using software process functions that are specifically tailored to tackle each problem – see Chapter 6 dealing with data processing. However, there are limitations to the extent to which these errors can be removed and you will always end up with better quality data if you try to avoid the errors in the first place.

It is a good idea to get an observer to provide feedback on how you can improve your walking style. Typical problems include: completing traverses at too fast a pace – running should be avoided, 'regimental' or 'bouncy' styles of walking, failure to keep the sensor tube vertical and at a constant height above ground. These and other sources of error are discussed in Chapter 7. Paying good attention to alignment and balance can also reduce data quality problems.

Dealing with Obstacles

The FM256 has special provision for dealing with situations where blocks of the survey area cannot be surveyed and which occur at the edge of a grid. The method used depends on the relationship between the traverse direction and the position of the obstacle in the grid. Example obstacles are shown in figures 5-8 to 5-13 which are 10 m grids with a sample interval of 0.5m and traverse interval of 1m. The left hand grids have zig-zag traverses and the right hand grids have parallel traverses.

Traverse Direction Perpendicular to Obstacle

In figures 5-8 and 5-9 the traverse lines run perpendicular to the obstacle. Although you must start surveying the first traverse by inserting individual dummy readings using the Dummy Log key, you can use the Finish Line and Image line keys on subsequent traverses, as you reach the obstacle, resulting in much faster dummy logging. Proceed as follows:

Figure 5-8 - Zig-zag traverses.

1. Calculate how many dummy readings are required to represent the obstacle (in this case 4 readings - 2m). Enter readings using the Dummy Log key. Check survey tracking position which should be at P=5 (Remember P= *next* reading position)
2. Move to the edge of the obstacle, just before the next true reading position. Press the Start/Stop switch and move off smoothly to continue the traverse.
3. On the 2nd traverse press the Start/Stop switch when you reach the obstacle to pause operation and check the survey tracking position – in the example P=17. Press the Finish Line key to insert dummy readings to represent the obstacle.
4. On the 3rd traverse you can start by using Image line key to reach survey tracking position, L=3, P=5, then move to the edge of the obstacle and press the Start/Stop switch to continue the traverse.

Complete surveying of the grid in this manner.

Figure 5-9 - Parallel traverses.

Dummy readings need to be entered at the beginning of each traverse using the Dummy Log key. Follow instructions as for figure 5-8 steps 1 and 2 for each traverse.

Traverse Direction Parallel with Obstacle

In figures 5-10 and 5-11 the traverse lines run parallel to the obstacle. You must complete the grid with dummy readings to ensure that grid statistics are properly calculated for processing results. This is easily done by pressing the Finish Line key as many times as necessary.

Figure 5-10 - Zig-zag traverses

Survey the grid as normal until the end of 8th traverse, point A (survey tracking position L=9, P=1). The obstacle prevents further surveying so dummy readings need to be inserted. As the whole of the 9th traverse requires dummy readings, press Finish Line. To complete the grid, press the Finish Line key for the 10th traverse. The grid is now complete.

Figure 5-11 – Parallel traverses

Survey the grid as normal until the end of the 8th traverse. The grid is then completed using Finish Line key as with figure 5-10.

Isolated Obstacle

In figures 5-12 and 5-13 the traverse lines run across a small obstacle that intrudes into the grid. There is no alternative but to calculate the number of dummy readings required at the point where the obstacle intrudes, ensuring correct position is maintained for true readings logged either side of the obstacle.

Figure 5-12 - Zig-zag traverses

1 Start the first traverse as normal. After the reading at B is logged press the Start/Stop switch to pause operation. Check the survey tracking position is correct – in the example L=1, P=9. Calculate the number of dummy readings to be inserted – in the example the obstacle covers 2m and needs 4 dummy readings logging as the sample interval is 0.5m. Press the Dummy log key to log the 4 readings. In the example survey tracking position should now read L=1, P=13.

2 Move to the edge of obstacle just before the next true reading (survey tracking position L=1, P=13). Press the start/stop switch and move off smoothly to continue the traverse.

3 Complete the second traverse in the same manner reversing the process. Continue then as normal to complete the grid.

Figure 5-13 - Parallel traverses

The first traverse is completed as in figure 5-12 and the second traverse is identical. Continue then as normal to complete the grid.

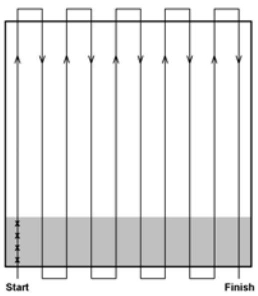


Figure 5-8

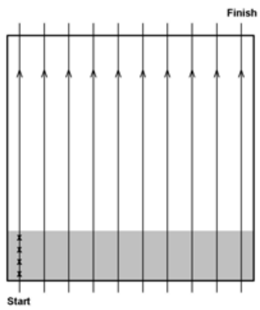


Figure 5-9

Traverse and Obstacle Perpendicular

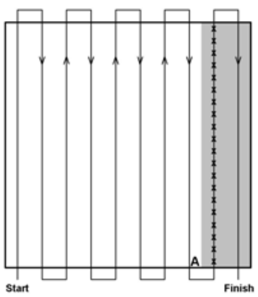


Figure 5-10

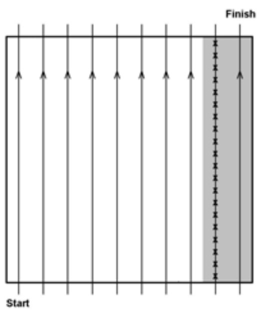


Figure 5-11

Traverse and Obstacle Parallel

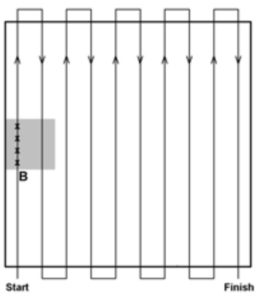


Figure 5-12

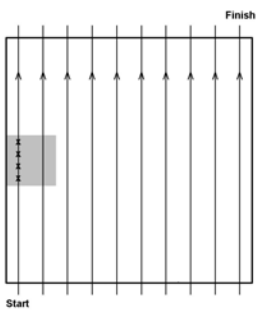


Figure 5-13

Isolated Obstacle

Dual Gradiometer Surveys

Introduction

The procedure for a Dual Gradiometer survey is very similar to that already described for the Single Gradiometer. It is recommended that you familiarise yourself first with the section dealing with Single Gradiometer surveys. The differences are highlighted in this section.

You should be fully aware of the information given in Chapter 4 about the operation of Dual Gradiometer Systems, see page 4-23 of Chapter 4. It is assumed you have already made choices with regards to mapping parameters, such as grid size, sample interval etc, which are discussed in the earlier section ‘Planning a Detailed Survey’.

Survey Guides

Dual gradiometer surveys use the same survey guide systems as single gradiometer surveys. The first system, using guide lines gives good positional accuracy as required for traverse intervals of less than 1m or for high sampling densities. Guide lines will generally be used for double and quad density surveys. The second system, using sighting pegs, gives minimal positional guidance but is ideal for fast and efficient evaluation surveys at 1m traverse intervals. Sighting pegs will generally be used for double speed surveys.

Survey Procedure

Figure 5-14 shows the survey patterns used in double speed, double density and quad density modes. The diagram in the bottom right hand corner shows the representation used for the two gradiometers, ‘a’ and ‘b’. Reading positions are shown as ‘x’; with the dual system two traverses are effectively made on each pass. There are guide markers for each survey mode at intervals along the CF6 carrying frame, see figure 2-3. The appropriate guide marker, shown as ‘O’ in figure 5-14, is lined up with the guide line at the start of each traverse pass. Survey procedure is straightforward and follows the instructions already given for single gradiometer surveys. Remember operations such as ‘Log Zero Drift’, zeroing etc should be applied to both gradiometers.

Double speed survey mode is shown in the top illustration of figure 5-14. One sighting peg is shown at 2m (see figure 5-7 for the complete pattern of pegs), and each pair of pegs is used as a guide for two traverses, one either side. Although shown as parallel traverses in figure 5-14, zig-zag traverses would normally be used for fastest coverage.

Double density survey mode is shown in the middle illustration of figure 5-14. Two guide lines are shown at 1m and 3m. Double density mode requires the first traverse pass to have the centre of the gradiometer array offset 25 cm from the guide line. Therefore the CF6 carrying frame guide marker, labelled ‘Double Density’, at 25cm needs to be lined up with the guide line before the first traverse pass is made. The second traverse pass is also offset 25 cm but this time the opposite 25cm marker on the CF6 will be used to line up with the guide line. You can see from the letter pattern above the figure the way in which a 2m strip of ground is covered by the gradiometers: aabb. Although shown as parallel traverses in figure 5-14, zig-zag traverses would normally be used for fastest coverage.

Quad density survey modeis shown in the bottom illustration of figure 5-14. Two guide lines are shown at 1m and 3m. Double density survey mode also requires the centre of the gradiometer array to be offset either side from the guide lines. In this case the offsets are 37.5 cm, 12.5cm, 12.5 cm and 37.5 cm for the four traverses making up one measurement set - you can see from the letter pattern above the figure the way in which a 2m strip of ground is covered: aaaabbbb. Guide markers, labelled ‘Quad Density’, on the CF6 carry frame provide the position of the 12.5 cm offsets whilst the positions of the rear legs provide the position of the 37.5 cm offsets. In order to maintain positional accuracy parallel traverses would normally be made.

Dual gradiometer surveys are carried out in a similar way to single gradiometer surveys so the procedure shown on page 5-13 should be followed with the following differences:

- You will need to press Enable Log on both instruments
- When reference is made to the Start/Stop switch this now refer to one of the Start/Stop switches on the carrying frame, not on the instrument.
- If you delete lines, add dummy readings etc this should be applied to both instruments.
- When downloading data ensure that the traverse interval setting in Geoplot, for both FM256 and FM18/36, is equal to the traverse interval setting on the master FM256 not the final merged traverse interval.
- If you are using an FM256 + FM18/36 in Double Speed or Quad Density mode, the survey tracking on the different gradiometers will not match, so take this into account when performing operations such as Delete Line etc. See figure 5-15.

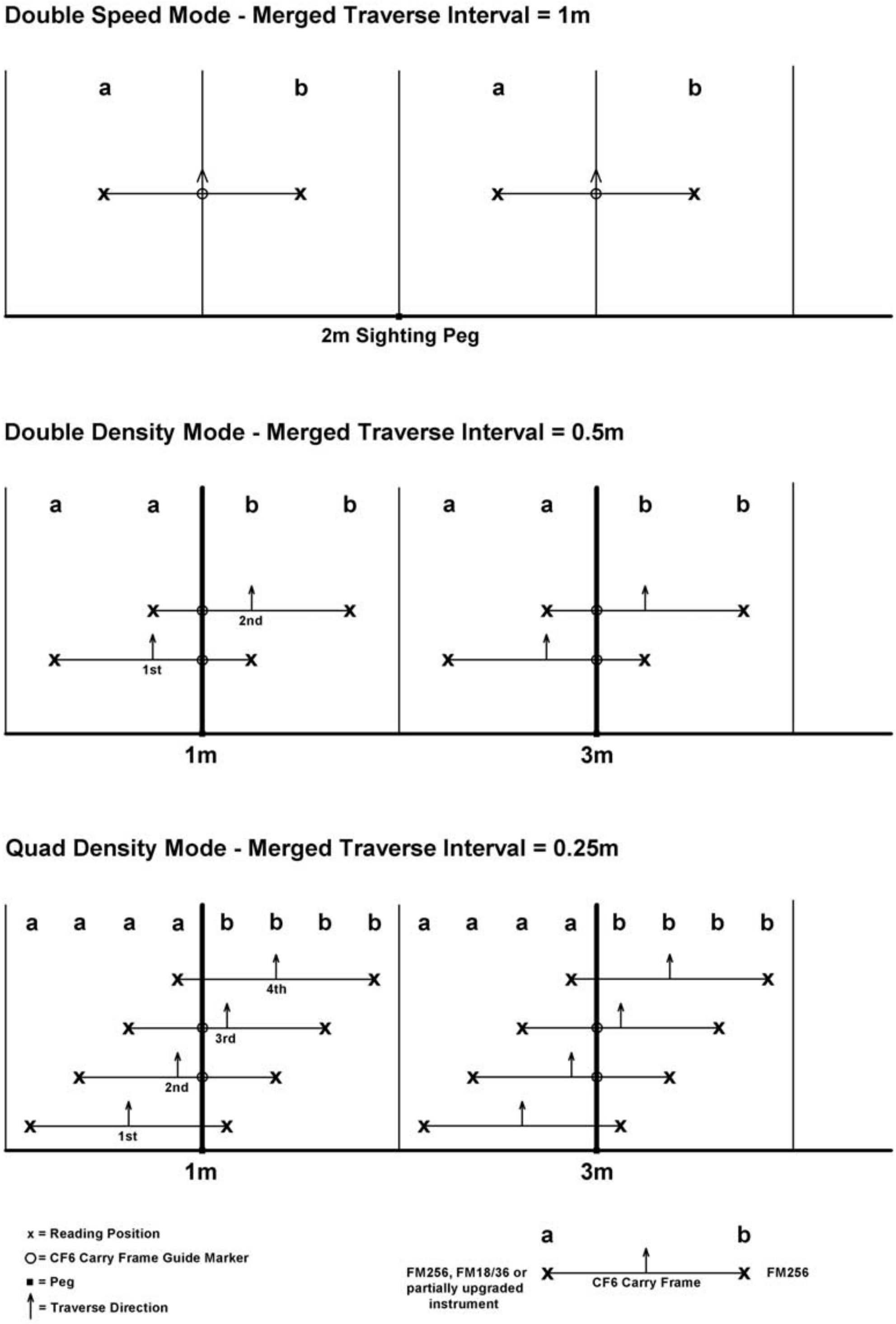


Figure 5-14. Survey patterns used in double speed, double density and quad density modes

The differences in survey tracking for FM18/36 and FM256 when surveying two grids with an FM256 + FM18/36 dual system are shown in Figure 5-15. Traverse interval is always 1m on an FM18/36. This means that the FM256 and FM18/36 tracking is compatible for double density surveys but not for double speed or quad density surveys – in double speed surveys one FM18/36 grid is logged for every two FM256 grids, in quad density surveys two FM18/36 grids are logged for every one FM256 grid.

Only numbers for grid and traverse, G and L, are shown in figure 5-15 not position, P, since this will match for both FM256 and FM18/36 instruments. The solid squares or rectangles represent complete counted grids in each instrument, but only the FM256 grid count represents the area that has been covered. Keep in mind these differences in survey tracking when comparing progress in each instrument and especially when using such key functions as Delete Line, Finish Line and Image Line. When downloading FM18/36 data use the FM256 grid count and traverse interval for setting up the download software.

If you are using a double FM256 system then there are no such complications with regard to tracking.

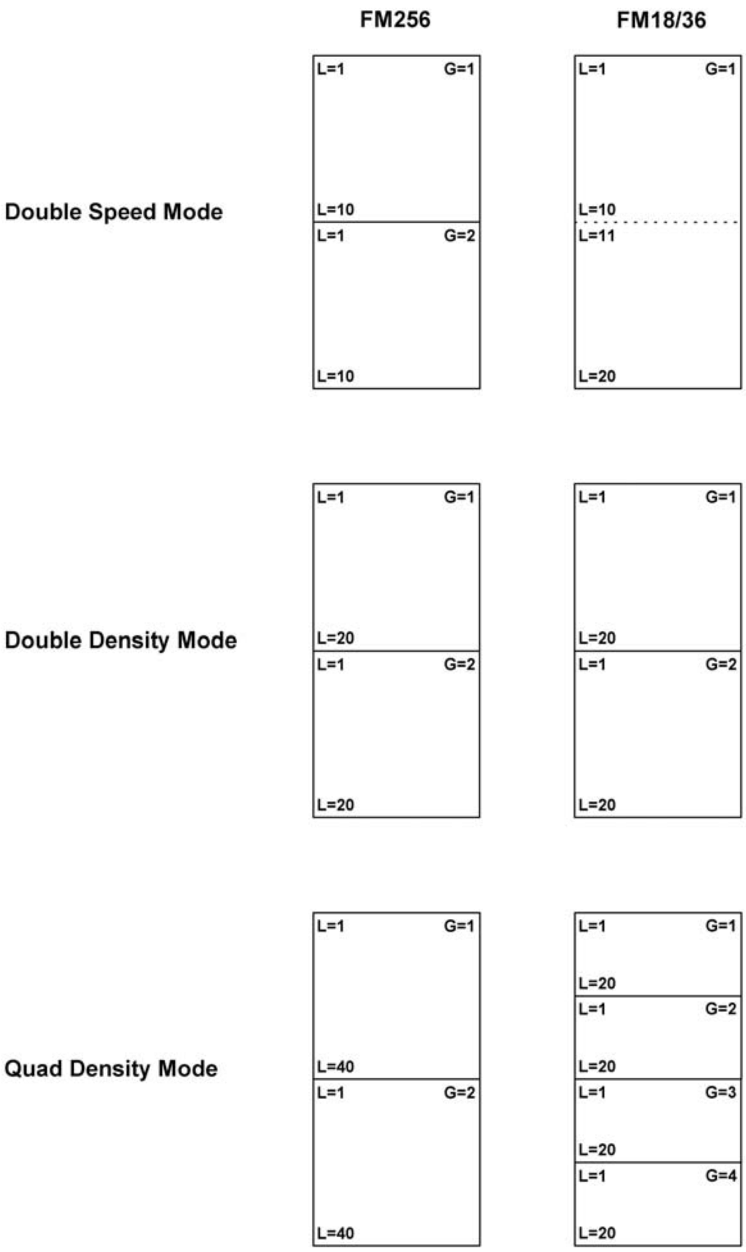


Figure 5-15. Comparison of FM18/36 and FM256 survey tracking in an FM256 + FM18/36 dual gradiometer system.

Dealing with Obstacles

Obstacles in a dual gradiometer survey are dealt with in exactly the same way as for single gradiometer surveys, page 5-14, except that you must use Finish Line, Image Line and Dummy Log on both instruments.

Chapter 6

DATA HANDLING

Introduction

This chapter provides brief guidance on data output to a computer, describes merging of dual gradiometer data sets and provides guidelines on how to process gradiometer data. Detailed examples of processing single and dual gradiometer data sets are provided, along with an introduction to statistical analysis. This chapter is based on use of Geoplot 3 software but other software can be used.

Data Transfer to a Computer

Detailed instructions on how to download, or dump, logged data to a computer are given in Chapter 4, ‘Operating Instructions’, page 4-7 and 4-26. Full details of the dumping sequence used in Geoplot 3, is given in the instruction manual for Geoplot in Chapter 4, ‘Data Input’. Those instructions apply to both single and dual FM256 surveys. This section provides a brief reminder of Geoplot 3 ‘Input Template’ settings for the FM256, and discusses file naming conventions and traverse interval settings used for dual gradiometer surveys.

Figure 6-1 shows the default Input Template for an FM256 in Geoplot 3.

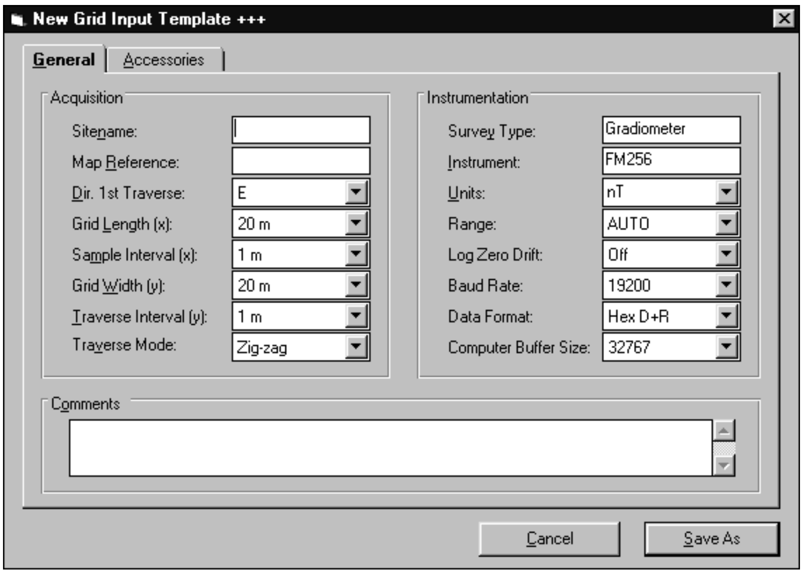


Figure 6-1. FM256 Grid Input Template.

Input Template – Acquisition Details

In the ‘Acquisition’ section enter Sitename, Map Reference, Dir. 1st Traverse, Grid Length, Sample Interval, Grid Width and Traverse Mode as usual. If setting up the template for a single gradiometer survey, enter the Traverse Interval you are using. If setting up the template for a dual gradiometer survey make sure you enter the correct Traverse Interval Setting as shown in Table 6-1 – note that you cannot use Traverse Interval settings greater than 2m or less than 0.5m. *You MUST make sure you enter the Traverse Interval Setting and not the final Merged Traverse Interval.* Geoplot 3 uses the traverse interval to decide which dual gradiometer mode has been used and merges the two data sets accordingly.

Mode	Traverse Intv. Setting	Merged Traverse Intv.	Survey Pattern
Double speed	2 m	1 m	ab
Double density	1 m	0.5 m	aabb
Quad density	0.5 m	0.25 m	aaaabbbb

Table 6-1. Traverse Interval settings for different dual gradiometer modes.

If you using an FM36 as part of a dual system, acquisition details will be identical to that of the FM256, but the instrumentation details for theFM36 will be different.

Input Template – Instrumentation Details

In the ‘Instrumentation’ section Units will automatically be set to nT. Leave Range set to AUTO since the software will interpret the correct range from the data input. Normally the fastest baud rate of 19200 will be used. Leave Computer Buffer Size set to the maximum value. I*t is extremely important that the instrument settings and the software settings match. If the settings for Log Zero Drift do not match the data will be stored incorrectly and you may not be able to unscramble it. It is also essential that the settings match for Data Format status so that the data stream is properly interpreted. In the latter case, if the settings do not match, the downloaded data may be unrecoverable.*

File Naming Convention for Dual Gradiometer Data

In a dual gradiometer survey two separate grid data sets will be collected for each grid surveyed, one for each gradiometer. Usually this data will be stored under the same sitename for convenience. You can differentiate between these grids using, for example names such as 1a, 2a, 3a etc (slave data) and 1b, 2b, 3b etc (master data). These will eventually be merged to form the final grids 1, 2, 3 etc, though this will be done at the composite stage – see the next sections. *It is vitally important to download and save the data from each instrument with names that indicate and preserve their relative positions in the dual configuration otherwise the data will not be merged correctly. The file name suffixes play an important part in merging the data sets as will be seen later.*

Outline Procedure for Merging Dual Gradiometer Data

An outline of the sequence of steps involved in merging dual gradiometer data is listed below. Steps 1, 4 and 5 are discussed in more detail in the sections following.

1 Download the two separate data sets, one from each gradiometer, using identifying file name suffixes as discussed above.

2 Create a master grid for each data set (a master grid just defines how individual grids of data fit adjacent to one another, it does not contain data).

3 Create a composite for each data set using the two master grids (a composite is a data file that contains all grid data arranged in the correct location with respect to one another).

4 Pre-process each composite. This will usually just consist of using the Zero Mean Grid process function to normalise the level of the background readings to zero. Other steps may be required in some cases:

- Remove slope in grid data using Deslope
- Remove periodic errors using Spectrum and Periodic Filter
- Match noise characteristics of gradiometers using Random

5 Merge the pre-processed composites to form one final composite.

Merging Dual Gradiometer Data

Introduction

Full details for merging dual gradiometer data is given in the instruction manual for Geoplot 3 in Chapter 6, ‘Data Processing’. This section replicates that information for users who do not have access to the Geoplot 3 manual. There is a further example of merging dual gradiometer data given later in this chapter, as well as the example discussed below.

When merging data Geoplot uses the suffix at the end of a composite name to identify slave and master data sets. By convention the data set ending in ‘a’ is the slave gradiometer data and that ending in ‘b’ is the master gradiometer data. This corresponds with the positions of the gradiometers on the carrying frame, figure 2-3.

As outlined above, the grid data from each instrument is first downloaded using file names such as ‘1a’, ‘2a’, ‘3a’ etc for the slave gradiometer data and ‘1b’, ‘2b’, ‘3b’ etc for the master gradiometer data. A Master Grid is then created for each data set – these might called ‘ma’ and ‘mb’ to identify slave and master data. A composite is then created for each data set – likewise these might called ‘ma’ and ‘mb’ to identify slave and master data. The Merge Composites facility on the File menu can then be used to merge the two data sets into one final composite – see figure 6-2 for the Merge Composites form.

Before the two composites are merged however, they may require some processing to make them match properly. This may include: (a) shifting the background level of one data set relative to the other, caused by any slight remanent magnetisation of the carrying frame or different instrument zero points, (b) application of Deslope to correct for drift within the grids within the data sets and (c) adding some random noise to one data set to enhance visual matching (usually not required). In addition, if periodic errors are present these may be different for each instrument so you should then consider using Spectrum and Periodic Filter before merging data sets; this avoids the unnecessary introduction of artifacts at a particular frequency into a data set had no problem. The data is usually clipped as a matter of routine.

Step (a) is usually achieved using either Zero Mean Grid to quickly and easily match the background levels. However, if there are extended high magnitude ferrous responses, individual grid background levels may not match, even when the Zero Mean Grid Threshold is adjusted. In this case the Add function can be used to bias individual grid pairs – see the next section, ‘Dealing with Difficult Merging of Composites’ for details. Usually Step (b) is not required since the Zero Mean Traverse function will be applied to the merged data at a later stage and this will automatically remove slope errors. Once data is successfully merged follow the steps discussed in the next section, ‘Guidelines for Processing Gradiometer Data’.

Example Merge

Figures 6-3 and 6-4 show two gradiometer composites collected using the dual carrying system operated in Double Density mode, prior to merging. Data set ‘a’ was collected with an FM36 acting as a slave whilst data set ‘b’ was collected with an FM256 acting as a master to the FM36; zig-zag traverses were used. Sample interval was 0.25m and traverse interval was 1m for both instruments. The resultant traverse interval after merging becomes 0.5m.

There is no slope in the data and no signs of periodic error (confirmed using Geoplot’s Spectrum process function). In order to estimate any random noise that might need adding, either compare the noise characteristics of the two instruments prior to surveying in the lab or select the same quiet area in each composite and compare standard deviations. Adopting the latter route here, and selecting a rectangle of 28 x 6 readings in the bottom left hand corner which was clear of iron responses, gave standard deviations of 0.59 and 0.58 indicating no need to add any noise. This is in agreement with the known noise characteristics of the two instruments. If noise needs to be added, use Geoplot 3’s Random process function. In general, routine final processing applied to the merged data, i.e. low pass filtering and interpolation, will remove any need to match noise characteristics closely.

A comparison of the images of figures 6-3 and 6-4 indicates that a bias needs to be added before the data sets are merged. The Complete Statistics forms also indicate this but since iron spikes are present these will distort the statistics; standard clipping of the data at +/-3 SD still gives different background means: 0.23 nT for ‘a’ and –1.63, confirming a bias is still required. The simplest approach for preparing the data is to use Zero Mean Grid and this is used in our example, saving the composites as ‘acya’ and ‘bcyb’ to comply with the suffix requirements of the Merge facility. If edge matching is not correct adjust the Zero Mean Grid Threshold until matching is correct. If Add is used to prepare the data then the data is clipped at +/-5nT to reject the effect of iron spikes and the mean is noted. In the data sets in our example, the resulting means are –0.3094 for ‘a’ and –1.5836 for ‘b’ and these are subtracted from each standard clipped data set respectively before saving as ‘aa’ and bb’.

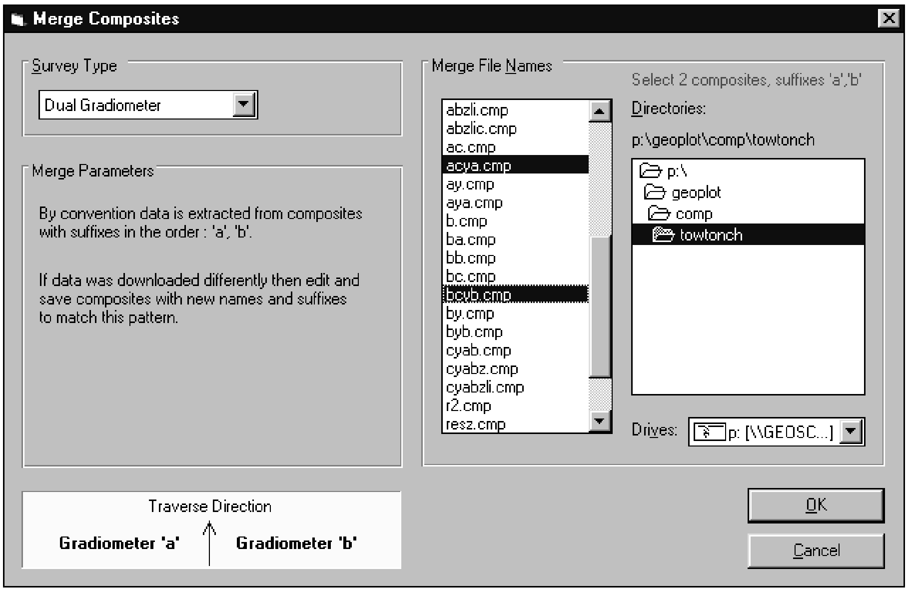


Figure 6-2. Merge Composites form showing composites ‘acya’ and ‘bcyb’ selected.

When no further processing is required choose ‘Merge Composites’ on the File menu to combine the two data sets into one final composite. Figure 6-2 shows the Merge form and the selections that would be made to merge these two particular data sets. The graphic in the bottom left hand corner of the Merge form reminds you of the two gradiometer positions whilst the instructions in the top right hand corner remind you of the two files to select – they *must* have suffixes of ‘a’ and ‘b’.

Figure 6-5 shows the two data sets ‘acya’ and ‘bcyb’ merged to form composite ‘cyab’. Further processing includes application of Zero Mean Traverse (with thresholds of +/-5nT) to remove the slight banding in the right hand grid, figure 6-6. Use of Spectrum still shows no periodic error and there is no need to Destagger the data. Final processing is a small amount of low pass filtering (X=2, Y=1) and a single interpolation in the Y direction to produce the final plot of figure 6-7 which has sample and traverse intervals of 0.25m.

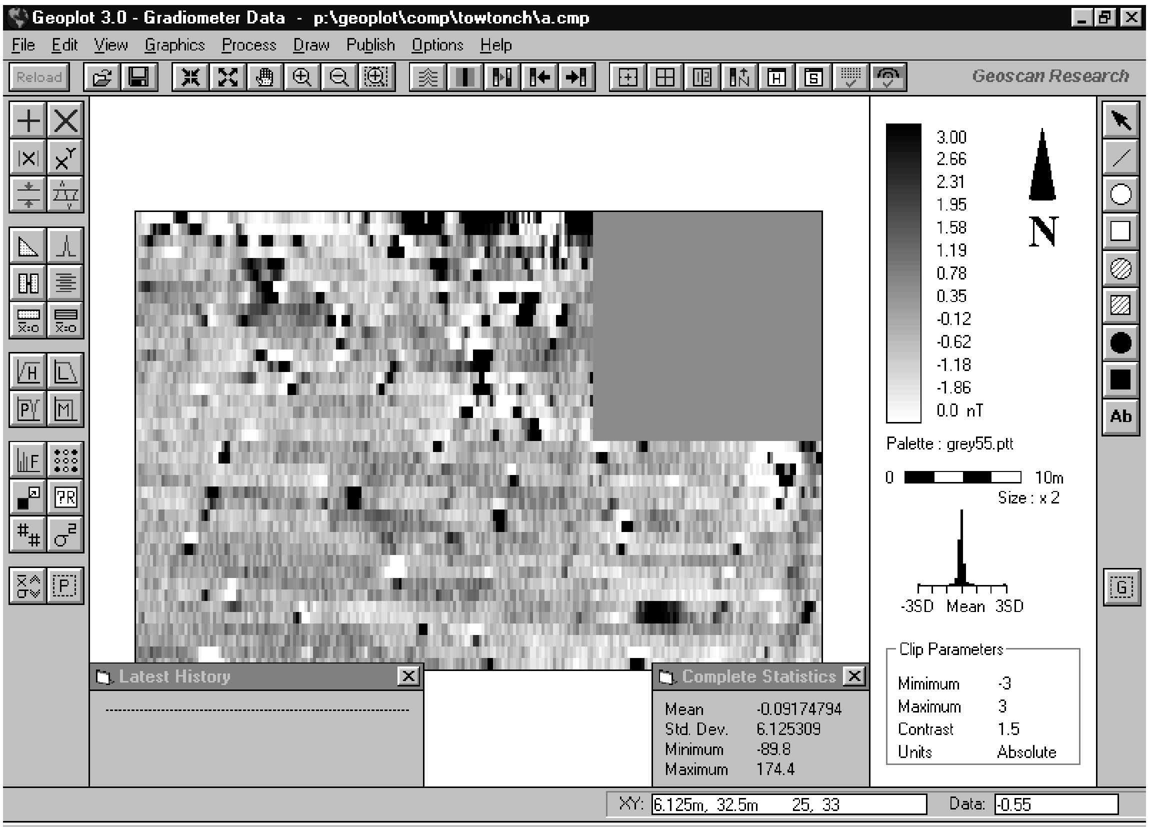


Figure 6-3. Data set ‘a’, half of a dual gradiometer data set, prior to merging with data set ‘b’.

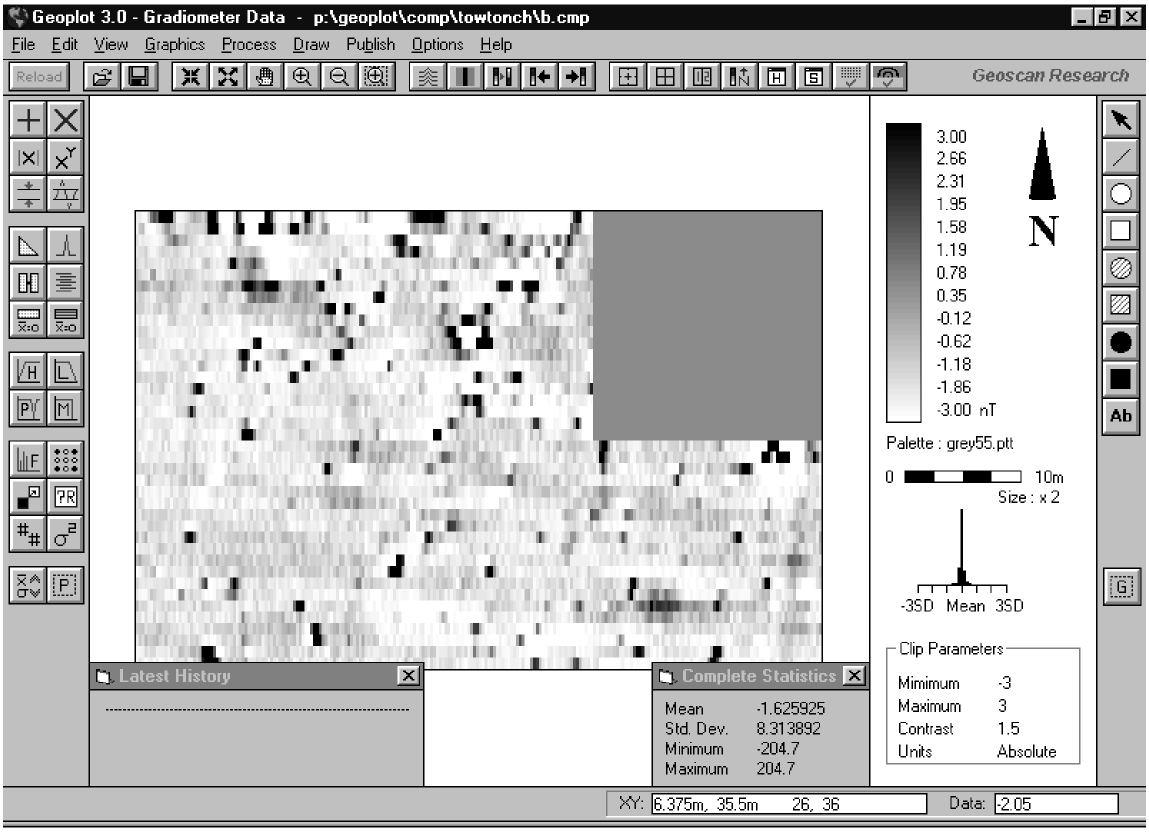


Figure 6-4. Data set ‘b’, half of a dual gradiometer data set, prior to merging with data set ‘a’.

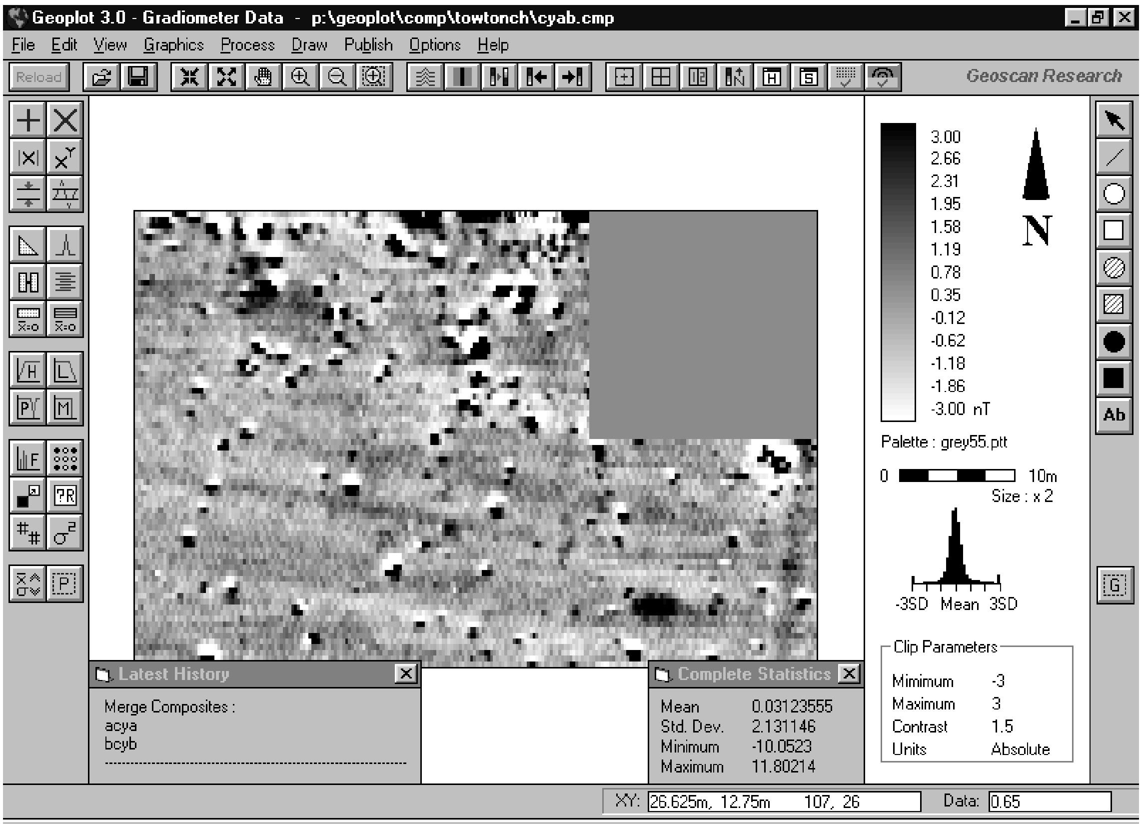


Figure 6-5. Data sets ‘acya’ and ‘bcyb’ merged.

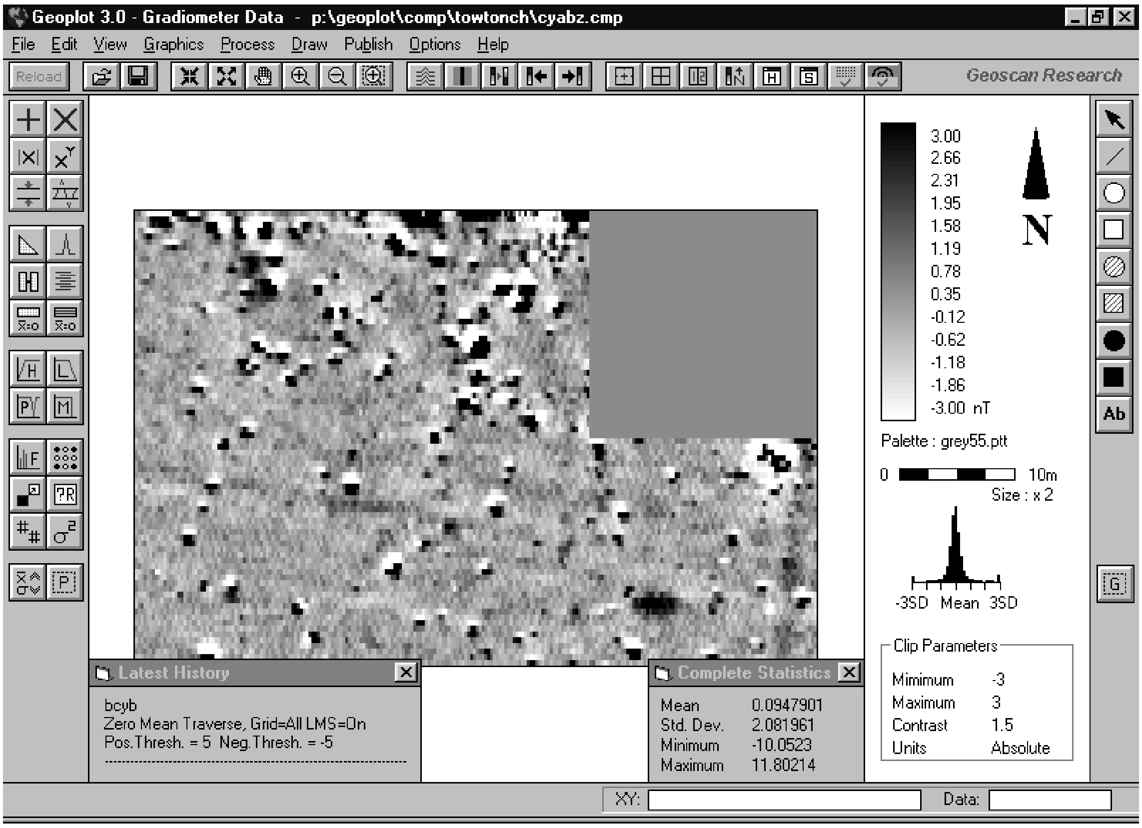


Figure 6-6. Application of Zero Mean Traverse to remove slight banding present in figure 6-5.

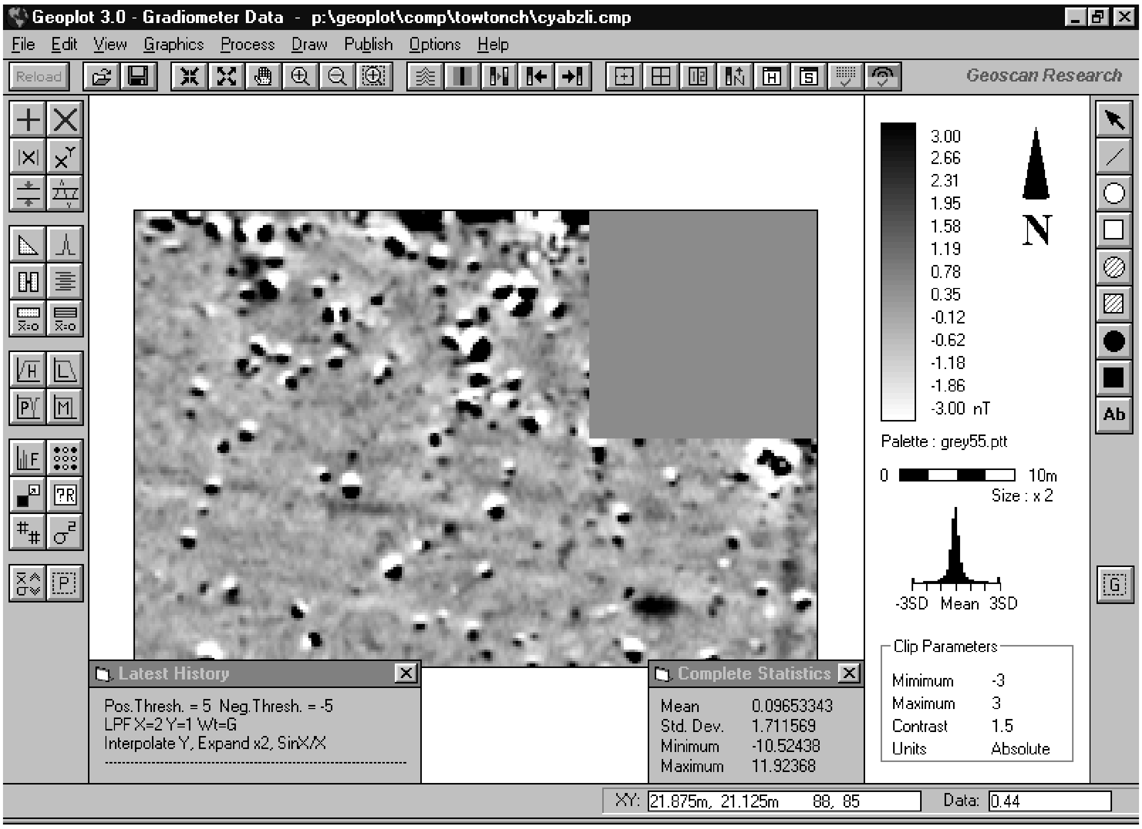
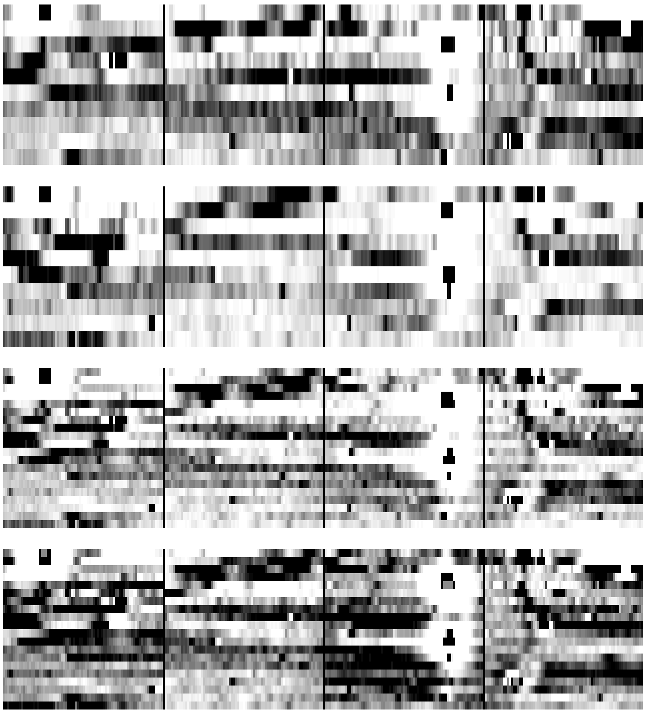


Figure 6-7. Final processing stages with application of Low Pass Filter (X=2, Y=1) and Interpolate x2 in the Y direction, resulting in a sample and traverse interval of 0.25m.

Difficulties in Merging of Composites

As we noted in the previous section, if there are extended high magnitude ferrous responses, individual grid background levels may not match, even when the Zero Mean Grid threshold is varied. To work around this problem some grid pairs must have bias added on an individual basis using the Add function. These are then pasted onto the main merged composite. Figure 6-8 illustrates the problem. This is part of a much larger dual gradiometer survey over a Roman Fort, the majority of which was merged successfully using just Zero Mean Grid. However this particular section was surveyed over the edge of the ramparts and ditches where the ground slope was nearly 45 degrees in places. This made carrying the system difficult and has resulted in background zero errors. Some large magnitude ferrous responses compound the problems making merging of the grids difficult.



Data set ‘a’, of dual gradiometer data set

Data set ‘b’, of dual gradiometer data set

Data sets ‘a’ and ‘b’ merged

Data sets ‘a’ and ‘b’ merged after first using Zero Mean Grid for each composite.

Figure 6-8. Group of four 20m square grids illustrating the problems sometimes encountered when trying to merge composites that were surveyed in difficult conditions. Sample interval is 0.25m and merged traverse interval is 1m. Plotting range is –5nT to +5nT.

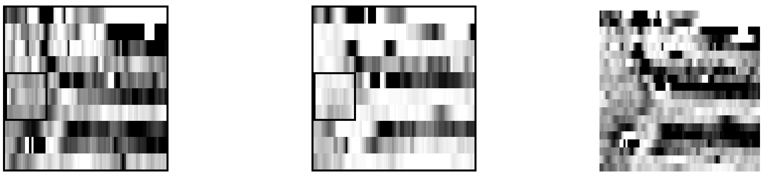
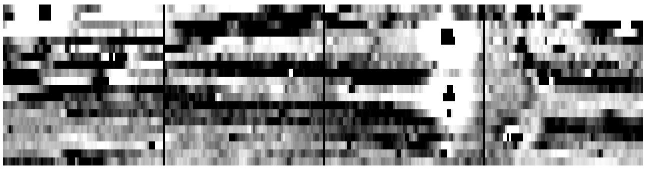


Figure 6-9. The first two plots show the ‘a’ and ‘b’ parts of the end grid of figure 6-146. The right hand plot shows the resulting merged composite after shifting each composite according to the mean value in the process areas shown. Plotting range is –5nT to +5nT.

The bottom two plots of figure 6-8 show signs of mismatch striping that could normally be removed using Zero Mean Traverse, especially on the right hand side. However, in this situation Zero Mean Traverse removes the ditch responses, even using the thresholding facility, so an alternative means of matching the grids prior to merge is required. This is done by converting the ‘a’ and ‘b’ parts of each grid into individual composites and then measuring the mean of a quiet area in each composite using the Statistics function. A number equal in value to the mean, but opposite in sign, is then added to the whole of each composite to shift its background level to zero. Figure 6-9 shows, in order, the ‘a’ and ‘b’ parts of the end grid of the group of four (converted into composites), followed by the resulting merged composite after each part has been shifted by the mean value. In this case 'a' was shifted by +0.36nT and 'b' by +2.56nT. The matching is now much better with the striping effect no longer apparent.

Figure 6-10 (bottom plot) shows the results of applying the same process to each grid in turn and pasting them all together using Cut and Combine. For comparison, the usual approach of using Zero Mean Grid is shown in the upper plot of figure 6-10 – processing grids individually in this case greatly improves the resulting merged composite. Figure 6-11 shows the same data after final processing with Low Pass Filter and Interpolate.

Merge using Zero Mean Grid



Merge using statistics of quiet areas

Figure 6-10. Comparison of (a) merged composites after biasing individual grids by the mean of selected quiet areas (top plot), with (b) merged composites using normal Zero Mean Grid.

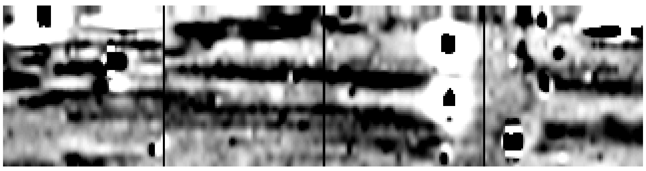


Figure 6-11. Final processing stages with application of Low Pass Filter (X=2, Y=1) and Interpolate x2 in the Y direction, resulting in a sample and traverse interval of 0.25m.

Guidelines for Processing Gradiometer Data

Introduction

These guidelines are primarily written for processing large area gradiometer surveys using Geoplot 3 – see Appendix B for a description of the process functions available in Geoplot 3. If you use other software you should aim to adopt a similar approach in order to optimise data quality. The following information is extracted from the Geoplot 3 instruction manual – please refer to that manual for in-depth discussions and applications of individual process functions.

Processing Sequence

A typical processing sequence would be to initially display and review the data, clip the data, identify and neutralise the effect of major geological and ferrous responses if they are a potential problem, remove data collection defects, and finally enhance and present the archaeological response. Initial clipping is to reduce the effect of iron spikes. Neutralisation of the effect of major geological and ferrous responses involves replacement with dummy readings, where necessary, though in many cases the process functions are able to handle these situations without replacement. Defect removal includes: (a) removal of grid slope, (b) edge matching, (c) removal of traverse stripe effects, and (d) removal of traverse stagger effects, (e) removal of periodic errors. Enhancement and presentation includes: (a) removal of iron spikes (b) smoothing, (c) interpolation, (d) separation of positive and negative features, (e) variability plots, (f) use of compression to optimise graphics plots. Statistical analysis can also be applied and an example of this is discussed later in this chapter. The order of processing can be very important for some functions - for example you should despike before applying a low pass filter, to avoid the spike energy smearing out.

Initial Data Display and Review

Before starting any process session you should look at the data using the Graphics menu. Shade plots (Clip parameters) and Trace plots are the best way to view the raw data. Since gradiometer data is bipolar, centred around zero, it is best to use absolute plotting parameters, say Clip plotting parameters of Minimum=-10nT, Maximum=+10nT initially, and Trace resolution of 1nT initially. This is because surface iron can significantly distort the standard deviation of a composite and hence, if you used standard deviation parameters, you would get a distorted initial view of the data, showing the ferrous response rather than the archaeology. Examine the plots for archaeological features, ferrous objects, geological features and data collection defects.

The archaeological features may show up strongly or weakly, depending on the depth, size and contrast of the features with respect to the surroundings. Generally speaking, they tend to be weaker than the ferrous response that can predominate on some sites, especially in an urban environment. If the survey is over a quiet site, with few apparent features, then you should try much smaller Clip plotting parameters, say Minimum=-2nT, Maximum=+2nT to see if there are any very low level features present - some weak, but archaeologically significant, features may have strengths of under 1nT.

Ferrous objects are usually unwanted modern iron features that are deemed to be archaeologically uninteresting (although occasionally there may be ferrous responses of archaeological interest). These objects may be scattered randomly throughout the site, often near the surface, have a strong response, often bipolar (depending on the sample interval used), and are very localized. We refer to these as "iron spikes". Some iron dumps may show up as broad regions of very strong positive or negative response, surrounded by a region with strong response of opposite polarity (as opposed to kilns which have a more characteristic response). Modern ferrous pipelines usually show up as strong regular alternating patterns of positive and negative regions, distributed along the length of the pipeline, although they can also show up as strong, linear, single polarity, responses. Wire fences at the boundary of a survey often give a strong response.

Geological features are often more difficult to positively identify. Since gradiometers inherently perform their own high pass filter they will already have reduced the broad scale geological response (and, incidentally, any broad scale archaeological response such as that due to an extensive midden). The high pass filtering action may not, however, have reduced any response to local changes in topsoil thickness, natural depressions in the subsoil etc which can produce anomalies similar to those produced by archaeological pits. Nor will this action have removed the strong response due to large linear regions such as igneous dykes.

There are several data collection defects that can arise in a fluxgate gradiometer survey. These include: slope in the grid data, discontinuities at the edges of grids, traverse striping, traverse staggering and periodic errors.

Slope errors in grid data show as a very small and slow drift in the average data value throughout a grid, leading to a small difference in the background levels between the first and last traverses. However, it is essentially constant during the time required to scan an individual traverse.

Grid edge discontinuities arise due to improper choice of the zero reference point, incorrect zeroing at the reference point, or failure to regularly check alignment and re-zero the instrument every few grids.

Traverse striping is where alternate traverses have a slightly different background level. They show up in graphics plots as a series of stripes orientated in the traverse direction, and are especially noticeable if the plotting parameters are set to look at very weak features. They occur because lf instrument tilt, usually due to improper alignment, failure to check alignment regularly or inattention of the operator to carrying angle. It can be particularly noticeable with zig-zag traverses.

Stagger defects arise due to poor positioning of the instrument along the traverse when a reading was recorded. For example, a linear anomaly running perpendicular to the traverse direction shows, not as a clean linear response, but as a chevron type pattern, with the maximum of the response being displaced first forward and then backwards in each alternate traverse. It usually occurs when zig-zag traverses are being used at a rapid walking pace and small sample interval.

Periodic errors (periodic modulation of the data) show up as a series of linear bands, *perpendicular* to the traverse direction, with a periodicity usually approximately equal to one or two walking paces (1 c/m or 0.5 c/m). They usually arise because the operator changes his stance or elevation slightly whenever the left or right foot is placed on the ground, or when launching forward for the next pace. It is more likely to be a problem if the speed of walking is high, the ground has a higher than normal magnetic susceptibility, the terrain is uneven e.g. ploughed, the alignment of the gradiometer sensors is not checked often enough or done over a poor alignment and balance station, or any combination of these factors. It is also more likely to be noticeable if you are setting plotting parameters to look at very weak responses.

Clipping of Iron Spikes

It is useful to clip noise spikes prior to any further processing. This will make the statistical calculations of some other process functions less liable to be compromised by wild data values. It is further useful because it reduces the demands on the limited dynamic range of the display devices.

Depending on the data set, you could initially consider clipping at +/- 3 standard deviations (SD) about the mean - you can obtain a value for 1 SD using the Statistics function or, for saved data, look at the histogram and statistics in the Graphics dialog screen, which gives a value for 3 SD already calculated. However, it is very important that you subsequently check that the chosen clipping level has not clipped features of interest - this can often happen on sites with low standard deviation. You can check the effect of clipping, either by careful inspection of the graphics plots (shade colour plots especially), or by using Cut and Combine to examine the clipped data. If clipping is removing data then consider clipping instead at +/- 4SD about the mean, or higher if necessary. You may even wish to clip at standard levels, e.g. +/-10 nT about the mean, but this depends on the features of interest. For example to preserve kiln responses you may have to clip at levels greater than +/-100 nT about the mean.

Note that after using Clip, noise spikes will still remain in the data, though at a reduced and controlled magnitude. However, it is best not to consider using the Despike function until much later. In any case, the process functions that might be used next, Zero Mean Grid, Zero Mean Traverse, Spectrum and Periodic Filter, will not be affected by the presence of these spikes, since they have their own internal mechanisms for dealing with spikes. The only process function that may be affected, Deslope, can have its parameters set manually so again noise spikes can be present and still accounted for. Destagger has its parameters set manually also and will be unaffected.

Neutralisation of Major Responses.

Major anomalies such as pipelines, ferrous dumps, wire fences and igneous dykes can occasionally cause problems with some of the subsequent process functions such as Spectrum, Periodic Defect, Zero Mean Grid, and Zero Mean Traverse. The net effect may be that the functions make the graphics plot far worse than if they were not used. The problem becomes noticeable as the sphere of influence of the major anomaly becomes comparable with the grid dimensions. This leaves the process functions with very few, possibly no, data points with which to calculate the true background. Simply clipping the data will not help.

To see if there will be a problem you should try each of the above processes in turn (having first saved any previous processes). If the anomaly is not too wide (for example less than half a grid wide) then the functions will probably work correctly. If it is wider than this and the functions cannot cope then you should adjust the threshold value in Zero Mean Grid and set ‘Apply Threshold’ to ‘On’ in the other functions that should allow the functions to operate correctly. Should the response still be very disruptive you can reduce the problem by replacing the major anomaly with dummy readings using the Search and Replace function. Be sure to restrict Search and Replace to just the areas in the immediate vicinity of the major anomaly, by using the block facility.

Defect Removal - Slope Errors

If required, the Deslope function can be used to remove small linear trends with grid data. Remember, though, that if you plan to subsequently use the Zero Mean Traverse function (see next section), and any slope is in the Y direction, then there may be no need to use the Deslope function itself. The Zero Mean Traverse function will automatically perform any slope correction for you in each grid. However, there are times when you would not want to use the Zero Mean Traverse function (for example, if it removes linear features in the traverse direction). Also, if the slope is in the X direction then Zero Mean Traverse cannot help in this regard. In such situations you will have no alternative but to use the Deslope function if there are slope errors. Often, though, you will find there is no need to apply any slope correction.

Defect Removal - Edge Match

The principle method of removing grid edge discontinuities is to use the Zero Mean Grid function. Initially use the default settings for the Threshold and ensure that you have applied Deslope first, if necessary, to individual grids. Zero Mean Grid will simply shift each grid up or down with respect to zero, hence producing minimal distortion to the data. If grids are not edge matched using the default Threshold value then increase the value a step at a time until better matching is achieved – this may not be totally possible in grids where there is an extensive ferrous response. Also, if there is a non-linear slope within grids, which Deslope is unable to completely correct for, then you may still observe edge discontinuities even after use of Zero Mean Grid.

To overcome these last two problems you could consider using the Zero Mean Traverse function, providing traverses are in the X direction. This function will perform a very effective edge match (as well as removing stripe effects - see next section). However, Zero Mean Traverse does have a tendency to remove linear features in the traverse direction unless ‘Apply Thresholds’ is activated. For this reason it is perhaps best to consider Zero Mean Grid as a first method of correcting edge match problems, and if that fails consider using Zero Mean Traverse, though you must then examine the results carefully for signs of feature removal or distortion.

In general you should apply Zero Mean Grid to match grids prior to merging dual gradiometer data as we have just seen in the earlier section, ‘Merging Dual Gradiometer Data’.

Defect Removal - Traverse Stripe Errors

The Zero Mean Traverse function can be used to remove stripe effects within grids. It can also correct for any slope or drift along a traverse if the Least Mean Square Fit parameter is set to On, the default setting. As an additional benefit it will also automatically edge match grids. Try using Zero Mean Traverse with Least Mean Square Fit set to ‘Off’ if the site is noisy or results are unsatisfactory. As noted earlier, major anomalies such as pipelines, ferrous dumps, wire boundary fences and igneous dykes can occasionally cause problems, so either activate ‘Apply Thresholds’ and vary the levels or neutralise the source using dummy readings prior to application of Zero Mean Traverse.

Remember that Zero Mean Traverse tends to remove linear features in the traverse direction unless you activate ‘Apply Thresholds’ so you must examine the results carefully for such signs and vary the threshold values accordingly. If this is apparent, even using thresholds then it is sometimes feasible to correct for this by using the Cut and Combine function to temporarily store linear features before using Zero Mean Traverse and then restore them afterwards.

Defect Removal - Stagger Errors

Stagger defects can be corrected for by using the Destagger function. You will probably find that different parts of the survey require different degrees of stagger correction and so the function is applied on a grid by grid basis.

Defect Removal - Periodic Errors

Periodic defects are removed by using a combination of the Spectrum and Periodic Filter functions. Spectrum is first used to identify the frequency of the offending periodic error and this information is then used by the Periodic Filter function to adjust the offending spectral components in each traverse, generating a new filtered data set with any periodicity removed. An internal, non-linear, filter caters for spurious effects associated with large dynamic range spikes (e.g. modern iron) if they are also present. If extensive ferrous responses are present then set ‘Apply Thresholds’ to ‘On’ in both Spectrum and Periodic Filter to allow these responses to be catered for. If periodic errors are low level, say < 1nT, then it is normal to remove these at this point in the processing sequence. If, unusually, the periodic errors are significant, say > 5nT, then they may require removing fairly early on in the process sequence otherwise they could distort any estimation of the normal background level by functions such as Zero Mean Grid or Zero Mean Traverse.

Removal of Modern Iron Spikes

Modern surface and near surface iron objects are often found, scattered randomly over archaeological sites. Their presence can clutter the survey results and make interpretation difficult, sometimes impossible. It is possible to minimize these features with the application of the Despike function, and possible additional use of the Clip function.

The data will already have been clipped. However, it may be useful to perform a further clip prior to use of the Despike function. Examine the data set using a Trace plot and note the maximum data values (both positive and negative) associated with the archaeology of interest. Clip the data with the Minimum and Maximum Clip parameters set equal to these positive and negative data values. Check that the archaeological features are still present after clipping.

After using Clip, noise spikes will still remain in the data and can be removed using the Despike function as follows. In general, it is advisable to start with a symmetrical, square window with radii X=Y, Threshold set to the maximum value of 3 standard deviations (SD), and Spike Replacement set to Mean. Remember that the window radius is expressed in units of readings, not metres, and that the actual diameter of a processing window is equal to (2 x radius + 1) readings.

With these settings a window of X=Y=3 will apply moderate despiking. Decreasing X and Y to X=Y=1 will substantially increase the despiking effect. Decreasing the window size to increase the amount of despiking is preferable to decreasing the Threshold since lower Threshold values (2 SD and below) can start to remove features as well. A combination of larger window sizes and lower Threshold values also can be prone to removing features as well as noise spikes. Whichever parameter values you try you are strongly advised to save the despiked data then use the Cut and Combine (subtract) function to examine the effect of the despike operation - if you can see traces of features present in the difference plot then you should reduce the despiking.

Asymmetric window sizes (e.g. Y=0, X=4) may be useful if the spatial distribution of iron spikes is predominately in the X or Y direction. However, use such windows with great caution since they will tend to remove features perpendicular to the length of the window, even with a high Threshold value. It is especially important to use Cut and Combine afterwards to examine the effect of despike for asymmetric windows.

If you Despike gradiometer data then it is very important that you remember the Despike function will only remove the large positive or negative readings and may leave behind associated, encircling low level negative or positive readings. You should take great care not to forget the origin of such areas when subsequently interpreting the processed data - it is all too easy for ‘pits’ to appear in this way. This is one very good reason why you might like to leave despiking of gradiometer until this late stage in the process sequence.

Remember also that, whilst Despike can remove most modern iron spikes features, it can also remove archaeological features if they are spike like, i.e. have a strong response and have dimensions comparable with the sample and traverse interval. For example a 1m pit surveyed using a sample and traverse interval of 1m may only show as one reading. If it has a strong response, then, depending on the window size and Threshold, Despike might possibly remove it. However, if the sample and/or traverse interval is smaller then there is much less chance of the feature disappearing.

Smoothing

It is often desirable to smooth gradiometer data. This process is implemented with the Low Pass Filter function that reduces the variability of the data at the expense of spatial detail. This can improve the visibility of weak archaeological features such as deeply buried foundations, wide ditches, subtle linear features. It can also be used to improve the appearance of relief or artificial sunshine plots, especially if data has been sampled at 0.5m intervals or better. The procedure is as follows.

Select the Low Pass Filter function; this requires entry of a window size and type of weighting. In general it is advisable to use small window sizes. If sample and traverse interval are both 1m then consider X and Y radii of the order of 1 to 2 readings. Radius values greater than 2, may result in increasing suppression of the desired archaeology. Often smoothing with radii between 1 and 2 would be desirable. An approximation to this can be made by repeated smoothing with radii of X,Y = 1, say three to five times. However, this may be at the expense of slight ringing and generation of artifacts in the data so results should be carefully examined. It is common to use filter window dimensions that are equal in units of metres, rather than readings, so take into account differences in sample and traverse intervals when entering the X and Y radii.

If sample intervals are 0.5m, 0.25m or 0.125m, not uncommon in gradiometer surveys, then there is greater flexibility in the choice of radii, especially in the X direction, to achieve the desired smoothing. Window radii (readings) may be set to different values in the X and Y directions so you might consider initially setting Y=0 and X set to a length equal to or slightly greater than the features to be smoothed. By adjusting the X and Y radii it is possible to obtain the desired smoothing. In general it is better that the X and Y radii of the window are chosen to match the ratio of sample and traverse intervals so that the resulting window size, in terms of metric dimensions, is square; this will help reduce artifact generation when interpolation is used next.

Gaussian or Uniform weighting is available. Gaussian weighting is always recommended for generalized processing. Uniform weighting will introduce processing artifacts in the vicinity of large data values (impulsive, spikes) and will remove Fourier components with a period equal to multiples of the window diameter. Regardless of weighting, you should always remove or suppress noise spikes first, using Despike and/or Clip as described earlier, to prevent the noise spike energy from smearing.

Interpolation

Interpolation (expand) can also be used to give a smoother appearance to the data and can improve the visibility of larger, weak archaeological features. Remember that if you are using interpolation to improve the visual appearance, this is only a cosmetic change. You are creating artificial data points and you cannot subsequently use other processes to extract better information than was contained within the original data set. Indeed, beware of the danger of reading too much into expanded data, especially if you have used interpolate several times. Expansion using Interpolate is no substitute for good data sampling in the first place. Also if used too soon it will unnecessarily increase subsequent processing times. It is recommended that Interpolation is one of the last process functions to be used in a process session.

If you do use Interpolate then always choose the Sin(x)/x expansion method for best results. You can use interpolate (expand) to improve the appearance of relief or artificial sunshine plots which benefit from greater data density. However, remember that the Sin(x)/x interpolation method must be used since the relief plot will emphasise the imperfections in linear interpolation, rather than the archaeology, and would thus defeat the objective.

One caution: multiple expansions using Sin(x)/x can introduce “ringing” distortion at edges. In some cases it may be better to use Sin(x)/x for the first expansion and Linear for second and subsequent expansions; try both approaches and examine the results for the chosen display format.

Separation of Positive or Negative Magnetic Features

It is possible to separate out positive and negative magnetic features within a composite since gradiometer data has a zero mean. This can help when trying to interpret some sites. Features such as ditches, pits, kilns, hearths etc will usually (but not always) occur as positive readings and stone features such as walls etc will usually (but not always) occur as negative readings. The Clip function may be used to separate these two types of features as follows. To isolate just the positive magnetic features set the Minimum clip level to zero and Maximum clip level equal to the most positive reading. To isolate just the negative magnetic features set the Minimum clip level equal to the most negative reading and the Maximum clip level to zero.

There are several ways of looking at the clipped data. You can use Shade plots (Clip parameters), where plotting parameters Min and Max are symmetrical about zero (for example Min=-3, Max=+3), and Contrast=1. Use of the colour palettes will be useful here. If you use Pattern plots then the corresponding Clip plotting parameters are best entered as Min=0 and, for example, Max=3. Alternatively you could use either Shade plots or Pattern plots with Relief plotting parameters, as these can be especially effective. Trace plots are especially useful since you can observe both the location and magnitude of features at the same time.

Areas of Statistically Different Activity

Areas of statistically different activity can be located by using the Standard Deviation / Variance Map function and may be used to compliment standard graphical methods for site interpretation. This function replaces the data set by either the local variance or local standard deviation, whichever parameter is chosen, so make sure you have saved any intermediate results. The new data set will consist of all positive numbers, with a value of zero indicating uniform activity in that region. Numbers greater than zero indicate by their magnitude the increasing level of activity or degree of change in that region.

Small window sizes (radii 1m to 3m) will give a more detailed picture of activity, whereas larger window sizes (5m to 10m) will give a less detailed, broader picture of changes (remember radii are entered in units of readings, not metres).

Graphics in Processing and Use of Compression

The Graphics menu contains a versatile suite of tools for viewing gradiometer data, whether it be raw, smoothed, high/low separated, or variability data. Shade and Pattern plots are particularly useful with Clip, Compress or Relief plotting parameters. Trace plots are especially useful since you can observe both the location and magnitude of features at the same time. However, it is very important to keep in mind the dynamic range of the data and the dynamic limits of the screen and the printer. Often gradiometer data will exceed the capability of these display devices.

Often use of Clip plotting parameters is sufficient to cope with such circumstances, and large value readings are simply limited to a set level. If you wish to view both large and small magnitude features at the same time then you can do this by compressing the data. Three of the Graphics types, Shade, Pattern, Dot-Density (but not Trace) offer Compress plotting parameters, which apply an auto-scaling arctangent compression to help in this respect. However, for maximum flexibility, it may be best to use the Compress function in the Process menu, then you are free to choose subsequent plotting parameters, which can then include Clip and Relief. You can then also look at compressed data using Trace plots. The entry under Compression in the Geoplot 3 manual gives guidance on how to compress the desired range of data into the number of available display levels, using either Logarithmic or Arctangent compression.

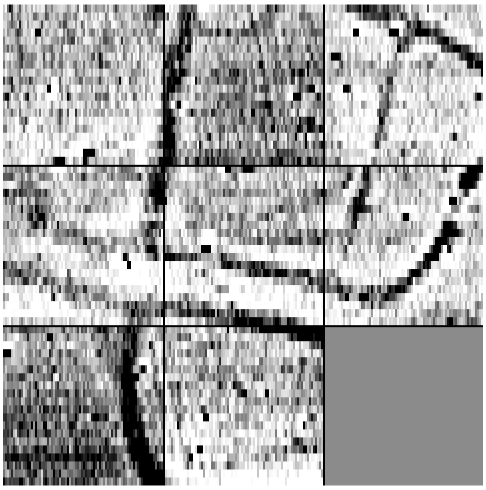
Finally, it is recommended that gradiometer data be viewed using all the parameter modes of Shade or Pattern plots: Clip, Compress or Relief, along with Trace plots, with hidden line turned on and off. A combination of these will often help resolve subtle archaeological and cultural features. For example, rotating the sun direction and changing the elevation in Relief plotting parameters often reveals features that would otherwise be missed. Similarly, adjusting the Contrast between 0.1 and 10 in Clip and Compress will render subtle features visible.

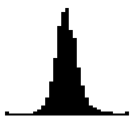
Processing Examples

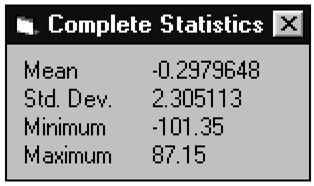
The following case studies illustrate how the preceding processing advice may be applied to single and dual gradiometer data sets.

Example Survey 1 – Single Gradiometer

The first example is a single fluxgate gradiometer survey made over a Romano British enclosure in a heavily ploughed field. A single gradiometer was used with parallel traverses 1m apart and sample interval of 0.125m. Resolution was 0.1nT. The survey comprises 9 x 20m x 20m grids, one of which is a dummy grid.







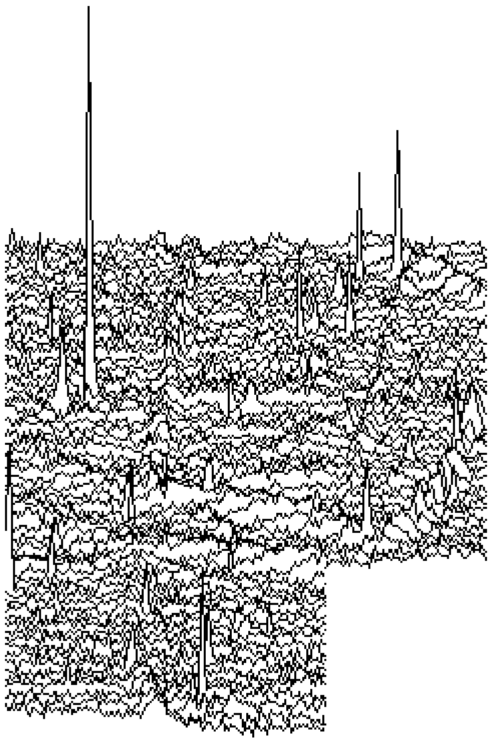


Figure 6-8. Single Fluxgate gradiometer survey over a Romano-British enclosure, heavily ploughed field. Shade plotting parameters : Maximum = +2, Minimum = -2nT, Contrast = 1.5. Trace plot resolution = 0.5nT, absolute units. Histogram range +/-3 standard deviations.

For comparison all the shade plots, apart from the spectrum plot, are made using absolute parameters of Minimum = -2nT, Maximum = +2nT, Contrast = 1.5. The spectrum plot uses the same Minimum and Maximum but standard deviation units. The trace plot above used a resolution of 0.5, absolute units.

Following the suggested sequence in the processing guidelines first review and identify: background, archaeology, weak and strong ferrous, geology and defects. We can see from the statistics form that the data is roughly bipolar (mean = -0.298). Archaeology is clearly present in the form of enclosures and ditches, with anomaly strength ranging from +1 to +3nT (obtained by tracing the mouse over the plot and observing the data value reported in the bottom right hand corner). The trace plot and statistics clearly show weak ferrous anomalies most likely due to surface iron. There does not appear to be any significant broad scale change in background. Defects that are present include some slope errors, grid edge mismatch and traverse striping, but overall these errors are under 1nT.

The first step is usually to clip the data using the Clip function. This is safe to do at this stage since we have seen the data is roughly bipolar. Since archaeology is no more than 5nT, we can clip at +/-3SD; this is calculated by multiplying the statistics form SD by 3, i.e. Minimum = -6.9nT, Maximum = +6.9nT. Using the notation suggested at the beginning of this chapter we could give this new processed file the name **c** as a shorthand for the process applied. There will be no obvious change in the shade plot but the spikes will be much reduced in a trace plot. The left hand plot of figure 6-9, made by subtracting the clipped data from the original, shows the clipped spikes. If the data had a significant offset then you should take this into account when calculating the clipping levels, making sure clipping is symmetrical about the offset. If the archaeology is stronger or you are looking for stronger features, e.g. kilns or hearths, then you may need to broaden the clip range.

The second step is to remove the defects. Although you could attempt to use the Deslope function we will not at this stage since they are very small and it is likely we will be using the Zero Mean Traverse function later and this will automatically remove any slope errors. Instead, we will use Zero Mean Grid, default threshold of 0.25SD, to edge match the data. The result is shown in the right hand plot of figure 6-9 which shows noticeable improvement: ZMG shifts the grids by up to +/-0.7nT. Now that we have clipped the data, note that the histogram to the right of figure 6-9, is now broader and reflects more archaeology and less iron spikes. This data set could be saved as **cy.**

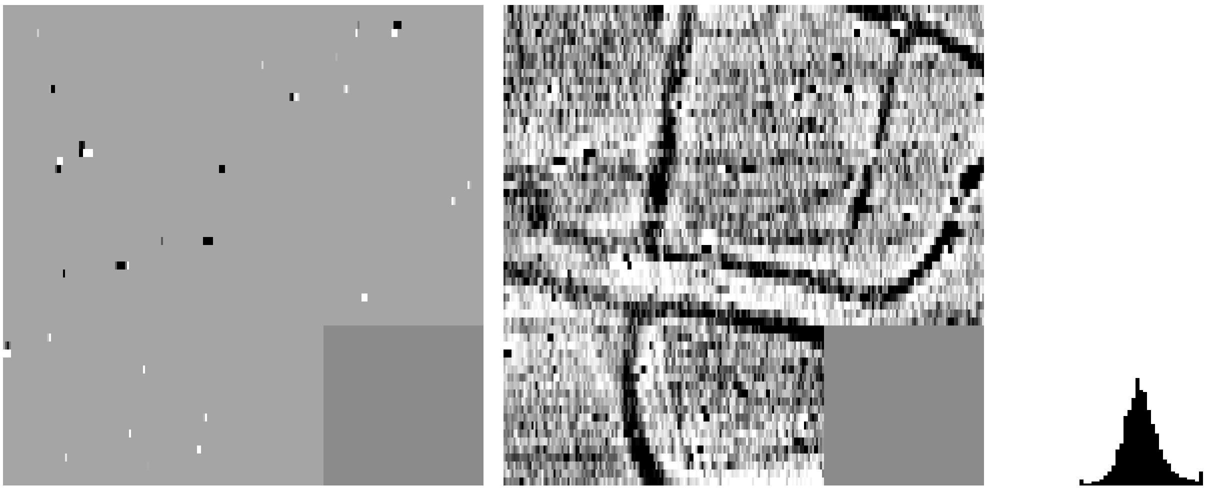


Figure 6-9. Left hand plot shows iron spikes reduced by clipping at +/-3 standard deviations. Right hand plot shows data after edge matching using Zero Mean Grid.

It is obvious that some striping and sloping is present in the data so the Zero Mean Traverse function is used with Least Mean Fit = On to remove these; since there are no extensive responses there is no need to use Thresholds. The resulting plot is shown in figure 6-10 on the right hand plot whilst the left hand plot shows the shifts applied to each traverse. Save the processed data set as **cyz**. The maximum negative shift was –3nT, maximum positive shift was +2.2nT and most shifts were in the range +/-0.5nT. The plot now shows considerable improvement, though note that the light coloured negative that ran between the two central parallel ditches is now reduced in amplitude which should be noted in final interpretations.

Now that the individual traverse backgrounds have been shifted relative to one another, the next step is to investigate whether there are any periodic errors present. Applying the Spectrum function with Thresholds Off produces the left hand plot of figure 6-11 where the plotting parameters are now in terms of standard deviations for ease of display. A single periodic response can be seen at a frequency index of 65, equivalent to a frequency of 1c/m (the plotting range is between +0.07nT and –0.04nT). Reloading the data and applying Periodic Filter with Spike Tolerance On, Thresholds Off produces the right hand plot of figure 6-11, saved as **cyzd**. There is very little difference to be seen in fact, indicating the error is due to very low-level system noise. Examining the effect of the Periodic Filter using Cut and Combine produces the plot of figure 6-12; the statistics show that the standard deviation is less than 0.1nT, explaining why it is virtually invisible to the naked eye on this site.

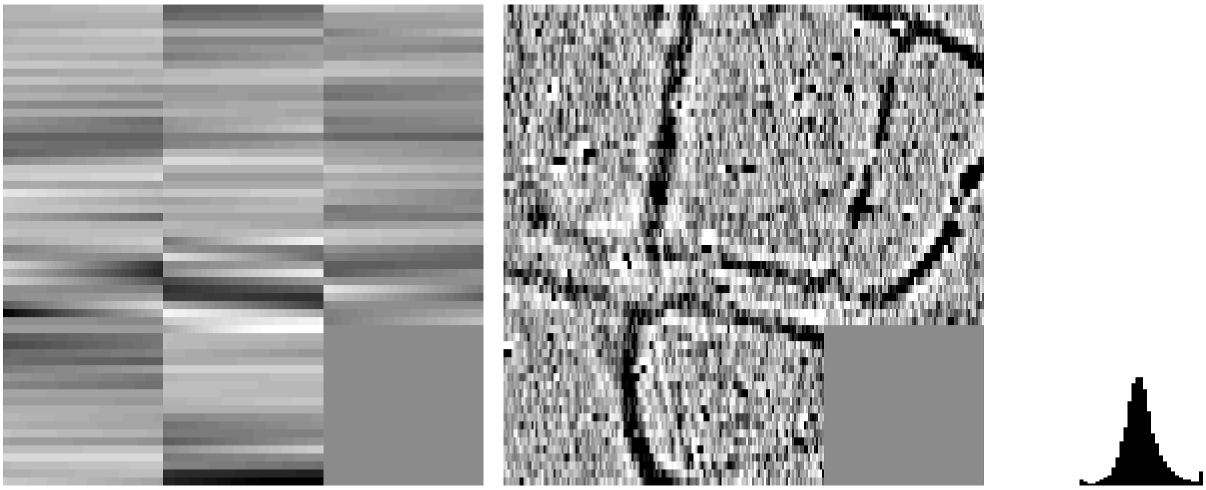


Figure 6-10. The right hand plot shows the data after applying Zero Mean Traverse and the left hand plot shows the shifts applied to each traverse.

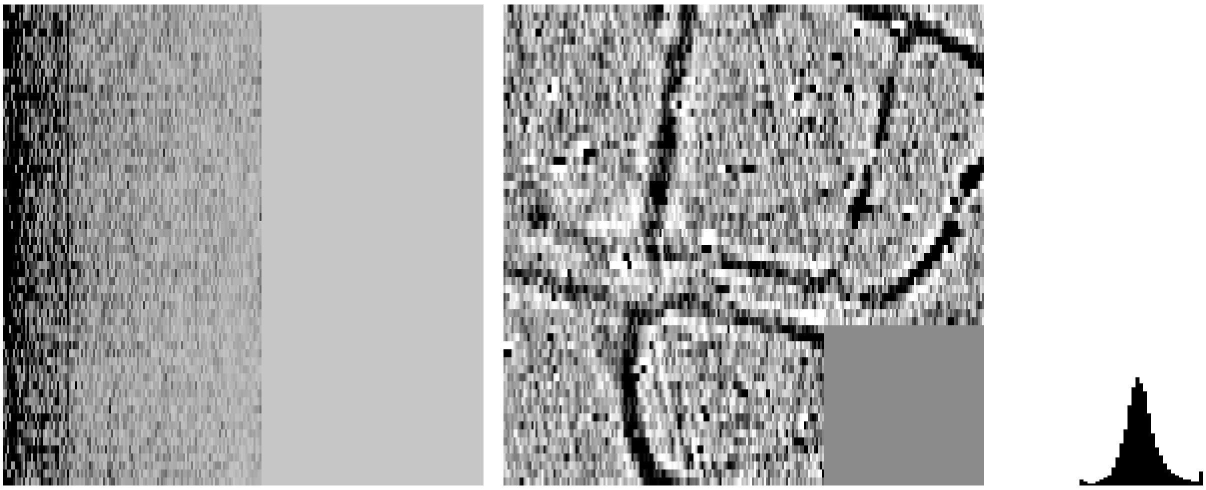


Figure 6-11. The left hand plot shows a frequency spectrum plot of the data (+/-2SD plotting parameters) with a periodic error at 1c/m. The right hand plot shows the data after using Periodic Filter to remove the 1c/m frequency component.

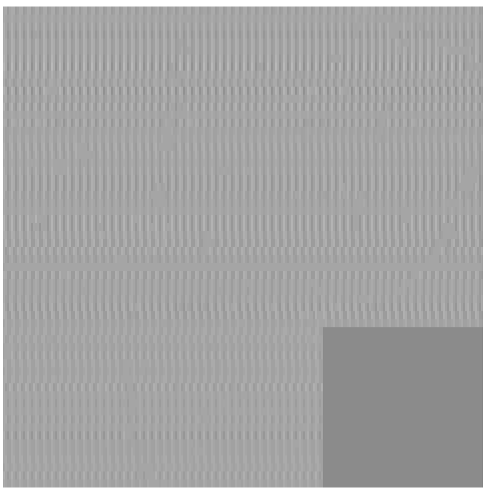


Figure 6-12. Difference plot showing the periodic error of 1c/m removed using Periodic Filter. The statistics show this to be a low level noise component of magnitude less than 0.1nT standard deviations.

All the errors noted in the preliminary examination of the data have now been dealt with so the final stage is to enhance the graphic plot. At this stage consider whether to despike or not, remembering that if sample interval is large (say 0.5m to 1m) then wanted features such as pits could be inadvertently removed by this process and should be avoided in such cases. Similarly if there is a possibility of post-hole alignments, which may be smaller in size then also avoid despiking. In the case of this survey we have used a small sample interval of 0.125m that gives us greater opportunity to despike and we know from the results and field walking that there is a noticeable scatter of surface iron which could potentially be removed. Figure 6-13, right hand plot, saved as **cyzdk**, shows the result of using default despiking whilst the left hand plot identifies the spikes removed for future reference (a trace plot can also be useful here). All the spikes removed are very small scale, low amplitude (+/-2 to +/-5nT) and show no discernable pattern so the despiking, in this case, will be useful in reducing overall noise or clutter in the survey – the obvious iron spikes observed at the start are still present though. Increasing the amount of despiking by lowering the threshold, for example, starts to remove parts of the observable archaeology so is not performed.

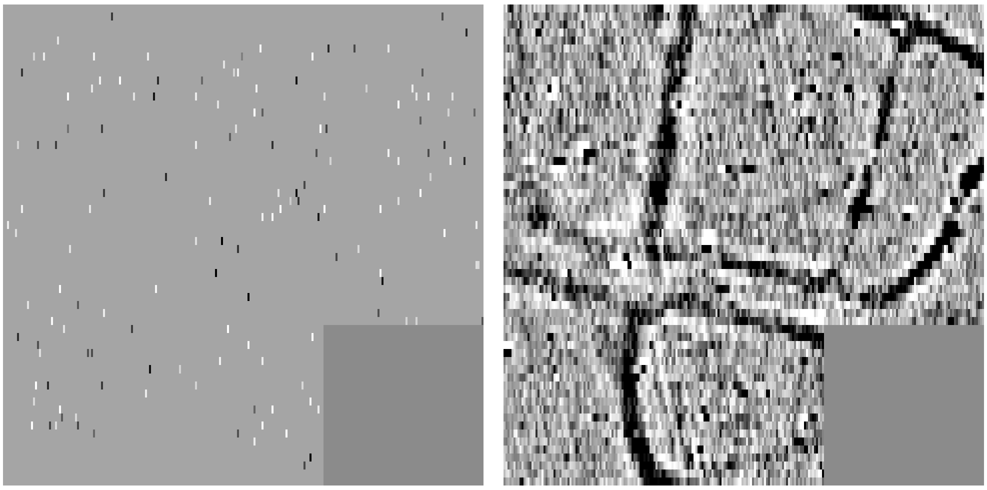


Figure 6-13. The right hand plot shows the data after applying Despike and the left hand plot shows the spikes removed.

As a general rule, aim for final presentation plots which have an equal sample and traverse interval, typically 0.25m. This is done using a mixture of shrink (when needed) and expand in the Interpolate function, together with a small amount of smoothing applied first using Low Pass Filter; this reduces noise and reduces production of interpolation artifacts. We can apply these functions safely at this point since we have done all we can to reduce spike amplitude. First shrink the sampling interval in the X direction from 0.125m to 0.25m, using Interpolate, X, Sin x/x, Shrink, resulting in plot of figure 6-14 (saved as **cyzdki**). Next apply smoothing using Low Pass Filter to the data. First of all we will apply an asymmetrical low pass filter that preserves information in the X direction a much as possible: X=2, Y=1, Gaussian – this ratio of X and Y results in a window size of 0.5m in the X direction and 1m in the Y direction. The resulting plot is shown in the left hand plot of figure 6-15, saved as **cyzdkil**.

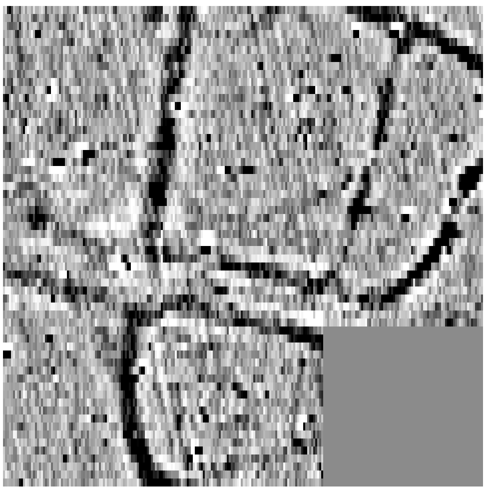


Figure 6-14. Data after shrinking the sample interval from 0.125m to 0.5m.

The final step is to interpolate twice in the Y direction using the Sin x/x method – the right hand plot of figure 6-15 shows the final result, with the final plot being saved as **cyzdkili.**

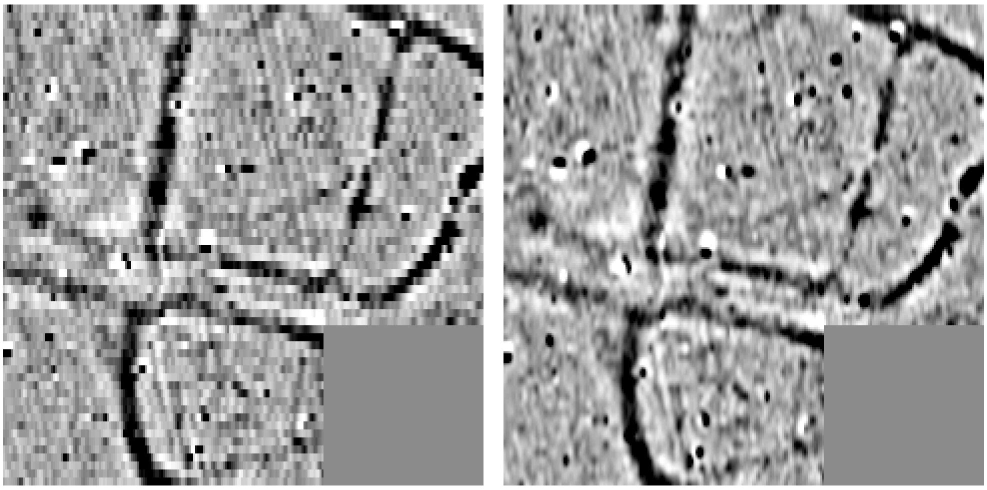


Figure 6-15. The left hand plot shows the data after low pass filtering with X = 2, Y = 1, Gaussian (0.5m x 1m window). The right hand plot shows the results of interpolation twice in the Y direction using the Sinx/x method.

Although the detail in the X direction is retained there are signs of artifacts being generated in the Y direction due to the asymmetrical low pass filter window used before interpolation. To avoid these a symmetrical low pass filter window can be used: X=4, Y=1, Gaussian – this ratio of X and Y results in a window size of 1m in both the X and Y direction. The resulting plot is shown in the left hand plot of figure 6-16. Again, interpolation twice in the Y direction is used to obtain the right hand plot of figure 6-16. There is virtually no sign of artifacting in the Y direction now, though the plot is not as crisp. However, the small semi-circular feature at the top is now better defined. A comparison of background noise in the bottom left hand corner shows this reduces from 0.3nT to 0.2nT when the 1m width filter is used.

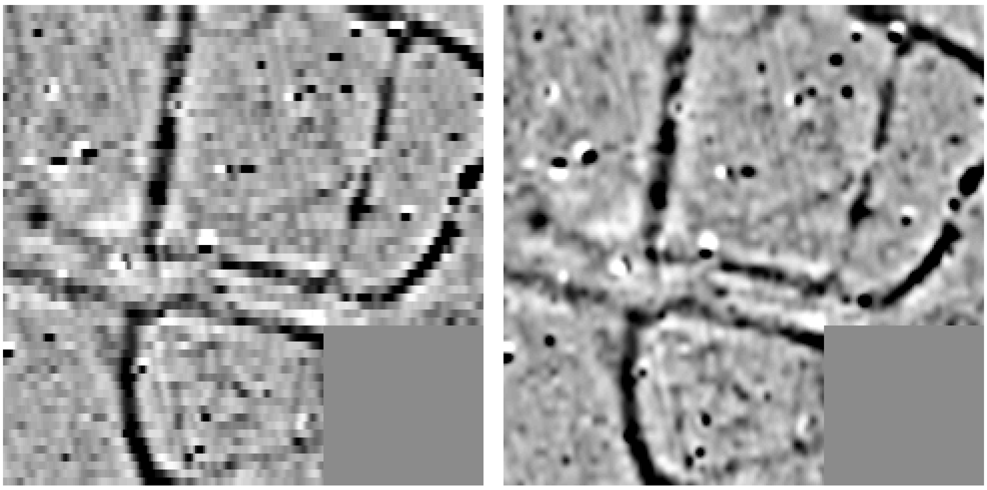


Figure 6-16. The left hand plot shows the data after low pass filtering with X = 4, Y = 1, Gaussian (1m square window). The right hand plot shows the results of interpolation twice in the Y direction using the Sinx/x method.

Example Survey 2 – Dual Gradiometer Survey

The second example is a dual fluxgate gradiometer survey made over an iron-age enclosure. This was situated in a grassy field that was somewhat waterlogged and grazed by cows, making walking difficult at times. An FM256 was used as the master ‘b’ gradiometer and an FM36 was used as the slave ‘a’ gradiometer in Double Speed mode; resolution was 0.1nT. Zig-zag traverses were used with traverse interval set at 2m and sample interval set at 0.25m. The survey comprises 25 x 20m x 20m grids, 1 hectare, and was surveyed in just over 2 hours.

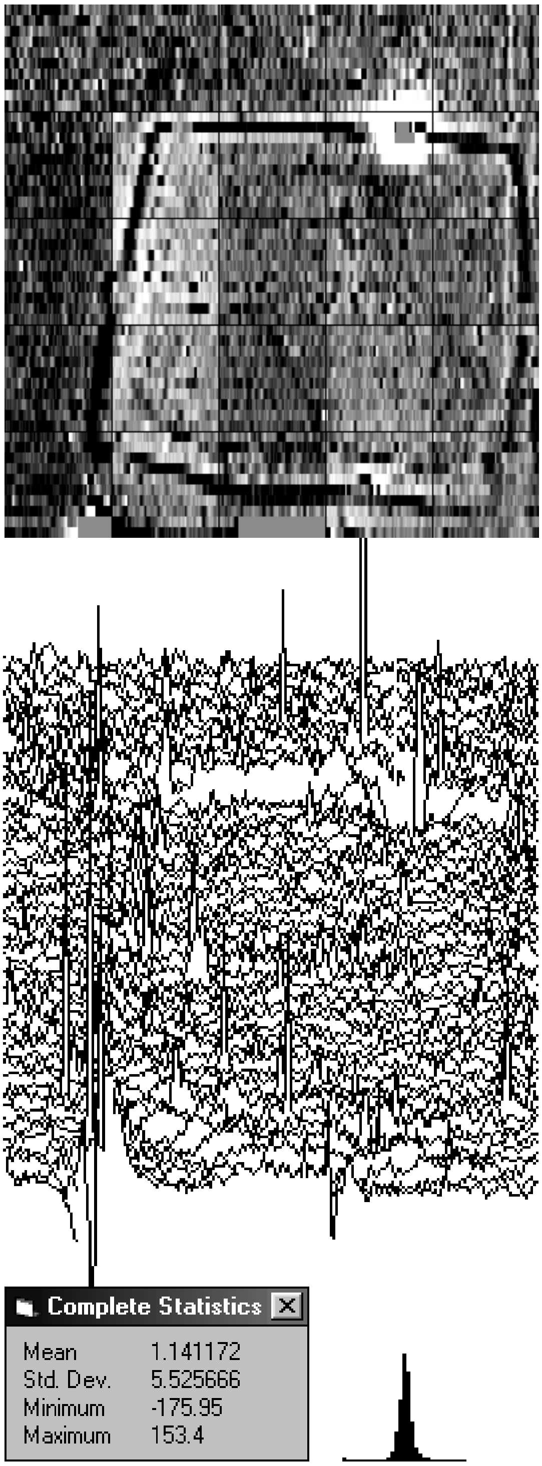


Figure 6-17. Slave FM36 ‘a’ gradiometer data.

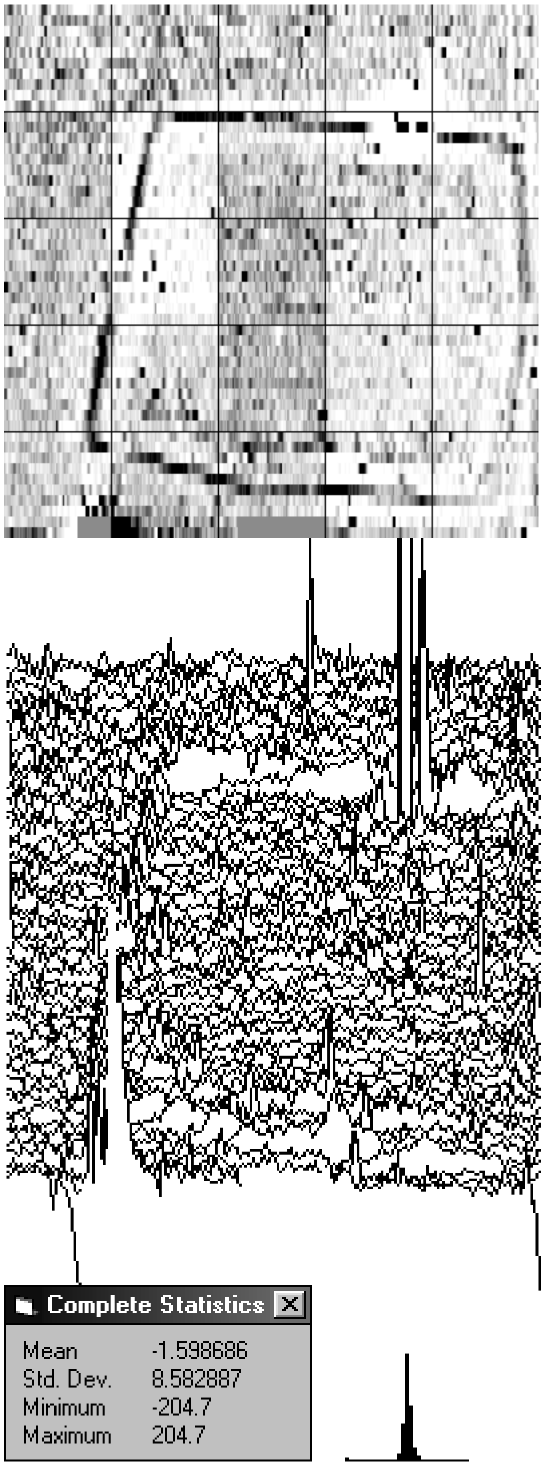


Figure 6-18. Master FM256 ‘b’ gradiometer data.

Shade plotting parameters : Maximum = +3, Minimum = -3nT, Contrast = 1.5. Trace plot resolution = 0.5nT, absolute units. Histogram range +/-3 standard deviations.

For comparison all the shade plots, apart from the spectrum plot, are made using absolute parameters of Minimum = -3nT, Maximum = +3nT, Contrast = 1.5. The spectrum plot use Minimum = -2, Maximum = +2 and standard deviation units. The trace plots above used a resolution of 0.5, absolute units.

Following the suggested sequence in the processing guidelines first review and identify: background, archaeology, weak and strong ferrous, geology and defects. We can see from the statistics forms and shade plots that although the data is roughly bipolar (means of 1.14 and –1.60) a bias will be required before the two data sets are merged. Archaeology is clearly present in the form of the enclosure and possible inner ditch, with anomaly strength ranging from +1 to +6nT (obtained by tracing the mouse over the plot and observing the data value reported in the bottom right hand corner. The trace plots and statistics clearly show ferrous anomalies most likely due to surface iron. The shade plots and narrowness of the histogram indicate very large ferrous responses – these are visible in the upper right hand corner (a probable anchor point for a barrage balloon) and along the lower edge (due to two metal gates). There does not appear to be any significant broad scale change in background. Defects that are present include grid edge mismatch of up to 2nT and smaller levels of traverse striping. There is no obvious sign of periodic errors.

Before preparing the data sets for merging some pre-processing is required. Data set ‘a’ was collected with an FM36 that records over-range readings as the maximum reading possible, 2047.5, which also happens to be the dummy reading. We need to ensure that FM36 data in the area of the possible barrage balloon mooring appears as valid data values – in figure 6-17 it appears as a block of dummy readings. Equivalent FM256 data appears as a large value 204.7 that is distinct from the dummy value of 2047.5. Therefore Search and Replace is used to replace +2047.5 with +204.7 in data set ‘a’ in a block at the mooring point. Using the notation suggested in the Geoplot 3 manual we could save this new processed file as ap as a shorthand for the process applied.

The next step is usually to clip the data using the Clip function. This is safe to do at this stage since we have seen the data is roughly bipolar for both ‘a’ and ‘b’. Since archaeology is no more than 6nT, we can clip at +/-3SD; which is calculated from the statistics form, giving a maximum clip value of 3 x 8.6 = 25.8 nT. However, since there is fairly extensive ferrous clutter we will lower this clip level to +/-10 nT, still above the archaeology, to allow subsequent process functions to work better. The data sets could be saved as apc and bc respectively. There will be no obvious change in the shade plot but the spikes will be much reduced in a trace plot. The left plots of figure 6-19, made by subtracting the clipped data from the original, shows the clipped spikes. If the data had a significant offset then you should take this into account when calculating the clipping levels, making sure clipping is symmetrical about the offset. If the archaeology is stronger or you are looking for stronger features, e.g. kilns or hearths, then you may need to broaden the clip range.

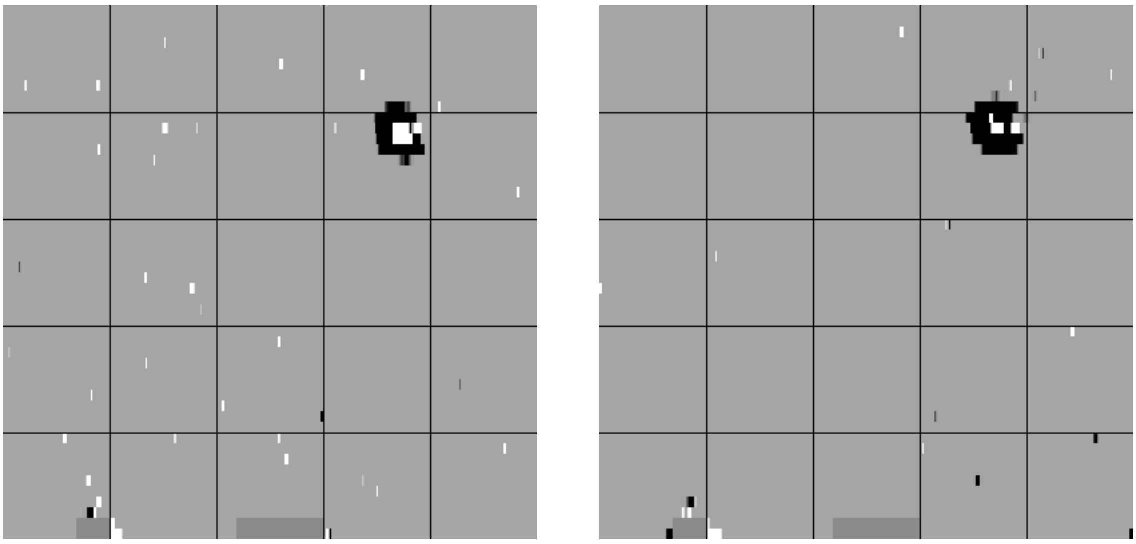


Figure 6-19. Plots showing locations of ferrous responses reduced by clipping at +/- 10 nT. Data set ‘a’ on the left hand side, data set ‘b’ on the right hand side.

The next pre-process step is to prepare the composites for merging using Zero Mean Grid. Whilst using the default threshold value of 0.25 SD works well throughout most of the survey, figure 6-20 shows that the proces does not work properly in the vicinity of the balloon mooring point. Adjusting the threshold value to 1.5 SD enables Zero Mean Grid to produce a much better leveling of the background response in all the grids, figure 6-21. Zero Mean Grid shifts the grids by up to +/-2.7 nT in this example.

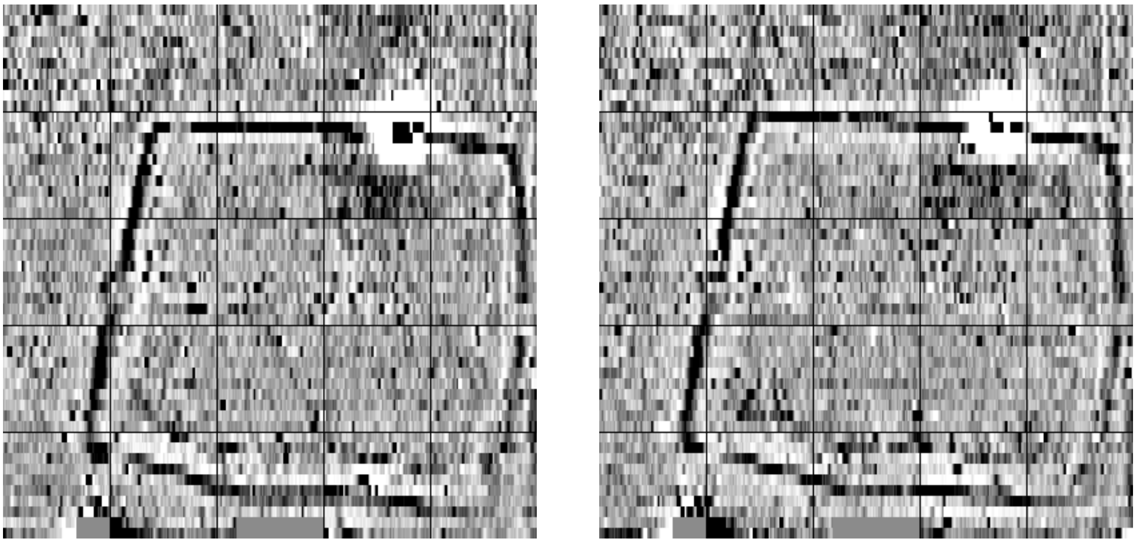


Figure 6-20. Data after applying Zero Mean Grid with default threshold value of 0.25 SD, showing mismatch in the vicinity of the large ferrous response. Data set ‘a’ left, data set ‘b’ right.

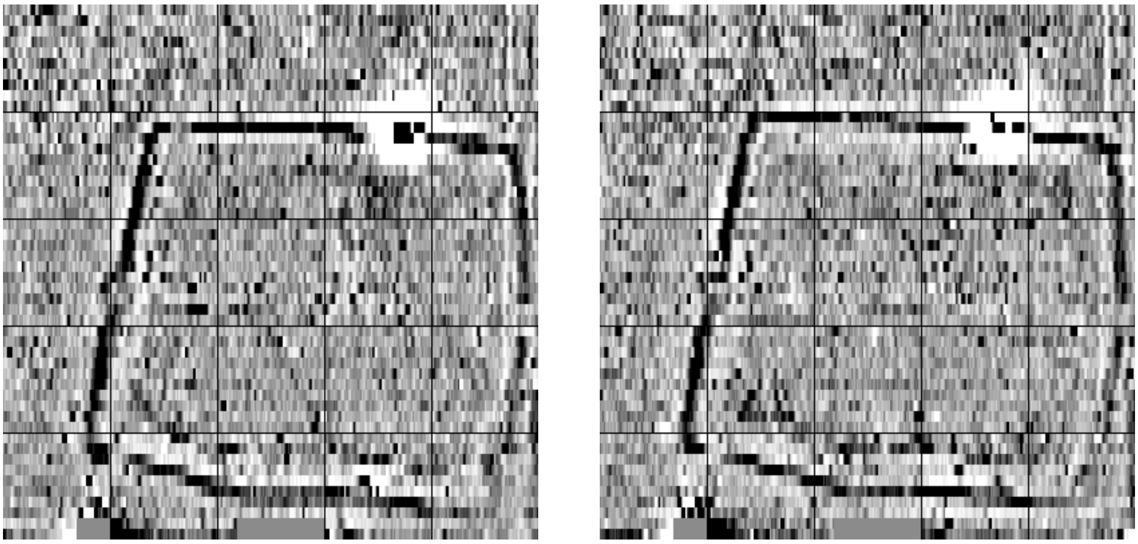


Figure 6-21. Data after applying Zero Mean Grid with threshold value of 1.5 SD, showing much better matching in the vicinity of the large ferrous response. Data set ‘a’ left, data set ‘b’ right.

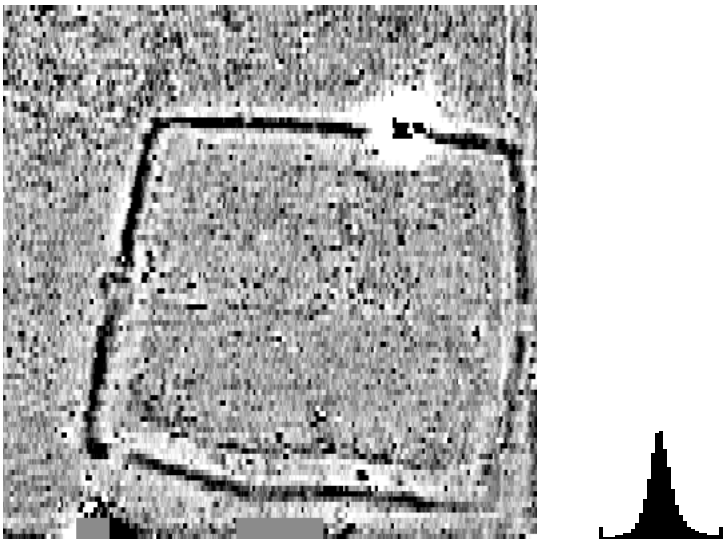


Figure 6-22. Data sets ‘a’ and ‘b’ combined using ‘Merge Composites’ on the File Menu of Geoplot.

The two data sets could be saved with file names apcya and bcyb respectively, where we have added the letters 'a' and 'b' at the end of the file names so they are in the correct format for using the merge facility in Geoplot – see earlier. Figure 6-22 shows the two data sets combined using 'Merge Composite' on the File Menu. Save the new merged composite with the name ab. Note that now we have clipped the data the histogram to the right of figure 6-22 is now broader and reflects more archaeology and less ferrous response, with the ferrous response now apparing as the single width responses at the outer limits of the histogram.

The next step is to remove the defects. There is no slope present in the data, but should there have been note that we woud not have been able to use the Deslope function here since each grid is composed of two different merged data sets. The Zero Mean Traverse function used next this will automatically remove any slope errors.

Some striping is present in the data so the Zero Mean Traverse function is used with Least Mean Fit = On to remove these; since there are extensive ferrous responses in places we need to use Thresholds. Low Thresholds values of +/-2 nT are chosen to try and preserve as much of the linear enclosure responses running parallel with the traverse direction. The resulting plot is shown in figure 6-23 on the right hand plot whilst the left hand plot shows the shifts applied to each traverse. Save the processed data set as **abz**. The maximum negative shift was –2nT, maximum positive shift was +2.2nT and most shifts were in the range +/-0.5nT or less.

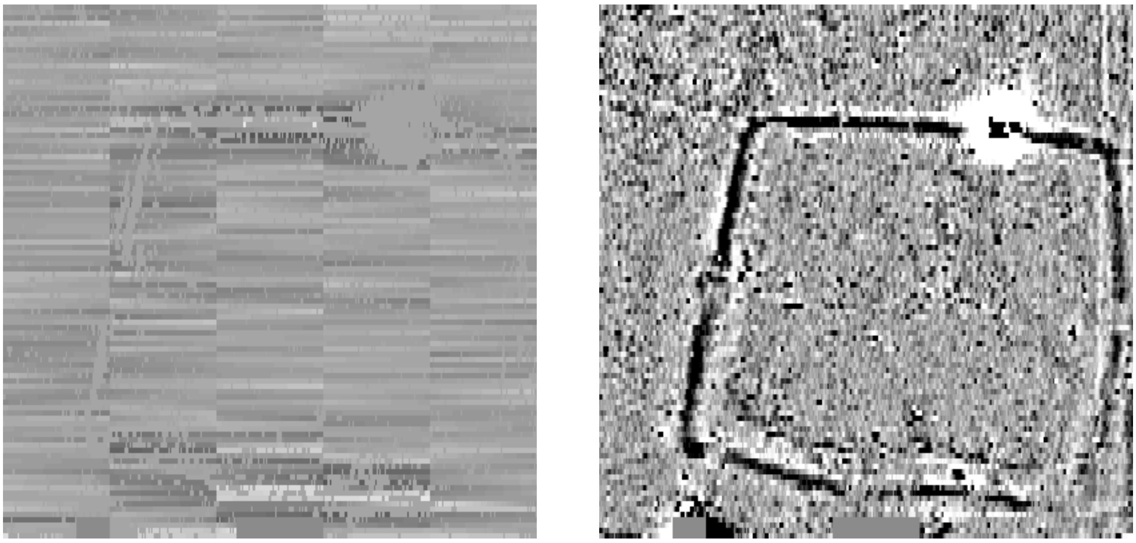


Figure 6-23. The right hand plot shows the data after applying Zero Mean Traverse (ZMT) and the left hand plot shows the shifts applied to each traverse.

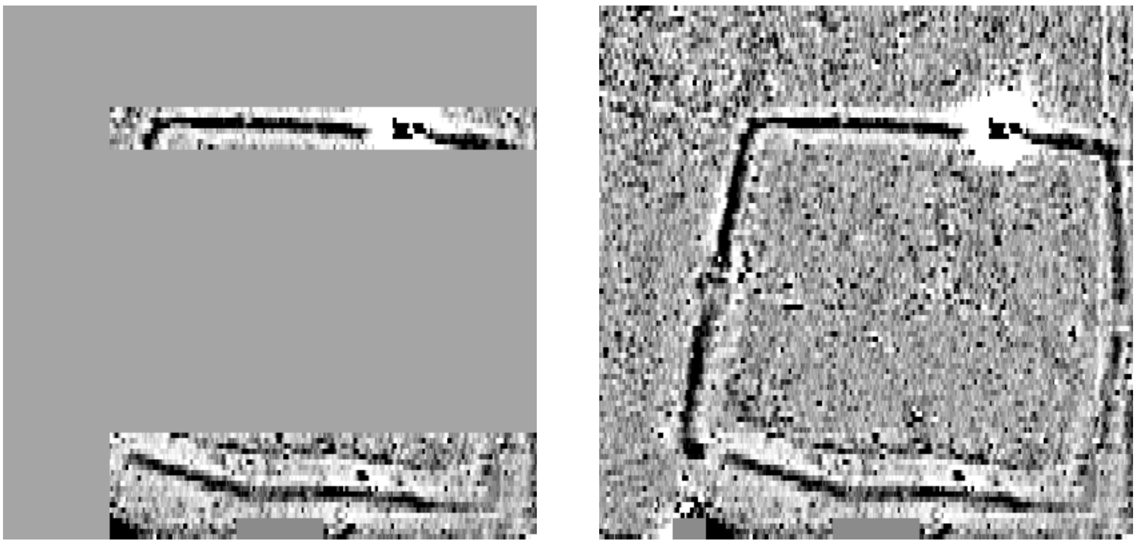
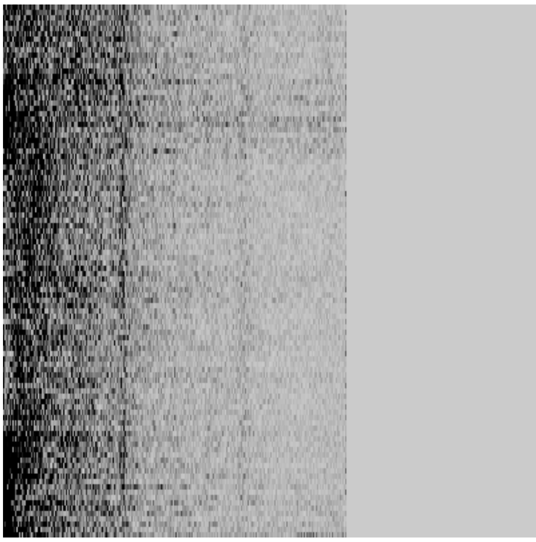


Figure 6-24. The right hand plot shows the ZMTdata after pasting back some areas from the data set prior to application of the Zero Mean Traverse – these areas are shown in the left hand plot.

Striping is much reduced, though note that the light coloured negatives that ran either side of the upper ditch response are now reduced in amplitude and, more noticeably, part of the lower ditch response has started to disappear in places. We can restore these areas by using Cut and Combine to select areas from the data set prior to application of Zero Mean Traverse and pasting theses back onto the Zero Mean Traversed data. The result is shown in figure 6-24 on the right hand side, with the selected areas on the left hand side. Data is saved as **abzt.**

The next step is to investigate whether there are any periodic errors present. Since there are large ferrous responses, apply the Spectrum function with Thresholds On and set to +/-5nT; this produces the left hand plot of figure 6-25 where the plotting parameters are now in terms of standard deviations for ease of display. A pair of periodic response can be seen at centre frequency indices of 90 and 180, equivalent to frequencies of 0.7 c/m and 1.4 c/m (the plotting range is between +0.09nT and –0.05nT). The higher frequency component, being high frequency and low in amplitude, will have very little effect on the data. The lower frequency component is stronger in magnitude and needs removing. Its spectral response is broad, equivalent to three frequency indices, so Periodic Filter will need applying three times. Reloading the data and applying Periodic Filter in turn at Frequency Indices of 90, 89 and 91, all with Spike Tolerance On, Thresholds On and equal to +/- 5nT, produces the right hand plot of figure 6-25, which is saved as **abztd**. There is very little difference to be seen in fact, indicating the error is due to very low-level system noise. Examining the effect of the Periodic Filter using Cut and Combine produces the plot of figure 6-12; the statistics show that the standard deviation is less than 0.15nT, explaining why it is virtually invisible to the naked eye on this site.



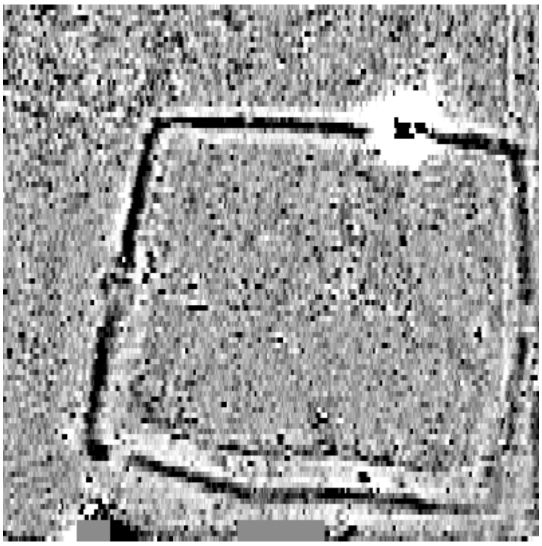


Figure 6-25. The left hand plot shows a frequency spectrum plot of the data (+/-2SD plotting parameters) with a periodic errors at 0.7c/m and 1.4 c/m. The right hand plot shows the data after using Periodic Filter three times to remove the 0.7c/m frequency component.

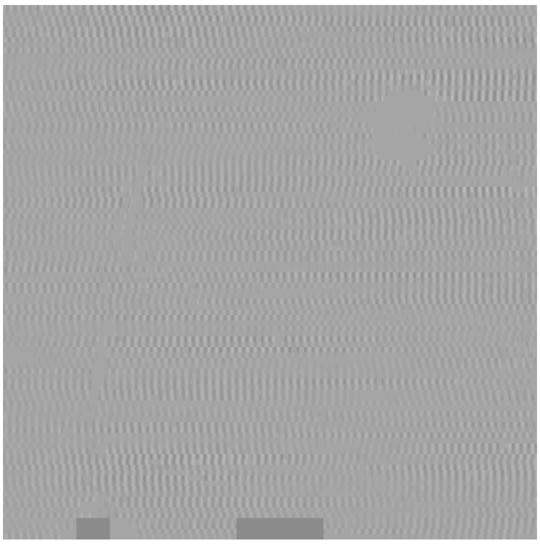
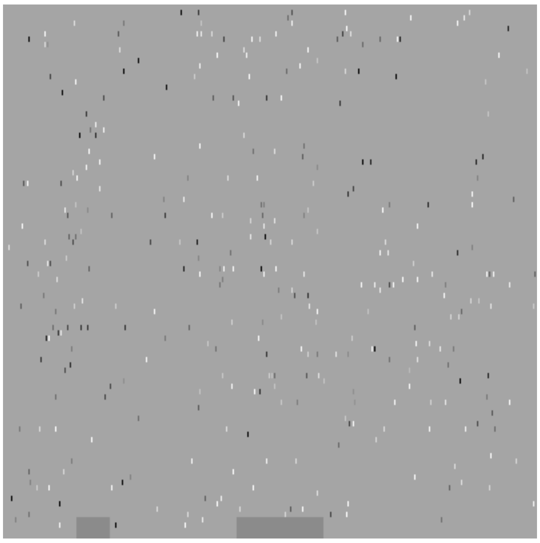


Figure 6-26. Difference plot showing the periodic error of 1c/m removed using Periodic Filter. The statistics show this to be a low level noise component of magnitude less than 0.15nT SD.

All the errors noted in the preliminary examination of the data have now been dealt with so the final stage is to enhance the graphic plot. At this stage consider whether to despike or not, remembering that if sample interval is large (say 0.5m to 1m) then wanted features such as pits could be inadvertently removed by this process and should be avoided in such cases. Similarly if there is a possibility of post hole alignments, which may be smaller in size then also avoid despiking. In the case of this survey we have used a small sample interval of 0.25m that gives us greater opportunity to despike and we know from field walking that there is a noticeable scatter of surface iron which could potentially be removed. Figure 6-26, right hand plot, saved as **abztdk**, shows the result of using default despiking whilst the left hand plot identifies the spikes removed for future reference (a trace plot can also be useful here). All the spikes removed are very small scale, low amplitude (+/-2 to +/-9nT) and show no discernable pattern so the despiking, in this case, will be useful in reducing overall noise or clutter in the survey – the obvious iron spikes observed at the start are still present though. Increasing the amount of despiking by lowering the threshold, for example, starts to remove parts of the observable archaeology so is not performed.



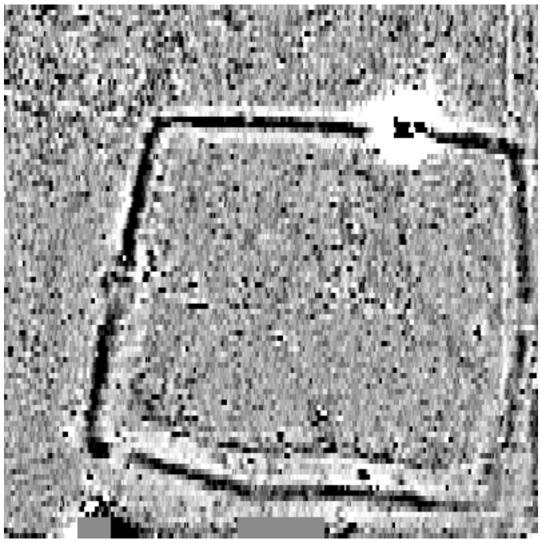


Figure 6-27. The right hand plot shows the data after applying Despike and the left hand plot shows the spikes removed.

As a general rule, aim for final presentation plots which have an equal sample and traverse interval, typically 0.25m. This is done using a mixture of shrink (when needed) and expand in the Interpolate function, together with a small amount of smoothing applied first using Low Pass Filter; this reduces noise and reduces production of interpolation artifacts. We can apply these functions safely at this point since we have done all we can to reduce spike amplitude. First of all we will apply an asymmetrical low pass filter that preserves information in the X direction a much as possible: X=2, Y=1, Gaussian – this ratio of X and Y results in a window size of 0.5m in the X direction and 1m in the Y direction. The resulting plot is shown in the left hand plot of figure 6-28, saved as **abztdkl.** The final step is to interpolate twice in the Y direction using the Sin x/x method – the right hand plot of figure 6-28 shows the final result, with the final plot being saved as **abztdkli.**

Although the detail in the X direction is retained there are signs of artifacts being generated in the Y direction due to the asymmetrical low pass filter window used before interpolation. To avoid these a symmetrical low pass filter window can be used: X=4, Y=1, Gaussian – this ratio of X and Y results in a window size of 1m in both the X and Y direction. The resulting plot is shown in the left hand plot of figure 6-29. Again, interpolation twice in the Y direction is used to obtain the right hand plot of figure 6-29. There is virtually no sign of artifacting in the Y direction now, though the plot is not as crisp. However, broad low-level responses are now better defined.

Thanks for permission to use the above data set goes to the Huddersfield and District Archaeological Society who first discovered and investigated the site.

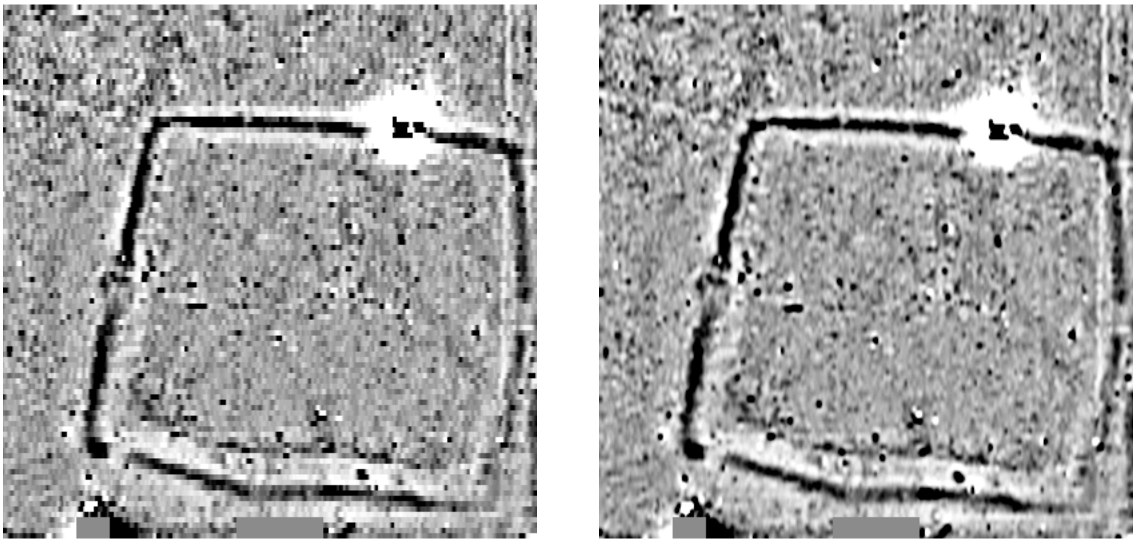


Figure 6-28. The left hand plot shows the data after low pass filtering with X = 2, Y = 1, Gaussian (0.5m x 1m window). The right hand plot shows the results of interpolation twice in the Y direction using the Sinx/x method.

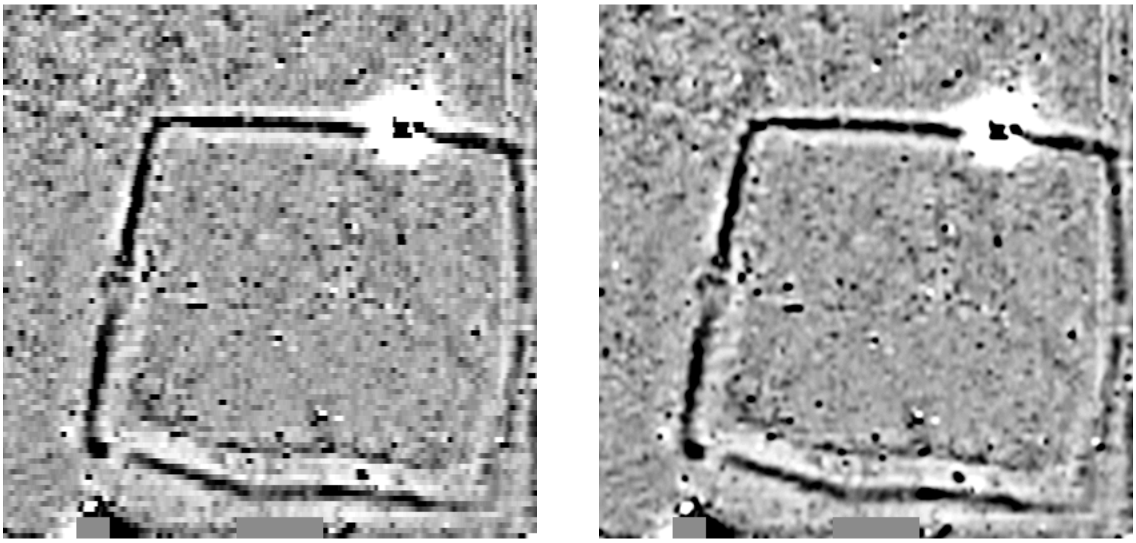


Figure 6-29. The left hand plot shows the data after low pass filtering with X = 4, Y = 1, Gaussian (1m square window). The right hand plot shows the results of interpolation twice in the Y direction using the Sinx/x method.

Statistical Detection applied to Gradiometer Data

Gradiometer data in a uniform magnetic field has a mean of zero and a Gaussian random distribution centred about zero. The standard deviation of this random noise for Geoscan instruments is of the order of 0.15 nT or lower with appropriate sampling and data processing. The total random noise in a survey map is made up from contributions from the magnetometer, the site geology and defects in the operator's field method.

Statistically speaking any noise data with a magnitude greater than approximately 2.5 standard deviations is unlikely (0.5 %), and at the 3 standard deviations level very unlikely indeed (0.1%). The corresponding likelihood at 2 standard deviations is 2.5%.

Therefore, by setting a threshold at 2.5 standard deviations and accepting only data greater than this threshold, we can create a statistical detection method or technique with which we can say "we are statistically confident that there is only a 0.5% chance that data greater than the threshold was caused by noise in the survey". This suggests that features that exceed the threshold are from a different population, i.e. one with a feature induced signal level greater than zero. Even greater certainty can be obtained by setting the threshold at 3 standard deviations. The detection threshold is site and survey dependent but can easily be obtained by measuring the standard deviation of the survey data in a "quiet" or feature free area.

Figure 6-30 shows an FM36 gradiometer survey over a collection of low level burnt hearths (plotting parameters: Minimum = -2nT, Maximum = +2nT, Contrast=1.5). A combination of high sampling density (16 readings per square meter) and appropriate data processing (see earlier in this section) results in a background noise level, as measured in the square shown, of 0.14nT. This includes soil, instrument and field method noise. The processed data shown has sample and traverse intervals 0f 0.25m.

Statistical detection can be helped if a low pass filter with uniform weighting is applied first to smooth out noise. The overall width of the filter should ideally match the likely diameter of the targets of interest since this optimises the response to the target but at the same time maximises noise reduction. A uniform filter is used since it easier to match the filter width to likely target width. Figure 6-31 shows the results of applying a uniform weighted low pass filter with X=Y=2; the noise measured in the square is now 0.1nT. The filter diameter in this case is 5 x 0.25m = 1.25m which most nearly matches the expected diameter of the smallest hearths which are of the order of 1m in diameter. If you are looking for larger diameter targets then a larger filter, commensurate with target width, can provide even more rejection of noise.

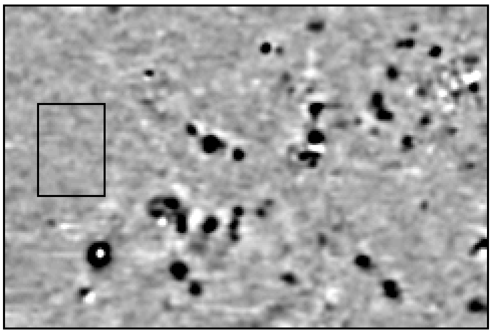


Figure 6-30. FM36 Gradiometer data over a collection of low level burnt hearths, the smallest of which have diameters of the order of 1m. Standard deviation of process area shown is 0.14nT.

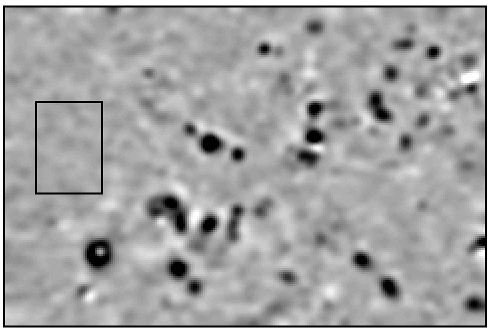
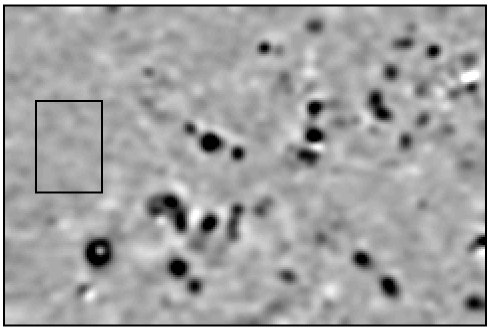
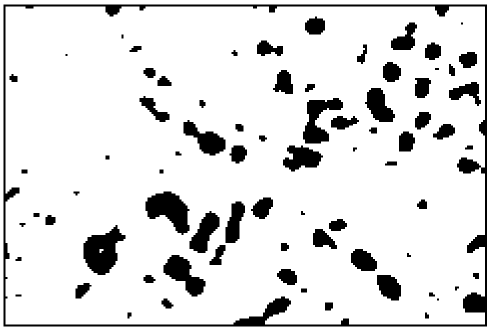


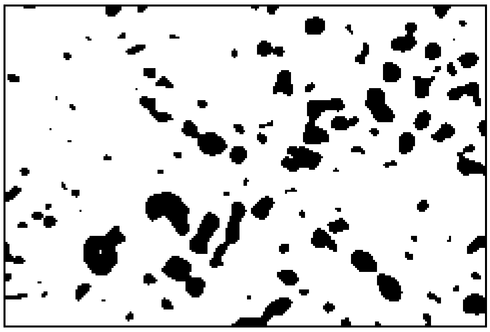
Figure 6-31. Data of figure 6-30 after a uniform weighted low pass filter with X = Y = 2 (overall width 1.25m). Standard deviation of process area shown is now 0.1nT.



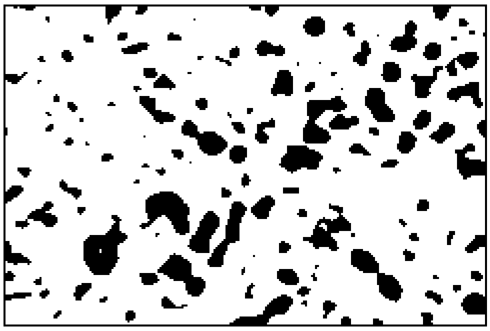
Data prior to statistical detection



Detection with threshold = 3.0 standard deviations



Detection with threshold = 2.5 standard deviations



Detection with threshold = 2.0 standard deviations

Figure 6-32. Sequence of statistical detection thresholds, between 2 and 3 standard deviations.

The sequence of plots above, figure 6-32, show statistical detection applied to this data set. Detection thresholds set by multiples of this measured noise level are : 2 standard deviations = 0.2nT, 2.5 standard deviations = 0.25nT, 3 standard deviations = 0.3nT. To apply these thresholds, use the Search and Replace function to (a) replace all readings between –1000 and +nSD with 0, (b) replace all readings between +nSD and +1000 with 1, where nSD can be 2, 2.5 or 3 standard deviations. Use shade plotting parameter of Minimum = 0 and Maximum = 1. Three threshold levels are shown on the right hand side. A large number of hearths have been statistically detected at the 2.5 and 3 standard deviation levels (i.e. greater than 0.25nT or 0.3nT respectively), subsequently confirmed by excavation. Note that the eye is capable of detecting very subtle changes buried in noise so you should not use the above technique to automatically discard information, but rather as an aid to understanding a data set.

Chapter 7

TROUBLE-SHOOTING

How do I obtain the latest information?

The most up-to-date trouble-shooting information is available on our web site at: www.geoscan-research.co.uk

How do I prevent defects that are visible in my data?

Introduction

There are several defects that can arise in a fluxgate gradiometer survey data. These include : slope in the grid data, discontinuities at the edges of grids, banding, traverse striping, stagger errors and periodic errors. Most of these errors can be corrected for by using software process functions specifically tailored to tackle each problem, as provided in Geoplot 3. Since many of these errors have their origin in the way the instrument is carried by the operator, you can minimise their appearance in future surveys by getting an observer to be critical of your surveying stance. A good walking style will use the body as a stabilising system that maintains the gradiometer at a constant height above ground, keeps the sensor tube positioned vertically and in the same heading all the time.

Slope Errors

Slope errors in grid data show as a very small and slow drift in the average data value throughout a grid, leading to a small difference in the background levels between the first and last traverses. However, it is essentially constant during the time required to scan an individual traverse. You can use the FM256 Log Zero Drift correction facility to help reduce this effect. However, there is usually no need to use Log Zero Drift since the Zero Mean Traverse function, which will almost always be used in routine data processing, (see Chapter 6, page 6-11 for details) automatically removes any slope in the data.

Grid Mismatch

Grid edge discontinuities can arise for a number of reasons:

- Poor choice of the zero reference station.
- Inconsistent positioning at the Zero Reference station.
- Failure to periodically check alignment, balance and re-zero the instrument.
- Traverse direction different from that adopted when zeroing the instrument at the Reference Station.

Grid mismatch is usually present to some extent in most surveys since the zero reference station is rarely perfect. Zero Mean Grid and/or Zero Mean Traverse process functions can correct for this error.

Banding

This may be observed running at right angles to the traverse direction at the start and/or end of a grid. It arises due to the operator adopting a slightly different posture at the start and/or end of the traverse. Be sure to start walking at the start of a traverse at least a metre before the grid edge, and ensure that when the Start/Stop switch is pressed you are careful not to change posture at that point. Likewise, continue walking normally for at least a metre past the end point before relaxing to avoid a change of posture introducing an error signal. Techniques do exist for removing these errors though there are no straightforward process functions to achieve this – see ‘Processing Techniques’ in the Geoplot manual for further details.

Traverse Striping

Traverse striping is where alternate traverses have a slightly different background level. It shows up in graphics plots as a series of stripes orientated in the traverse direction, and is especially noticeable if the plotting parameters are set to look for very weak features. The error can occur for a number of reasons:

- Failure to maintain the instrument at the same height on alternate traverses.
- A tendency to twist the body slightly for each alternate traverse, resulting in a slight change of instrument orientation.
- Tilting of the instrument forwards or backwards from vertical, which becomes compounded with zig-zag traverses and improper alignment.
- Poor choice of Alignment and Balance Station which leads to improper alignment and noticeable tilt errors.
- High walking speeds leading to poor angular control of the instrument.

The Zero Mean Traverse process function can be used to reduce this error in most cases.

Stagger Errors

Stagger defects arise due to the sensor tube not being directly adjacent to a guide marker when a 1m marker ‘beep’ is sounded. When using zig-zag traverses data will be slewed or displaced backwards or forwards for successive traverses. The result is that a linear anomaly running perpendicular to the traverse direction will not show as a clean linear response, but as a chevron type pattern, with the maximum of the response being displaced first forward and then backwards in each alternate traverse. It usually occurs when zig-zag traverses are made too fast and sample interval is small. The Destagger process function can be used to correct for these errors to some extent. However, it cannot fully compensate for poor marker alignment, and there will inevitably be some subsequent loss of signal in the correction process.

Periodic Errors

Periodic errors show up as a series of linear bands perpendicular to the traverse direction, with a period usually approximately equal to one or two walking paces (1 c/m or 0.5 c/m). They usually arise because the operator changes his stance or elevation slightly whenever the left or right foot is placed on the ground, or he launches himself forward for the next pace. It is more likely to be a problem if the speed of walking is high, the ground has a higher than normal magnetic susceptibility, the terrain is uneven, if the alignment of the gradiometer sensors are not checked often enough, or any combination of these factors. It is also most likely to be noticeable if you are setting plotting parameters to look at very weak responses. When it occurs the typical strength is 1nT but can be up to 5nT in extreme cases.

Other factors that can cause periodic errors include the following:

- A poor choice of Alignment and Balance Station, or failure to align and balance periodically, can cause angular motion of the gradiometer to introduce periodic errors.
- ‘Regimental’ style of walking.
- ‘Bouncy’ style of walking.
- High susceptibility soils and/or rough terrain, with mud sticking to boots causing an effect as each foot moves past the bottom sensor.
- The trimmer tool is slightly magnetic and should not be carried on the person, e.g. back pocket.
- Magnetic wellington boots - although usually non-magnetic some boots have been found to contain small quantities of ferrous material, sufficient to cause periodic errors.
- Magnetic clothing. Double check every piece of clothing for small items of metal by holding against a static gradiometer.
- Some coins are *extremely* magnetic.
- Keys, wallets, credit cards etc carried in the pocket.

Why does tilting the gradiometer make the reading change?

When you tilt a gradiometer a small change in reading will occur even when properly aligned and balanced – this is known as a tilt error and will introduce in effect a small amount of noise to the observed or logged readings. Operators try to minimise this error by holding the gradiometer tube as vertical as possible. However, the magnitude of the tilt error is dependant on the direction or heading in which the gradiometer is pointed, with respect to magnetic north (heading direction is defined as the direction in which the electronics housing and handle axis is pointed). Since each instrument behaves differently in this respect there are unique optimum headings for each instrument that will minimise these tilt errors. You should ideally survey with the instrument pointing in one of these directions for lowest tilt error. Take care to remember that optimum heading direction refers to the direction in which the instrument is pointing – this may not necessarily be the same as the traverse direction, since it depends on the instrument holding technique you use.

The optimum heading will vary depending on your geomagnetic latitude. You can find the optimum headings at your latitude as follows:

1 Align and zero the instrument normally over a high quality alignment and balance / zero reference station.
2 Hold the instrument about 1m above the ground.
3 Observe the shift in reading as the instrument is tilted about 10 degrees from vertical in all four directions, with it facing in turn North, South, East and West.
4 The optimum directions are those that show the smallest change in reading.

In normal use you should be able to hold the instrument steady to about +/- 2.5 degrees from vertical so the observed tilt errors during a survey should be lower than just observed.

Why does the displayed reading flicker?

Some flickering of the reading will be observed with 0.1 nT resolution in normal circumstances in the field. However, if flickering is greater than normal, say greater than 1 nT then this may be caused by external interference. On urban sites this is likely to be due to the magnetic fields from underground mains power earth currents, telephone earth return currents, or currents conducted along underground pipes. On rural sites interference can occur when operating in the vicinity of radar, radio or television transmitters or booster stations. Interference will increase as you get nearer the source, though it is difficult to give precise indications of the level of interference. As an example, you may observe fluctuations of about 3 nT at distances less than 50m from a radio booster station, though the distance and degree of fluctuation will vary from situation to situation. Some radar stations including those of air traffic control, ship harbour and military establishments can transmit at very large signal strengths, causing interference at up to 15-100 Km distances.

You can try to improve the signal to noise ratio by using digital averaging. If this does not effect a cure then either move further away from the interfering source or reduce the sensitivity of the gradiometer.

Overhead mains cables, suspended from pylons, do not in general cause any interference problems, though the pylons themselves, being made of steel will show as a very large response.

Note that the instrument is not designed for laboratory use so if you try to operate in such an environment you may observe interference in the form of flickering readings. This is usually due to the magnetic fields generated by mains operated devices, in particular, mains transformers such as those found in computers, televisions etc.

How do I download data if I do not have the latest Geoplot?

If you have a copy of Geoplot earlier than version ‘3.00h1’ then there will be no specific provision in the Input Template for an FM256. (You can check version by selecting ‘About Geoplot’ on the Help menu). You can still download data by fooling Geoplot into thinking that it is dealing with an FM36 instrument; you will also require an FM18/36 data dump lead – this method will not work with an FM256 data dump lead. Set Input Template details as though it were an FM36 (Baud Rate normally = 2400) and on the FM256 set Baud Rate = ‘2400’ and Data Format = ‘Fast ASCII’. Proceed as though you were downloading from an FM36; the data will be recorded as though it were FM36 data, observable when you view File Details in Geoplot.

A higher download speed can be achieved as follows, but *only* if you are not using Log Zero Drift. Set Input Template details as though it were an RM15 (Baud Rate normally = 9600) and on the FM256 set Baud Rate = ‘9600’ and Data Format = ‘Fast ASCII’. Proceed as though you were downloading from an RM15; the data will be recorded as though it were RM15 data, observable when you view File Details in Geoplot. You will need to change units from ohms to nT for each grid by using Units on the Edit menu. Survey Type will still be recorded as Resistance in File Details so for archiving purposes you should use Windows Notepad or any other text editor to modify the .grd file accordingly.

If you have an early copy of Geoplot 3 then please ask for the latest version, stating serial number and if you have dongle or software protection – this code can usually be emailed to you free of charge. If you have DOS based Geoplot 2 then you will need to purchase an upgrade to Geoplot 3 to obtain full FM256 system support.

How do I download data if I only have an FM18/36 download cable?

Should you only have an older FM18/36 data dump cable available then this may be used in an emergency – however it should only be used for smaller data dumps and / or slower baud rates since handshaking is not implemented in this cable.

What do I do if I am having difficulty downloading the data?

Initial Checks

If you experience problems downloading data then initial checks should include the following initial checks:

- Ensure you are using the correct download cable – see Appendix C for details.
- Ensure the download cable is plugged into both the FM256 and the computer
- Inspect the cable for damage – if possible test continuity of the cable according to details in Appendix C.
- Check that the serial port on the computer is enabled – you may need to inspect the BIOS settings to confirm this. *Please note that making incorrect changes to the system bios may prevent your PC from booting so consult your system documentation very carefully before doing so.*
- Try downloading to another to eliminate the computer serial port as a problem.

Computer Setup

Before you download you ensure that screen savers, battery standby, battery monitor, hard disk standby are disabled – a reminder is given on the dialog boxes. If you do not disable them, then when these become active they can interrupt the real-time handling of the data flow into the PC, leading to loss of data. As well as disabling screen savers, battery standby and battery monitor, make sure there are no other background tasks operating that may interrogate the serial ports or acquire CPU time, for example:

- Some personal organiser synchronising software, by default, continually scans the serial ports for activity – this must be disabled before downloading data.
- Some virus checkers may need disabling if they monitor the serial port and hence interupt the flow of data.
- Software for modems may take control of the serial port and must be disabled. In some circumstance the serial port may not be active, most common on computers with internal modems and must be activated before you can download data. This may be done either using special utilities provided with your computer or by changing the system bios settings when you first start your computer. *Please note that making incorrect changes to the system bios may prevent your PC from booting so consult your system documentation very carefully before doing so.*
- It is possible that if Windows, or one of its components, is not correctly installed, or conflicts occur within the hardware installation then you may have difficulty downloading data correctly. For example, you may have a mechanical switch that connects a single serial port to either a modem or an instrument for download – however, the modem driver / installation may be permanently trying to access the serial port at the same time.
- You should disable Infrared ports since they also use the serial port and may interrogate it every 3 seconds by default.
- Do not use a serial mouse since this will generate interupts that may affect data handling.
- Running a portable computer from battery, rather than the mains supply can solve download difficulties (this was experienced on a DELL computer running Windows 98).

In all the above cases you should always restart your download software after making setup changes, and in many cases you will also have to reboot the operating system.

Geoplot Setup

If you are using Geoplot 3 to download data then check the following points:

- Make sure the “Download RS232 COMM port” setting in the Environment Options, Input tab is set to the correct port number – by default this is “1”. Ensure that there is not a break in the cable.
- Data download requires the version of MSCOMM.VBX dated 5/12/93. This is automatically installed with the other DLL and VBX files. If you experience problems with data download check to see if there are any other versions present on your machine and ensure it is not dated earlier than 5/12/93.

- A progress report consisting of a bar and reading count is shown as the data is downloaded. If there is a large quantity of data and the computer is slow then you may get a “Buffer Overflow” or “Port Overrun” error message. If so, then go to Environment options and change the progress report to either Bar only or none at all. Also, do not move the mouse or progress form during download since this will generate a Windows call that will be serviced in preference to handling the RS232 data. The internal buffer may not have sufficient capacity to temporarily store the incoming data in the interim.
- If you are using Windows 3.1 on an older, slower, computer (e.g. 486DX2) then it is advisable to make some changes to your System.ini file to improve throughput of data into the RS232 port and avoid buffer overflow. In the [386Enh] section add :
  - COMxBuffer=8192 (where x = the Comm port number)
  - COMxFIFO=On

  If you are using Windows 3.11 you may also need to add :

  - COMxFIFO=0

The Computer does not have a Serial Port

If your PC does not possess a serial RS232 port but does have a USB port then you should use a USB to serial adapter to download data. This could also be a solution if you continue to experience difficulties using a conventional serial port – see above. You will need Windows 95 with USB support, Windows 98 or higher. The driver software that accompanies the converter will probably assign its virtual COMM port to be other than “1”. Typically this is “4” and, if using Geoplot 3, you should set the Input tab in Environment Options accordingly. If you use a USB converter you will find that you have to exit Geoplot after a download in order to clear data left in the PC’s buffer. For example, if you come to dump data and see the message “Receiving data…” instead of the normal “Waiting for data…”, even though you have not yet pressed DUMP on the instrument, this is a sure sign that data is still left in the PC’s buffer. If you do not exit Geoplot at this stage and continue downloading, the data will be scrambled.

Why is the data is scrambled?

If the data appears to be scrambled check the following points as these can cause such a problem if not followed:

- When downloading data the settings for Log Zero Drift *must* match on the instrument and software.
- When downloading data the settings for Data Format *must* match on the instrument and software.
- You must exit from the download software after dumping via a USB to Serial converter in order to clear the computers buffer prior to the next download – see above.

Try downloading the data again if one of the above points was the cause of the problem. Even if the memory has been cleared, the old data still exists in memory and can be dumped again, providing no more data has been logged in the meantime which will have overwritten previous data.

What do I do if there is water in the FM256?

If you have been working in extremely heavy or driving rain and water has entered the electronics housing of the instrument then you should *not* use the instrument until it has dried out thoroughly. Remove the lid and leave the instrument in a warm dry environment for at least 24 hours, preferably longer. Take great care not to damage internal wiring if you remove the lid.

DO NOT OPERATE WITH MOISTURE INSIDE

If you attempt to operate the instrument with moisture inside electrolytic action could severely damage the electronics.

If water is present in sufficient quantities that you need to tip it out, an environmental seal may have been damaged and the instrument ideally requires servicing. Once dried out you could continue to use the instrument temporarily, providing weather conditions have improved, and then have a servicing performed after the survey.

Why does the NiMH battery pack not hold its charge?

The NiMH battery pack can be recharged up to approximately 600 times. After this number of recharges it will start to lose its ability to retain charge and will need replacing.

What can I do in an emergency if I cannot obtain the correct size memory backup battery?

A common battery is the CR2025, DL2025 or ECR2025 3V Lithium battery. It is smaller in diameter and thinner than the normal CR2450, DL2450 or ECR2450 battery. You can use this in an emergency if you cannot obtain the normal sized battery. To make up the thickness use this battery, together with a coin (such as a 10p pice) used as a spacer – ensure the coin is not too magnetic. Bear in mind that the contact method is not ideal and a normal sized battery should be fitted as soon as possible. *It is vital that you insert the battery the correct way up – the retaining clip is marked with a '+' sign and must connect to the positive side of the battery – if you connect it the wrong way round the circuitry inside will be damaged.*

What do I do if a Start-Stop button stops working?

The button of a Start-Stop switch can become stuck down sometimes when working in very wet weather. Water enters the very small gap between the button and the switch surround and capilliary forces hold the button down. Try blowing the water out and, at the same time, use your finger to gently move the button from side to side to release the water and button. If this does not work, taking the instrument into a dry atmosphere will allow the water to evaporate and then the button can be released by gently moving with a finger. The Log key on the front panel or an external hand-log key can be used as alternatives to starting the internal sample trigger system when the Start-Stop switch is out of action. Should a Start-Stop switch need replacing, a spare can be ordered for the user to fit – there is no soldering involved and an internal plug push fits into a connector on the back of the new switch.

What do I do if the gradiometer will not zero correctly on the 0.1 nT range?

Whilst the instrument can be aligned successfully in the N, S, E and W directions and the balance control can be adjusted so that an equal reading is obtained in the normal or inverted positions, pressing the Zero key produces a "balance" message. The reading will not be zeroed but will be some positive or negative value, usually less than +/-90 nT. Although very unlikely, this error can occur due to a slow drift in either the electronics or sensor offset over a number of years until the instrument is no longer able to compensate for this offset on the 0.1 nT range. A long term solution is to return the instrument for servicing and usually a simple resistor change will bring the offset back into the range of the zero key (however, please discuss this symptom with Geoscan Research *before* returning an instrument--some users have not been aligning the instrument according to the instructions and this can cause the problem; aligning properly solves the problem). In the short term, surveys can still be made successfully even if the instrument will not zero correctly providing you do *not* use the Log Zero Drift facility. To do this make sure you align properly N, S, E and W and balance in the normal and inverted positions, press the Zero key and accept whatever the offset value is. Survey each grid normally, except that you will not be collecting a zero drift figure. Download the data and use Geoplot to either (a) subtract a background value equal to the offset, (b) use Zero Mean Grid to remove the offset or (c) use Zero Mean Traverse to remove the offset.

Appendix A

FM256 DATA SHEET

Introduction

The FM256 Fluxgate Gradiometer System is designed as a one man rapid location, mapping and identification system for a wide range of targets, which can be archaeological, environmental, utility services, geological or military in origin. Archaeological targets include fired structures such as kilns, furnaces, hearths and ovens, and structures with an enhanced magnetic susceptibility such as pits, ditches, enclosures, field systems, barrows etc. Other targets include environmental waste, oil drums, pipelines, cables, unexploded ordnance and geological formations.

The FM256 can be operated as a single stand alone gradiometer or in dual gradiometer mode. The dual mode uses two instruments carried together to double the survey speed or, using interleaving, provide increased survey density (double or quad). Integration with Geoplot software provides excellent data capture, processing, analysis, graphics, interpretation and presentation facilities, allowing you to realise the full potential of your magnetometer data.

FM256 Gradiometer

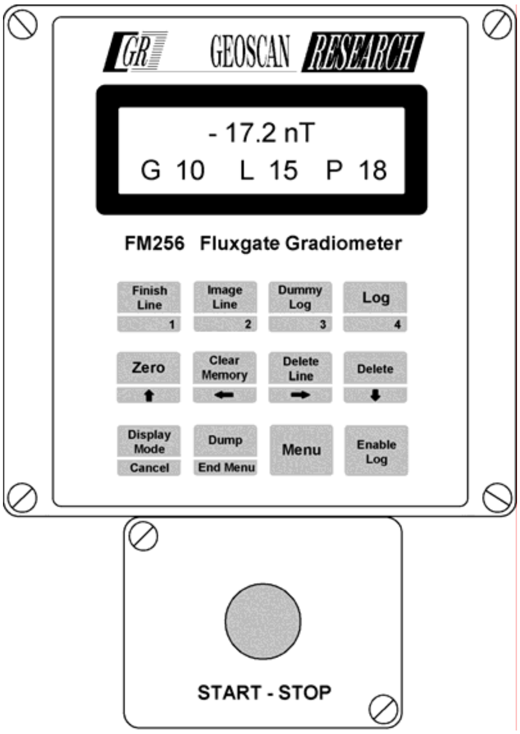
The FM256 instrument can be used in either scanning mode, to search rapidly for disturbed areas, or in logging mode, where detailed data are collected in parallel or zig-zag traverses. The data-logging facilities, with integral sample trigger, provide powerful functions for fast and efficient surveying, keeping track of survey position, and giving both audible and visual indication of current survey position. Data can be collected at up to 16 samples/m and stored in a 256000 reading memory.

Readings are displayed on an LCD display in either digital or analogue bar-graph form, the latter being useful for scanning. Backlight control for the LCD display enables work to continue in poor light conditions or short winter days; contrast adjustment improves visibility over temperature extremes. A Real Time clock facility is included which can be used to monitor progress since wristwatches are too magnetic for operators to wear. A Hold facility, which freezes the reading, is provided to allow easy sensor balancing. Although not often required, owing to the excellent stability of the instrument, any change in the instrument zero may be logged at the end of each grid and used to correct for drift. Geoplot software has standard processing routines that usually make drift correction logging unnecessary.

Cost effective upgrade routes allow existing FM18 and FM36 users to convert their instruments to FM256 specifications.

Data Logger

Readings are logged in a 256000 reading non-volatile memory which may be partitioned into square or rectangular grids with dimensions of 10, 20, 30, 40, 50 or 100m - typically these are 20m or 30m square grids. The wide range of grid sizes allows you to tailor logging to your survey requirements. Sample and traverse intervals can be set to 1, 2, 4, 8 or 16 samples per metre, with 16 samples giving maximum resolution. The data logger keeps track of survey position, displaying the current grid, line and position and provides audio feedback. Instead of menu systems, the front panel has been designed to provide fast and direct access to logging functions using 8 dedicated keys.



Readings and lines of readings taken by mistake can be deleted with one keystroke. A dummy reading can be inserted if a physical obstacle prevents a true reading being taken or a line may be completed with dummy readings, again with one keystroke. In zig-zag surveying these “Finish Line” dummy readings can be imaged with one keystroke - see keypad layout opposite. The 256000 reading memory is sufficient for 35 x 30m x 30m grids at 8 samples/m or 80 x 20m x 20m grids at 8 samples/m (about 3 hectares), allowing a full days data collection with no data transfer.

Data is downloaded to a PC via an RS232 interface, typically into Geoplot or any other suitable program. Downloading the full 256000 readings takes as little as 15 minutes, depending on the output format chosen - 5 are provided. Logged data can be inspected without having to download first, allowing the user to monitor data quality as the survey proceeds.

Sample Trigger or Manual Logging

Data logging is usually performed under control of an integral sample trigger but can also be done manually, one reading at a time. Logging is usually performed using the start/stop switch or the keypad. If preferred, an external hand-log key is available for manual or sample trigger logging. Sample trigger logging provides increased data sampling and enhances data quality and interpretation without increase in survey time. Pressing the start/stop switch initiates a sequence of “beeps” that sound every metre whilst internally the gradiometer logs readings at the set sample interval. The operator walks along the survey line at a pace that ensures the “beeps” coincide with 1m marks along the tape - with practice the tape can be dispensed with for even faster surveys. The “beep” rate is variable between 0.4s and 3.0s, in 0.02s steps. Data can be logged at 8 samples/m at an average rate of 0.8s/m or faster, according to site. If a reading goes over-range, this is recorded in the data and is distinguishable from dummy readings. Both manual and sample trigger logging can operate in the digital averaging mode for improved data quality.

Digital Averaging

The FM256 automatically integrates the readings at all times so as to minimise system noise. Digital averaging can be selected to improve further the signal to noise ratio, useful on sites where anomaly strength is comparable with system noise. A wide range of averaging cycles (2 to 32), allows the user to optimise the trade off between significant noise reduction and optimum speed. Digital averaging is automatically used when Zeroing and using Log Zero Drift for improved accuracy.

Power System

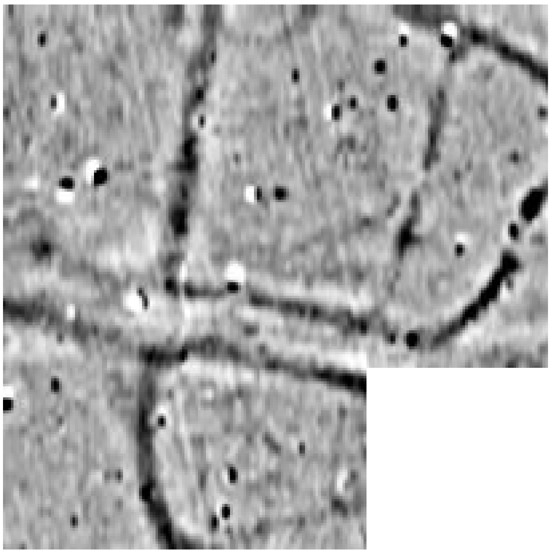
The FM256 is powered by 2 “C” sized cells, either a NiMH battery pack with temperature sensor or 2 standard alkaline cells mounted in the holder provided. The instrument operating period with NiMH cells is 21 hours without LCD backlight, 15 hours with LCD backlight (44 hours and 31 hours respectively for alkaline cells).

The NiMH cells can be fast charged in 3-3½ hours from the universal voltage power supply which is supplied with worldwide pin adapters (the charging circuit prevents accidental charging of alkaline cells). Charging status (fast or trickle) is shown by a dual colour LED. Operation from standard alkaline cells allows operation in remote locations with no charging facilities. A separate, easily obtained, lithium battery is used to backup the non-volatile memory for up to 10 years. The main and backup batteries are housed under the instrument housing in two separate sealed compartments with external access, making battery changes simple. This preserves environmental seals and isolates any alkaline battery leakage.

Practicality And Design

The FM256 builds upon the rugged and reliable design of its predecessor, the FM36, making it an instrument that can be used in a diverse range of demanding environments, such as harsh desert conditions, the tumbles of student field courses, time critical commercial surveys and peace time military environments. The design retains the proven benefits of a 0.5m sensor separation which gives good mobility, good ground clearance and the option to carry the instrument higher above the ground. This flexibility allows it to operate in scrubland, brushwood, long grass and in other overgrown areas, where other sensor systems operating nearer the ground may be difficult to use. The use of a short tube means it is much less prone to buffeting by the wind which can introduce significant measurement errors. A 0.5m sensor separation provides good rejection of signals from nearby ferrous clutter such as iron or barbed wire fences allowing you to survey close to such interference.

The versatile and ergonomic design incorporates many features requested by FM36 users, provides an economic upgrade route for existing FM18 / FM36 users and can be expanded into a dual gradiometer system. Environmental sealing to IP65 standard or better is used and a gold connector system is used internally for maximum reliability, especially in higher humidity climates. A rugged tube is used to support the fluxgate sensors which are housed in a robust outer case. A geared alignment system provides excellent stability and very fine control when aligning the sensors for optimum performance.



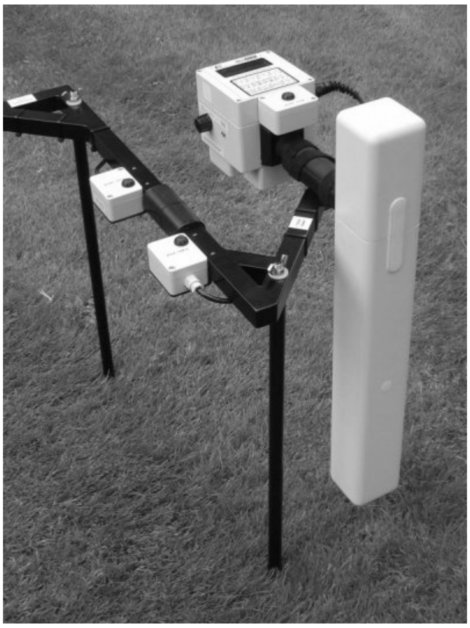
Example FM256 survey over a Romano-British enclosure, field heavily ploughed. Features of 1nT or less are visible. Plot range -3nT to +3nT. Area 60m x 60m.

Dual Gradiometer System

The dual gradiometer system uses two instruments carried together, 1m apart, either to double the speed at which a survey can be made or to increase the sampling density of a survey. Basing the system on two individual gradiometers gives optimum flexibility since they can also be used separately at different sites when required.

A three sided carrying frame (see photos on next page) supports the two gradiometers. One FM256 acts as a master sample trigger which controls a second slave gradiometer - this can be either another FM256 or an FM18/36. Once data sets have been collected in the two gradiometers they are downloaded, and assembled into two individual composites as normal. The two data sets are then easily merged together to form the final composite - Geoplot provides for this in one simple operation.

The system can be used in either parallel or zig-zag survey mode. When used in zig-zag mode the operator, not the frame, turns around at the end of a traverse, thereby avoiding the introduction of direction dependent heading errors. Since there is no need for restrictive harnesses, turnaround is very rapid.



The start/stop sample trigger button on the FM256 is replicated twice on the frame to cater for operator orientation during zig-zag surveying. Logging is simply performed by pressing the start/stop button. The four legs allow the system to be rested on the ground anywhere during survey - no need to return to a centralised support tripod. The frame is designed to support just one gradiometer at a time when resting on the ground, allowing each gradiometer to be aligned individually. The frame can also be used with the legs removed for operation over very overgrown areas.

Variations in angular orientation can introduce heading errors into the data collected. Using a handheld frame, in contrast to other instrument support systems, provides the user with greater awareness and control of angular variations which significantly improves the quality of the data collected. The sturdy frame is well balanced and easy to use even in long undergrowth, and can be lifted easily over other obstacles. The frame is very lightweight, packs flat and is easy to assemble and transport.

Double Survey Speeds

Double speed surveys are carried out by making traverses with the system every 2m, rather than the normal 1m traverse interval for a single gradiometer. This mode is very useful for rapid evaluations. Traverses may be either parallel or zig-zag and sample interval can be up to 16 samples per metre. A guide marker on the centre of the frame helps you maintain alignment with guide tapes (if used). Area coverage for evaluation surveys is very rapid : a 20m x 20m grid can be surveyed in about 3 minutes using zig-zag traverses, sample interval of 0.25m, sample trigger rate of 0.7s/m and 1m traverse interval.

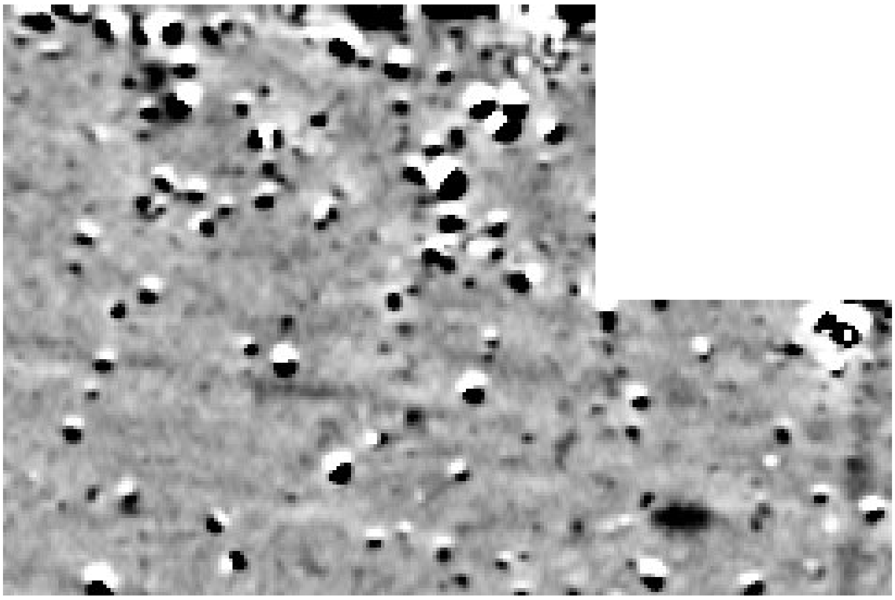
Increased Sample Density Surveys

Increased sample density surveys can be achieved by modifying the traverse pattern. Surveys with traverse intervals of 0.5m (double density) and 0.25m (quad density) can be achieved in half the normal time for a single gradiometer. The increased sampling density mode is useful for detailed evaluations or research applications where high resolution maps of sub-surface structures are required. The quad density mode is especially useful in this respect - see example survey 2 below. Traverses may be either parallel or zig-zag and the sample interval can be up to 16 samples per metre. Walking the modified traverse pattern is straightforward, and guide markers on the frame help you maintain alignment with guide tapes (if used). The resulting interleaved data pattern is simply merged together using software - again Geoplot provides for this in one simple operation.

Example Survey 1

The survey shown below was collected in double density mode. Grid dimensions were 20m, data was collected in zig-zag traverses at 4 samples per metre and the resultant traverse interval of the merged data is 0.5m. Trigger rate was set at 0.8s/m. Roughly a third of the site was covered with grass and nettles to the height of the frame yet this was successfully navigated with the dual system with no obvious signs of impairment in data quality.

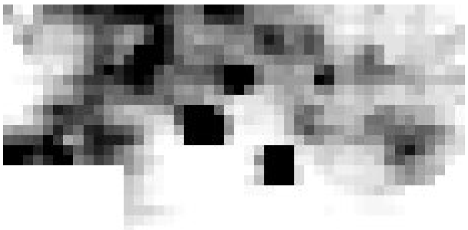
Several sub 1nT traces of ridge and furrow running E-W are visible, along with many ferrous responses - no destagger corrections were required to align the ferrous responses between adjacent traverses.



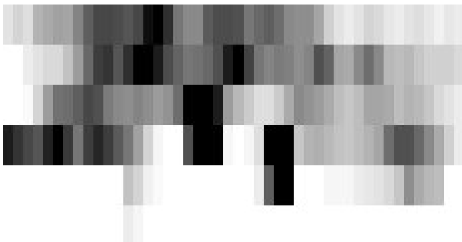
Double density survey made with a dual gradiometer (FM256 and FM36). Plot range -3nT to +3nT. Area 40m x 60m.

Example Survey 2

The results below compare the difference between raw data collected with a normal 1m traverse interval and data collected in quad density mode. Data were collected with parallel traverses in both cases at 4 samples per metre and with a trigger rate of 1s/m. The resultant traverse interval of the quad density data is 0.25m. The improvement in detail shown in the quad density survey is very striking. Even greater resolution is possible with the FM256 if sampling is increased from 4 to 16 samples per metre. (Plot range –5nT to +5nT).



Quad density survey (0.25m x 0.25m)



Standard survey (0.25m x 1m)

Data Quality—Processing and Analysis with Geoplot

To realise the full potential of magnetometer data, sophisticated data processing and analysis is essential. Geoplot software provides this support in the FM256 system. It provides simple download and dual gradiometer data merge facilities, combined with excellent graphics, editing, processing, analysis, interpretation, presentation, import and export facilities.

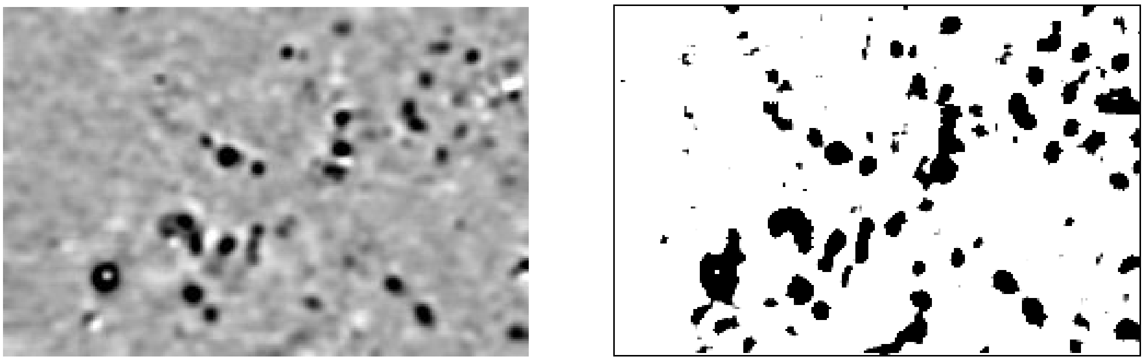
Often only minimal processing will be required before analysis and presentation. However, in common with all magnetometers, there will be noise present in the data which reflects a combination of soil noise, instrument noise, and field (operator) noise. This can limit feature detection when operating near measurement limits. Geoplot’s comprehensive range of functions provides the means to reduce significantly these noise components, allowing very weak features to be detected. Data analysis can further extend the confidence with which features are identified.

Processing

Geoplot's toolkit of specialised processing functions include the following : Absolute, Add, Clip, Compress, Cut and Combine, Deslope, Despike, Destagger, Edge Match, High Pass, Low Pass and Median Filters, Interpolate, Multiply, Periodic Filter, Power, Randomise, Search and Replace, Spectrum, Standard Deviation / Variance Map, Zero Mean Grid, Zero Mean Traverse. Correct processing of the data shown on the right using Geoplot results in an overall noise level of 0.1nT, including soil, instrument and field operator noise - this processing was achieved even in the presence of very strong and extensive ferrous responses (plot range –3nT to +3nT, area 140m x 60m). In another example, a 50cm thick Pueblo midden was detected (and confirmed by excavation) 1.9m below sand and clay layers and registered as a 0.05nT anomaly after appropriate processing.

Analysis

Geoplot provides a number of analytical tools including statistics, spectrum, standard deviation maps. Particularly useful for gradiometer data is statistical detection, illustrated by the data set below. A collection of weak hearths are visible in the left hand plot. A combination of high sampling density and appropriate data processing results in a background noise level of 0.13nT. This includes soil, instrument and field method noise. Setting a detection threshold of 2.5 standard deviations (high statistical confidence), reveals a large number of hearths (right plot) subsequently confirmed by excavation.



Statistical detection reveals a large number of hearths 0.3nT or greater in a background noise of 0.13nT after processing. Plot range –1nT to +2nT. Area 60m x 40m.

Upgrading from FM18/FM36 to FM256 System

If you have an FM18 or FM36 then a very cost effective way of improving your survey system is to upgrade your existing instrument to an FM256. If you have two FM18's or FM36's then upgrading only one instrument and using the other as a slave will give you a dual gradiometer system with all its associated benefits. Alternatively, you can purchase a new FM256 and use this with an existing FM18/36 to create a dual system with the FM18/36 again acting as a slave. These routes considerably reduce the overall cost of long term ownership, maintains the value of your investment and improves productivity.

The upgrade involves replacing the electronics housing and its internal electronics (ie half the instrument) but retains the existing sensors in their tube and the carrying handle. We can modify existing carrying cases to take the new outline of the FM256 instrument and the standard FM256 system accessories will be slotted into the existing cut-outs. Alternatively a new carry case can be obtained with cut-outs to the new layout. A new manual, data dump lead and charger is supplied as part of the upgrade. Please note that the upgrade does not include any refurbishment to the existing tube or carrying handle - if these are in very poor condition then this may have an influence on the feasibility of an upgrade. Please consult with Geoscan Research if in doubt.

After confirming suitability for upgrade instruments should be returned to Geoscan Research, except in North America, where instruments will be returned to Geoscan Research (USA). Other overseas customers should consult with their local agent, where applicable, to make arrangements.

Very recent instruments may be *partially* upgraded but with some functionality limitations. A partial upgrade essentially replaces the existing microprocessor pcb with an FM256 style pcb, along with some modifications to the other pcbs and a new keyboard lid is supplied with the Start/Stop switch. The limitations are:

1 A partially upgraded FM256 cannot be used as a master in a dual system.. It can be used as a slave however.
2 The power supply system will still be the existing 8 AA cells and charger - there will be no fast charging.
3 Access to the batteries (main and memory backup) will still be done by removing the top lid rather than accessing compartments underneath.
4 Memory backup will be via a small battery (CR2025 – 130mAh) on the new microprocessor pcb with a capacity about ¼ of that of the normal CR2450 cell so data retention time will reduce to about 2.5 years at 25 degrees C.
5 Battery voltage cannot be measured, only Normal/Low status displayed.
6 There is no LCD backlight or contrast adjustment – the existing LCD display is retained.

Accessories Supplied

The FM256 comes complete with robust padded carry case for transportation, instruction manual, data dump lead, universal charger and adapter pins sets, balance alignment tools, screwdriver and battery holder for alkaline batteries. The carrying case cut-out has compartments designed for the standard items provided and also compartments for other accessories. The FM256 manual is very comprehensive and provides all the information you need, even for non-technical users new to magnetic surveying. It includes chapters on system assembly, operation, field procedure, data processing, troubleshooting and several appendices. Most users find our manuals more than sufficient for their needs, but if you require additional support this is always available. Our website www.geoscan-research.co.uk also provides further information and support.

Optional Accessories

An optional carrying case for upgrades from single to dual FM256 systems is available which allows for the transportation of two instruments together (moulded sensor tube only) with a double set of accessories. The carrying case also has a compartment to take the legs of the CF6 dual carrying frame. Dimensions 640 x 660 x 220 mm. Weight (empty case): 6.6 Kg, weight (loaded): 14.5 Kg.

An optional external hand-log key, with a 1.2m lead, is available for manual logging or for controlling the integral sample trigger if preferred. A carrying frame, complete with legs and spare parts for the dual gradiometer system is available - see Dual Gradiometer System for details. Spare rechargeable NiMH battery packs are also available.

Guarantee

The equipment supplied by Geoscan Research is guaranteed against defective material and faulty material and faulty manufacture for a period of 12 months from the date of despatch. Our responsibility is in all cases limited to the cost of making good the defect in the instrument itself. The guarantee does not extend to third parties or other equiment, nor does it apply to defects caused by abnormal conditions of working, accidents, neglect or wear and tear.

Acknowledgements for use of data

BUFAU (Dr. Roger White), Huddersfield and District Archaeological Society, Towton Battlefield Archaeological Survey Project (T. Sutherland), Kerkenes Project (Dr. G. Summers), Geoscan Research USA (Dr. L. Somers)

Typical Specifications (FM18/36 can be upgraded to these specifications)

GRADIOMETER

Sensor separation	500mm		
Operating field range	+/- 100 uT, no latch-up for larger fields		
Analogue ranges	+/- 5, 10, 20, 40, 80, 160, 320, 640 nT		
Digital ranges	+/- 20000 nT	+/- 2000 nT	+/- 200 nT
Digital display resolution	10 nT	1 nT	0.1 nT
Data storage resolution	5 nT	0.5 nT	0.05 nT
Response time	20 mS	40 mS	120 mS
Display update rate	Digital - 3 readings/s. Analogue - 9 readings/s		

LOGGER

Memory capacity	256000 readings
Data retention time - full instrument	> 10 years at 25 degrees C (CR2450 coin cell)
Integral Sample Trigger 1m mark beep rate	0.4 - 4.0 S, adjustable in 0.02S increments
Grid dimensions (length, width independent)	10, 20, 30, 40, 50, 100m
Sample and Traverse Intervals (independent)	0.0625, 0.125, 0.25, 0.5, 1m (plus 2m Traverse Interval)
RS232 baud rate	600, 1200, 2400, 4800, 9600, 14400, 19200 baud
RS232 output	TXD, GND, CTS, RTS with handshake
Typical download time	15 minutes, for 256000 readings with fastest data format

GENERAL

Power Supply	2 x C Nickel Metal Hydride, rechargeable 3500 mAH battery pack or 2 x C Alkaline cells in holder
Battery life	21 hours (15 hours with LCD backlight) NiMH 44 hours (31 hours with LCD backlight) Alkaline
Working temperature	-10 degrees C to + 50 degrees C
Environmental rating	IP65 or better
Instrument weight (including batteries)	2.5 Kg (5.5 lb)
Instrument dimensions	620 x 380 x 120 mm
Carrying case dimensions	820 x 490 x 230 mm
Carrying case weight	6.6 Kg

CHARGER

Output	750mA at 7.5V constant voltage (constant current fast/trickle charge system inside FM256). Can be used with vehicle adapters.
Charging time	3-3½ hours (NiMH only)
Input voltage to charger	100-240 V, 47/63 Hz. International pins, UK, Euro, USA, Japan

DUAL GRADIOMETER CARRYING FRAME

Weight, including legs	2.3 Kg (5.1 lb)
Dimensions	1040 x 625 x 60 mm

All specifications subject to change without prior notice.

***Partially* upgraded instruments have restricted functionality and some reduced specifications – see previous page for details.**

Appendix B

GEOPLOT 3.0 DATA SHEET

Introduction

Geoplot 3.0 is a Windows program for the processing and presentation of geophysical data collected from a variety of instruments including : resistance meters, gradiometers, magnetometers, EM instruments, magnetic susceptibility instruments. Processing facilities include : high pass, low pass, median and periodic filters, spectrum and variance analysis, despiking, interpolation, edge matching, zero mean traverse correction, destagger correction, several numeric functions and a powerful cut and combine function for combing data sets mathematically. A record of every edit and process is maintained with each data file. Graphics may be produced as shade plots (grey scale or colour), trace plots (stacked profiles or 3D), dot-density or pattern plots and printed out at any scale or saved as bitmaps for use in other software packages. A publishing mode is included which allows you to combine many graphics images, text, drawn objects etc. Data may be imported and exported, allowing data exchange with other software packages.

Environment

Geoplot 3.0 retains all the functionality of the previous DOS version but adds the flexibility and convenience of a Windows environment. For example you can still navigate using the keyboard, menus and shortcut keys alone, essential for field use when a mouse or other pointing device is hard to use. However, the new Windows version brings the extra versatility of a mouse pointer and fast access to commonly used features using the new toolbars for process functions, graphics and drawing. You can identify data values by scanning the mouse over a graphics plot or select new graphics or process areas using the mouse. A typical opening screen consists of : a standard menu at the top, a horizontal toolbar just underneath which gives fast access to common menu items, a process toolbar to the left, a drawing toolbar to the right, status bar at the bottom, and floating complete statistics and latest history forms which can be invaluable aids for processing data. The View menu lets you turn toolbars etc on and off, though some control is also replicated on the horizontal toolbar.

There are four views you can have of opened data : graphics view, data view, history view and file details view. You can easily swop to a different view using the View menu or function keys. A fifth view, publish view, is available for creating a published presentation of your graphics plots. A hardcopy can be made of all the views using the File menu. There is extensive control in the Options menu over how Geoplot operates and your prefered defaults for different views and forms. For example default plotting parameters and default palette can be set, along with default screen colours. Default numeric resolution in the data view can be set together with dummy number status. You can define what your prefered view is when you load new data (graphics, data, history, file details or last view), and also if previous plotting parameters or default ones are to be used if a graphics plot is to be made. Many other options can be defined.

Data is handled in grid, master grid or composite format. A master grid defines how the individual grids lie in relationship to one another and can be used to combine individual grid data files into one file called a composite. Grids and composite files have associated with them an edit and process history respectively, as well as dimensional and other file information details. Input templates, which document data collection details and user comments, make data input rapid and easy to accomplish, and can avoid errors in the field. Files can optionally be date stamped when input in either European or USA format but date stamping can be turned off to avoid Year 2000 problems on older computers where the BIOS or RTC functions provide misleading information.

Data may either be downloaded from Geoscan Research instruments via the RS232 port, manually input via the keyboard or input via batch file transfer. Raw grid data downloaded from instruments is software writeprotected, preventing loss of data whilst in Geoplot. Imported data can be stored in grid or composite data format and a variety of input formats are recognised, including plain ASCII, XYZ and Spreadsheet, so that data from instruments other than those made by Geoscan Research can be handled. Data can also be batch exported in a variety of formats including plain ASCII, XYZ (comma, space or tab separated), Geosoft, Surfer grid files (ASCII and binary) and Grass for GIS. Generating direct Surfer grid files within Geoplot can save considerable time when using Surfer's facilities.

Usually you will use SVGA or higher for desktop work but the forms have been designed for VGA use too, which can be extremely useful for data download in poor lighting conditions or where older laptop computers with VGA LCD's are to be used.

The file manu also has facilities for combining several composites into one, creating blank composites for complex data manipulation, and the generation of stacked pseudo-sections from expanding Twin array data sets.

Whenever an edit or process function is applied to data the default is to immediately update the current view, be it graphics, data, history or file details. The floating history and statistics forms are updated too. You can, if you wish, turn off automatic graphics update. The Edit menu allows you to Flip Horizontal, Invert Traverse mode and directly change grid data. The Edit menu also allows you to change the North direction and change the Units, and Rotate both grids and composites. You can additionally document the recorded edits or processes by adding, inserting or deleting comments in the file history.

Graphics

Four graphics presentation types are provided : shade, trace, dot-density and pattern. Shade plots can have between 2 and 234 different shades of grey or colour. Trace plots represent data by a series of line graphs stacked vertically above one another. The data may be viewed from all four sides, and the trace angles adjusted to give a 3D style view. Dot-density and pattern plots represent data values by the number of dots within a cell plotted either randomly or in a systematic way. Plotting parameters can be entered in standard, clip, compress or relief mode, with default settings being defined in Graphics Options. Relief plots (artificial sun) are particularly effective at removing background resistance variations and present an almost photographic style quality (see adjacent figures). You can select a smaller portion of a graphics plot for display either by entering co-ordinates in the graphics parameter form or by selecting an area with the mouse. Plotting size varies between x 5 and x 1/32, providing a large dynamic range. You can magnify, reduce, zoom in or out at a point and pan in a graphics plot using either buttons on the toolbar or shortcut keys. A special toolbar button allows you to magnify x2 a small localised area of a plot (see figure).

A range of shade palettes are supplied and you can create and edit your own (see figure opposite). Each palette comprises one or more flooded regions and individual colour bands can also be superimposed anywhere on the palette. When in graphics view you can change the palette either by using the palette tools (next palette, previous palette, invert palette) or by bringing up the graphics parameter form. You can quickly display the Shade and Trace parameters forms by clicking on two special icons on the horizontal toolbar, or by choosing from the Graphics menu as normal.

Grid lines and numbers can optionally be superimposed on graphics plots, as well as your own user defined grid. As you move the mouse over a graphics plot its x, y co-ordinates are reported on the status bar (in both metres and reading units), along with the data value at that point. You can set any colour you like for the graphics screen background, dummy values etc. using the Graphics Options. Plot details can optionally be displayed on the right-hand side of the screen which includes palette or trace scale-bar, distance scale-bar, plotting parameters, direction of first traverse and histogram. The resolution of the numbers on the palette scale-bar can be controlled using the Graphics Options form. If you apply the Spectrum process to the data the plot details on the right-hand side will change to show spectrum units and the co-ordinates reported on the status bar, as the mouse moves, will show x position and frequency, instead of x and y co-ordinates.

A default style printout of a graphics plot can be made to any scale or print size using the File menu. You can choose whether you want to : (a) plot the whole data set, (b) a specific block, or (c) just what you see on screen. Graphics plots, palette scale-bars, north symbols histograms and distance scale-bars can also be saved to files. These can subsequently be imported into the publish view, at a specific scale, for publishing. Alternatively, you can use the saved bit-map for importing into other Windows packages.

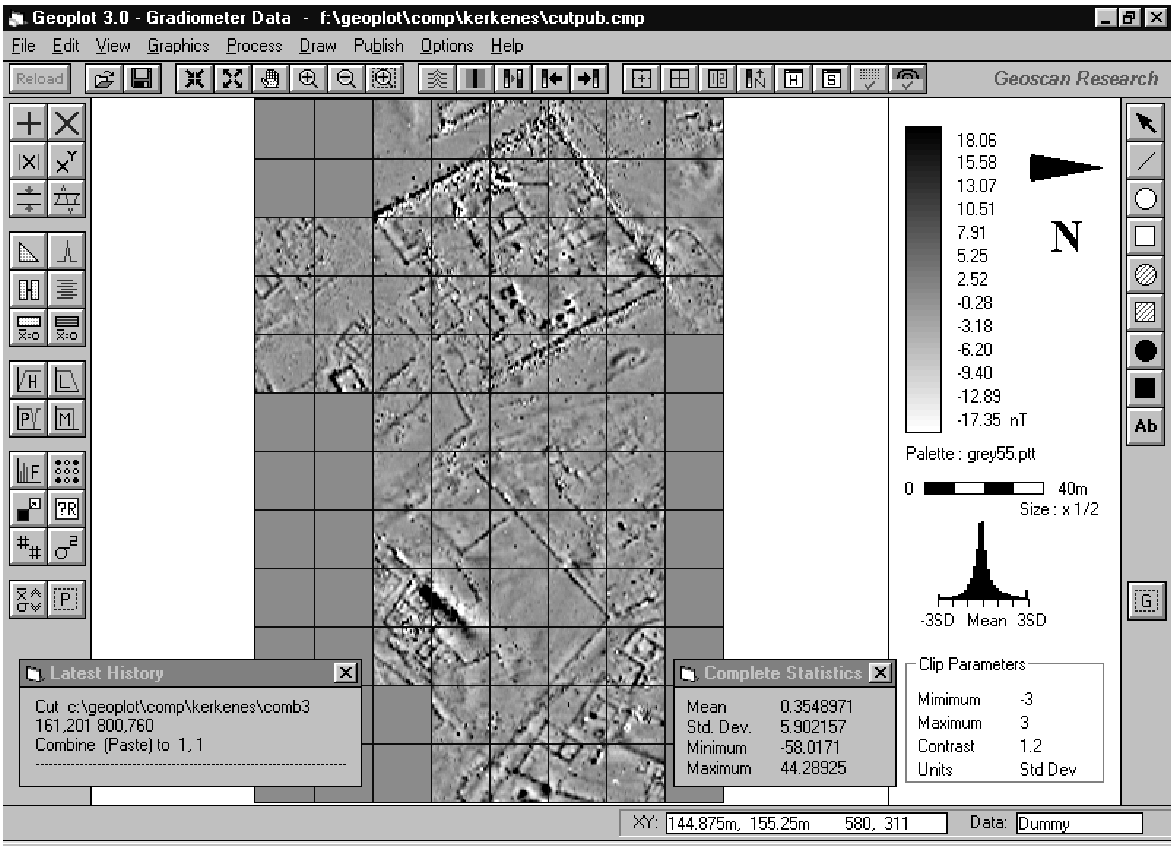


Figure A-1. Typical appearance of Geoplot 3.0 showing the graphics view.

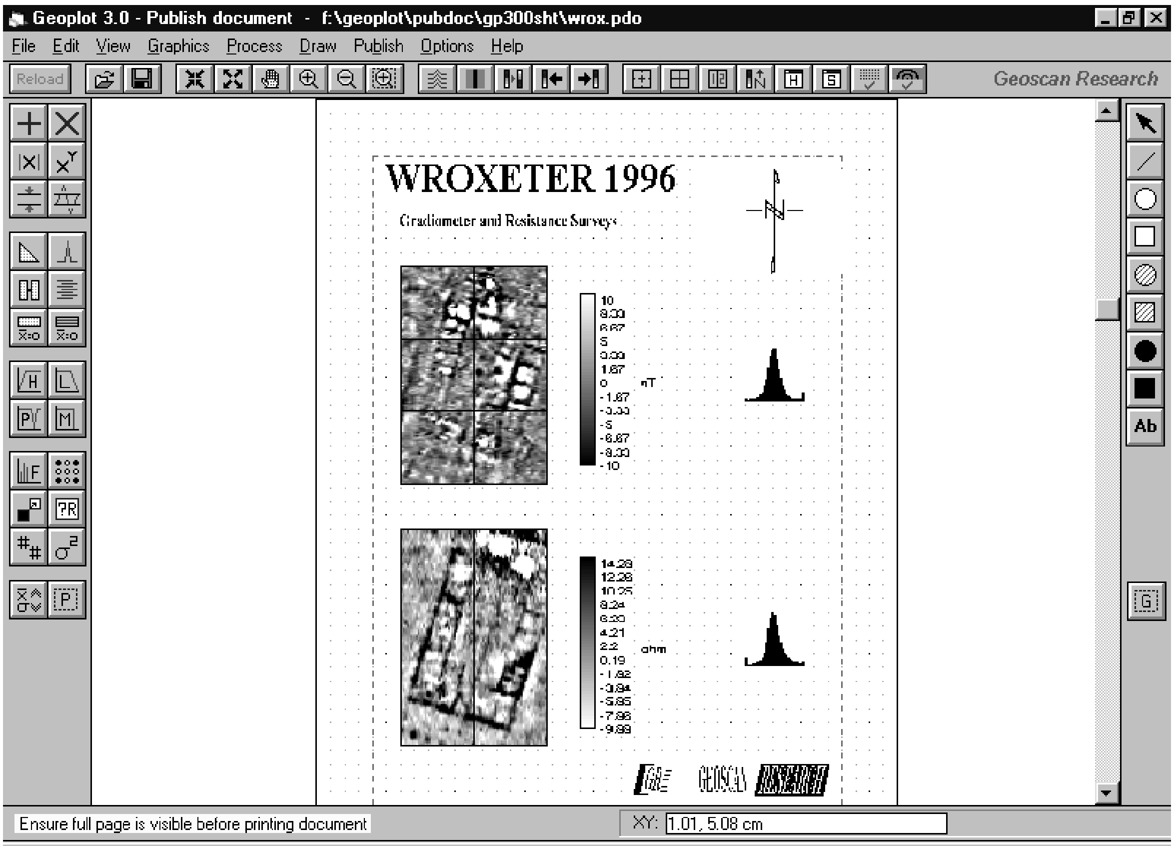


Figure A-2. Typical appearance of Geoplot 3.0 showing the publish view.

Publishing

Once you have processed your data and set the graphics plotting parameters you can save this image, along with scale bars, north direction and histogram for use in the publishing mode. This mode allows you to tailor the printout to your own requirements, rather than using the default presentation of the standard graphics view, allowing you, for example, to choose a border and add text in various fonts and sizes, select a north direction symbol. Images may be positioned, rotated and scaled to your liking. More than one image can be incorporated in the document, for example images from different sites, different graphics types (eg shade and trace plots) and even your own logo. The published graphics image is not just a screen grab with limited resolution, but a properly regenerated plot showing full detail on large size printers.

Processing

Processing includes a comprehensive range of functions for manipulation of all data types, together with specific routines to correct for data collection artefacts such as edge matching and drift correction. Some functions are designed specifically for Geoscan Research instrumentation but all may be equally applied to other instrumentation data sets. Mathematically, any real bipolar or monopolar two dimensional data array may be processed.

A processing tutorial is included in the instruction manual, together with "QuickStart" cards which guide you through the processing sequence appropriate for each data type. Both assist new users in becoming an adept and competent processor with a minimum of effort, and help to prevent inappropriate processing of the data.

Processing functions can be applied to the complete data set or any specific rectangular area, known as a block. You can specify a block either by entering co-ordinates in a form or, by selecting the area using the mouse. This block remains operational until turned off. You can select process functions and process area from the menu, or more conveniently from the process toolbar.

Processing history is stored with each data file. This records function applied, the chosen parameters and co-ordinates of any selected block, giving full traceability. A floating form, "Latest History" shows the last four processes applied and you can instantly switch to the history view to see a full listing of all processes. The process history shows a dotted dividing line between those processes that have been saved and any new functions that have been applied but not saved. History comments can be added, inserted or deleted when the history view is shown. Functions include :

Numeric Functions

Add, Multiply, Absolute, Power, Clip, Compress, Search and Replace, Randomise are general purpose numeric tools with a variety of applications. Some examples follow though they are by no means limited to these. The Add function can be used to edit a single data point or bias a block of data. Multiply can be used to normalise data or convert resistance to resistivity. Absolute can be useful in the generation of magnetic-resistance correlation plots. Power can be used to convert resistivity to conductivity. Clip can be used to limit data to specified maximum and minimum values for improving graphical presentation and also forms a useful pre-process procedure for many other functions. Compress can be used to fit data within the dynamic range of a display device or printer, allowing both large and small magnitude features to be visible at the same time. Search and Replace can be used, in conjunction with Clip, to convert regions strongly perturbed by nearby iron fences, pipelines etc. into dummy regions, allowing other statistical functions to perform correctly. Randomise may be used for introducing a controlled amount of noise so that surveys performed at different times or with different instruments visually match.

Cut and Combine

This function provides Cut and Paste, Add, Subtract and Multiply operations between two data sets (grid and composite). This can be applied between any block of source data and positioned at any location in the other data set. Applications include merging data sets, splitting data sets, generation of correlation plots between data sets etc. Another powerful application is to examine the effect of a process function (by subtracting the original data set), thereby ensuring that the process function has been applied with the correct parameters.

Deslope

Removes a linear trend within a data set. It is typically used to correct for drift in gradiometer data where the use of the Zero Mean Traverse function is inappropriate.

Despike

Automatically locates and remove random spurious readings present in resistance data and locates and removes random "iron spikes" often present in gradiometer data (see adjacent figures).

Destagger

Corrects for displacement of anomalies caused by alternate zig-zag traverses which are sometimes observable in gradiometer data.

Edge Match

Used to remove grid edge discontinuities which may be present in Twin electrode resistance surveys as a result of improper placement of the remote probes.

High Pass Filter

Used to remove low frequency, large scale spatial detail, typically a slowly changing geological "background" response commonly found in resistance surveys.

Interpolate

Increases or decreases the number of data points in a survey (linear or sinx/x method). Increasing the number of data points can be used to create a smoother appearance to the data. Interpolate can also be used to make the sample and traverse intervals of differently sampled composites match, prior to combining them.

Low Pass Filter

Removes high frequency, small scale spatial detail, useful for smoothing data or for enhancing larger weak features.

Median Filter

Automatically locates and removes random spurious readings present in survey data and smoothes the data at the same time. Most useful for high sample density data.

Periodic Defect Filter

Used to remove periodic features which may be present in the soil (eg plough marks) or which may be introduced as defects during gradiometer data collection.

Spectrum

Analyses the frequency spectrum of the data, splitting it into Amplitude, Phase, Real or Imaginary components. The Amplitude spectrum can be used to identify periodic defects in gradiometer data which can then be removed with the Periodic Defect filter.

Standard Deviation or Variance Map

Replaces the data set by either the local standard deviation or the local variance. A graphics plot of this new data set indicates areas of statistically different activity.

Statistics

Provides a statistical analysis of any block of data within a data set : localised mean, standard deviation, minimum, maximum and a localised histogram (this is in addition to the floating statistics report for the whole of the data set). Statistics can often be used to determine appropriate parameters for other process functions. The report form can be positioned anywhere on screen or minimised (see figure opposite) and can be retained whilst a new data set is loaded, so that the statistics can be compared.

Zero Mean Grid

Sets the background mean of each grid within a composite to zero. It is useful for removing grid edge discontinuities often found in gradiometer or similar bipolar data.

Zero Mean Traverse

Sets the background mean of each traverse within a grid to zero. It is useful for removing striping effects in the traverse direction which can occur in gradiometer data. This also has has the effect of removing grid edge discontinuities at the same time (see adjacent figures).

Hardware Requirements

Geoplot 3.0 is supplied on three 3.5 inch floppy disks with instruction manual. Geoplot is protected using either (a) a hardware lock (dongle) that plugs into the parallel port of the computer or (b) a software authorisation that is installed on your hard-disk. The software will only run if the hardware lock or software authorisation is present. The software authorisation can be transferred to another computer by using the floppy disk provided. New copies of the software are supplied using a software authorisation whilst upgrades from an earlier version to 3.0 normally use the the hardware lock issued earlier.

The software is normally supplied for one user operating on a stand-alone PC or a computer network. Multiple user versions are available for use on client-server network systems. Multiple user educational versions, with restricted functionality, are available for use on client-server network systems. Note that if you wish to use a hardware lock protected version on a network then you should first disable the network connection.

Operating system should be one of the following : Windows 3.1, 3.11, 95, 98, ME, NT4, 2000 or XP. If you are using a hardware lock and NT4 then you should have installed at least service pack 2. A software lock is required if you are using Windows 2000, XP or higher. Recommended hardware is a Pentium II class processor, cpu speed 266 Mhz or faster, with SVGA display or better for desktop work. Geoplot 3.0 will also work on PC's as slow as a 486 DX2 40Mhz processor so an older laptop computer running Windows 3.1, for example, could be used for downloading data in the field. The minimum colour setting should be 256 colours for desktop work and any higher setting can be used. Colour settings below 256 colours will result in a dithered graphics display but could be acceptable for field use. Usually you will use SVGA or better for desktop work but Geoplot 3.0 forms have been designed for VGA use too, which can be extremely useful for data download in poor lighting conditions or where older laptop computers limited to VGA LCD's are to be used. An RS232 communication port is required if data is to be downloaded from instruments into Geoplot 3.0.

Upgrades and Support

Geoplot is undergoing constant improvement and refinement. Future upgrades will include interfaces to new instruments and new data formats, together with new processing and presentation facilities. If there are specific facilities not mentioned above that users would like to be included in future versions then we would be happy to consider suggestions. A charge will be made for upgrades. Full technical support is provided free of charge.

Compatibility with earlier versions

Grid data, composite data and master grids (meshes) generated using earlier versions may be used directly with Geoplot 3.0. However, version 3.0 data is not backward compatible with version 1.2. Version 3.0 data may be read by version 2.0 but the resulting layout on the file information and history forms may not be as normal. Input templates generated with earlier versions are not compatible.

Educational Version

A multiple user (25) educational version, with restricted functionality is available for use on client-server network systems. Functions that are disabled are : New Input Template, Open Input Template, Download Data, Keyboard Input, Import Data, Export Data, and Create Pseudo-section. There are no other restrictions.

Appendix C

INTERFACE CONNECTOR

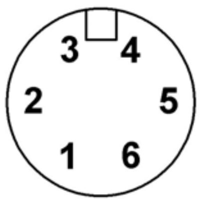
Introduction

The six-way interface connector, item 3 in figure 2-2, has four functions. Firstly it is used to output stored data to a computer using an RS232 interface. Secondly, the optional external hand-log key plugs into this connector. Thirdly it may be used for the synchronisation of two gradiometers when operated in dual gradiometer mode, acting as either trigger source or destination. Fourthly, the battery charger plugs into this connector.

In a *partially* upgraded instrument, the pin configuration will be different from an FM256 and functionality is reduced: in a Dual Gradiometer system a *partially* upgraded instrument cannot act as a master providing synchronisation pulses, though it can act as a slave.

Pin Connections – FM256

The pin connections for an FM256 are shown in figure C-1. *Note that the pin numbering applies to the external cable socket, not the plug on the FM256.* The RS232 cable provided uses only the three pins 2, 4, and 6. Pins 1 and 2 are used for the charger input, whilst pins 2 and 3 are used to provide synchronising trigger pulses to a slave gradiometer.

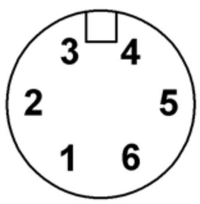


1 Charger +ve (FM256 charger 7.5V, 700mA constant *voltage* input)
2 Charger –ve / RS232 GND / Trigger pulse ground
3 Trigger pulse output / expansion power supply output
4 RS232 CTS – Clear to send (input) / Trigger pulse input / Hand-log connection
5 RS232 RTS – Request to send (output) / Hand-log connection
6 RS232 TXD – Transmitted data (output)

Figure C-1. Pin connections for interface connector – FM256

Pin Connections – *Partially* Upgraded Instrument

The pin connections for a *partially* upgraded instrument are shown in figure C-2. *Note that the pin numbering applies to the external cable socket, not the plug on the instrument.* The RS232 cable uses only the three pins 3, 4, and 6. Pins 1 and 2 are used for the charger input. There are *no* pins for synchronising trigger pulses.



1 Charger +ve (FM18 / 36 charger +25V, 70mA constant *current* input)
2 Charger –ve
3 RS232 GND – Signal ground
4 RS232 CTS – Clear to send (input) / Trigger pulse input / Hand-log connection
5 RS232 RTS – Request to send (output) / Hand-log connection
6 RS232 TXD – Transmitted data (output)

Figure C-2. Pin connections for interface connector – *partially* upgraded FM256

RS232 Connections

The functions of the RS232 connections are as follows:

TXD

Transmitted data. This is the output signal line over which data is sent from the instrument. Data is output in negative logic with an amplitude of +/-10V. The TXD line will be in a high impedance state whenever the FM256 is not transmitting data. It is connected to the RCV pin at the computer by the FM256 data dump cable.

GND

Signal ground. This signal line acts as a reference for all other RS232 signals. It is connected to the GND pin at the computer by the FM256 data dump cable.

CTS

Clear to send. This input signal line that may be used to control the flow of data from the instrument i.e. handshaking is implemented. If it is at a positive potential then the data will be output continuously (active - binary 0). Taking CTS to a negative potential (binary 1) will terminate data output once the current character is completed. An external device may use this in order to temporarily halt the flow of data until its internal buffers can be cleared of data. It is connected to the RTS pin at the computer by the FM256 data dump cable.

RTS

Request to send. This output signal line is active continuously and is hard wired to a positive potential (binary 0). It may be used to indicate to a receiving device that the FM256 is ready to transmit data. Alternatively, RTS may be connected to CTS, thus allowing continuous data transmission from the instrument when the Dump key is pressed. This line is not used in the FM256 data dump cable.

Data Dump Cables

FM256

The RS232 cable provided with an FM256 uses the three pins 2, 4, and 6. It is marked as : ‘FM256 Data Dump Cable’. Always use this specific cable since it provides for handshaking to control the flow of data and is designed to use pin 2 for signal ground.

Partially Upgraded Instrument

The RS232 cable provided with a *partially* upgraded instrument uses the three pins 3, 4, and 6. It is marked as: ‘Partial FM256 Data Dump Cable’. Always use this cable since it provides for handshaking to control the flow of data and is designed to use pin 3 for signal ground.

Emergency Cable

Should you only have an older FM18 / 36 data dump cable available then this may be used in an emergency – however it should only be used for smaller data dumps and / or slower baud rates since handshaking is not implemented in this cable.

Data Dump Format

The data can be output in one of five formats over the serial interface, the format being specified in ‘Data Format’ in the Setup sub-menu. The data formats are listed below in order of increasing efficiency, with the less efficient formats being retained for compatibility with older software. *It is essential that the receiving software is setup with matching data format and baud rate.*

1 ASC + SPCS

Each reading is output as a signed four digit number, representing the magnitude of the reading, followed by a single digit number representing the range. Each number is enclosed by SPACE characters and terminated by CARRIAGE RETURN and LINE FEED. All characters are output in ASCII format – each character consists of one start bit, eight data bits, and two stop bits. Parity is not transmitted.

... SPACE sign digl dig2 dig3 dig4 SPACE CR LF SPACE range SPACE CR LF ...

(msd) (lsd)

2 ASC

Each reading is output as a signed four digit number, representing the magnitude of the reading, followed by a single digit number representing the range. Each number is terminated by CARRIAGE RETURN and LINE FEED. All characters are output in ASCII format – each character consists of one start bit, eight data bits, and two stop bits. Parity is not transmitted.

... sign digl dig2 dig3 dig4 CR LF range CR LF ...

(msd) (lsd)

3 Fast ASC

Each reading is output as a 1 to 4 digit number, representing the magnitude of the reading, with sign included only if the reading is negative and is followed by a single digit number representing the range. Each number is terminated by CARRIAGE RETURN only. All characters are output in ASCII format – each character consists of one start bit, eight data bits, and two stop bits. Parity is not transmitted. The largest data packet will look like:

... sign digl dig2 dig3 dig4 CR range CR ...

(msd) (lsd)

The smallest data packet, taking much less time to transmit, would look like:

... dig1 CR range CR ...

(lsd)

Hex D+R

Each reading is output as a 1 to 3 hexadecimal number, representing the magnitude of the reading, with sign included only if the reading is negative and is followed by a single digit number representing the range. Each number is terminated by CARRIAGE RETURN only. This is the default data format used in the FM256. The largest data packet would look like :

... sign hexl hex2 hex3 CR range CR ...

(msd) (lsd)

The smallest data packet, taking much less time to transmit, would look like:

... hex1 CR range CR ...

(lsd)

5 Hex D

As above, each reading is output as a 1 to 3 hexadecimal number, representing the magnitude of the reading, with sign included only if the reading is negative and is followed by a single digit number representing the range *but for the first reading only*. On subsequent readings range is omitted for improved efficiency since the receiving software now has the range information it requires from the first reading. You can only use this format if all the data is logged using the same range as the first data point. However, this format is typically twice as efficient as Hex D+R for small readings and since most surveys are performed using the same range this format should be considered for its efficiency. Each number is terminated by CARRIAGE RETURN only.

First reading: data CR range CR Subsequent readings : data CR

The largest (and first) data packet could look like :

... sign hexl hex2 hex3 CR range CR ...

(msd) (lsd)

The smallest and subsequent data packet, taking much less time to transmit, would look like :

... hex1 CR ...

(lsd)

Data Dump Baud Rate

The Baud Rate controls the speed at which data is transferred from the FM256. Higher values give faster throughput and you will generally choose the highest speed. Baud Rate can be specified in the Setup sub-menu, and ranges from 600 baud to 19200 baud. The default baud rate is 19200.

Appendix D

INTERFERENCE

Introduction

Usually you should experience very few problems with interference. However, there are some circumstance when this may be a problem and the following sections attempt to help with this situation. Note that the instrument is not designed for laboratory use so if you try to operate in such an environment you may observe interference in the form of flickering readings. This is usually due to the magnetic fields generated by mains operated devices, in particular, mains transformers such as those found in computers and televisions.

Interference whilst Surveying

Some flickering of the reading will be observed with 0.1 nT resolution in normal circumstances in the field. However, if flickering is greater than normal, say greater than 1 nT then this may be caused by external interference. On urban sites this is likely to be due to the magnetic fields from underground mains power earth currents, telephone earth return currents, or currents conducted along underground pipes. On rural sites interference interference can occur when operating in the vicinity of radar, radio or television transmitters or booster stations. Interference will increase as you get nearer the source, though it is difficult to give precise indications of the level of interference. As an example, you may observe fluctuations of about 3 nT at distances less than 50m from a radio booster station, though the distance and degree of fluctuation will vary from situation to situation. Some radar stations including those of air traffic control, ship harbour and military establishments can transmit at very large signal strengths, causing interference at up to 15-100 Km distances.

You can try to improve the signal to noise ratio by using digital averaging. If this does not effect a cure then either move further away from the interfering source or reduce the sensitivity of the gradiometer.

Overhead mains cables, suspended from pylons, do not in general cause any interference problems, though the pylons themselves, being made of steel will show as a very large response.

Interference whilst Dumping Data

Though you should successfully transfer data from the FM256 to a computer in most environments we strongly recommend you avoid doing this inside, or adjacent to, a motor vehicle which has its engine running (or similar noisy environments). If the vehicle electrical system is badly suppressed then the interference may corrupt the data transferred. Always check that the data transfered to a computer is sensible before clearing the memory. If you find the data has been corrupted, and you suspect it is because of a noisy environment then move to another location and then repeat the data transfer.