

Multi-Sensor Core Logger

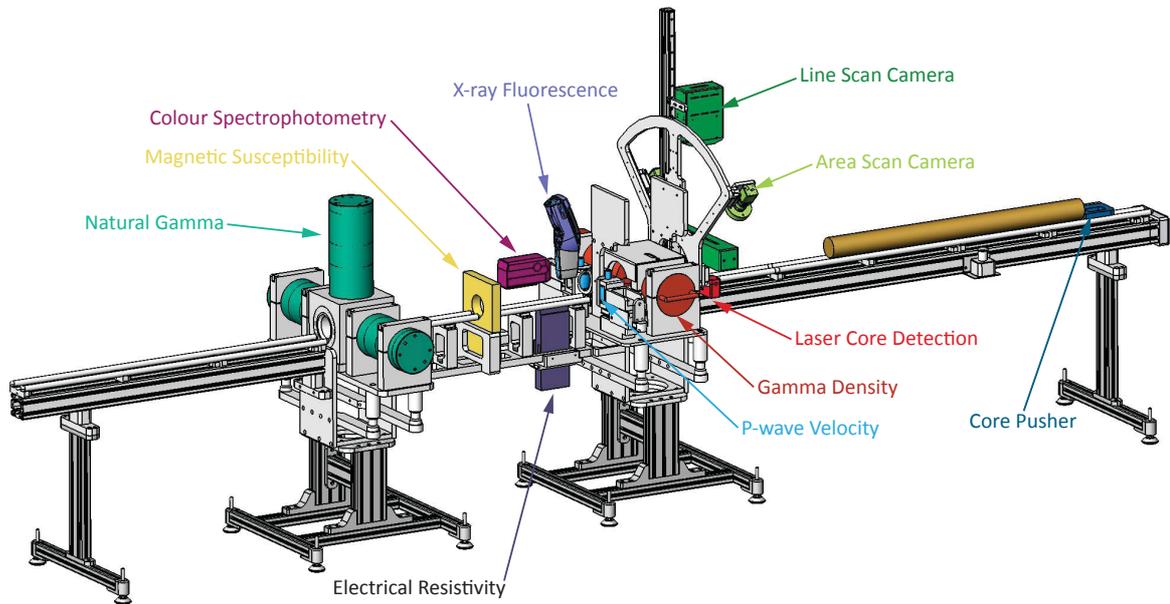


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1- Introduction

Chapter Overview

This introduction presents an overview of the capabilities and features of the Multi-Sensor Core Logger (MSCL). It describes the major features of the logging systems and outlines variations that occur between different generations of logging systems. The organisation and use of this manual are described, notational conventions safety symbols and abbreviations are explained.

This manual covers the Geotek Standard Multi-Sensor Core Logger (MSCL-S) in its various stages of evolution, as well as the vertical MSCL-V. The MSCL-XZ is covered in an appendix to this manual. The MSCL-XYZ, MSCL-CIS, and MSCL-XCT are covered in separate manuals.

The Standard Multi-Sensor Core Logger (MSCL-S)

The MSCLs sold by Geotek today are versatile core measurement systems. They can be floor- or bench-mounted, and packed and taken to buildings or containers at field locations if required. Measurements can be made on plastic-lined sediment core or unlined rock core, and the cores may be whole cylinders (whole round core) or split in half. The standard MSCL system will accept pieces of core up to 150 cm long, with outer diameters between 50 and 150 mm.

The strength of the Standard MSCL (MSCL-S) lies in its ability to save time by simultaneously measuring multiple parameters in an automated fashion. Core is moved past the array of stationary sensors, and data is collected from all sensors at once when the core pauses at a measurement point (see schematic diagram in Chapter 2). As the MSCL has evolved, more sensors have been integrated into the system, and new sensors are being added each year. The MSCL can be operated with as many or as few sensors as desired, and new sensors can be added to an existing system .

Gamma density and P-wave velocity can be measured in a horizontal direction (for whole cores) or a vertical direction (for split cores). Non-contact sensors, such as electrical resistivity, magnetic susceptibility (loop sensor), and natural gamma, are mounted along the track to make measurements on whole or split cores. Contact sensors are mounted on an arm that moves up and down to bring the sensors on and off the surface of the core. Currently integrated contact sensors include a point magnetic susceptibility sensor, a colour spectrophotometer, a visible/infrared spectrophotometer, and an X-ray fluorescence spectrometer. A linescan camera, with both visible and ultraviolet fluorescence imaging capability, can also be mounted on the system.

MSCL-XZ & MSCL-XYZ Systems

The MSCL-XZ is a simple track for imaging and surface measurements on core, where the sensors move along the core (X direction) and down onto the core surface (Z direction). The MSCL-XYZ, with the addition of a horizontal Y axis, enables the user to load multiple split core sections (typically 8 or 9) and log them in a single operation. A stationary frame contains a number of trays in which the split core sections are placed.

The sensor systems move over and along each core section taking measurements by moving the sensors down on to the split core surface that is detected using a laser distance profiler. A counterbalanced sensor cradle compensates for any unevenness in the core surface and measurements are taken at spatial intervals or discrete positions as defined by the user. With the MSCL-XYZ, a complete core can be logged in a continuous process without the need for the user to change sections. Sensor systems that can be mounted on the MSCL-XZ or -XYZ currently include the colour or colour/NIR spectrophotometer, the magnetic susceptibility point sensor (MS2E), the X-ray fluorescence sensor, and the GeoScan imaging system. The MSCL-XYZ system, in addition, can accept a natural gamma detector, which is very useful for multi-day measurements.

Custom & Legacy Systems

The Geotek Multi-Sensor Core Logger has been built for a range of users since 1989. During that time the logging system has inevitably evolved with significant improvements being made to the simplicity of the mechanical arrangements, the effectiveness of the sensors and in particular with the sophistication of the software. Consequently there are a number of slightly different systems in use. Despite this natural evolution Geotek has been conscious of the need to update older systems so that important new features can be incorporated. This is particularly true with the software, which has been designed to function on all systems with only minor modifications to the electronics and hardware. If you find features described in this manual that do not seem to apply to your system then contact Geotek directly for an assessment of the upgrade potential.

Most of this manual is applicable to both current and old systems. However, where significant operational differences occur, specific references to older systems, or appendices, are provided.

Single Section Logger: Core Boat System

The first MSCL system moved core sections back and forth through the sensors using a boat, into which the core section was placed. Each core section was logged individually. Data files were subsequently manually concatenated by the user within a spreadsheet.

Multiple Section Logger: Long Belt System

Later versions of the logger moved individual sections through the sensors using a belt that went around the complete length of the track, through each of the sensors. This configuration was otherwise very similar to the existing MSCL.

Moving Sensor Systems: Horizontal

Custom systems have been built with moving sensors, rather than moving core. These systems are more compact and are good for extremely fragile core but do not have the same time-savings as the standard configuration.

Moving Sensor Systems: Vertical

The MSCL-V is a moving-sensor system designed to measure cores that need to remain in a vertical orientation. This configuration can also be useful for those with a severe space shortage. It can accept a subset of the standard MSCL sensors.

Notation

This manual uses the following notation:

Commands which must be executed from the PC keyboard are printed in **bold type**. Keys that are to be pressed simultaneously or in succession are linked with a hyphen. For example, press **CTRL-A**.

Commands which must be executed by placing the cursor arrow on a software button, or in a specific position on the screen, followed by clicking the mouse button, are shown in **[bold square brackets]** where the name in the bracket is the name of the software button.

Warning Symbols

The following warning and safety notation is used:

Safety warning regarding ionizing radiation risk	
--	--

Safety warning regarding ultraviolet radiation risk	
Safety warning regarding risk of electrocution	
Safety warning regarding risk of poisoning	
Safety warning regarding personal injury from heavy weights	

Acronyms and abbreviations

The following are abbreviations are used in this manual:

AD	Analogue/Digital
ADC	Analogue to Digital Converter
AGC	Automatic Gain Control
CPS	Counts Per Second
DT	Displacement Transducer
GD	Gamma Density
LCD	Liquid Crystal Display
LH	Left Hand
MP	Microprocessor
MS	Magnetic Susceptibility
MSCL	Multi-Sensor Core Logger
NCR	Non Contact Resistivity
PC	Personal Computer (Windows Compatible)
PRT	Platinum Resistance Thermometer
PWT	P-Wave Transducer
RH	Right Hand

UV Ultraviolet (light or radiation)

XRF X-ray Fluorescence

2 - Installation

Chapter Overview

This chapter familiarises the user with the installation of the Multi-Sensor Core Logger assuming no prior knowledge of the system. It contains information about the unpacking and assembly of the core logger, as well as safety issues and computer requirements. It provides important information for laboratory managers and may also be valuable in the event that the logger is moved to an alternative site.

If you are using the gamma attenuation density system it is assumed that you have registered your premises for the handling of the ^{137}Cs source, and that you have planned a code of practice for the safe operation of the system. If you have not done so, do not open the packing case containing the gamma source before completing the preparation of your safety plan.

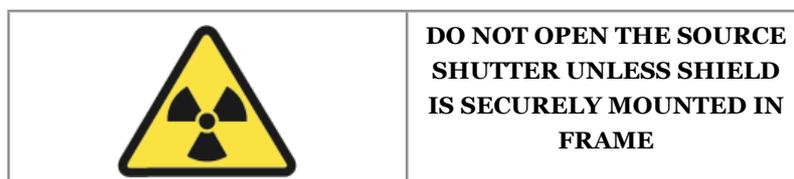
Unless the user is already familiar with the MSCL then on first installation Geotek personnel will install, commission and provide instruction on the use of the equipment. Consequently this chapter is not intended to provide a comprehensive set of instructions for the new user but is intended to provide pertinent notes that may prove valuable, especially if the user moves the equipment to a new site or from a land based laboratory to a shipboard laboratory.

Unpacking

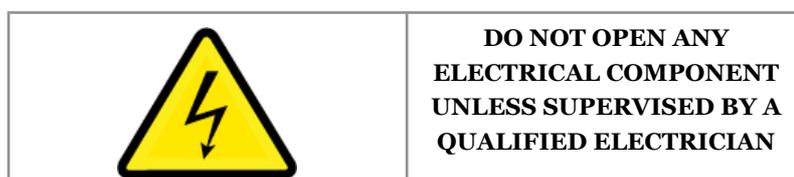
Safety

Before unpacking the MSCL please ensure that you have made adequate preparations with regard to safety. The following general notes can be used as a starting point for your preparations.

Radiation Hazard: If the core logger has a gamma density sensor system then it will have a ^{137}Cs source that has an activity of about 10 milli-curies. This is securely located in a shield that when closed restricts the exposure to less than $5 \mu\text{Sv/h}$. The shield has an asymmetric rotating shutter that allows the user to align a narrow collimator, which will allow a narrow beam of gamma rays to pass through the sample for making the gamma density measurements. This shutter can be simply closed and locked in position when it is not in use. (see Chapter 5 for details).



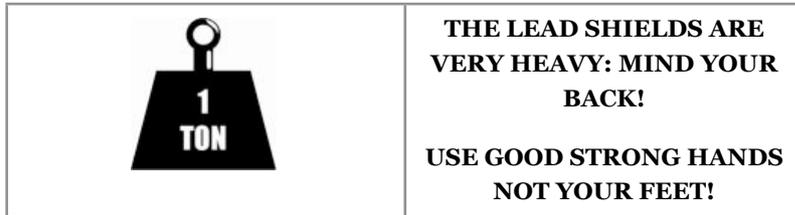
The source is classified as a sealed source and copies of its certificate of manufacture and wipe tests will be provided by Geotek.



Some components contain high voltages (e.g. gamma detector and P-wave TX box).



After handling the shield ensure hands are cleaned.



Use 2 people to handle and place on soft surfaces - do not drop!

Laboratory requirements

Depending on the system configuration being used the MSCL can either be a free standing device, mounted on legs, or it can be mounted on a bench. In either case it is best situated against a wall.

The electronics rack and controlling PC should be installed on a bench at the RH end of the system, so that water and soil are kept away from the electronics (Fig. 2-1).

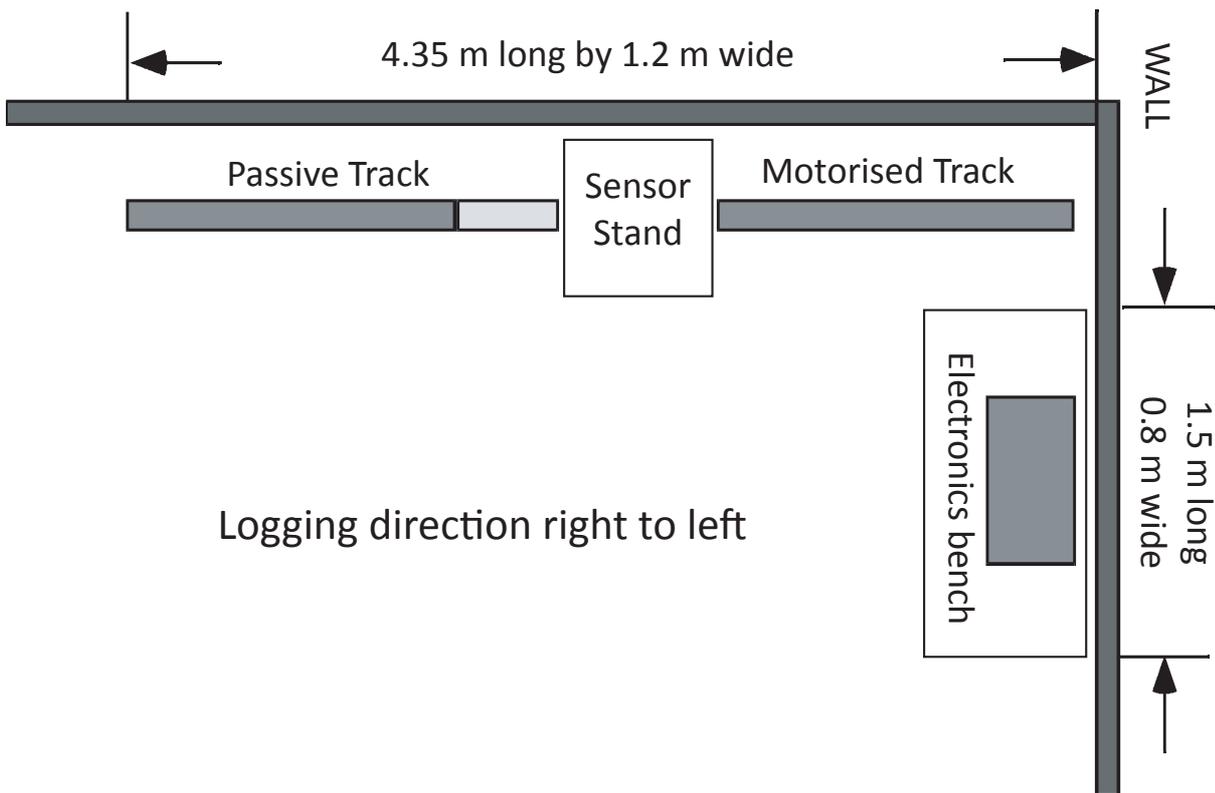


Figure 2-1. MSCL Laboratory Layout

Computer requirements

The MSCL needs a controlling PC computer, which will be provided by Geotek. This will be a Windows compatible PC with a dual core 1 GHz or faster microprocessor with at least 1 Gbytes of RAM, a hard disk and a spare ethernet port. Preferably the PC will have Windows 2000 or XP™ installed. If you need to replace the PC

on an MSCL, please contact Geotek for advice on purchasing a new computer and help with re-installing software. Note that older systems will need a spare serial COM port on the computer.

Re-packing

All of the strong wooden packing cases are designed for re-use. Use ample packaging material to ensure that the equipment is not damaged in transit.

Assembly

List of parts (standard MSCL-S)

Note that this list is generalised as it will vary depending on which options have been purchased.

- Motorised RH track assembly
- Passive LH track assembly
- Track support feet (3 off)
- Main centre Sensor stand
- Magnetic Susceptibility centre assembly
- Main electronics rack with cables and junction boxes
- Set of core rails
- Magnetic susceptibility loop sensor
- Magnetic Susceptibility point sensor
- Gamma detector
- Gamma detector housing
- Gamma source
- Non-Contact Resistivity sensor
- Perspex gamma covers
- 2 off P-wave Transducer and Displacement Transducer assemblies (PWT & DT)
- Cables and power distribution board
- Manuals and documentation
- "T" handled hex keys

Assembly Instructions

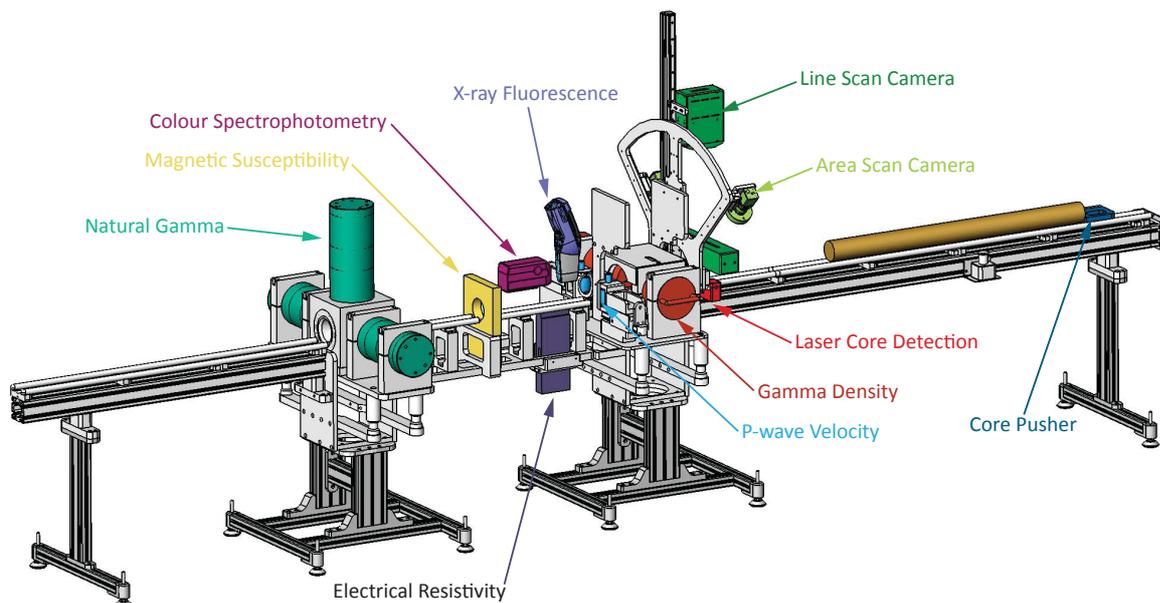
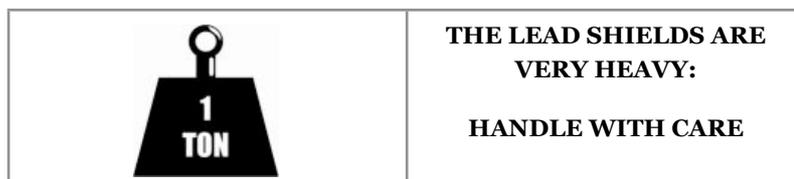


Figure 2-2. MSCL schematic layout (in whole core horizontal logging mode).

- Place the main centre sensor stand in its correct position in the laboratory. (2 people are needed to carry out this operation).
- Fit the leg to the RH end of the RH motorised track section.
- Bolt the RH track assembly to the main centre section. Two people are required to do this.
- Fit the two remaining legs to the LH track section so that it can stand on its own, and place it in line with the RH section and the correct distance away from the sensor stand.
- Attach the MS section to the LH box section using both the bolts at the bottom of the MS assembly and the nylon screws that fix the track to the top. You can now let go of the MS section and line its right hand bolts up with the fixing points at the LH side of the main sensor stand. Fix the other end of the MS assembly to the main sensor stand.
- Fit the resistivity sensor to the MS assembly in its mounting bracket. Ensure that the plastic cover is installed on the top of the sensor.
- Use an empty core liner of the largest size (with end caps) laying on the rails to ensure that it passes freely through the loop when run along the rails. The MS loop sensor can be moved vertically by loosening the clamp.
- Check the position and alignment of both sections on the bench and adjust using the adjustment bolts at the top of the feet.
- Unpack and place the electronics rack on a table at the right hand end of the logger.
- Install the scintillation detector into the housing (if it has been removed). Use the temporary handle on top of the housing to lower it into the sensor stand.
- Fit the remaining rail section across the gap in the sensor stand.



- Before commencing, check that the source shutter is closed and locked. Lift the Gamma source shield onto the step in the source support bracket with the shutter lever pointing to the right. (2 people are needed to carry out this operation) **DO NOT LET GO OF THE HANDLE** until the source clamp and bolts are securely in place. Adjust the source until the shutter lever is in the correct position, and can be moved through 180° (loosen the clamps a little to rotate into the correct position). Do not to open the gamma beam shutter on the source at this stage but wait until all other aspects of the system are set up.

DO NOT PLACE HANDS ARMS OR ANY OTHER BODY COMPONENTS BETWEEN THE SOURCE AND DETECTOR

- Fit the perspex guard around the source.
- Adjust the position of the lower PWT by placing a core on the rails and holding it down while sliding the PWT up towards the core. The exact position is not crucial but the user should ensure that the lower transducer is always in contact with the core. Tighten and check that the core moves through the spring-loaded assembly without difficulty. Re-adjust if necessary. Tighten only sufficiently to prevent accidental movement. Do not over-tighten.
- Re-check the positions of all sensors by manually running a core along the complete length of the system.

CAUTION

TAKE CARE NOT TO RUN THE CORE INTO ANY OF THE SENSORS OR ANY OTHER OBSTRUCTION. SIGNIFICANT MECHANICAL DAMAGE COULD RESULT. BE PARTICULARLY CAREFUL OF THE P-WAVE TRANSDUCERS AND THE MAGNETIC SUSCEPTIBILITY LOOP.

Special notes for ship-board installation

The MSCL support feet can be anchored to the deck with special plates depending on the type of deck and fixings available. Ideally the mountings should be attached directly to the swivel pads which provide some vibration isolation. Please consult Geotek if you have any difficulties.

The MSCL should be assembled while the ship is in port, and should not be disassembled in any way at sea. Some components are very heavy and could cause serious injury if they broke loose on board a moving ship.

Make sure that the complete system is securely bolted to the ship's structure. Check that the structure you have bolted it to is both fixed and is strong enough for the purpose. The MSCL-V especially should be tethered to a bulkhead. Eyebolts can be installed in the channels in the aluminium box sections or in holes in the top corners.

For added support, the feet can be anchored to the deck with special plates depending on the type of deck and fixings available. Ideally the mountings should be attached directly to the swivel pads which provide some vibration isolation. Please consult GEOTEK if you have any difficulties.

Wiring

The electronics for the MSCL system are mounted in a sturdy standard 19" rack. A cable bundle from all the sensors, stepper motor and control box, enables the rack to be positioned at the RH end of the system on a bench.

Position the electronics rack and remove the protective front and back cover panels for access to connectors.

Mains supply

All the mains power for the standard system is supplied via the mains distribution board from which 5 or 6 cables are run depending what is installed. There will be cables for the computer and screen; for the MSCL electronics

console; for the motor control; for the resistivity meter (if installed); and the GeoScan imaging system (if installed). Mains power can be 100-240V, 50-60 Hz.

CAUTION

The MSCL-V and other custom systems may contain servomotors which have fixed voltage requirements.

Cable connections

All the cables from the logging system enter to the rear of the electronics rack. Most of the connectors (apart from serial connectors) are different. Figure 2-4 gives a schematic wiring diagram for the free cables.

Pre logging checks

It is valuable at this stage have 1 or 2 lengths of core together with an empty length of similar core liner.

- Ensure that the correct rails are fitted for the size of core to be logged and that they and the core liner are clean.
- On older belt-driven pusher systems, check that the belt is suitably tensioned.
- Use the 'Manual' control to ensure that the core pusher and core section moves freely in both directions with the PWTs and MS point sensor well clear.
- Check that the LH and RH limit switches on the track function correctly when the core is moving by trial and error. Reverse the connections on the rear panel of the 2U motor control unit if incorrect.
- Use the 'Manual' control to ensure that the vertical slide moves freely in both directions.
- Check that the limit switches on the vertical slide functions correctly when the slide is lowered and the PWT contacts the core.

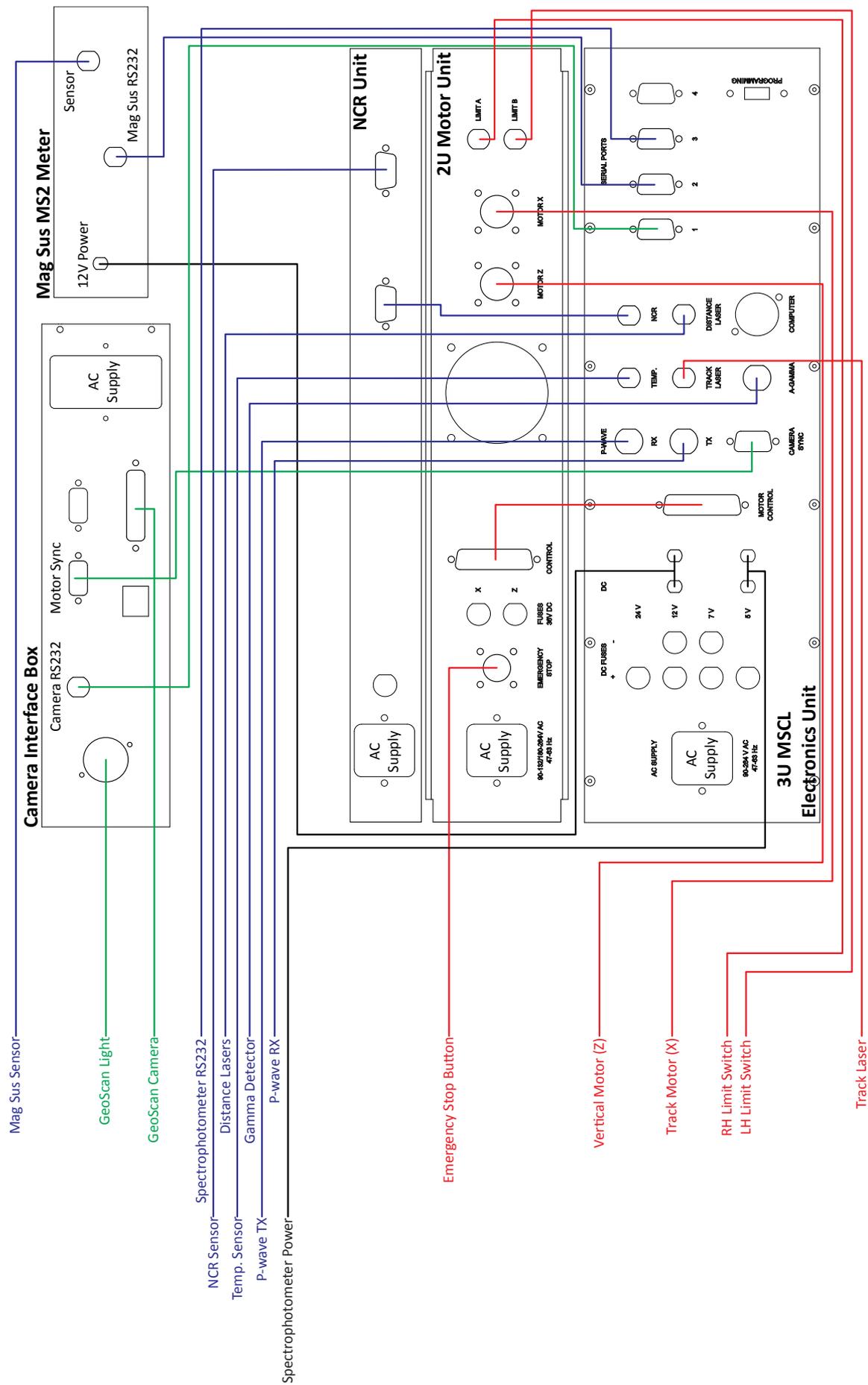


Figure 2-4. Interconnecting wiring layout.

3 - Logging Core with the MSCL

Chapter Overview

The purpose of this chapter is to provide the user with a short-form guide to automated core logging. It first describes the principles and numbering conventions used in automated core logging together with notes on the variations between different types of systems. This is followed by a short-form guide providing step-by-step instructions of how to perform automated logging using the main application software. It is aimed at the new user who needs simple operational instructions on how to operate the system in an automated fashion. For a detailed description of all the software facilities available the user is referred to Chapter 12. To calibrate the various sensor systems the user should refer to their individual chapters.

The MSCL operating software is Windows™ based. It is a user-friendly application that both acquires raw data and processes the data in real time. It presents the data graphically but also enables the user to view data in a tabulated form. The same application can also be used to view and process previously collected data (old data).

In addition to the main operating and processing application there is an associated utilities program. This enables the user to run tests of individual sensor systems and to set important configuration parameters specific to the users system. Within this utilities application there is also a terminal mode option that enables the advanced user to edit/modify the software in the microprocessor. Details of this application can be found in Chapter 13.

Numbering and Depth Conventions

It is necessary when logging core material in a “continuous” fashion to follow a numbering convention. The most commonly used convention has been adopted for the MSCL software. A “core” consists of a number of adjacent “sections”. Section 1 is deemed to be at the top of the core and all subsequent sections (2,3,4 etc.) are assumed to be adjacent to each other. There is no limit to the number of sections that make up a core and each section can be any length although they are normally cut into nominal section lengths (normally 1.0 m or 1.5 m). Initially (as raw data is collected) the depth is calculated assuming that the top of section 1 has a depth of zero. All other depths are automatically calculated assuming that all other sections are sequentially logged and adjacent to each other. In the processed data the depth can be recalculated by assigning a value to the top of section 1 (depth offset) and by assigning a butt error distance. The butt error distance is the increase in length caused by the addition of end-caps that are normally placed around the end of the core liners on each section. This is described in more detail in Chapters 12 and 16.

Logging Overview

In the sections below the general logging principles are described for the Standard track type, and any variations that exist for the alternative types of track systems are discussed separately in the appendix to this chapter.

Ensure that the ‘track type’ is set to ‘Standard’ or ‘Standard - Ballscrew’ in the ‘settings file’ and that the right and left-hand limits are set correctly (see Settings, Chapter 15). A core is automatically logged by sequentially loading core sections onto the RH track with the top of each section on the left. The logging process is started by loading the first section (which can either be a calibration/control section or section 1) onto the RH end of the track with the top to the left and clear of the laser detect system and the reference position. (The reference position is the position on the track from which the positions of all the sensor systems are defined, and is generally ~1cm to the left of the laser). The MSCL automatically measures the core section and starts logging.

The core pusher is positioned against the RH end of the first section before the logging begins. The user defines, through the use of a configuration panel, which sensors are active for the section about to be logged and at what spatial intervals data must be collected from each sensor. Logging begins automatically by pushing the core along the track until the top of the first section is at the first active sensor. The first measurement is made and then the core is pushed until the next measurement position is beneath the appropriate sensor. Measurements are performed incrementally in this way at locations down the core section as defined by the configuration panel.

Measurements continue in this incremental fashion until the pusher reaches the reference point. At this stage the pusher automatically checks its position using the laser detect system and moves back along the track by a distance 2 cm greater than the nominal section length, allowing the user to insert the next section onto the RH track. The user must simply ensure that the next core section is positioned on the RH track and to the right of the laser detect system then continue logging. The MSCL automatically measures the core section and butts it up against the previous section and continues logging.

The process continues, this time with the pusher moving both core sections along the track. When the pusher again reaches the reference position it returns and the user loads the 3rd section and the whole process continues again. Sections continue to be loaded in this fashion until all the core sections have been logged. The user must ensure that core sections from the LH part of the track are removed once they have passed the last active sensor (normally the magnetic susceptibility loop or point sensor). Normally a core section can be removed each time a new section is added.

To end the logging process, one or more dummy core sections must be used which is at least as long as the distance between the reference position and last active sensor. Normally this dummy is the length of a nominal section. No measurements are made on the dummy section if the sensors are turned off in the configuration panel. Consequently these dummy sections can be lengths of real core.

Logging a New Core

In the short-form instructions below it is assumed that all pre-checks have been carried out (see Chapter 2) and all sensor systems are properly calibrated (see Chapters 5 to 11). Note that in the process of logging a core the user is prompted to perform most of the normal necessary actions by messages that appear in the control panel on the screen. For more detailed information the user is referred to Chapter 12 which explains all the options in detail. The instructions assume you are using a standard track system (see Chapter 1).

- I. From the main menu:



Figure 3-8. Main Menu panel.

- II. Click **[Log New Core]** from the Main Menu.

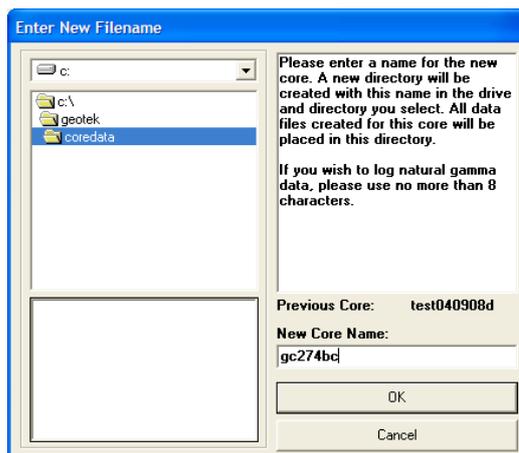


Figure 3-9. Enter New Filename panel.

- III. Enter New Core name in the 'Enter New Filename' Panel and choose the directory in which the data is to be stored. Click **[OK]** when ready.

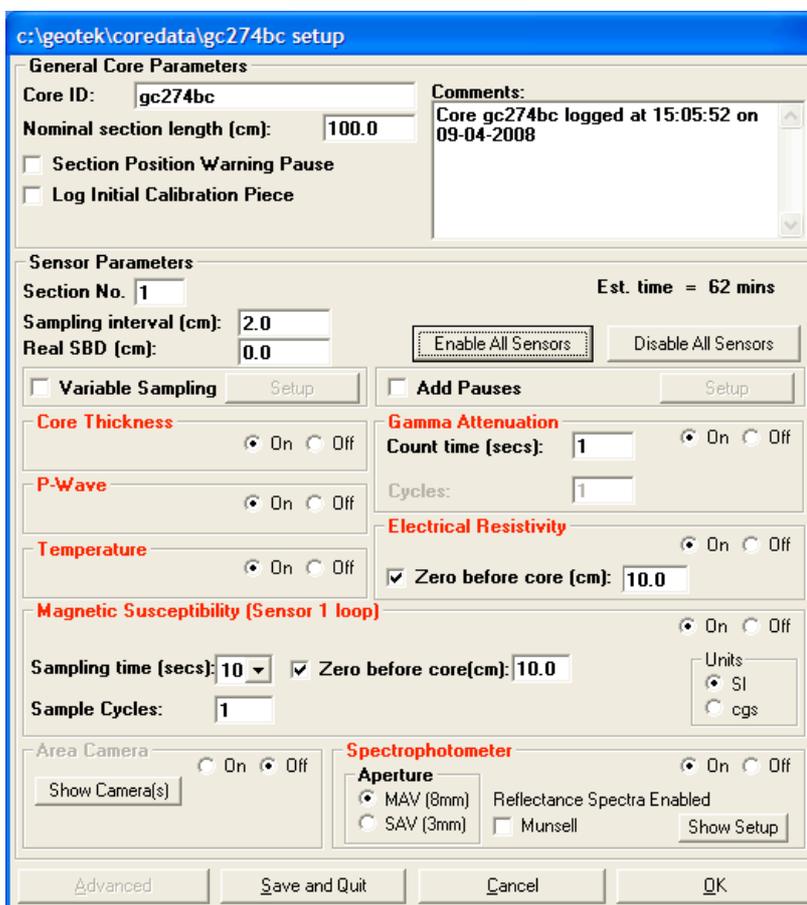


Figure 3-10. Configuration panel.

- IV. Complete the configuration panel.
- V. Remember that the sensor parameters refer only to the next section to be logged and can be changed for subsequent sections if desired. Click **[OK]** when ready.

- VI. Place the reference thickness piece for the core being logged between the P-wave transducers. Adjust the P-wave transducers if necessary, including manually moving the vertical (Z) motor down if the P-wave transducer is motorized, into a position that allows proper movement of the PWTs and click **[OK]**.

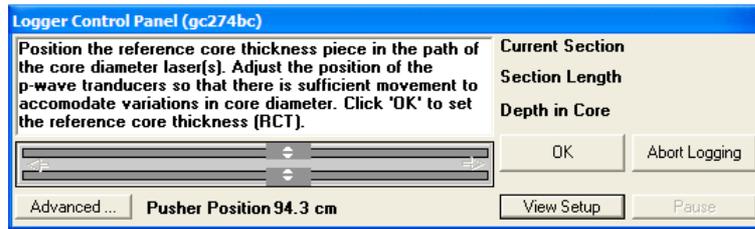


Figure 3-11. Logger control panel (pusher system – set reference core thickness).

- VII. The Excursion Distance control panel will then be displayed if the Z motor is in use. Enter the vertical excursion distance for the vertical (Z) motor and click **[OK]** when ready.

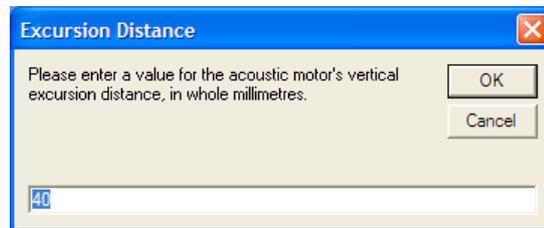


Figure 3-12. Excursion Distance panel.

- VIII. Note that this distance must be sufficient for the P-wave transducer (and the spectrophotometer, if fitted) to clear the core when it moves and a sufficient distance for the MS point sensor (if used) to obtain valid 'zero' readings when in its uppermost rest position. The normal excursion distance may be 30-40 mm.

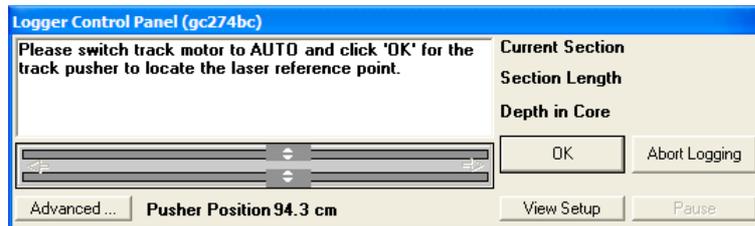


Figure 3-13. Logger control panel (pusher system - set Reference Point).

- IX. Switch track to 'Auto' and click **[OK]** in the Logger Control Panel. The logger automatically finds the position of the pusher using the laser detect system.



Figure 3-14. Logger control panel (pusher system - begin logging).

- X. Using the scroll bar in the Logger Control Panel move the pusher to a position on track which is just greater than the length of the first section to be logged (either section 1 or a calibration section). If a mistake is made the user can press the **ESCAPE** key while the mouse button is still pressed down and the pusher will stay in its original position.
- XI. Place the first section on the track with the top of the section on the left and not obstructing the laser detect system. It is often valuable to have an empty core section to the left of the reference position. In this way

the user ensures that the core will not come across any obstructions (especially the PWTs) as it moves through the sensors.

XII. Click **[Begin Logging]**.

XIII. The configuration panel will be displayed again. Check (and edit if necessary) and click **[OK]** when ready. This is the point where the automated core logging starts.

XIV. Ensure whilst the core section moves to its first measurement position that there are no obstructions to its movement.

XV. Data will be collected from the different sensors according to the information entered into the configuration panel. The logger control panel remains active and informs the user on the current status. It also displays the values of the last data set obtained.

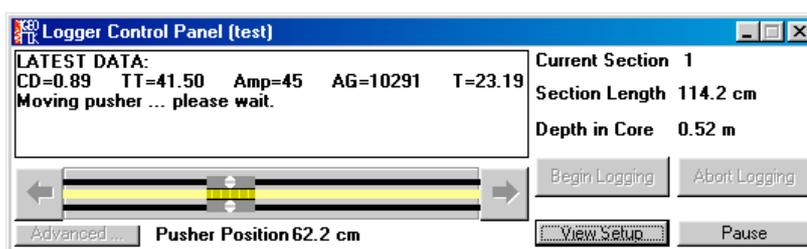


Figure 3-15. Logger control panel (pusher system - Latest Data).

XVI. While it is doing this the user can observe the raw data being collected in the Raw Data Display Panel which appears automatically and can be formatted as desired (see Chapter 12).

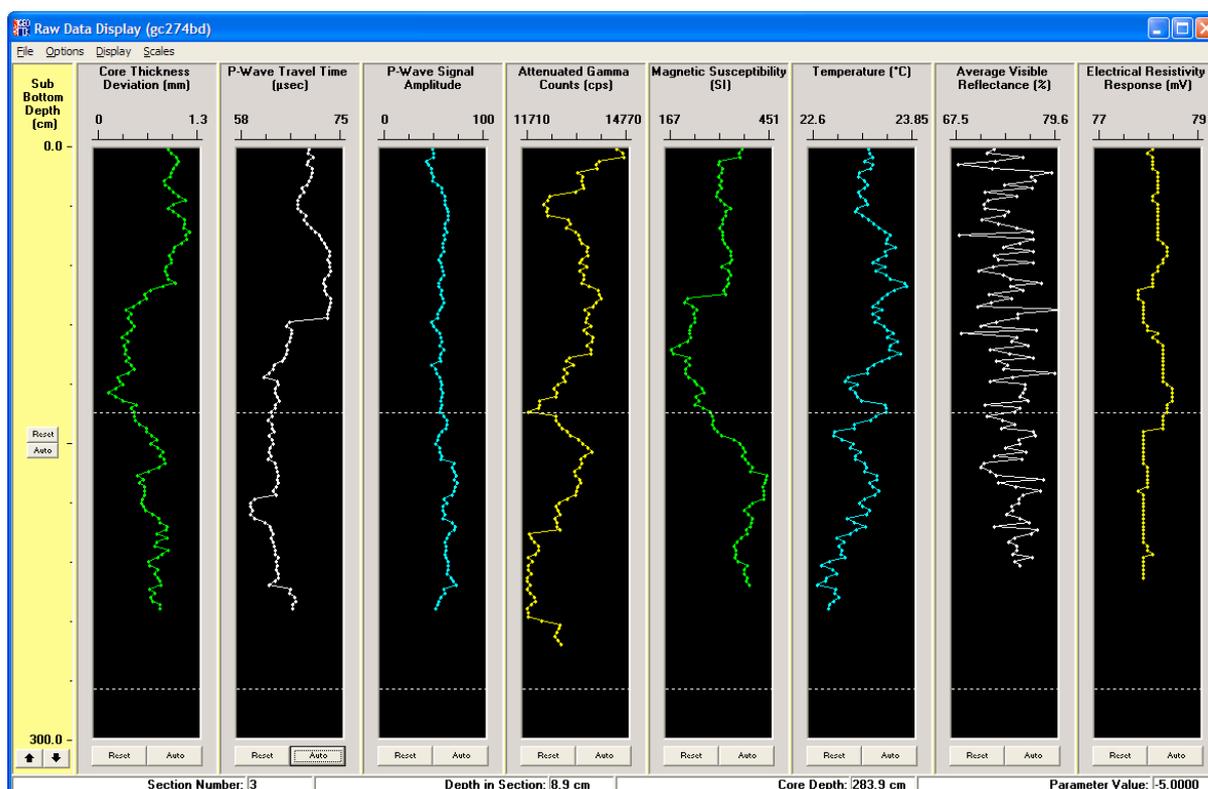


Figure 3-16. Raw Data Display panel.

XVII. The user can also observe and process the data by selecting the processed data display (see Chapter 12 for details).

XVIII. In the event that something is wrong the user should click **[Pause]** in the Logger Control Panel and assess the situation before continuing.

- XIX. The logging process will continue until the core pusher reaches the reference position. The pusher will then move back and check its position using the laser detect system, notify the user of any error and move along the track by the nominal core length entered in the configuration panel.
- XX. Place the second section on the track with the top of the section clear of the laser detect system. Click **[Continue]** in the Logger Control Panel.
- XXI. Edit the configuration panel as required for the new section and click **[OK]**.
- XXII. Both core sections will be pushed through the sensor systems and will be logged incrementally according to the configuration set-up for each section.
- XXIII. The process is continued until the last core section has been placed on the track.
- XXIV. To finish logging a core place a final dummy section on the track that is long enough to push the final section past the last sensor and turn off all sensors in the configuration panel. This will enable the last core section to finish the logging process.
- XXV. When the logging process is complete, click **[End Logging]** in the Logger Control Panel and close all active windows which will return the user to the main menu ready for logging another core.

Relog Old Core

In the event that core logging is interrupted during the normal process of 'Log New Core' it can sometime be desirable to start the core logging process again where the logging was previously aborted. In this way new data can be appended to the existing data file. This can sometimes happen due to operator error (for example placing the wrong section on the track or placing a section on the track round the wrong way). To relog an old core follow the instructions below noting that the user will be prompted to perform these actions by messages that will appear in the logger control panel.

- I. Click **[Relog Old Core]** from the Main Menu. The select data file box will be shown.

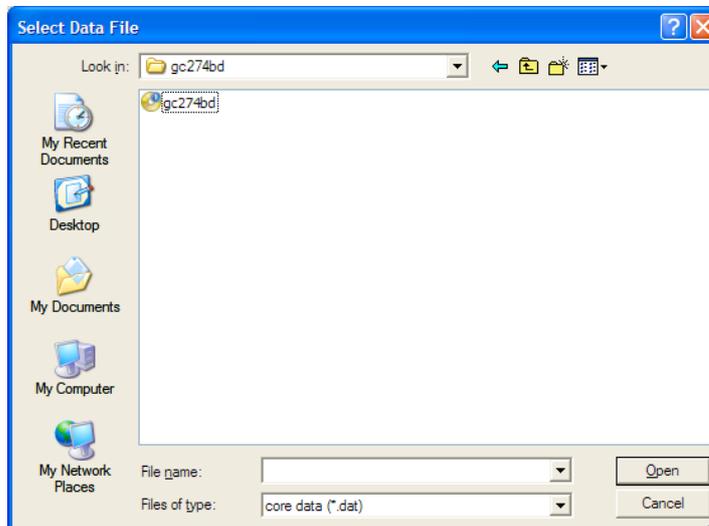


Figure 3-17. Select Data File panel (relog old core).

- II. Select the appropriate file and click **[OK]**. The raw data of the core selected will be displayed together with a dialogue box with information pertinent to the data set.

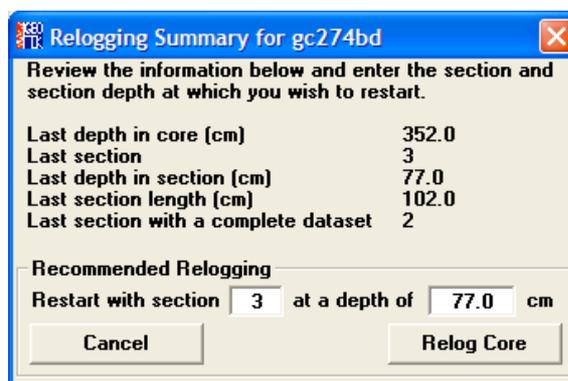


Figure 3-18. Re-log core panel.

- III. The user should decide at what point (at the reference position) he/she wishes to relog the core and enter the values in the boxes **[Restart with section]** and **[at a depth of]** and click **[Re-log Core]** when ready (see Figure 3-18). All data below this point will be deleted.
- IV. The user will be asked to reset the reference position and zero the vertical (Z) motor if necessary before being asked to place the appropriate core section on the track.

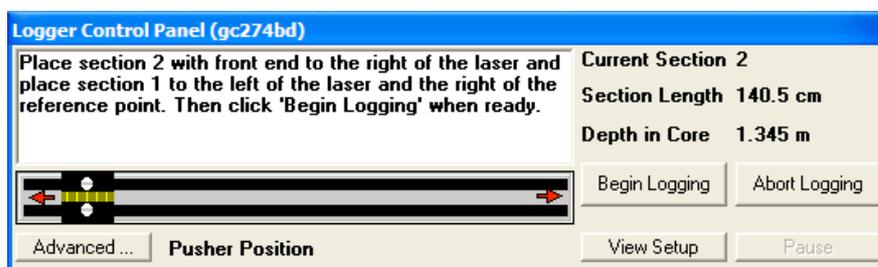


Figure 3-19. Logger control panel (relog old core).

- V. It is most important that the length of the section should match exactly the value as recorded previously. If in any doubt the user can look up the previously recorded by core length by using the **[View Set-up]** button in the Logger Control Panel.

Chapter 3 Appendix. Logging with Alternate Track Configurations

Whilst most logging principles are common between the different generation and types of core loggers there are some subtle differences that occur depending on which track type is being used. The track types fall into five categories as described in the Introduction, and these are defined in the 'settings file' as 'track type':

Standard:	Multiple Sections - Whole Cores/Split Cores- Core Pusher - Short Belt
Unrestricted pusher:	Multiple Section - Whole Cores - Core Pusher - Long Belt
Boat:	Single Section - Whole Cores - Core Boat
Moving Sensors:	Single Section - Whole Cores - Moving Sensors
Vertical Moving Sensors:	Single Section - Whole Cores - Moving Sensors

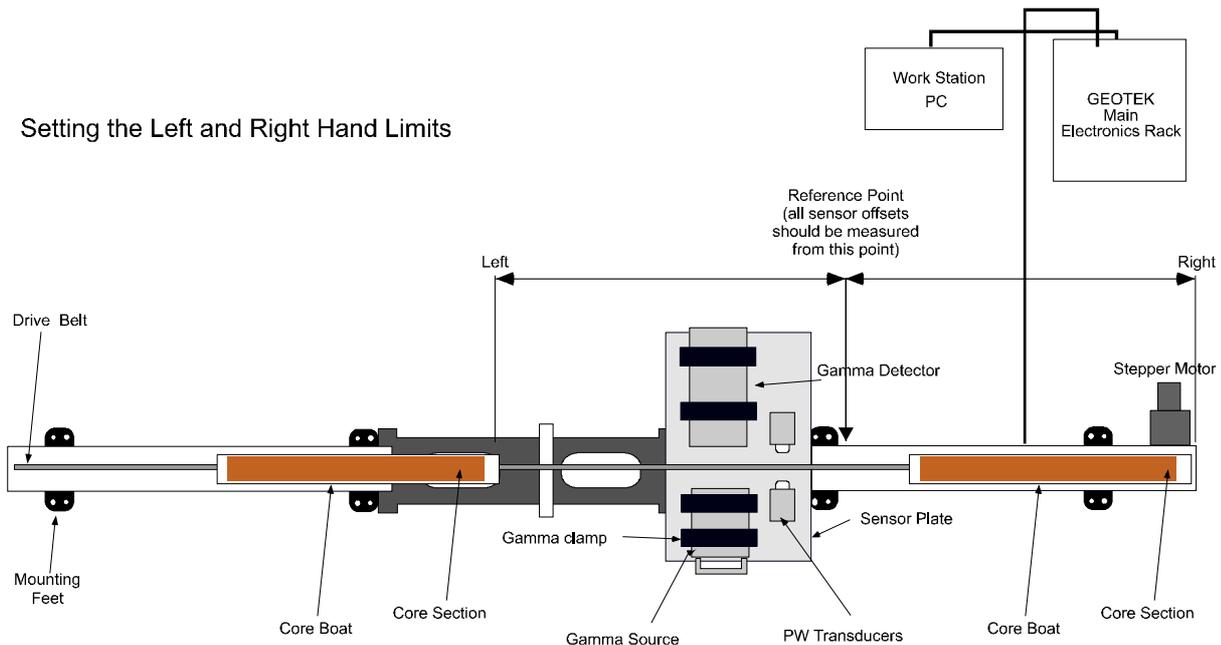
Unrestricted Pusher System

Ensure that the 'track type' is set to 'Unrestricted pusher' in the 'settings file' and that the right and left hand limits are set correctly (see Chapter 13). The only difference between the standard system and the unrestricted pusher system is that the pusher can move all the way through the sensors. The user must ensure that the 'left limit' of pusher movement is set greater than the position of the last sensor.

Boat System

The main disadvantage with the boat system compared with the core pusher systems is that each section has to be logged individually which: a) takes more time and b) introduces end effects with some measurement parameters (e.g. MS measurements with the loop sensor). Please note that this type of old "captive" boat system should not be confused with the boats described in Chapter 4 for use with rock cores and standard MSCL systems.

Ensure that the 'track type' is set to 'Boat' in the 'settings file' and that the right and left hand limits are set correctly (see Chapter 12). With a core boat system the core is always placed in the boat in the same way with the RH end of the core butted against the far RH end of the core boat. In this way the reference point still refers to the RH end of the core (not the outside end of the core boat). RH limit should be set to slightly less than the RH extent of the track and the LH limit must be set to a point beyond the last sensor on the system. For example, if your track extends 200 cm to the right of your reference point the RH limit should be set at 195 cm. If the last sensor (usually the Magnetic Susceptibility sensor on Geotek MSCL systems) is 70 cm to the left of the reference point you should set the LH limit to 80 cm. See Figure 3-1.



The system is now ready to start logging a core. When the user wants to start logging the messages in the logger control panel are slightly different as explained below.

- I. Once the configuration panel is completed the Logger Control Panel will appear as shown below. The user is being prompted to move the back end of the boat to the reference point and click **[OK]**. This effectively tells the microprocessor where your reference point is. The back end of the core boat is the point at which the end of the core section lies in the core boat (see below)

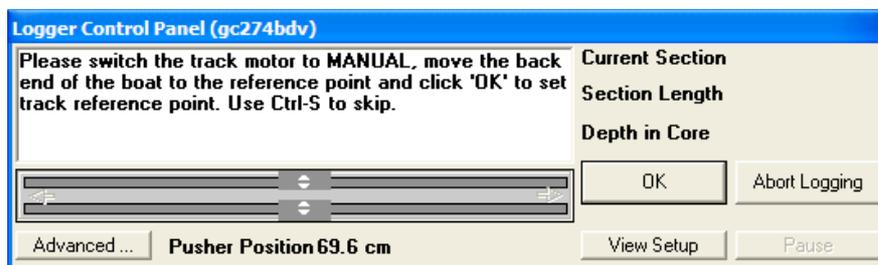


Figure 3-2. Logger Control Panel (Set Ref Point - boat system)

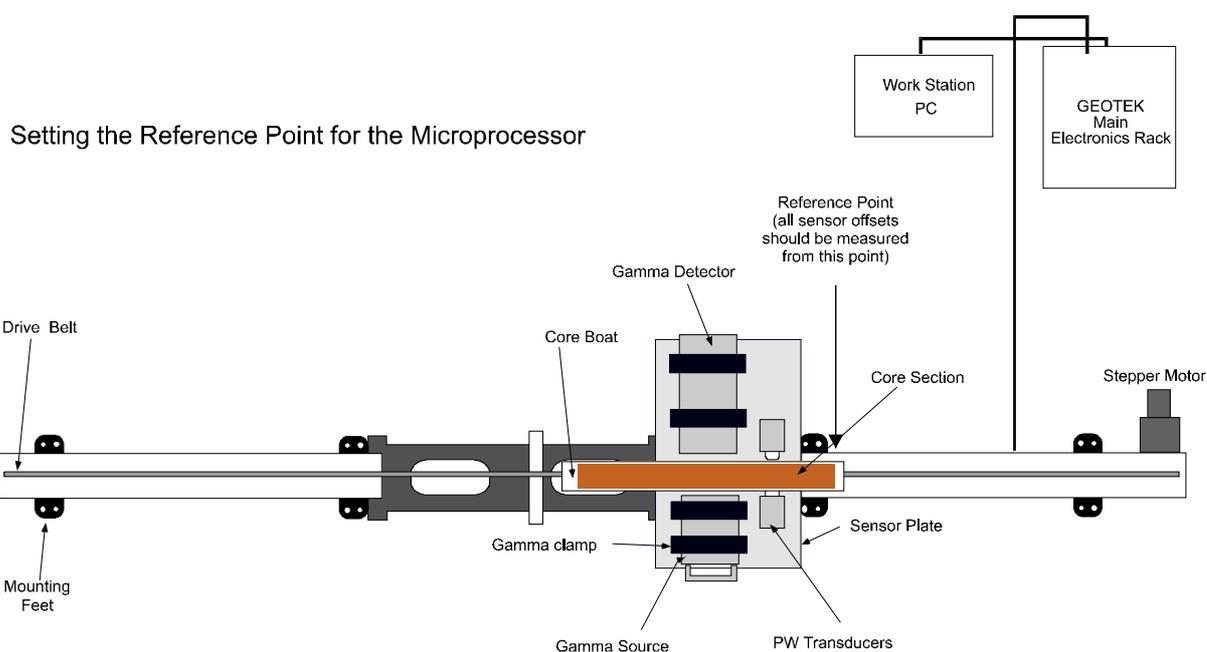


Figure 3-3. Setting the Reference point (boat system).

- II. Once Set Ref. is clicked the user will be prompted to move the boat back to allow the first section to be loaded. Load the core into the boat ensuring that it is butted up against the RH end (i.e. the place the reference point was aligned with). Use the logger control scroll bar and nudge controls to align the LH end of the core with the reference point as instructed (see Figure 3-4).

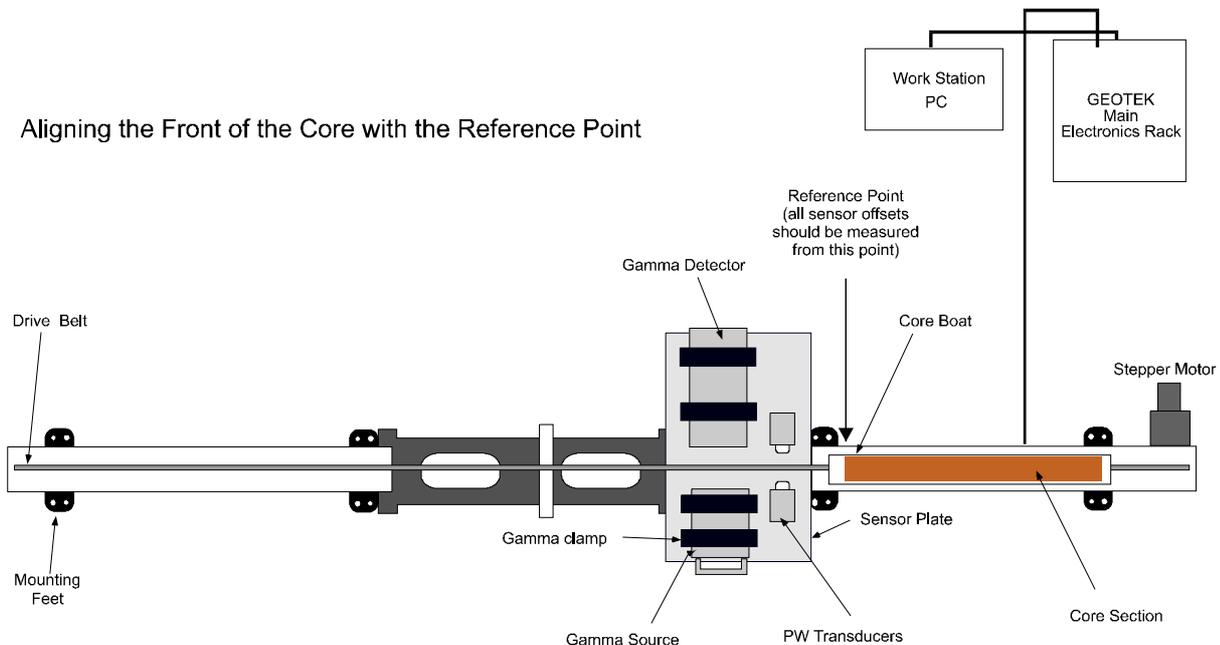


Figure 3-4. Aligning the front of the core with the reference point (boat system).

- III. When the core and core boat are in the correct position click **[Begin Logging]**. When the core section has been logged the core boat will be returned to the right hand side of the track ready to load the next section. Repeat step 3 above and resume logging.
- IV. When the last section has been logged simply click **[Abort Logging]** in the control panel.

Moving Sensor System

The principle of operation of the moving sensor system is similar to that of the boat system except that the mechanics are arranged so that the sensors move past a single section of core on a linear slide. The main disadvantage with the moving sensor system compared with the core pusher systems is that each section has to be logged individually which will take more time.

Ensure that the 'track type' is set to 'Moving sensor' in the 'settings file' and that the right and left hand limits are set correctly. With a moving sensor system the core is always placed on the track in the same way with the bottom of the section butted against the reference point, at the LH side of the track. The RH limit should be set to slightly less than the RH extent of the track and the LH limit must be set to the point of the last sensor on the system.

The system is ready to start logging cores.

When the user wants to start logging the messages in the logger control panel are slightly different as explained below.

- I. Once the configuration panel is completed the Logger Control Panel will appear as shown below. The user is being prompted to move the first sensor to the reference point and click **[OK]**. This effectively tells the microprocessor where your reference point is.



Figure 3-5. Logger control panel at startup when using a moving sensor system.

-
- II. Once the reference point is set the user will be prompted to move the sensors back to allow the first section to be loaded. Load the core onto the track ensuring that it is butted up against the Reference Point. Use the logger control scroll bar and nudge controls to align first sensor with the top of the core section.
 - III. When the core and the sensors are in the correct position click [**Begin Logging**]. When the core section has been logged the sensors will be returned to the right hand side of the track ready to load the next section. Ensure the sensors are in the correct position and click [**Continue**].
 - IV. When the last section has been logged simply click [**Abort Logging**] in the control panel.

Vertical Moving Sensor System

The principle of operation of the vertical moving sensor system is similar to that of the horizontal moving sensor system except that the mechanics are arranged so that the sensors move vertically past a single section of core. The main disadvantage with the vertical moving sensor system compared with the core pusher systems is that each section has to be logged individually, which will take more time.

MSCL-V Setup

Ensure that the correct pedestal heads are fitted for the size of core to be logged and that the two core pedestals are in line. Make sure the core liner is clean. Use the 'Manual' control to ensure that the sensor array moves freely up and down the core, with all sensors well clear. Check that the 'track type' is set to 'Vertical' in the settings file.

Ensure that the upper and lower limits are set correctly (see Chapter 4). With a vertical moving sensor system the core is always placed in the frame with the bottom of the section at the bottom of the frame. The upper limit should be set to slightly less than the highest point of the sensor platform movement and the lower limit must be set to 2 cm beyond the last sensor on the system. Check that the limit switches function correctly when the platform is in motion.

The system is ready to start logging cores.

Logging Cores with the MSCL-V

The overall philosophy and most of the software is exactly the same for the MSCL-V vertical moving sensor core logger as it is for the standard MSCL. This section highlights the differences (mainly involved in loading core).

- I. With the MSCL-V empty of core, open the software and choose a filename. The Setup Pane opens.
- II. Choose a background file for the magnetic susceptibility and electrical resistivity sensors. The background file is an MSCL-V data set, run with the machine empty, and it is used to correct the data for artefacts introduced by the frame of the MSCL-V. Each sensor can have a separate background file, or both sensors can use the same file.

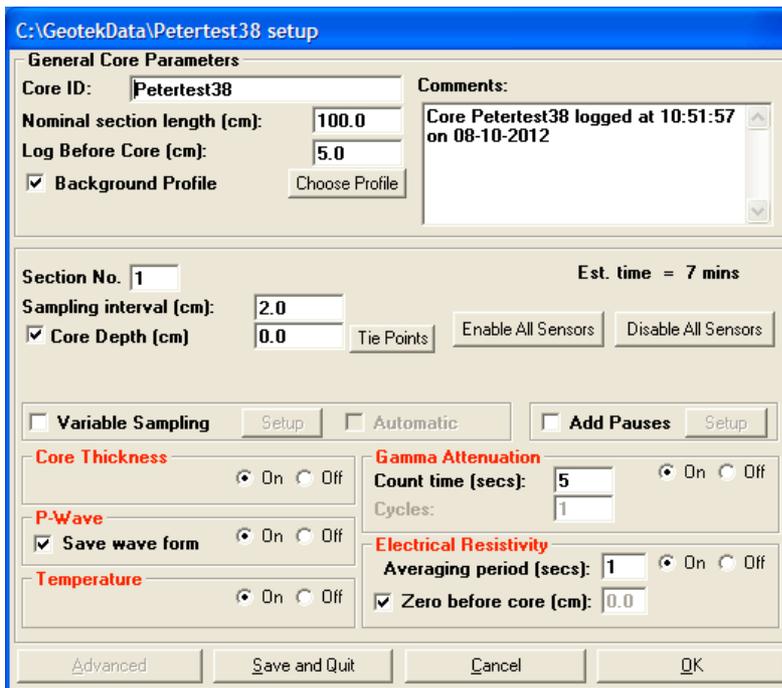


Figure 3-6. Setup pane for vertical moving sensor system, showing “Background Profile” checkbox.

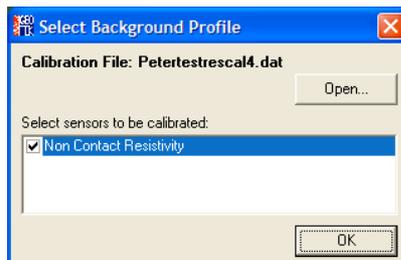


Figure 3-7. Select Background Profile Pane, which appears after clicking [Choose Profile].

- III. Continue choosing logging parameters as normal. Click **[OK]** when finished to bring up the Logger Control Pane. Check the width of the rolling transducers to make sure that they will pass over the lower core pedestal. Click **[OK]** for the sensor platform to move to the zero position.

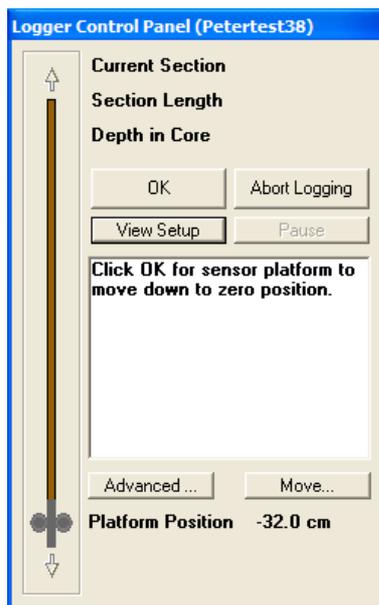


Figure 3-8. Logger Control Pane as it first appears.

- IV. When the sensor platform has moved to the zero position, the P-wave transducers should be gripping the top of the lower core pedestal. This part of the core pedestal serves as the reference core thickness piece. Ensure that the P-wave transducers are adjusted such that there is sufficient movement to account for the deviations in the diameter of the core liner, including endcaps. Also ensure that the resistivity and magnetic susceptibility sensors are free, as the sensors will be zeroed.

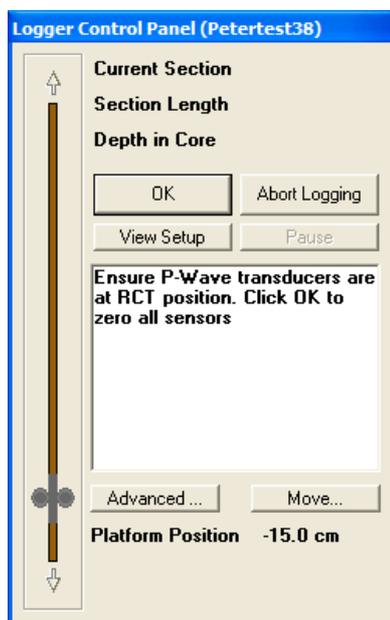


Figure 3-9. Logger Control Pane, requesting Reference Core Thickness & zero.

- V. After the sensors have zeroed, the user will be prompted to load the core and move the sensor platform to the start position. Use the logger control scroll bar and nudge controls to align the first sensor with the top of the core section.

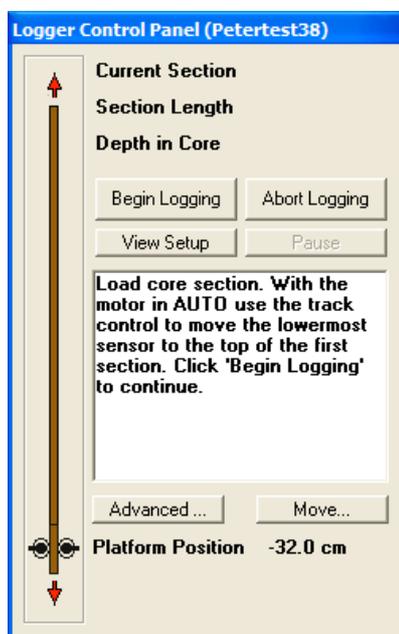


Figure 3-10. Logger Control Pane, requesting core load and user-defined top of core.

- VI. When the core and the sensors are in the correct position click [**Begin Logging**]. When the core section has been logged the sensors will remain at the bottom of the frame ready to load the next section. Move the sensor platform to the top of the section and click [**Continue**].
- VII. When the last section has been logged simply click [**Abort Logging**] in the control panel.

4 - Mechanical Configuration and Motor Control

The Track and Core Pusher

The track mechanism is constructed in two sections referred to as the 'RH section' and the 'LH section' (right and left hand sections). The sections are aligned and mounted on feet end to end (see Chapter 2 on installation). Each section comprises of an extruded aluminium box section base on which parallel, cylindrical plastic rails are mounted on plastic sleepers and over which the plastic core pusher travels.

Two sets of rails and core pushers are provided to accommodate the range of core sizes that may be used. The appropriate rail set for a given core diameter is shown below:

Small rails Core diameters 50 mm to 90 mm

Large rails Core diameters 80 mm to 150 mm

Ball-screw Drive Systems

The core pusher is driven from the stepper motor and gearbox assembly mounted at the end of the RH motorised section. The pusher is attached to a yoke that in turn is attached to a ball-screw drive mechanism inside the RH track section. This enables the pusher to move along the RH track section in either direction.

The stepper motor and gearbox assembly provide the torque required to drive the core along the track at speeds of up to 3.5 m/min. The stepper motor will, however, stall if it is started at too high a speed BUT will not if the core is driven into an obstruction. In practice this means that if the core inadvertently comes up against a solid obstruction some damage might be caused. Care is required to ensure that this does not occur as substantial damage could occur if the core is inadvertently driven into any of the sensors. The sensors most at risk after the initial set up are the P-wave transducers and sensors attached to them because they are adjustable. An emergency stop button is mounted on the RH track that will cut the power to the stepper motors instantly so this should be used when necessary. Alternatively the power switch on the 2U motor control unit in the electronics rack or the wall outlet will have the same effect.

KEEP FINGERS AWAY FROM THE PUSHER WHILE IT IS MOVING!

If fingers get caught between the pusher and other parts of the track mechanics it will be very painful so it is important that the user is within reach of one of the power shut off methods when handling core sections on the RH track when the pusher is moving. To help with this the emergency stop button can be moved to any position along the track.

To change the rails from one spacing to another the rail assemblies should be removed from all of the track and the rails detached from the sleepers then reattached in the other position and the rail assemblies mounted back onto the track. Where rails are fixed to the magnetic susceptibility section of the track and the centre stand the sleepers are specific to a rail spacing so additional sleepers are supplied for the different rail spacings.

Belt Drive Systems

On older belt-drive systems, a Kevlar-reinforced nylon-toothed belt is attached to the pusher and passes around the driven toothed pulley wheel at the RH end of the motor section. It runs beneath the complete length of the RH section and back over the free running pulley wheel at the LH end of the section to the LH side of the core pusher where it is attached. In this way a complete drive loop is formed enabling the stepper motor to drive the core pusher in either direction.

The stepper motor and gearbox assembly provide the torque required to drive the core along the track at speeds of up to 2.5 m/min. The stepper motor will, however, stall if it is started at too high a speed or the core is driven into an obstruction. In practice this means that if the core inadvertently comes up against a solid obstruction then it will stall. However, care is required to ensure that this does not occur as substantial damage could occur if the core is inadvertently driven into any of the sensors. The sensors most at risk after the initial set up are the P-wave transducers because they are adjustable.

There is some backlash (approx. 5 mm) in the drive assembly that can be negated for all practical purposes, by ensuring that the core pusher was last driven to the left prior to automatic logging. When using the Windows™ software this is done automatically.

To change the rails on the RH box section the belt must be removed first. To remove the belt simply dismantle the clamp on the core pusher and unthread the belt from the RH box section. To change the rails remove all the fixings in the sleepers and replace with the alternative rail set.

To replace the drive belt thread the belt around the motor pulley at the RH end, under the complete system and around the free pulley at the LH end and back to the core pusher. It can be useful to run the motor to help the belt feed around the motor pulley

KEEP FINGERS AWAY FROM THE PULLEYS WHILE THEY ARE MOVING!

Clamp the belt to the LH side of the core pusher so that it is flush with the pushing face. Fix the belt into the bracket at the RH end of the core pusher keeping the tension as tight as practically possible. The core pusher can be clipped into the rails at any position between the sleepers, where the rails will flex apart. The top part of the fixings on the core pusher can be used either way round to obtain the best tension (this provides adjustment of 1/2 pitch - 2.5 mm).

Positioning and Distance Control

As explained in Chapter 3 each core section passes through the sensor array by using the pusher system. The electronics does not independently 'know' at any time the position of the pusher. The position of the pusher is known only when it is at the 'reference position' after finding the laser (if fitted) or the user informs the computer that it is there by the **[Set Ref. Point]** instruction. All other positions are continuously calculated by summing all the subsequent pusher motions.

The motion of the core pusher is calculated as the number of steps needed to move a set distance. The relationship is:

$$NS = (D * SPR * GBR) / (P * NT)$$

where:

D =	the distance moved (mm)
NS =	Number of steps
P =	the pitch of the toothed belt (1.0 cm)
NT =	the number of teeth on the drive pulley
	On a ball-screw system (P*NT) is the ball-screw pitch (0.5 cm)
SPR =	the number of steps for a revolution of the stepper motor
GBR =	the gearbox ratio

All these parameters are defined in the settings, apart from the belt pitch, which is assumed to be 1 cm.

The Vertical Slide

The upper PWT and DT together with any surface measurement sensors (MS, colour spectrophotometer, XRF) are fitted to the vertical slide. This slide is driven via a stepper motor (Z) and rack and pinion assembly. If the slide is driven too high then the pinion gear disengages from the rack preventing any damage. It will re-engage when the slide is driven down again. If the slide is driven too low with the P-wave transducer and housing in place then a limit switch will cut the power and prevent any further motion. If the slide disengages because it is too low then the user can re-engage by simply applying a slight upward pressure on the rack while the motor is turning.

Positioning and Distance Control

The positioning of the slide is similar to the way the pusher operates in that all movements are monitored after a zero position is set.

The motion of the vertical slide is calculated as the number of steps needed to move a set vertical distance. The relationships is:

$$NS = (D * SPR * GBR) / (P * NT)$$

where:

D =	the distance moved (mm)
NS =	Number of steps
P =	the pitch on the rack (1.0 mm)
NT =	the number of teeth on the pinion
SPR =	the number of steps for a revolution of the stepper motor
GBR =	the gearbox ratio

All these parameters are defined in the settings, apart from the rack pitch that is assumed to be 1 mm.

Reciprocating P-wave Transducers

MSCL systems equipped for rock core logging may have reciprocating P-wave transducers, which are driven by a stepper motor. This motor is controlled by the same ports on the electronics (Z motor), and on belt-drive reciprocating systems it is the same physical motor. The vertical slide and the reciprocating transducers cannot be used at the same time unless the system is customized to include a third motor control.

Limit Switches

Three limit switches are installed on the system to prevent accidental damage occurring in the event of an error. The user should note that in normal use in the automatic logging mode the switches will not be contacted unless an error occurs and if they do contact then logging should be paused whilst appropriate measures are taken to 'reset' the system.

Two switches are located at either end of the motor track section to prevent damage occurring to the system by cutting the power to the stepper motor should the core pusher (or a damaged core liner) run into them. Note that only the limit switch located at the end towards which the core is traveling is active. This prevents the system from 'locking up' in either of the end positions.

The 3rd limit switch is mounted on the Z motor (vertical slide or reciprocating transducers) to prevent the core from being crushed in the event of an operational error. This limit switch is connected in series with the track switch at the LH end. Consequently it is possible if an operational error occurs to lock the system if both this switch and the RH track switch are closed.

Laser Core Detection System

A laser based core detection system is fitted as standard on MSCL systems Serial #39 and higher. The laser 'looks' across the right hand track to the right of the reference position and detects either the LH end of the core section or the pusher depending which part of the logging cycle the system is in. Having a laser detect system achieves several objectives;

- I. The user does not have to align the first section with the reference position before logging begins.
- II. All core sections are measured and automatically butted against the previous core section without the user having to position the core accurately by hand. This automatic operation enables the process to be achieved more accurately and insensitive to user errors.
- III. At the end of logging each section the software checks and resets the position of the pusher. If there is a difference in the actual and assumed position of greater than 5 mm then this error is reported to the user. The user can decide whether to relog that section or to ignore the error and reset the pusher position. In

this way if small errors do occur (for example if the motor stalls briefly) the user does not have to reset the position manually and can continue knowing that the error will not be accumulated into the next or subsequent sections.

Motor Control

There are 2 switches and 1 knob on the control panel located on the face of the 2U motor control unit in the electronics rack:-

- **‘Auto/manual’:** In the ‘Auto’ position the stepper motor is under control from the PC through the serial interface on the stepper motor controller. In the ‘Manual’ position the stepper motor is controlled by the knob on the control panel. In the ‘Auto’ mode both the speed and direction of movement are controlled from the PC. On MSCL Serial #39 onwards the auto/manual switch has been made into a “smart” switch by linking it to the microprocessor. In this way whenever the software ‘assumes’ that the switch is in the ‘auto’ position it can now check and prevent the user proceeding until it is set appropriately. This prevents user errors occurring by starting the logging process when in ‘manual’ and hence losing reference between the position the computer ‘thinks’ the pusher is at and the actual pusher position.
- **‘Motor X/Motor Z’:** The track stepper motor is controlled when the switch is in the ‘Motor X’ position. The ‘Motor Z’ position is for controlling the height of the vertical (or Z motor). This controls the upper PWT height as well as the height of the MS point sensor. During normal operation this switch should be kept in the ‘Motor X’ position to help prevent accidental manual movement of the vertical motor after it has been set.
- **‘Speed <--- / --->’:** This knob controls both the direction and speed of the core pusher system when in the manual mode. It has no effect in the ‘Auto’ mode. Note that the motor may stall if it is started at too high a speed. The red lights indicate the direction of travel and the centre stop position.

Centre Sensor Section

The gamma density, P-wave velocity and core thickness sensors are mounted on the centre sensor stand. For high quality cores (where the sediment completely fills the liner) the axis of measurement through the liner does not affect these measurements in any way. However, there are circumstances when the user may wish to log whole cores where the core material does not completely fill the liner. This can occur with very soft sediments and with cores where the core is cut a little smaller than the ID of the liner. Under these circumstances it is better to log whole cores with the P-wave and gamma attenuation measurements oriented horizontally.

Changing the orientation of the sensor plate.

To change from a vertical mode to a horizontal mode follow the instructions provided below.

- I. Remove the following parts from the centre sensor section:
 - Gamma Source and delrin bracket
 - Perspex cover
 - Short rail above the gamma detector
 - Short rail to left of P-wave transducers
 - Gamma Detector and delrin brackets
 - Delrin sleeper and support
 - Upper P-wave assembly and vertical drive mechanism
 - Lower P-wave assembly
- II. Remove the two aluminium back plates from the centre section.
- III. Remove the Gamma Source support plate from between the 2 upright side plates.

- IV. Fix the 2 long feet with adjusting pillars attached to the side plates
- V. Fit to the sensor plate;
 - the spring loaded rear P-wave assembly
 - in both cases ensure that the transducers are correctly sprung
 - the front P-wave assembly
 - the delrin brackets for holding the gamma source and detector
- VI. Lower the horizontal sensor plate into position with the LH side plate through the large slot in the plate. Locate on the delrin pillars.
- VII. Adjust the pillars to ensure that the plate is horizontal and the load is spread evenly between all 4 pillars.
- VIII. Locate the gamma source and gamma detector onto the brackets and secure with the top halves.
- IX. Re fit the short rail sections
- X. Adjust the positions of the P-wave transducers to suit the core.
- XI. Fit the horizontal perspex cover between the gamma source and detector and check that the core is free to move between the sensors.

Core Boats

If unlined, fractured rock cores will be logged on the MSCL, core boats should be used. Geotek can supply fiberglass core boats that fit on the track rails and under the reciprocating P-wave transducers. Many standard sizes to fit mining cores are available; custom manufacture is also possible.

To use the core boats, place the pieces of core section onto a boat, with the front of the core section at the front of the boat. The core does not have to fill the boat. Measure the length of the core section. Check the “Boat” box in the Setup pane and enter the measured length of core in the “Section Length” field to the right.

The user-measured length of the core section will be automatically used to adjust the depths to remove the effect of the boats. The mechanism that is used is the “Edit Depths” pane (see Chapter 14); the user can re-edit these depths at any time.

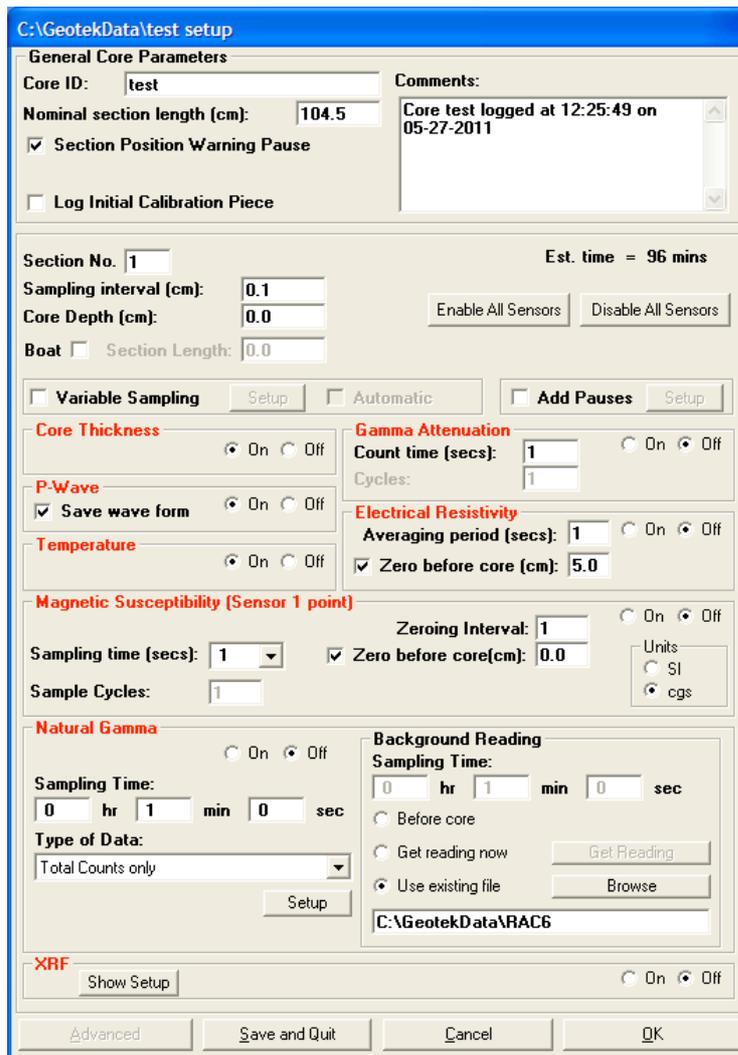


Figure 4-1. Setup pane for new section, showing "Boat" checkbox.

Chapter 4 Appendix. MSCL-V Mechanical Configuration

The MSCL-V uses many of the same parts as the standard MSCL, but put together to create a moving-sensor system.

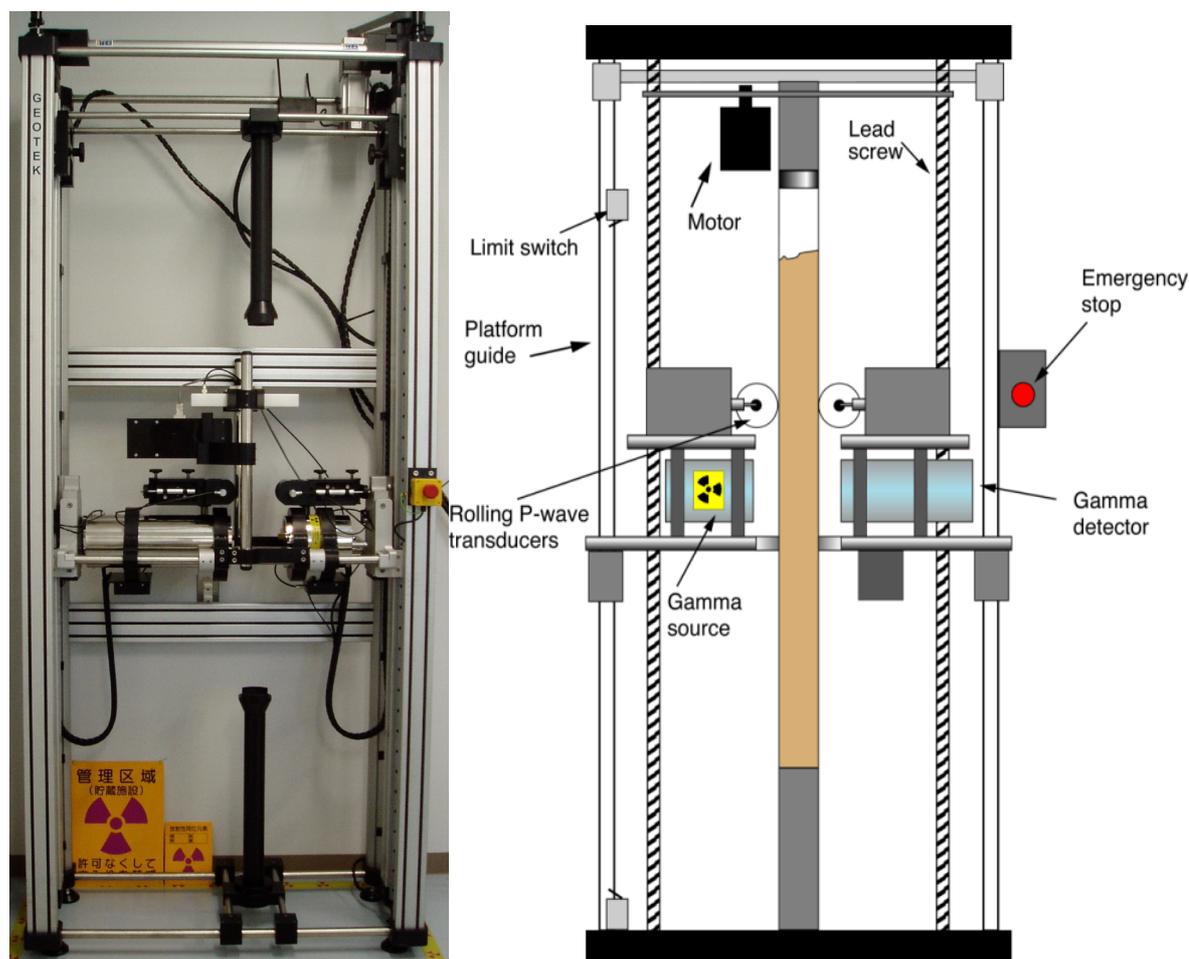


Figure 4-2. Picture and schematic layout of a vertical moving sensor MSCL (MSCL-V).

Sensor Platform Movement

The sensor platform moves up and down the core to make measurements. A servomotor at the top of the logger frame drives a belt which in turn drives the two ball screws that move the sensor platform. The servomotor and gearbox assembly provide the torque required to drive the sensor platform along the frame. The motor is extremely strong, and substantial damage could occur to sensors or people if they are in the way of the moving platform. The sensors most at risk after the initial set up are the P-wave transducers because they are adjustable; there is a red emergency stop button on the logger frame to prevent equipment damage or injuries.

Core Pedestals/Heads

In the MSCL-V, the core is held between two Delrin pedestals, with pedestal heads that are specific for the diameter of the core being logged. The user must ensure that the two pedestals are exactly in line with each other and with the sensor platform so that the sensors view the centre of the core section. The pedestal heads must fit the core sections exactly, or the core section may shift off centre during the logging process. New pedestal heads can be manufactured by the user or the user can contact Geotek.

Limit Switches

The upper and lower limit switches limit the vertical motion of the sensor array and must be set correctly. The limit switch stops (upper and lower) are easily adjusted vertically in the frame and must be positioned to ensure that the sensor platform does not hit either the bottom of the frame or the travelling upper core pedestal. The lower limit switch stop should be fixed at a position stopping the platform when the uppermost sensor (magnetic susceptibility) is 2cm beneath the top of the lower core pedestal. The upper limit switch stop should be positioned

to stop the platform when the lowermost sensor (gamma density) is 2cm above the bottom of the upper core pedestal. In this way under normal automatic movement the platform should not hit the limit switches.

The user should note that in normal use in the automatic logging mode the switches will not be contacted unless an error occurs and if they do contact them, then logging should be paused whilst appropriate measures are taken to 'reset' the system. Note that only the limit switch located at the end towards which the core is travelling is active. This prevents the system from 'locking up' in either of the end positions.

Motor Control Panel

There are 2 switches and 1 knob on the control panel located on the front of the electronics box:

'Auto/manual': In the 'Auto' position the motor is under control from the PC through the serial interface on the stepper motor controller. In the 'Manual' position the motor is controlled by the knob on the control panel. In the 'Auto' mode both the speed and direction of movement are controlled from the PC.

'Motor': The MSCL-V has only one motor, and the switch should remain in the 'V' position.

- 'Speed <--- / --->': This knob controls both the direction and speed of the sensor array platform when in the manual mode. It has no effect in the 'Auto' mode. Note that the motor will stall if it is started at too high a speed. The red lights indicate the direction of travel and the centre stop position.

5 - Gamma Density

Background

The density (ρ) of a material is a measure of how tightly the matter within it is packed together and is given by the ratio of its mass (m) to its volume (V). Its SI units are kilograms per cubic metre (kg/m^3). It is also sometimes given in the cgs units of grams per cubic centimetre (g/cm^3).

Bulk density is a property of powders, granular and multi-phase materials, especially used in reference to soils and sediments. It is defined as the mass of any particles of the material divided by the total volume they occupy. The total volume includes particle volume, inter-particle void volume and pore volume. The bulk density of soils and sediments depends greatly on their mineral make up and the degree of compaction and as a result bulk density can change as a result of handling. Bulk density is usually measured using gravimetric and volumetric techniques so to differentiate the measurements made using the MSCL the term gamma density is used. The measurement can also referred to as GRAPE (gamma ray attenuation porosity evaluator) after Evans (1965)¹ who used the technique in a device to compute porosity.

Operating Principle

A gamma ray source and detector are mounted across the core on a sensor stand that aligns them with the centre of the core. A narrow beam of collimated gamma rays is emitted from a Caesium-137 source with energies principally at 0.662 MeV. These photons pass through the core and are detected on the other side. At this energy level the primary mechanism for the attenuation of gamma rays is by Compton scattering. The incident photons are scattered by the electrons in the core with a partial energy loss. The attenuation, therefore, is directly related to the number of electrons in the gamma ray beam (core thickness and electron density). By measuring the number of transmitted gamma photons that pass through the core unattenuated the density of the core material can be determined.

To differentiate between scattered and transmitted photons the gamma detector system only counts those photons that have the same principal energy of the source. To do this a counting window is set which spans the region of interest around 0.662 MeV.

Gamma Ray Source

A 10 milli-curie Caesium-137 capsule (active element CsCl) is used as the gamma ray source. ¹³⁷Cs has a half-life of 30.2 years and emits gamma energy principally at 0.662 MeV.

The small Caesium capsule is securely housed inside a 150 mm diameter lead filled, 3 mm wall stainless steel container. The design restricts the radiation at the surface of the container to less than 5 $\mu\text{Sv}/\text{h}$.

The gamma beam is collimated through a choice of 2 collimators (5 and 2.5 mm diameter) in the rotating shutter at the front of the housing. The shutter has three operating positions; 2 for the use of different diameter collimators and 1 which closes the beam.

Position 1.	Source closed.
Position 2.	2.5 mm collimator open
Position 3.	5.0 mm collimator open

¹ Evans, H.B., 1965. GRAPE - A device for continuous determination of material density and porosity. In: *Proceedings of 6th Annual SPWLA Logging Symposium*. 2. Dallas, TX. pp. B1-B25.

In position 1 a padlock can be inserted for security purposes when the equipment is not in use or is being transported.

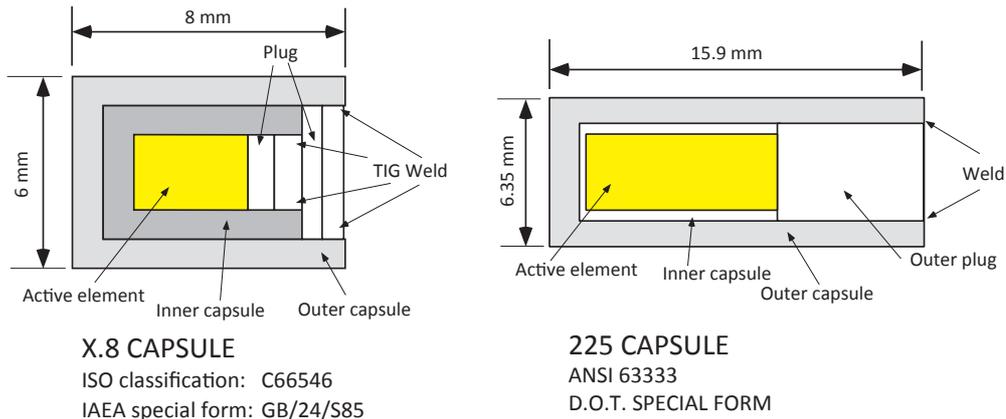


Figure 5-1. Caesium Source Capsule. To identify the type of your source look at the certificate supplied at the time of delivery - the X8 capsule is supplied by Nuclitec and the 225 capsule by Isotope Products.

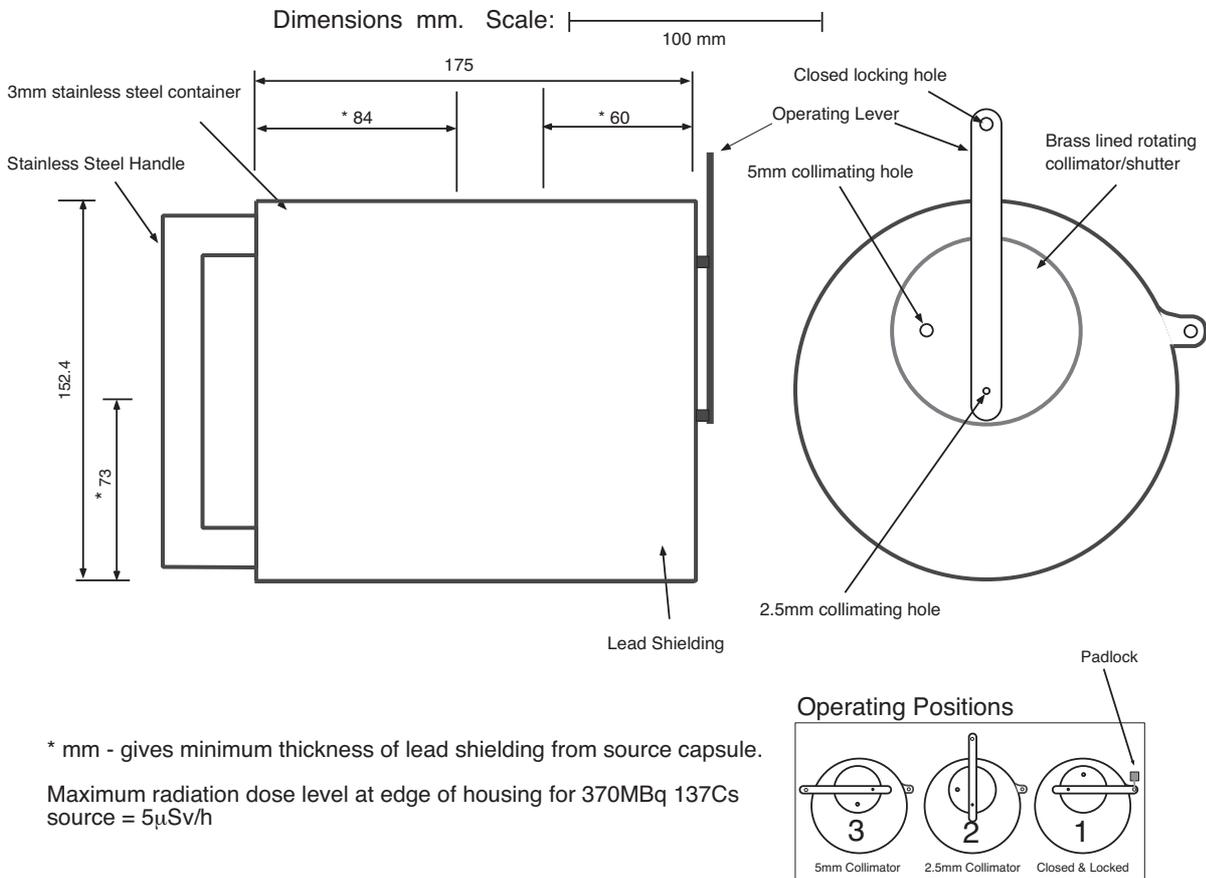


Figure 5-2. Gamma Source Shield.

The collimating holes permit a narrow beam of gamma rays to be emitted from the source, through the core sample to the detector opposite. The source should always be closed and locked when not in use and when being removed or installed in the apparatus.

Unless a spatial resolution of less than 5 mm is required then the 5 mm collimating hole should be used to minimise the counting time needed to obtain accurate data.

Gamma Ray Detector

The gamma ray detector comprises a scintillator (a 2” diameter and 2” thick NaI(Tl) crystal) and integral photo-multiplier tube. The tube also contains the internal high voltage supply and electronics to window the primary gamma rays (0.662 MeV). Pulses from the detector unit are sent continuously to a counter in the main electronics rack. The count period and count rate are determined through the software control interface.

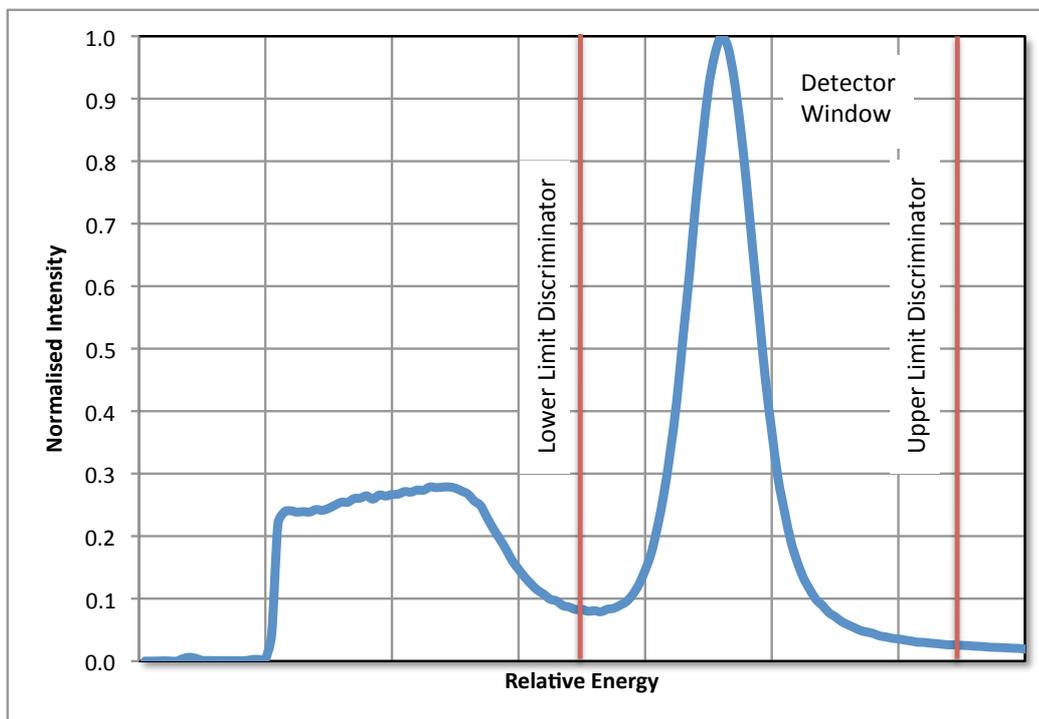


Figure 5-3. Gamma spectrum showing the ¹³⁷Cs peak and the detector counting window.

The whole detector unit is mounted inside a 150 mm diameter stainless steel housing. Internally this consists of lead shielding at the front, a central nylon tube that holds the detector and a lead back-plate through which the connecting cable passes. The lead shielding around the detector is designed to attenuate scattered gamma photons and reduce the radiation level around the equipment to very safe levels.

It is recommended that the detector is always kept in its housing (even during shipping) as the housing provides mechanical and thermal protection to the sensitive components. If the detector has to be removed from the housing then the following procedure should be followed:

Remove the short rail above the detector and fix the handle to the top of the housing. Remove the upper clamp and lift the complete assembly clear of the centre section taking care to ensure that the cable is free.

Lay the housing on a padded bench (be careful to ensure that it can not roll) and remove the locating screw at the rear in the side of the housing and loosen the opposite screw (located in the slot).

.....



THE BACK PLATE IS HEAVY AND MUST BE HELD SECURELY

WHILE THE COMPLETE ASSEMBLY IS WITHDRAWN

.....

Carefully withdraw the rear lead back-plate and nylon tube revealing the PMT that can then be disconnected and removed.

To install the detector into the housing, reverse the above procedure.

Gamma System Testing

The gamma counting electronics can only be tested when the utilities software is running (see Chapter 13). Set the gamma count time to 1 second and check the count rate with the gamma source shutter in all 3 positions through air. Depending on the system the following (very approximate) count rates should be obtained.

Position 1.	Source closed.	Approx. 50-200 CPS
Position 2.	2.5 mm collimator	Approx. 5000-10000 CPS
Position 3.	5.0 mm collimator	Approx. 25000-35000 CPS

The detector should not be exposed to very high count rates, for example when the 5 mm collimator is open and no sediment core or calibration piece is in the path of the gamma beam. Exposure of the detector to very high count rates will increase the slight drift of count rate that occurs with time and temperature and this should be avoided to ensure high quality data.

Calibration and Processing

The basic equation for calculating bulk density from gamma ray attenuation measurements is:

$$\rho = \frac{1}{\mu d} \ln \frac{I_0}{I}$$

where:

ρ =	sediment bulk density
μ =	the Compton attenuation coefficient
d =	the sediment thickness
I_0 =	the gamma source intensity
I =	the measured intensity through the sample

In practice many experimental factors need to be addressed in order to obtain valid bulk density measurements; for example; beam spreading, the attenuation through the liner wall and the effect of water in the sediments which has a significantly different attenuation coefficient to the sediment minerals.

Consequently the simplest and most reliable method for the calibration and calculation of gamma density is to use an empirical approach which has been shown to provide excellent results. The technique relies on calibrating the system using both the liner in which the core is contained and the fluid which the sediment contains. For example; when using a whole core with water saturated sediments a calibration section should be made which consists of a cylindrical piece of aluminium of varying thickness surrounded completely by water in a sealed liner (see Figure 5-4). For a dry core the calibration should be done with aluminium in a dry half liner.

Gamma counts should be taken through the calibration sample for long count times (e.g. 100s) at different aluminium thickness' and plotted as a graph of average $\rho * d$ vs. $\ln I$. $\ln I$ is the natural log of the measured intensity in counts per second (CPS) and $\rho * d$ is the average density * thickness of the aluminium and water. The resulting graph may deviate from the theoretical straight line because of the factors cited above. Each thickness of aluminium and water has an average density as follows:

$$\rho_{av} = (d_i / D) * \rho_{Al} + (D - d_i) / D * \rho_{water}$$

where:

D =	total thickness
d_i =	thickness of aluminium
ρ_{Al} =	density of aluminium

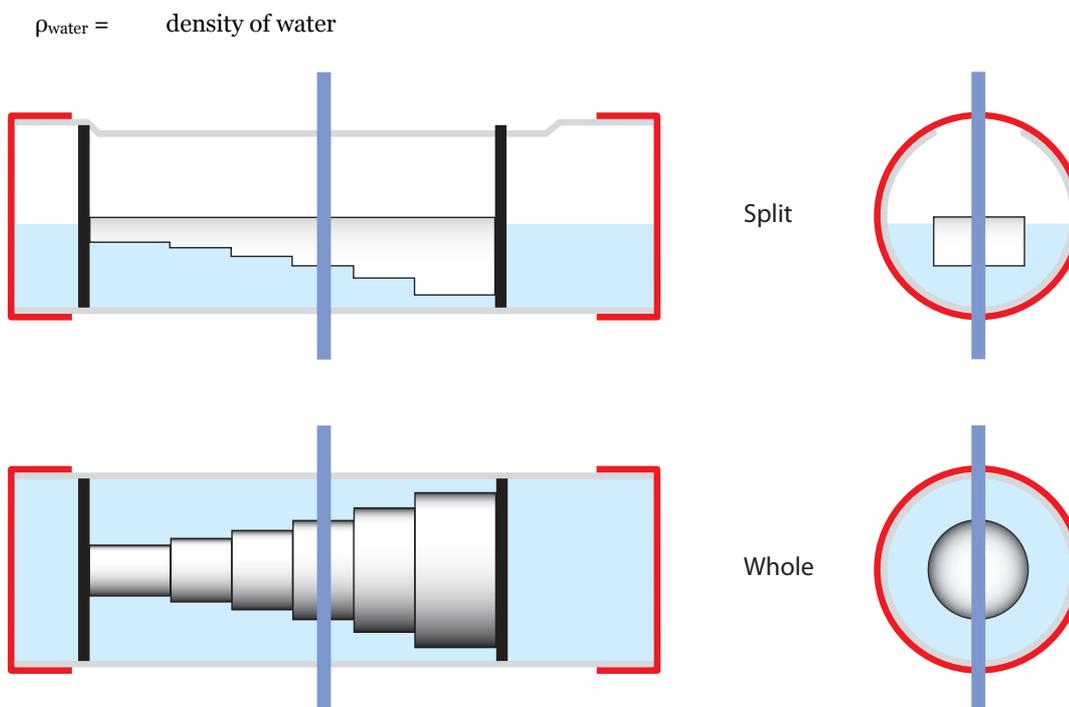


Figure 5-4. Gamma calibration pieces.

To make a good split core calibration section cut a slot in a full round section of liner then insert the calibration piece aligned with the slot, seal the ends of the section using the end caps and fill to a level just beneath the top surface of the calibration piece. Take care not to get water on the top surface as this will affect the calibration. An example split core calibration section is shown in Figure 5-5.

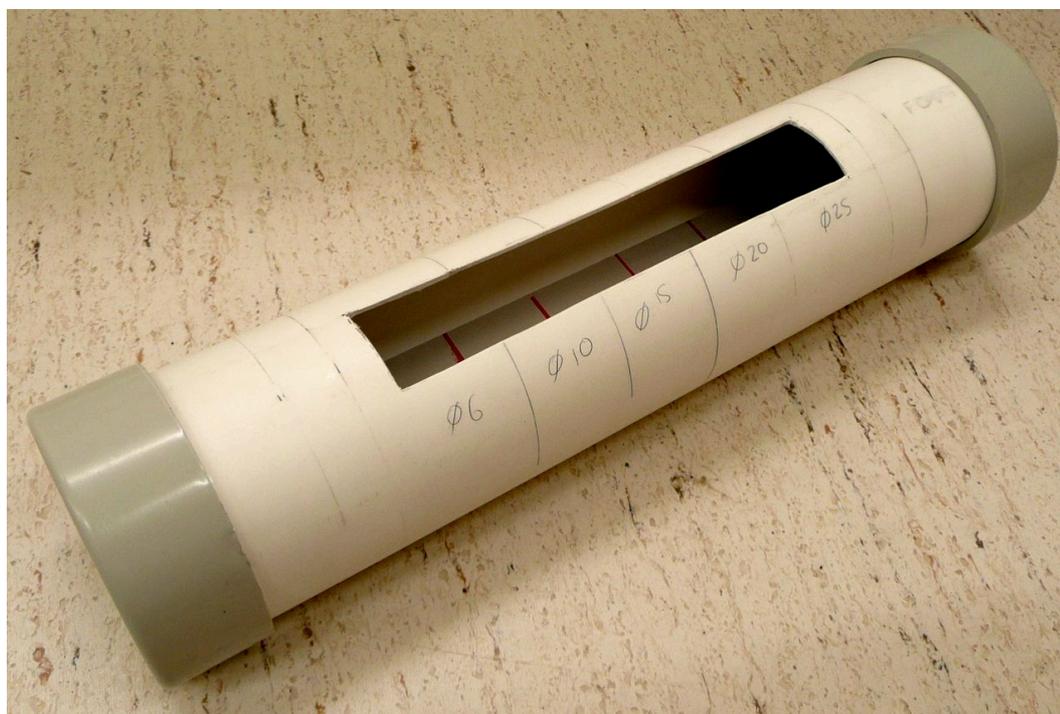


Figure 5-5. An example split core calibration section.

To accommodate any variations from a straight line a second order polynomial equation can be fitted to the graph of the type (see Figure 5-6):

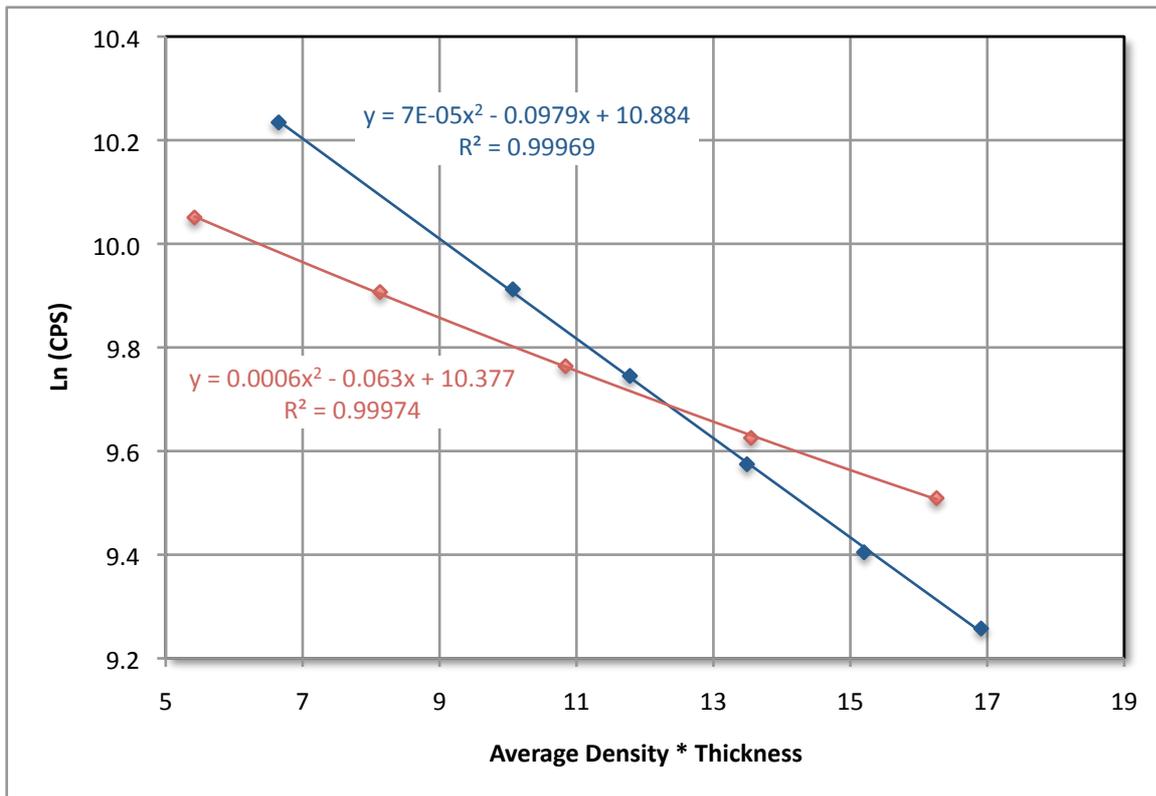


Figure 5-6. An example of a density calibration for dry (red) and saturated (blue) cores.

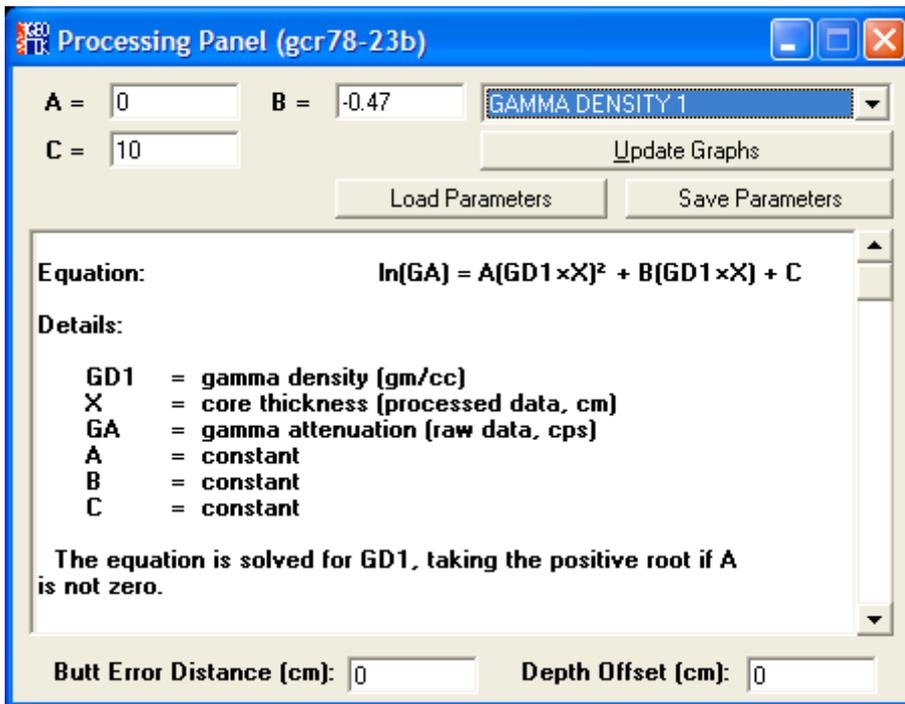


Figure 5-7. Gamma density processing panel.

$$y = Ax^2 + Bx + C$$

where:

$$x = \rho * d$$

$$y = \ln I$$

If the calibration data is better represented by a straight line then simply set A=0

The coefficients A, B & C in the equation can then be entered directly into the gamma density processing panel. This calibration and calculation will then make all the necessary empirical adjustments.

Fractional Porosity

Porosity can be calculated directly from sediment density if the following is known or can be sensibly assumed:

- I. the sediment is fully saturated (this can be water, air or anything else)
- II. mineral grain density
- III. fluid density

If so then the user can use the Fractional Porosity processing panel. Simply enter the values for mineral grain density (MGD) and fluid density (WD) in the boxes provided. To get porosity data in % (also sometimes referred to as PU or porosity units) multiply fractional porosity by 100.

The fraction porosity is then calculated from the following equation:

$$FP = (MGD - GD_1) / (MGD - WD)$$

where:

- FP = fractional porosity
 MGD = mineral grain density (gm/cc) (typically 2.65)
 GD₁ = gamma density as determined by the gamma density processing panel
 WD = fluid phase density (gm/cc) (typically 1.02)

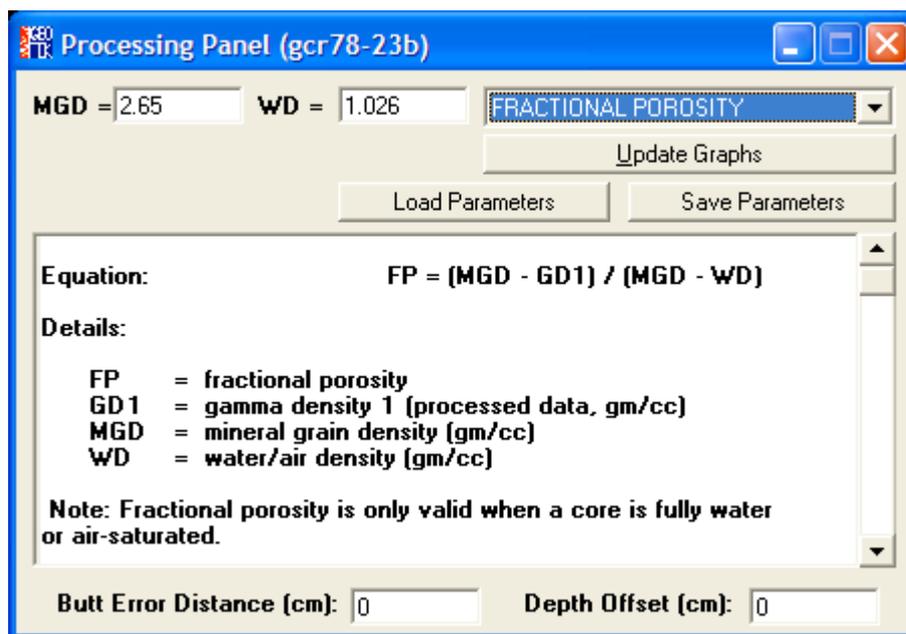


Figure 5-8. Fractional porosity processing panel.

Mineral grain density can vary quite considerably and the table below illustrates this. Fluid density can also vary, ranging from 1 for fresh water saturated material to 0 for unsaturated material.

Mineral	Density (g/cc)
Calcium carbonate, CaCO ₃ (calcite)	2.71
Calcium carbonate, CaCO ₃ (aragonite)	2.93
Quartz, SiO ₂	2.65

Mineral	Density (g/cc)
Biogenic silica, $\text{SiO}_2 \cdot n\text{H}_2\text{O}$ (opal)	2.15
Pyrite, FeS_2	4.95-5.10
Galena, PbS	7.4-7.6
Haematite, Fe_2O_3	4.9-5.3

Chapter 5 Appendix - Radioactive source handling instructions

These instructions follow some of the procedures used at Geotek to maintain safe operating procedures and to remain compliant with UK regulations regarding the sources. You should note that local regulations regarding health and safety and compliance with your own national regulations will require modification to these procedures. However, you should not modify these procedures unless you have done so in consultation with your local H&S representative and Radiation Protection Advisor.

Emergency procedures

You should develop emergency procedures in the event of fire, theft or other extraordinary events. These should be agreed with your Radiation Protection Advisor and any other interested authorities as required under your regulations. You should maintain a list of emergency telephone numbers, authorised key holders and written instructions on what should be done in the event of an emergency.

For example, in the event of a fire, the source should be kept cool if possible. If the source container has been exposed to prolonged extreme heat it should not be approached nearer than 300cm.

For example, in the event of theft, the local police authorities should be informed immediately.

For example, in some jurisdictions, it is a requirement to secure the source in a locked room with access to authorised keyholders only.

Storing sources

When not in use, sources should be stored in a locked room with access to authorised keyholders only.

The room should not contain any flammable items (for example a flammable liquids storage locker) and should be clearly labelled in accordance with your local regulations.

The location of the room, (and the source within) should be noted in your fire plan. Procedures for keeping it cool in the event of a fire should be written into that plan.

Using sources

When mounted on the MSCL you should develop procedures to prevent access to the beam when the shutter is open. These should include:

- I. Only fully trained personnel may have access to the shutter key.
- II. When the MSCL is not being used, the shutter must be kept shut and locked.
- III. When in use, the guards must always be in place, and a core, a calibration piece or a dummy core must be placed in the path of the beam.

Loading and unloading a source onto an MSCL

Before loading or unloading a source, four important points must always be observed:

- I. The shutter must always be locked SHUT when the source is not on the MSCL.
- II. The source is heavy and should not be handled by one person alone, there must always be assistance at hand to help support the source when required.
- III. The source should only be loaded on the MSCL IF the detector is already loaded and secured.
- IV. If you are performing this operation on a ship it should only be done in port or in calm conditions.

To load the source on the MSCL in a horizontal orientation

- I. Remove the Perspex guard and both top clamps.
- II. Lift the source onto its brackets with the lock to the left.
- III. Replace the clamps but do not tighten.
- IV. Place the calibration piece between the source and detector and adjust the spacing between the source and detector so that there is a gap of approximately 5mm each side of the widest part of the core (normally the end caps).
- V. Tighten the clamps and replace the Perspex guard.



To load the source on the MSCL in a vertical orientation

- I. Remove the Perspex guard and source clamp.
- II. Lift the source onto its support with the lock to the right. Ask an assistant to hold the source against its bracket while you replace the clamp.
- III. Replace the clamp but do not tighten.
- IV. Ensure that the Perspex guard is in place and a calibration piece or dummy core is in place over the detector.
- V. Unlock the source and ensure that the shutter can be turned to both the 2.5 and 5mm positions, adjust the position of the source if necessary.
- VI. Tighten the clamps.



To prepare the source for transport

The source shield and packaging has been designed such that it may be designated as an EXCEPTED PACKAGE and may be shipped under UN code 2910. There is a specification for the packaging and labeling that must be followed in order to comply with this code:

- I. The source must be packed in a shock and water resistant case.
- II. When the case is opened it must be obvious that the goods inside contain radioactive material.

- III. A certificate must accompany the source that describes the contents, type and leak test.
- IV. The outside of the case should not bear any radiation warning signs but:
 - When shipped by air should bear the NOTOC label (see right).
 - Should be labelled to show the address of both the consignor and consignee.
 - The writing UN2910 should be clearly visible on the outside of the box.



National jurisdictions differ in respect of other documentation that may be required to accompany the source. Please refer to the safety and handling instructions in the Geotek customer advice pack (available on request), and consult your Radiation Protection Advisor for advice.

Packing and unpacking the source

- I. Clean old labels from the transport box and inspect it for any damage (see note 1 of the UN2910 code above). If you need a new box, Geotek is able to supply these within approximately 2 weeks of placing an order.
- II. Remove the two top pieces of foam and one side piece.
- III. Place the locked source in the box with the lock facing up.
- IV. Replace the foam.
- V. Place the cross of warning tape across the top of the foam (see note 2 of the UN code 2910 above).
- VI. Place the source certificates on top of the tape and seal the box.
- VII. Place a “banding tape” around the box.
- VIII. Place labels on the outside of the box as required.
- IX. When sources are shipped from Geotek, the banding tape is covered by Geotek packing tape to act as a deterrent against tampering. You may consider using your own packing tape in this way but this is not a requirement of UK regulations.



6 - P-wave Velocity

Background

P-waves (primary waves) are longitudinal or compressional waves, which means that the material they propagate through is alternately compressed and dilated in the direction of propagation. In solids, these waves generally travel almost twice as fast as S-waves and can travel through any type of material. In air, these pressure waves take the form of sound waves, hence they travel at the speed of sound. Typical speeds are 330 m/s in air, 1480 m/s in seawater and about 5000 m/s in granite. They follow ray paths bent by the varying density and moduli of incompressibility and rigidity of the material. The density and moduli, in turn, vary according to temperature, composition and phase. P-wave velocity is defined as:

$$V_{\rho} = \sqrt{\frac{\kappa + \frac{4}{3}\mu}{\rho}}$$

where:

κ = modulus of incompressibility
 μ = modulus of rigidity
 ρ = density

but is calculated from measurements of the travel time of the wave and distance travelled:

$$V_{\rho} = \frac{d}{t}$$

where:

d = distance travelled
t = time taken to travel distance d

Operating Principle

A short P-wave pulse is produced at the transmitter and this pulse propagates through the core and is detected by the receiver. Pulse timing software is used to measure the travel time of the pulse with a resolution of 50 ns. The distance travelled is measured as the outside core diameter with an accuracy of 0.1 mm. After suitable calibration procedures have been followed (see below) the P-wave velocity can be calculated with a resolution of about 1.5 m/s. The accuracy of the measurements will largely depend on any variations in liner wall thickness. However, experience has shown that an absolute accuracy of ± 3 m/s is normally achievable with some care.

The P-wave Transducers

The ultrasonic P-wave system measures the P-wave velocity through the core. The P-wave transducers (PWTs) are mounted on the centre sensor stand with the gamma system. The upper PWT can be mounted on the vertical slide which is raised or lowered by the 'Z' stepper motor. When logging whole cores the position of the slide can be fixed during the logging process. When logging split cores the upper PWT is lowered onto the split core surface to take a measurement and raised prior to the core moving to the next increment along the track. The PC carries out this operation automatically. When logging whole cores both PWTs are spring loaded against the core liner.

There are two types of P-wave transducers available with the Geotek MSCL:

- I. Stainless steel 'Piston' transducers

II. Oil filled Acoustic Rolling Contact (ARC) transducers

'Piston' Transducers

The two PWTs are similar, apart from the mountings. These transducers are typically used in a horizontal reciprocating mode on rock core, or in a vertical orientation on split core. If used in the vertical orientation, the receiver is normally mounted on the lower bracket, and the transmitter is mounted on the upper vertical slide. Connection between the rear of each transducer is made to the transmitter and receiver electronics modules (Tx and Rx) at the rear of the sensor stand.

The active element of each PWT is a thickness mode 500 kHz or 250 kHz piezoelectric crystal, which is mounted in epoxy resin and housed in a stainless steel cylinder. Each PWT acts as a spring-loaded piston within a bronze sleeve. This arrangement is mounted within the plastic housing. Using these transducers in the horizontal mode both PWTs should be sprung so that they press against the core. To avoid any disturbance to the core surface during split core logging the spring must be removed from the upper transducer housing when in the vertical mode.

ARC Transducers

These transducers have been designed so that they can be used on older bench mounted systems and so are interchangeable with the old style piston transducer housings. The active element is a piezoelectric crystal, mounted on the central spindle of the rolling transducer, surrounded by oil and encapsulated in a soft epoxy sheath. The PWTs are mounted on spring loaded linear slides in a plastic housing. The main advantage of these transducers is vastly improved acoustic coupling characteristics. Also, a new active element has been incorporated to enhance the frequency content of the transmitted pulse. Connection to the Tx and Rx boxes, located at the rear of the main sensor stand, is made at the top of the central spindle.

Acoustic Coupling

When using the ARC transducers, there is no need to wet the core liner for a good acoustic coupling. It should be noted that a good acoustic coupling is also required between the sediment and the liner. Consequently, when logging whole cores, only high quality cores where the liner is full of sediment will provide consistently good data.

When using the piston transducers, it is essential to maintain a good acoustic coupling between the transducer faces and the core or core liner. This is achieved by wiping the core liner with a wet sponge prior to logging and dropping a few drops of distilled water onto the contact points. A very small amount of detergent in the water can sometimes help the wetting characteristics, which depends on the core liner material.

Piston transducers that will be used horizontally with rock cores in boats may be supplied with coupling extensions affixed to the face of the transducer. Most rock cores will not require wetting when used with these modified transducers, though wetting can sometimes improve the signal.

For horizontally split cores it is necessary for the upper PWT to be lowered onto the split surface at each measurement increment. To avoid contamination along the core in soft sediments it is normal to cover the split surface with a layer of thin plastic film ('cling-film', 'glad-wrap' etc.). A few drops of water spread along the surface of this film will provide the acoustic contact necessary. With rock cores water or acoustic gel is needed both on the top surface of the material and in the bottom of the core boat or liner to maintain good acoustic contact.

Pulse Timing

The accuracy of the measurement system revolves around the principle by which the pulse timing software operates. Although a manual system can use the first break to time the onset of the signal, an automated system needs a more definitive technique for consistently good measurement resolutions. Consequently, the automated P-wave measuring system uses an easily identifiable zero crossing to measure the travel time of the pulse. In this way the timing is very insensitive to signal amplitude which can vary by as much as 60 dB depending on the sediment type.

The transmitter pulse is sent to the transmitter transducer that generates an ultrasonic compressional pulse at 230 kHz or 500 kHz (depending on the transducers installed, usually 230 kHz). The transmitter pulse level is

adjustable in software from 0 to 250 V, this control allows the amount of energy imparted to the sample to be varied according to the acoustic characteristics of the sample and is the primary mechanism for ensuring that a good signal reaches the timing software. This transmitted pulse propagates through the core and is detected by the receiver and is amplified by a pre-amplifier providing the signal returned to the electronics for digitisation using a high speed analogue to digital converter (ADC). The pre-amplifier applies a fixed 150x gain. Before the signal is digitised it is possible to apply further variable gain under software control to ensure that the best use is made of the dynamic range of the ADC, although in the first instance this is done by adjusting the transmit pulse level.

The system will automatically attempt to optimise the dynamic range of the ADC by adjusting the transmit voltage to bring the signal level within a target input range on the ADC (this target input range is defined in the settings - see Chapter 13). When measuring through very highly attenuating samples it is possible that the transmit voltage will be set to maximum and the signal level will not be at a target level at this point the variable gain amplifier may be used to bring the signal level into the target range. When the signal is within the upper and lower acceptable levels a reading will be made and an adjustment will be made to the TX voltage (of gain level) to bring the level closer to the target level (see Figure 6-1 for details).

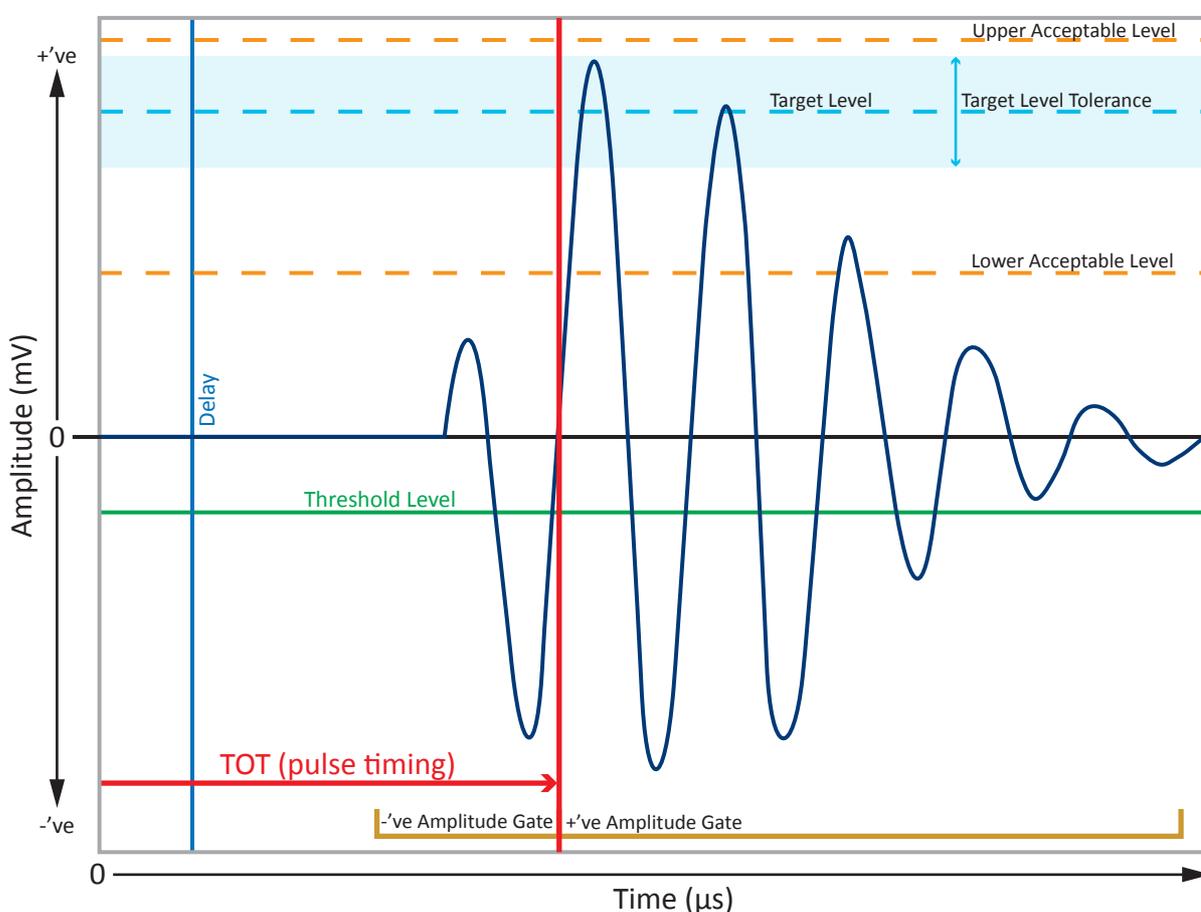


Figure 6-1. Pulse timing, automatic level settings and amplitude gate.

The received signal is processed through an analogue to digital converter before being displayed in the software window. The signal is (by default) digitised at a default sampling frequency of 12.5 MHz. In the software a threshold detector determines the first positive or negative going excursion (as defined by the user using the Threshold Level) on the received pulse after the user defined Delay (Figure 6-1). The pulse timing is achieved by measuring the time to the first zero crossing after the threshold has been exceeded. In this way the travel time measured (TOT) is approximately one half or one wavelength after the start of the pulse but is measured without any errors caused by signal amplitude. The Delay that can be used to define the point at which the software should start its threshold detection. The Delay should be set before the start of the signal to ensure good signal timing measurements. The interface to the P-wave pulse timing is shown in Figure 6-2 and is described below. The P-wave interface shows the pulse as it enters the ADC, so after any gain has been applied, the maximum input range

of the ADC is ± 500 mV. A bar plot indicates the signal strength as calculated using the method described below for signal amplitude.

If the transducers are touching or there is a sample between them a waveform will appear in the window. The screen view can be changed using the time base and voltage divisions drop down boxes (the x and y scales respectively). The user can move along the time base by moving the mouse over the zero line of the y-axis (in bold black) when the mouse pointer will become a hand icon. Clicking and dragging the mouse will move the time base in the direction of the movement.

There are five traces on screen these are; the waveform in dark blue; the y-axis zero line in bold black; the Delay in light blue; the Threshold Level in green and the measurement (TOT) in red. The red vertical line is the timing measurement so this should be monitored to ensure it is in the correct place on the waveform.

The green and blue lines can be moved by positioning the mouse pointer over the line and clicking and dragging (if they have not been locked - use right click and select from contextual menu). These two lines define how the measurement will be made. Alternatively a right click on the scope window will show a contextual menu in which either of these lines can be set at the mouse pointer position. Two other options are available from the drop down contextual menu: 'Set As Default View' - sets the current view (x and y scales y-axis position) as default and; 'Show Data Points' - this is self explanatory.

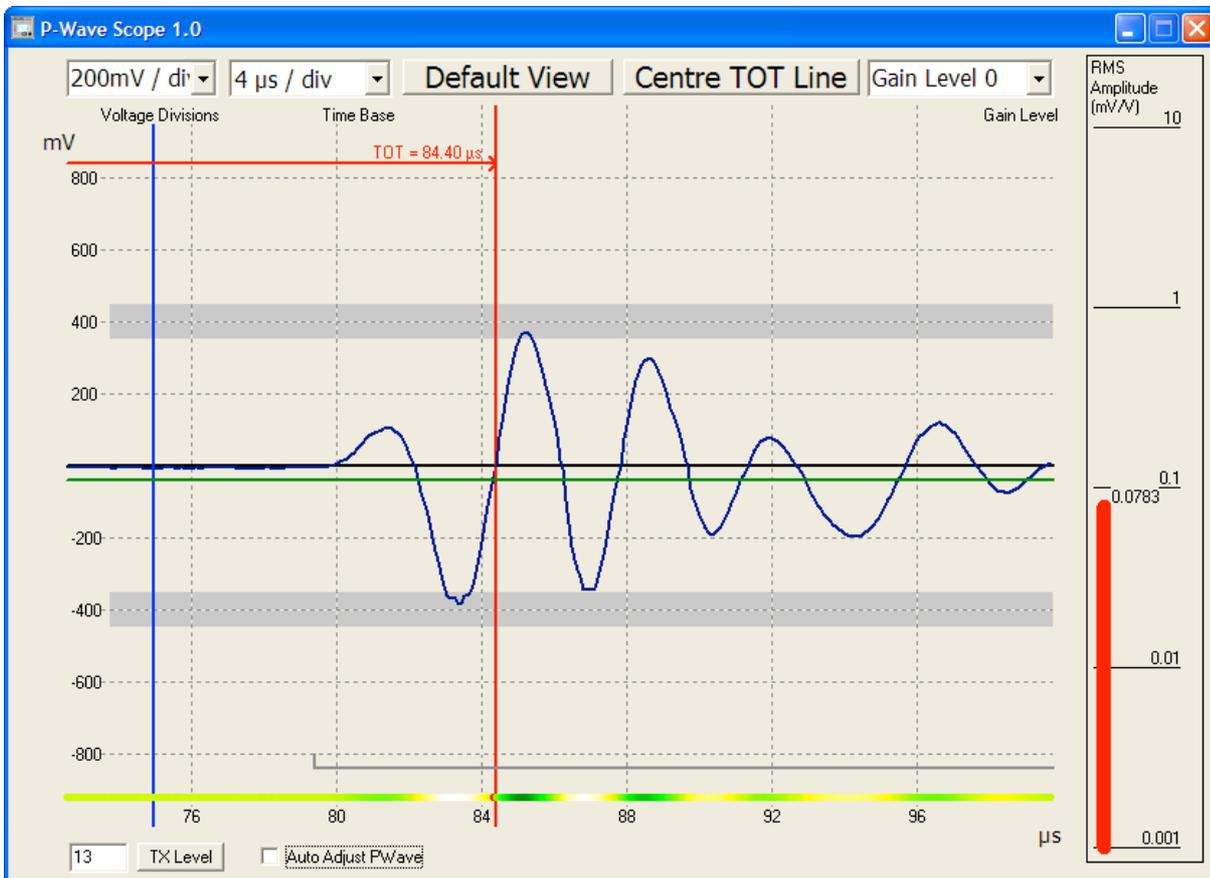


Figure 6-2. The P-wave pulse timing window.

Above the scope display there are two buttons and three drop down boxes. Clicking the **[Default View]** button will return the scope view to the user defined default view. Clicking the **[Centre TOT Line]** button will centre the red timing measurement line in the middle of the scope view. The right hand drop down box can be used to apply one of three levels of gain to amplify a weak signal and underneath the scope window there is a text box and a button that can be used to set the TX voltage (enter a number, 0-250, and click **[TX Level]**). The automatic procedure that is used during core logging can be switched on using the 'Auto Adjust PWave' tick box. The automatic procedure changes the TX voltage and the gain level to bring the signal into the target zone so that:

- I. the dynamic range of the ADC is maximised

II. there is a larger signal for timing measurements.

The two drop down boxes at the top left of the scope display allow the user to change the scale on the scope, just as a normal bench top scope might work by changing the voltage level or time increment per division. To the right of the scope display there is a bar plot showing the signal level calculated as described below.

P-wave Signal Amplitude Measurements

The strength of the received signal is measured by taking the root mean square (RMS) value of the signal (in volts) within a defined time window. The amplitude measurement window is specified by two parameters, a positive and negative TOT gate, i.e. how long before and after the TOT measurement point (in μs) the amplitude window should start (negative) and end (positive), see Figure 6-1. The final amplitude values are reported as RMS mV amplitude per transmit V level.

Calibration and Processing

The P-wave velocity of the ultrasonic pulse through the sediments inside the core liner is given by;

$$VP = X / TT$$

where:

X = the sediment thickness inside the core liner as measured.
 TT = the pulse travel time in the sediment.

The measured total travel time, TOT, is given by;

$$TOT = TT + PTO$$

where:

PTO = the P-wave Travel time Offset which is all the additional time delays.

PTO includes the pulse travel time through the liner, the pulse travel time through the transducer faces, the delay caused by picking a point on the wave form which is about 1 cycle after the onset, as well as a small electronic delays in the system circuitry. This parameter must be determined to calibrate the system. It will vary depending on both the core liner being used and whether whole core or split core measurements are being made.

Determining PTO

For whole cores: Cut a short length of liner (about 30 cm) of the type (and preferably the same manufacturer's batch) being logged. Fill the liner with distilled water and place between the P-wave transducers as if logging a normal core. When using whole cores the whole core liner should be capped, taped and inserted between the transducers (see Figure 6-3).

For unlined rock cores: Move the two transducers together until they are touching each other with a similar pressure to which they touch the core.

For split cores: Move the two transducers together as above, but insert a small square of core liner between them. Alternately, cut a hole in the side of a capped section of liner (similar to Fig. 5-5, but with a larger hole to accommodate the upper transducer), fill the liner halfway with water, and insert the upper transducer just beneath the water surface.

The following numbers should be recorded:

T = water temperature
 D = distance between the transducers
 TOT = total travel time recorded using the test panel

The velocity, V_t , of the distilled water at the given temperature T should be looked up from a standard reference source (also see Figure 6-4).

PTO can then be simply calculated from the following equation

$$PTO = TOT - (D - W) / V_t$$

where:

W = the total liner wall thickness as used in the core thickness calculation

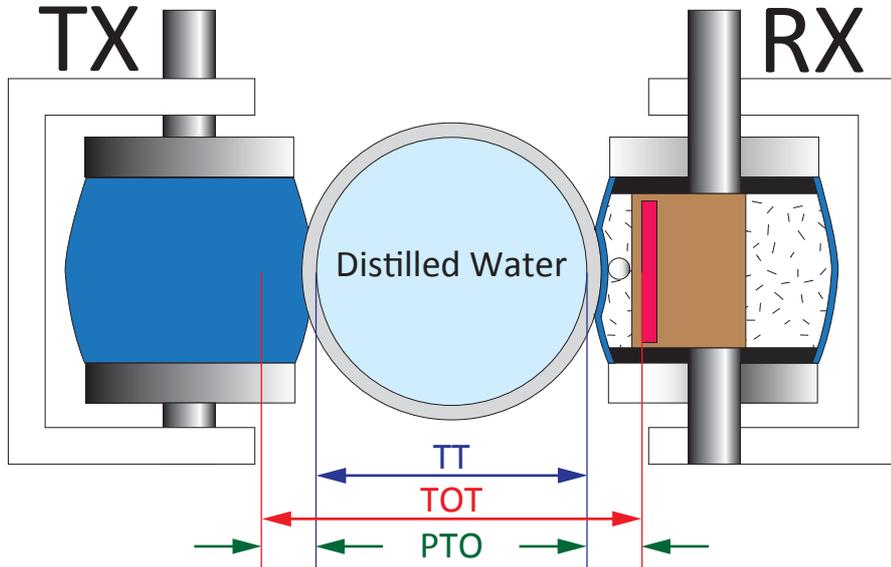


Figure 6-3. Schematic view of P-wave calibration.

Having determined the value of PTO this can be entered into the box provided in P-wave velocity processing panel. The velocity will then be automatically calculated using the equations shown for VP

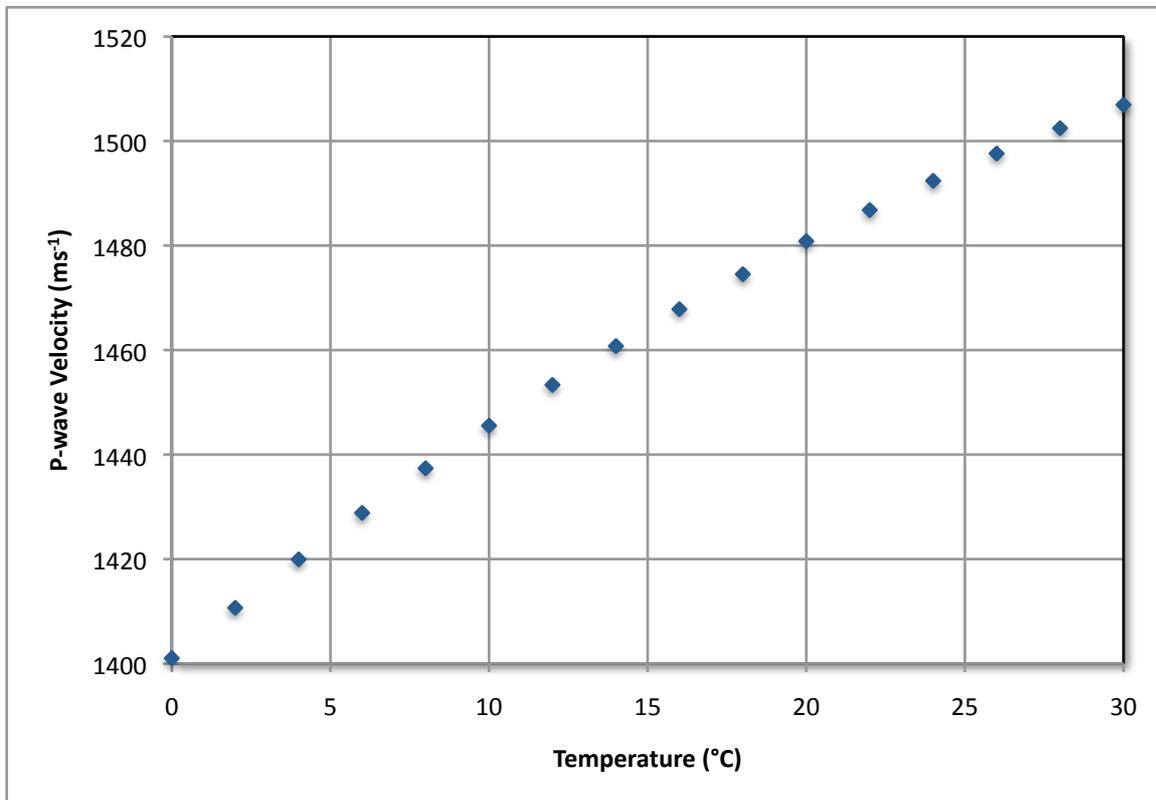


Figure 6-4. Variation of sound velocity with temperature. From Leroy (1969)¹.

Salinity, Temperature and Depth corrections

It is often the case that cores are inevitably logged at different temperatures and because velocity is affected by temperature it is important to compensate the measured sediment velocity for temperature. Velocity measurements are often corrected to a velocity at a set temperature. Of course, velocity is also affected by salinity and pressure (water depth) and so it is convenient to correct for these parameters as well.

The temperature of each core section can be measured during logging by inserting the temperature probe into the end of each section, the salinity of the water from the core site may also be known and the depth will certainly be known. This means that all of these parameters can be corrected for in the processed data. Geotek use an empirically derived formulation developed by Leroy (1969) in the processing panel to apply a correction factor to the measured P-wave velocity.

This correction is simply defined as:

$$VP_{\text{Corr}} = VP * VP_{\text{Fac}}$$

where:

VP_{Corr} =	corrected P-wave velocity
VP =	measured P-wave velocity
VP_{Fac} =	ratio of V_w at required conditions / V_w at measured conditions
V_w =	P-wave velocity in water

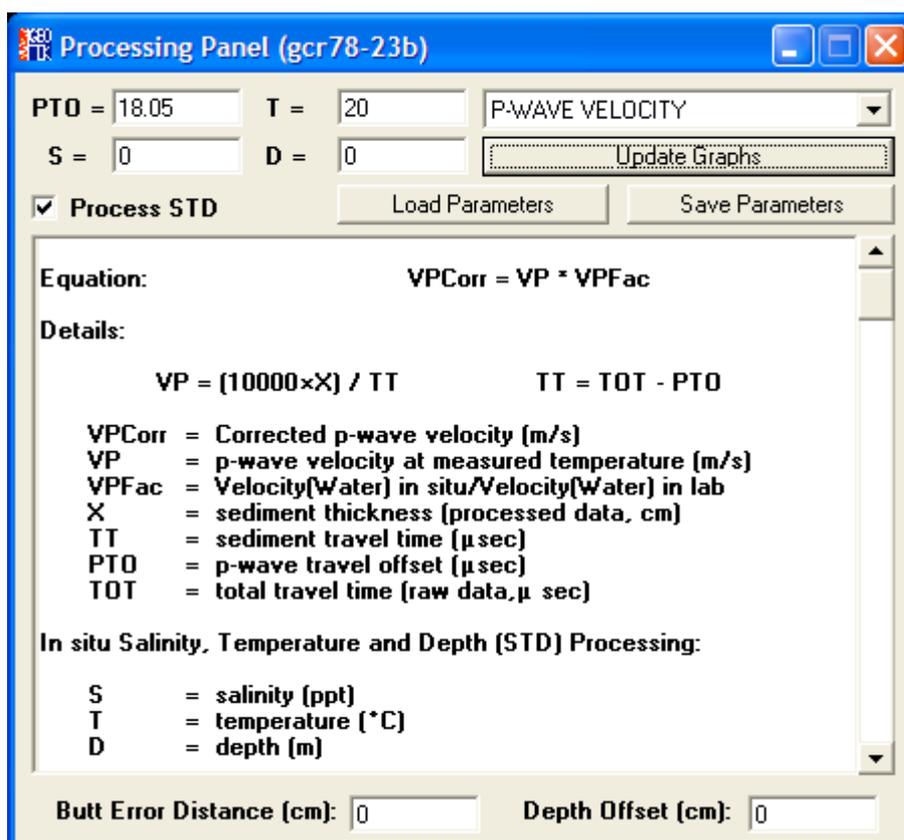


Figure 6-5. P-wave velocity processing panel.

Signal Amplitude

The P-wave amplitude processing panel simply allows the user to make a linear correction as required.

¹ Leroy, C.C., 1969. Development of simple equations for accurate and more realistic calculation of the speed of sound in seawater. *Journal of the Acoustical Society of America*. **46(1)**. pp. 216-226.

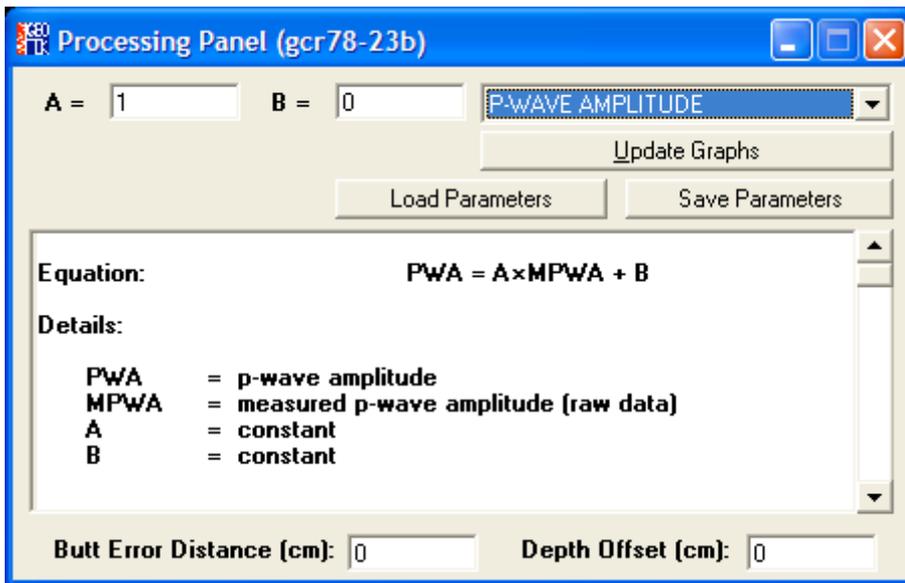


Figure 6-6. P-wave amplitude processing panel.

Acoustic Impedance

Acoustic impedance is the product of P-wave velocity and density:

$$Z = V * \rho$$

The processing panel is self-explanatory and requires no inputs from the user. Acoustic impedance is reported with units of $10^3 \text{ kgm}^{-2}\text{s}^{-1}$.

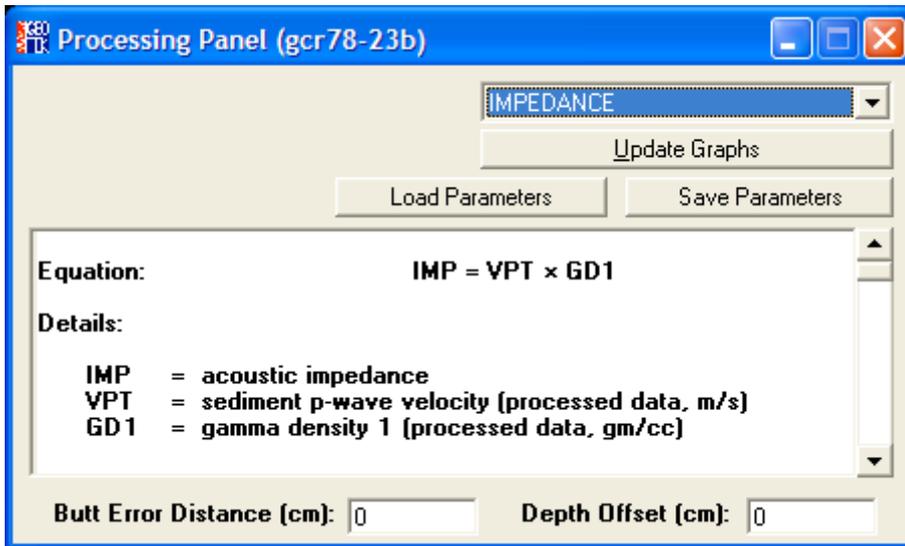


Figure 6-7. Impedance processing panel.

Acoustic impedance can be used to generate synthetic seismograms by calculating the reflection coefficients between boundaries (assuming normal incidence, no multiples or reverberations and no absorption). Depth can be converted to time (two way travel time - TWT) by integrating the measurement depths and velocities.

The reflection coefficients are calculated using the following equation:

$$R_i = \frac{Z_i - Z_{i-1}}{Z_i + Z_{i-1}}$$

And the depth to (two way travel) time conversion can be made using the following equation:

$$t_i = \sum_{j=1}^{i-1} 2 * \Delta z_j / V_j$$

where:

Δz_j = the layer thickness

The reflection coefficient data must then be spaced on a constant time interval and an acoustic wavelet convolved with the data to produce the synthetic seismogram. In the example shown in Figure 6-8 a zero phase Ricker wavelet (see Figure 6-9) with a dominant frequency of 3.5 kHz has been convolved with the data.

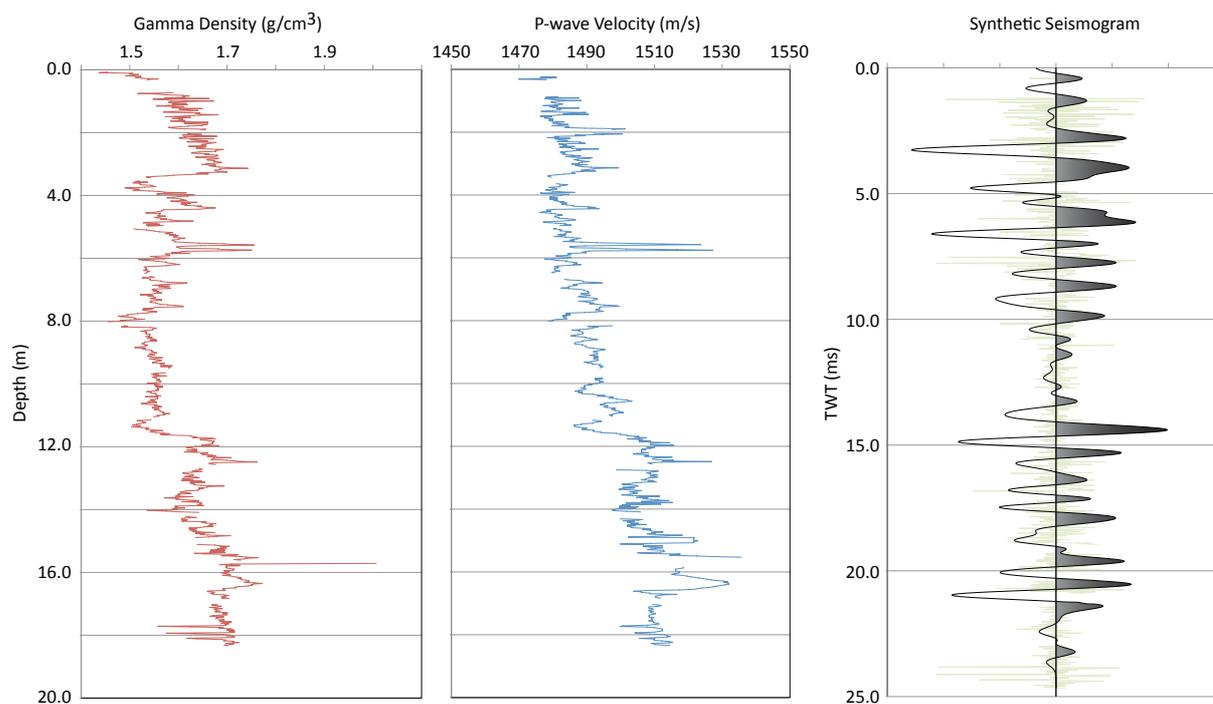


Figure 6-8. P-wave velocity and gamma density data used to produce a synthetic seismogram.

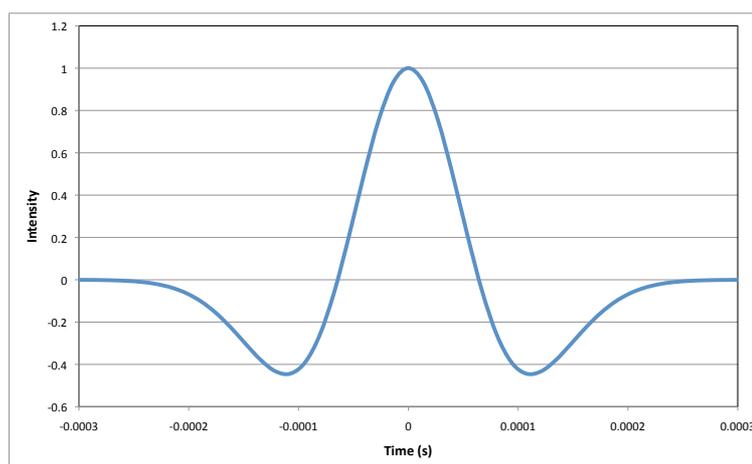


Figure 6-9. A zero phase Ricker wavelet with a dominant frequency of 3.5 kHz used in the creation of the synthetic seismogram in Figure 6-9.

Chapter 6 Appendix - Mark I P-wave measurement system

A short P-wave pulse is produced at the transmitter. The length and repetition rate of this pulse can be adjusted to suit the type of the transducer elements supplied (contact Geotek for more details). This pulse propagates through the core and is detected by the receiver. Pulse timing circuitry is used to measure the travel time of the pulse with a resolution of 50 ns.

Pulse Timing

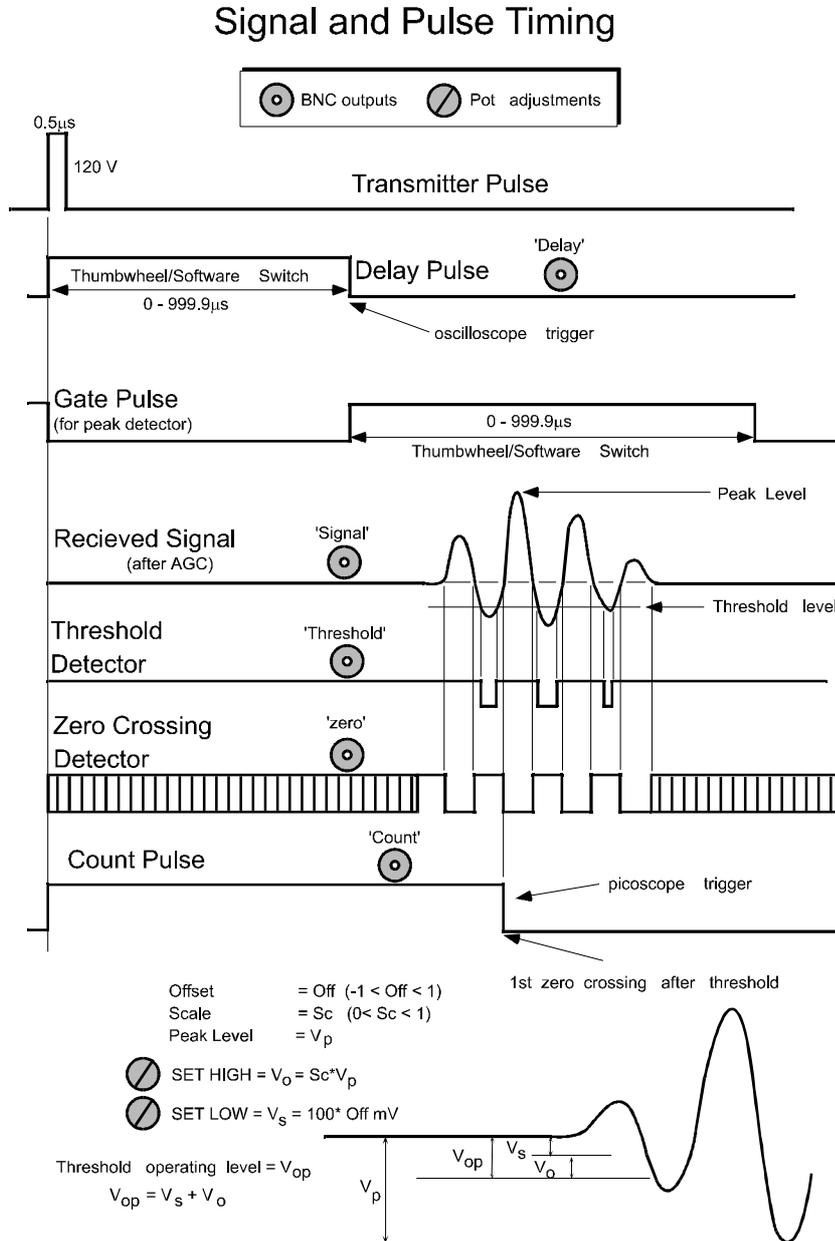


Figure 6-10. Signal and Pulse timing diagram for the Mark I P-wave system.

The accuracy of the measurement system revolves around the principle by which the pulse timing circuitry operates. Although a manual system can use the first break to time the onset of the signal, an automated system needs a more electronically definitive technique for consistently good measurement resolutions. Consequently, the automated P-wave measuring system uses an easily identifiable zero crossing to measure the travel time of the pulse. In this way the timing is very insensitive to signal amplitude which can vary by as much as 60 dB depending on the sediment type.

A threshold detector determines the first negative-going excursion on the received pulse. The pulse timing is achieved by measuring the time to the first zero crossing after threshold. In this way the travel time measured is

approximately one wavelength after the start of onset of the pulse but is measured without any errors caused by signal amplitude. Obviously a good calibration technique is required to ensure and maintain accuracy.

The transmitter pulse is sent to the transmitter transducer that generates an ultrasonic compressional pulse at 250 kHz or 500 kHz. This pulse propagates through the core and is detected by the receiver and is amplified by the AGC (automatic gain control) producing the received signal. A delay pulse is generated by the system after the transmit pulse has been sent. The delay time is set either in software or by the thumb-wheel switch¹ and should be a few microseconds less than the travel time for the beginning of the received pulse. A gate pulse is generated after the set delay time, during the gate period a peak detector measures the amplitude of the incoming signal. The AGC operates from this peak detector. A threshold detector detects any negative excursions below a set threshold level and can be monitored through the 'Threshold' output. A zero crossing detector detects all zero crossings and can be monitored through the 'Zero Crossings' output. The count pulse, which is the signal required for a measurement, is triggered at the 1st zero crossing after the threshold has been exceeded. In practice, it is necessary to check that the 'Count' pulse consistently aligns itself with the designated part of the received pulse - one wavelength on from the start of the signal.

Setting up Signal levels

Check that the transducers move freely in their housings against the spring pressure.

- I. Position a water filled test core between the 2 PWTs and adjust the position of each transducer. If the PWTs are mounted horizontally (on a whole core logger) then the transducers should be positioned so that they are about in their mid travel position.
- II. Wipe the core liner with a wet sponge or cloth and drop a little water onto the contacts between the transducer faces and the core liner to provide a good acoustic coupling (not necessary with ARC transducers). Do not over-wet the system, it does not help!
- III. Connect the dual beam oscilloscope or the virtual scope to the front panel of the P-wave electronics using BNC cables provided. With the dual beam oscilloscope use 'Delay' as the negative trigger pulse, 'Signal' on channel 1 and 'Count' on channel 2. Set the Delay to 0 and set up the oscilloscope to clearly display the received signals. A large pulse should be clearly visible on channel 1. When using the virtual oscilloscope swap the BNC cable from 'Delay' to 'Count' and miss out the next step.
- IV. Increase the delay time (for the dual beam oscilloscope) and adjust the time base on the oscilloscope until the direct pulse is expanded and clearly visible on the screen.
- V. Check that the count pulse occurs at the zero crossing following the first negative excursion (see Figure 6-10). If not, the 'scale' and 'offset' adjustments for the threshold detector need resetting. Note that the threshold and zero crossing pulses can be monitored directly from the front panel.
- VI. Remove the water core and observe the transmission through air. Check that the count pulse occurs at the zero crossing following the first negative excursion (see Figure 9). If not, the 'scale' and 'offset' adjustments for the threshold detector need resetting.
- VII. Check that the travel time shown on the LCD (Serial # <39) or in the MSCL Utilities software (Serial # >38) is in approximate agreement with the travel time shown on the oscilloscope.
- VIII. Use the test panel in the MSCL Utilities software (see Chapter 6) to check that the travel time is in agreement with the LCD (Serial # <39). Small differences can occur but it should be noted that the computer value is more accurate (0.05µs) than the LCD display (0.1µs).

¹ On MSCL systems Serial #0-38 thumbwheel switches 'Delay' and 'Gate', for controlling the P-wave velocity measuring system, were incorporated into the the main electronics panel enabling the user to set these parameters manually. In MSCL Serial #39 onwards these thumbwheel switches have been removed and replaced with software selectable settings. The settings for Delay and Gate can be changed in the 'Settings file' and can be changed at any time during logging by accessing the 'Advanced Panel' when logging is paused.

-
- IX. Check that the signals remain fairly constant whilst the core is moving right to left past the transducers (remember to wipe the core liner with a wet sponge or drop a little water on the transducer faces, not required for ARC transducers).

Adjusting Threshold Voltage Level

- The threshold voltage level has been adjusted prior to delivery. However the following should be used as a guide to reset or adjust the threshold voltage level (should it become necessary) using the 'scale' and 'offset' pots (refer to Signal Timing Diagram in Figure 6-10). The purpose of these adjustments is to ensure that the threshold operating level V_{op} consistently picks first -negative excursion over as wide an amplitude range as possible.
- With a large signal (through water or preferably a mud core) adjust the 'Set High' so that the threshold operates just on the first -negative peak.
- With a very small signal (through air with the transducers at their closest position) adjust the threshold operating voltage using 'Set Low' such that the threshold operates above the noise level but detects the first real negative excursion. Repeat this procedure until the threshold operates correctly over the entire range of signal levels.

Using the Dual Beam Oscilloscope

If the dual beam oscilloscope is unfamiliar to the user then the following notes will help to get started.

- I. Connect the P-wave electronics to the oscilloscope using the 'BNC' cables provided.
- II. Connect 'Delay' to the external trigger input.
- III. Connect 'Signal' to Channel 1 input
- IV. Connect 'Count' on Channel 2 input

Set the following on the P-wave electronics thumbwheel switches/in the MSCL settings

- SET DELAY to 0000/0
- SET GATE to 1000/100

Set the following on the oscilloscope

- TIME/DIV 5 ms/DIV
- CH1 VOLTS/DIV 0.5V
- CH2 VOLTS/DIV 0.5V
- CH1 AC GND DC DC
- CH2 AC GND DC DC
- MODE ALT
- TRIG MODE NORM
- TRIG SOURCE EXT
- LEVEL PULL for - SLOPE

- I. Adjust the trigger level so that 2 traces are seen on the screen
- II. Adjust horizontal and vertical position of traces.
- III. Set intensity, focus and illumination controls.
- IV. Expand the time base (TIME/DIV) to allow the details of the pulse to be seen clearly (5 μ s/DIV)

- V. Increase the DELAY to move the pulse to the left side of the display if necessary.
- VI. Adjust CH1 VOLTS/DIV as necessary.

Using the 'Virtual' Oscilloscope

The 'virtual' oscilloscope is mounted within the electronics rack, at the side of the rack mounted PC or within the PC itself. Software is used to control the functions of the scope and the traces are displayed on screen. To start the program click on [Start-Programs-Pico Technology-Picoscope for Windows]. Once the program has started an oscilloscope window will appear on the screen within the program window. You should adjust the size of the program window so that you can view the oscilloscope traces whilst you are logging your cores (i.e. whilst the MSCL Software or MSCL Utilities is operating).

Whilst you are logging cores with the MSCL Software you will only need to use the Picoscope in one of two modes.

- As an observational tool to ensure the logger is receiving high quality signals as with the dual beam oscilloscopes supplied with older loggers.
- In a recording mode where the signals can be observed and recorded to disk at the users command.

For more comprehensive set of information on the virtual oscilloscope and the Picoscope software use the online software help (Help menu item). The Picoscope software will run whilst either of the MSCL applications are running so simultaneous monitoring of logger activity and signal quality can be conducted. To get started

- I. Connect the P-wave electronics to the oscilloscope using the 'BNC' cables provided.
- II. Connect 'Count' to the Channel B input.
- III. Connect 'Signal' to Channel A input

Set the following on the P-wave electronics thumbwheel switches/in the MSCL settings

- SET DELAY to 0000/0
- SET GATE to 1000/100

Set the following in the software interface

- X-scale 5 μ s/DIV
- Ch A scale ± 1 V and OFF
- Ch B scale ± 500 mV and OFF
- TRIG MODE AUTO
- TRIG SOURCE Ch B
- LEVEL 160 mV and Falling
- +/- -30%

The timebase (x) and y scale options are displayed at the top of the screen and the trigger setup is displayed at the bottom of the scope window.

- I. Adjust Channel A and B scales as necessary.
- II. Channels A and B are displayed in blue and red respectively.
- III. Adjust the timebase on the virtual oscilloscope as required
- IV. Adjust the +/- display button to show any signal before the trigger point.

To view part of the trace before the trigger point: at the far right of the trigger setup options is a box indicating the percentage of the screen displayed before the trigger point, adjust as necessary.

Other signals can be viewed by swapping the 'COUNT' BNC plug to the relevant BNC socket, e.g. THRESHOLD or DELAY. Ideally, during logging the user will use the Picoscope for monitoring the signal quality and the count integrity so the best setup then would be to trigger using the COUNT. For example, to view the ZERO signal (where the P-wave signal crosses the zero line) use the P-wave signal to trigger from; trigger source =Ch A and level = 50mV Rising.

Recording Signal Data to Disk

To save the signal to disk click on [File-Save as]. A dialogue box will appear into which a file name must be typed. There is a choice of file formats as follows:

- *.PSD The application's own data format. Saves signal and spectrum traces.
- *.TXT An ASCII output of the signal data. Saves signal data only.
- *.PSS The applications settings file that records all the trigger and scale settings.

The data displayed on screen is saved to the specified file. The *.TXT format saves two columns of data, channel A first then channel B.

Note: If triggering from the falling side of the delay pulse and the DELAY thumbwheels are set to greater than 0000 then the user must make a note of the value and use it to adjust the recorded signal timing in any subsequent analysis.

Spectral Analysis

A limited spectral analysis is available within the oscilloscope control software. The signal data are reduced to 1024 points for spectral analysis. The setup options for the Spectrum window appears at the top of the screen when the Spectrum window is active. To eliminate any aliasing effects it is advisable to set the frequency scale to the smallest possible range (1.5 MHz is suitable for most applications). The scales for channels A and B set the amplitude window that is analysed, if set to Auto (recommended) the entire signal is analysed. If a range is selected that is smaller than the signal amplitude then the analysis will clip the extremes of the signal giving an erroneous spectrum. Both channels can be analysed simultaneously.

7 - Magnetic Susceptibility

Background

Magnetic susceptibility is the degree of magnetization of a material in response to an applied magnetic field. If magnetic susceptibility is positive then the material can be paramagnetic, ferromagnetic, ferrimagnetic, or antiferromagnetic. In this case the magnetic field is strengthened by the presence of the material. Alternatively, if magnetic susceptibility is negative the material is diamagnetic. As a result, the magnetic field is weakened in the presence of the material. The following table illustrates the magnetic susceptibility of some common minerals.

Mineral	Magnetic Susceptibility ($\times 10^{-6}$ SI)
Water	9
Calcite	-7.5 to -39
Quartz, Feldspar	-13 to -17
Kaolinite	-50
Halite, Gypsum	-10 to -60
Illite, Montmorillonite	330 to 410
Biotite	1,500 to 2,900
Pyrite	5 to 3,500
Haematite	500 to 40,000
Magnetite	1,000,000 to 5,700,000

Two sensors are available, a point sensor for split cores only and a loop sensor for whole or split cores. Ordinarily only one sensor may be used at a time.

Loop Sensor: The Bartington loop sensor (MS2C), ruggedised for Geotek applications, is used for magnetic susceptibility measurements on whole cores. It is available in a range of internal diameters and is mounted between the two main box sections in such a way that no magnetic or metallic components come close to the sensor. For maximum resolution of magnetic susceptibility the loop-diameter/core-diameter ratio should be as small as possible. Hence for small diameter cores some data degradation may occur and a smaller magnetic susceptibility loop may be desirable. A wide range of internal diameters can be substituted to optimise the core diameter to loop size, please contact Geotek if you wish to obtain additional loops.

Point Sensor: The Bartington point sensor (MS2E) is mounted on an arm suspended from the upper PWT housing. This allows the sensor to be placed on the core surface for each measurement. It uses the same electronics as the loop sensor. Note that the original point sensor (MS2F) required an interface box that is placed in the line from the sensor to the MS2 electronics.

The point sensor gives much higher spatial resolution but is less sensitive. Its field of influence is about 1 cm in diameter and so it cannot be used on whole cores. It is also more sensitive to temperature fluctuations, so care must be taken to stabilise the temperature of the system and core before logging.

Operating Principle

An oscillator circuit in the sensor produces a low intensity (approx. 80 A/m RMS) non-saturating, alternating magnetic field (0.565 kHz for the MS2C sensor and 2 kHz for the MS2E sensor). Any material in the near vicinity of the sensor, that has a magnetic susceptibility, will cause a change in the oscillator frequency. The electronics convert this pulsed frequency information into magnetic susceptibility values. For further details refer to manufacturer's documentation.

Setting Up

- Ensure that the MS sensor does not obstruct the core.
- Switch the MS meter on at least 10 min. before testing. The system needs to warm up to minimise drift.
- Without a core present choose either the 0.1 Hz or 1.0 Hz sampling rate and zero the meter. This can be done either with the push buttons for a single reading, or by using the toggle switch for a continuous cycle mode (see MS manual).
- Run an empty core liner using the core pusher through the MS sensor with the MS meter on cycle mode. No significant change in readings should occur as there are no moving magnetic parts.
- **Note:** When making MS measurements ensure that no magnetically susceptible materials are near the sensor (including wrist watches!).
- **Note:** Because of the potential drift in the MS sensor and electronics, zero readings can be taken at the start and finish of each core section and appropriate calibrations made to the data.
- Use the test panel in the Utilities software (see Chapter 13) to check that MS value recorded is in agreement with the MS2 meter display.

Calibration and Processing

Loop Sensor

The magnetic susceptibility sensor is electronically set to measure a single standard sample of a stable iron oxide which has been tested and analysed by the manufacturer (Bartington Instruments Ltd). Therefore, all magnetic susceptibility sensors supplied should record exactly the same value for any given sample, and that value should be the same as a measurement made on a different measuring system. In that sense the magnetic susceptibility system is calibrated absolutely. Since the calibration has been set electronically it should not alter. A calibration sample is provided which can be used to check the long term consistency of the calibration. Any changes in the calibration are a fault in the system's electronics which only the manufacturer can rectify.

Note: Magnetic susceptibility measurements are temperature sensitive, so it is important to maintain a stable temperature environment during measurement.

Volume specific magnetic susceptibility

The data obtained from the magnetic susceptibility system provides uncorrected, volume specific magnetic susceptibility, κ_{uncor}

κ_{uncor} is dimensionless (* 10^{-5} SI units)

To obtain the corrected Volume Specific Magnetic susceptibility (K) the data must be corrected for the relative effect of size of the core and the size of the loop sensor being used:

$\kappa = \kappa_{\text{uncor}} / \kappa_{\text{rel}}$ (* 10^{-5} SI units)

κ (SI units) = $4\pi * 10^{-6} \kappa$ (cgs units)

The relationship between core loop diameter (D_l), core diameter (d) and κ_{rel} has been determined experimentally (see Figure 7-1) and the following relationship can be used:

$$\kappa_{\text{rel}} = 4.8566 * (d/D_1)^2 - 3.0163 * (d/D_1) - 0.6448$$

This relationship is used automatically in the processing panel for magnetic susceptibility.

Mass specific magnetic susceptibility

The volume specific magnetic susceptibility takes no account of the density of the sample being measured. Consequently it is possible to have variations in K down the length of a core that reflect changes in density only rather than changes in proportion of magnetically susceptible minerals to other minerals. Mass specific magnetic susceptibility overcomes this problem by taking into account the density of the sample being measured, using the measured gamma density at each point. The mass specific susceptibility (χ) is given by:

$$\chi = \kappa/\rho \quad (\text{m}^3\text{kg}^{-1})$$

where:

$$\rho = \quad \text{material density (kgm}^{-3}\text{)}$$

χ in cgs units has units of cm^3g^{-1} and can be converted from SI units as follows:

$$\chi (\text{SI units}) = 4\pi * 10^{-3} \chi (\text{cgs units})$$

For further, more detailed, information on the measurement of magnetic susceptibility the user is referred to the manuals supplied by Bartington. The nomenclature above is the same as that used in these manuals.

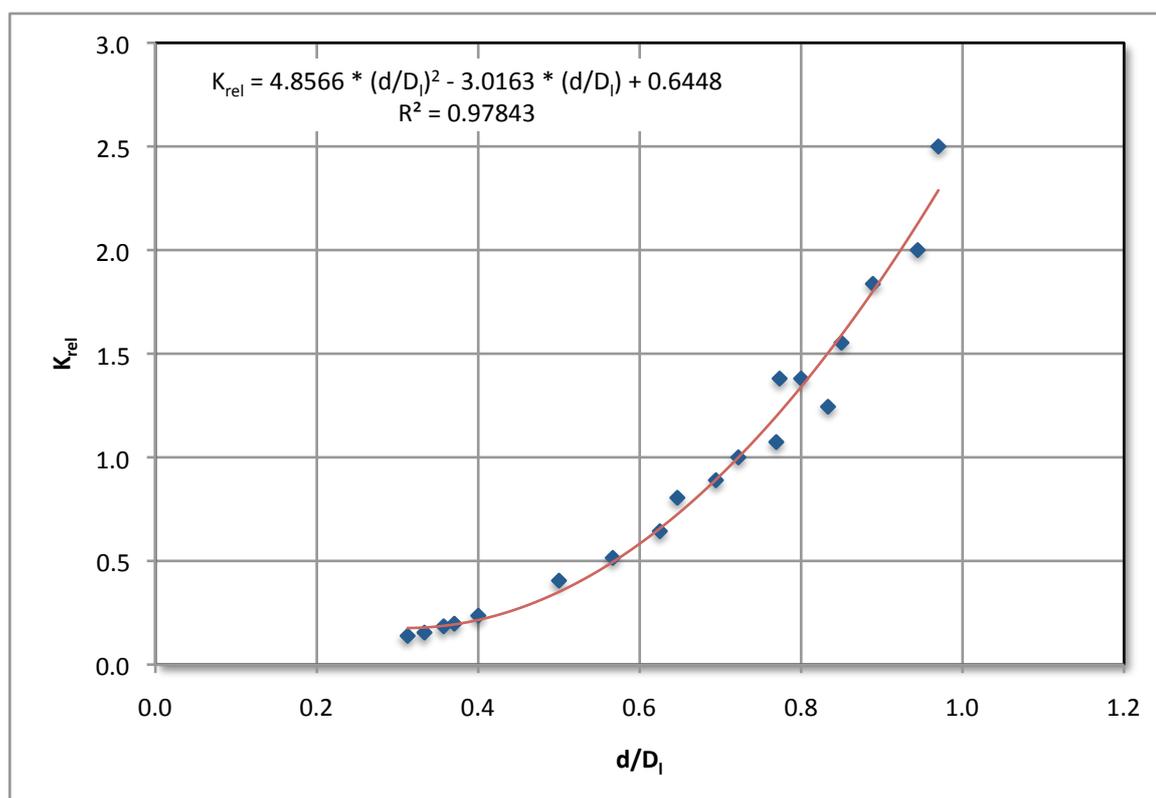


Figure 7-1. Response of magnetic susceptibility measurements to varying core and loop diameters.

Processing Panel

The user has the option in the processing panel of calculating either κ_{uncor} , κ or χ .

The general processing panel is shown below; the actual appearance of this panel will depend on whether the user is using a point or loop sensor and which form of data output is required. The nomenclature used in the processing panel is different from that used above.

CMS is the corrected magnetic susceptibility which can be either κ_{uncor} , κ or χ depending on the users requirements.

MS is the measured magnetic susceptibility, κ_{uncor} . The user can enter numbers into the boxes; A, B, Den and LD.

A and B are constants which enable the user to make a linear correction to the raw data (MS) if needed; so that $MS_{\text{corrected}} = A * MS + B$. This is most applicable when using the point sensor (see below). When using a loop and no correction to MS is required the set $A=1$ and $B=0$. Den is used to obtain mass specific susceptibility and LD is used to correct for the size of loop being used.

Calculating uncorrected volume specific magnetic susceptibility

If the user wants the output (CMS) to be the uncorrected volume specific magnetic susceptibility (κ_{uncor}) then set $A=1$, $B=0$, $Den=0$ and $LD=0$. The values then (if using SI) are $CMS * 10^{-5}$ SI units.

Calculating corrected volume specific magnetic susceptibility

If the user wants the output (CMS) to be the corrected volume specific magnetic susceptibility (κ) then set $A=1$, $B=0$, $Den=0$ and $LD = \text{loop diameter in cm}$. The values then (if using SI) are $CMS * 10^{-5}$ SI units.

Calculating corrected mass specific magnetic susceptibility

If the user wants the output (CMS) to be the corrected mass specific magnetic susceptibility (κ) then set $A=1$, $B=0$, $Den=1$ and $LD = \text{loop diameter in cm}$. The values then (if using SI) are given in $CMS * 10^{-8} m^3 kg^{-1}$.

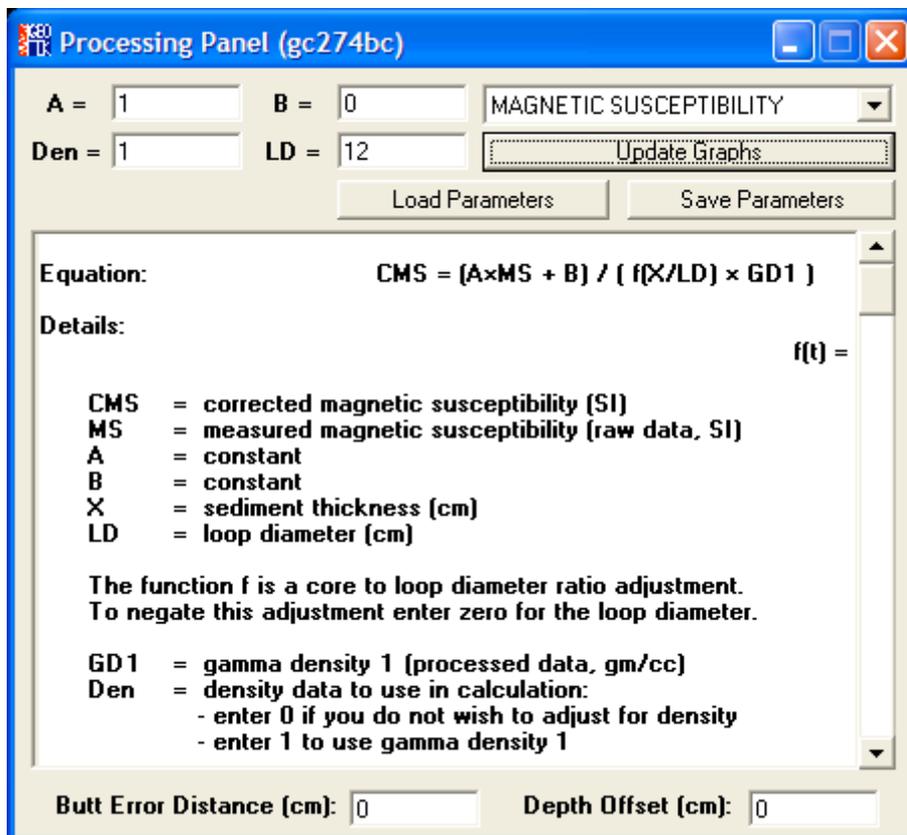


Figure 7-2. Magnetic susceptibility processing panel (loop sensor).

Point Sensor

The protocol for inter calibrating the new point sensor with the loop sensor is not well established. A calibration piece is supplied which can be used to check for any major problems. The user is advised to perform some comparative measurements between the point sensor and the loop sensor. Values of corrected volume specific magnetic susceptibility (κ_{loop}) should be obtained from a whole core using a loop and then a comparative set of uncorrected values obtained from a split core using the point sensor (κ_{point}). Fit this data to a linear relationship:

$$\kappa_{\text{point}} = A * (\kappa_{\text{loop}}) + B$$

These values of A & B can be used directly in the processing panel.

Processing Panel (gcr78-23b)

A = B = **MAGNETIC SUSCEPTIBILITY**

Den =

Equation:
$$\text{CMS} = (\text{A} \times \text{MS} + \text{B}) / \text{GD1}$$

Details:

- CMS** = corrected magnetic susceptibility (SI)
- MS** = measured magnetic susceptibility (raw data, SI)
- A** = constant
- B** = constant
- GD1** = gamma density 1 (processed data, gm/cc)
- Den** = density data to use in calculation:
 - enter 0 if you do not wish to adjust for density
 - enter 1 to use gamma density 1

Butt Error Distance (cm): **Depth Offset (cm):**

Figure 7-3. Magnetic susceptibility processing panel (point sensor).

8 - Resistivity

Background

Electrical resistivity is a measure of how strongly a material opposes the flow of electric current and is the inverse of electrical conductivity. A low resistivity indicates a material that readily allows the movement of electrical charge. The SI unit of electrical resistivity is the ohm-metre and the SI unit of electrical conductivity is Siemens per metre.

Non-contact resistivity (NCR) measurements on the Geotek MSCL are made using a non-contact system that is positioned on the plastic part of the track between the P-wave and the magnetic susceptibility sensor systems. Care should be taken not to place conductive objects around the sensor system and particularly below the sensor where measurements of background are taken (this includes parts of the body). The method is described in detail by Jackson *et al.* (2006)¹.

Operating Principle

The NCR technique operates by inducing a high frequency magnetic field in the core, from a transmitter coil, which in turn induces electrical currents in the core that are inversely proportional to the resistivity. A receiver coil measures very small magnetic fields regenerated by the electrical current. To measure these very small magnetic fields accurately a difference technique has been developed which compares the readings generated from the measuring coils to the readings from an identical set of coils operating in air. This technique provides the requisite accuracy and stability required. Resistivity between 0.1 and 10 ohm-meters can be measured at spatial resolutions along the core of approximately 2 cm.

Setting Up

- Ensure that the NCR sensor does not obstruct the core.
- Switch the NCR meter on at least 30 min. before testing. The system needs to warm up to minimise drift.
- **Note:** When making NCR measurements ensure that no conductive materials are near the sensor (including wrist watches and parts of the body!).
- **Note:** Because of the potential drift in the NCR sensor and electronics, zero readings can be taken at the start and finish of each core section and appropriate calibrations made to the data.

Calibration and Processing

The sensor electronics in the electrical resistivity unit need time to warm up after being switched on. Ideally the unit should be switched on half an hour prior to logging cores in order for the system to stabilise. The resistivity sensor is sensitive to changes in temperature so if the instrument is being used in a room without air conditioning then the user can re-zero the sensor using the Advanced Panel at regular intervals when logging cores.

To calibrate the non-contact resistivity a series of saline solutions are needed at different concentrations. Ideally these concentrations should span the range of resistivity to be measured. It is unlikely that a resistivity greater than seawater (35‰) will be encountered in marine sediments (0.21 ohm.m @20°C) and so this can be considered the upper bound for most applications.

¹ Jackson, P.D.J., Lovell, M.A., Roberts, J.A., Schultheiss, P.J., Gunn, D., Flint, R.C., Wood, A., Holmes, R., Frederichs, T., 2006. Rapid non-contacting resistivity logging of core. In: Rothwell, R.G., *New Techniques in Sediment Core Analysis*. Geological Society London, Special Publication **267**. pp. 209-217.

Laid out in the table below are a series of concentrations of saline solution that can be used for calibrating the system. These range from resistivities of 0.21-15.48 ohm.m (@20°C). The solutions should be prepared in a 30 cm long section of core liner the size that the cores to be logged were collected in. This is very important as the resistivity sensor is very sensitive to different measurement geometries.

Concentration (g/l)	Resistivity (ohm.m)	Conductivity (Sm ⁻¹)
35	0.209	4.785
17.5	0.390	2.564
8.75	0.749	1.335
3.5	1.730	0.578
1.75	3.321	0.301
0.35	15.481	0.065

This gives nearly 2 orders of magnitude range in resistivity. If the user wishes to use different saline concentrations than those given above then the equation below relates concentration to resistivity. Using this relationship the user can make up different saline solutions as required.

$$ER = 5.6878 * C - 0.9348$$

where:

- ER = electrical resistivity (ohm-m)
- C = salt concentration (g/l)

Ideally the calibration sections should be made so that they can be refilled and resealed; an example is shown in Figure 8-1.

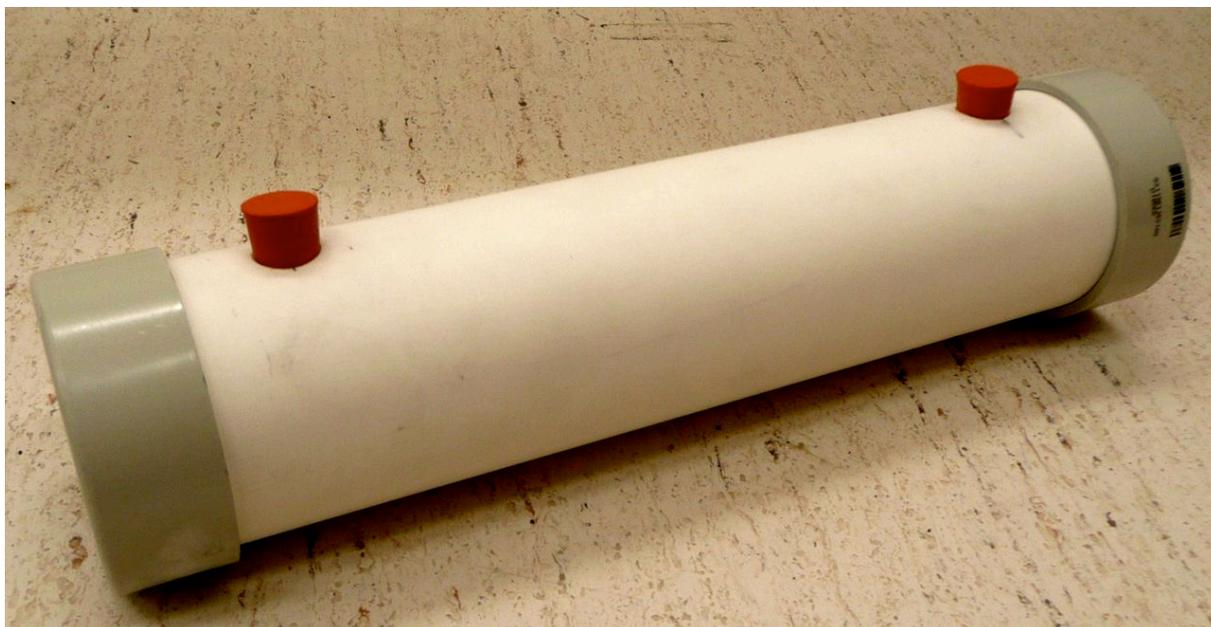


Figure 8-1. An example of a resistivity calibration section. The bungs used for sealing can be removed so the calibration section can be filled with fresh saline solutions when required.

Having produced the calibration pieces the user can then go on to calibrate the sensor to convert its response (mV) into resistivity (ohm-m).

To do this the user should use the Test Panel from the Utilities software and first of all zero the resistivity sensor with nothing on the rails above the sensor. Having zeroed the sensor an air reading should be taken and noted

(the zeroing process may not always bring the sensor response to exactly zero). Each of the calibration pieces can then be placed on the rails next to the sensor and readings taken for each one. The air reading taken after zeroing should be subtracted from the sensor response to each calibration piece and plotted against the conductivity of the calibration samples as shown in Figure 8-2 or the resistivity of the calibration samples as shown in Figure 8-3. The user should fit a linear trend line to the conductivity vs. sensor response data or a power law trend line to the resistivity vs. sensor response data, enter the coefficients (A and B) in the processing panel (see Figure 8-4) and select the appropriate equation type to use for calibration.

The calibration equations take the forms:

$$y = 1 / (A * x + B)$$

or

$$y = A * x^B$$

where:

- y = electrical resistivity (ohm-m)
- x = sensor response (mV)
- A & B = coefficients used in the processing panel.

The data can be displayed as resistivity (ohm-m) or as formation factor, the ratio of the sediment resistivity to the pore fluid resistivity. To display the formation factor the user must enter a non-zero value into the p field in the processing panel, where p is the resistivity of the pore fluid. If, for example, the pore fluid is seawater with a salinity of 35‰ then a value of 0.21 should be entered for p.

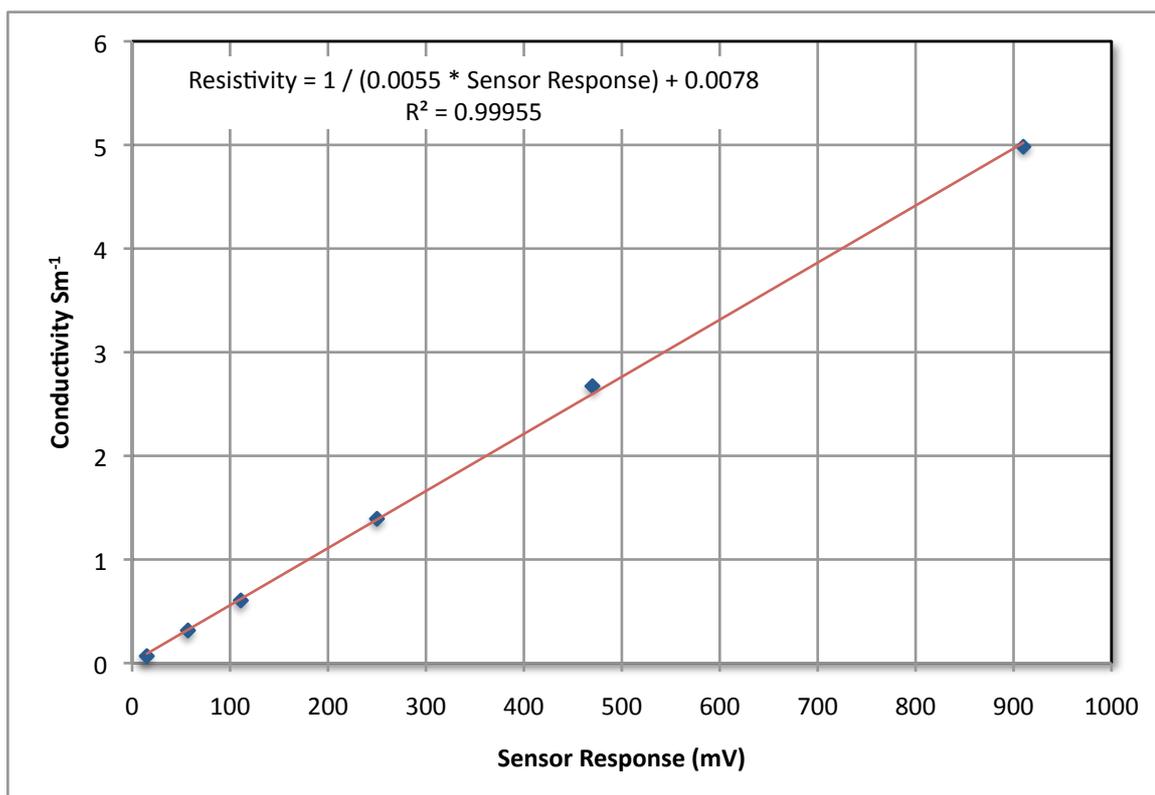


Figure 8-2. Conductivity (Sm⁻¹) vs. NCR sensor response (mV).

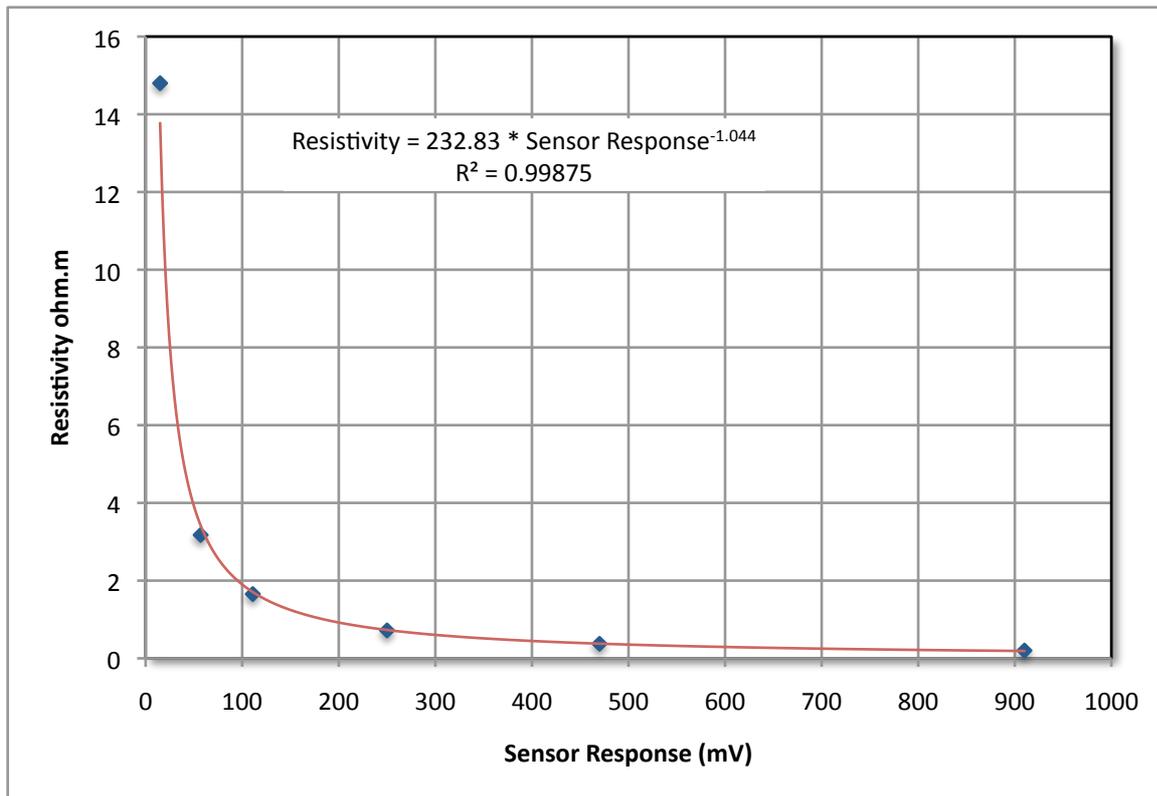


Figure 8-3. Resistivity (ohm.m) vs. NCR response (mV).

The resistivity of sediments varies with temperature and so a correction to 20°C is included in the processing panel. The user can choose whether or not to correct for temperature using the tick box.

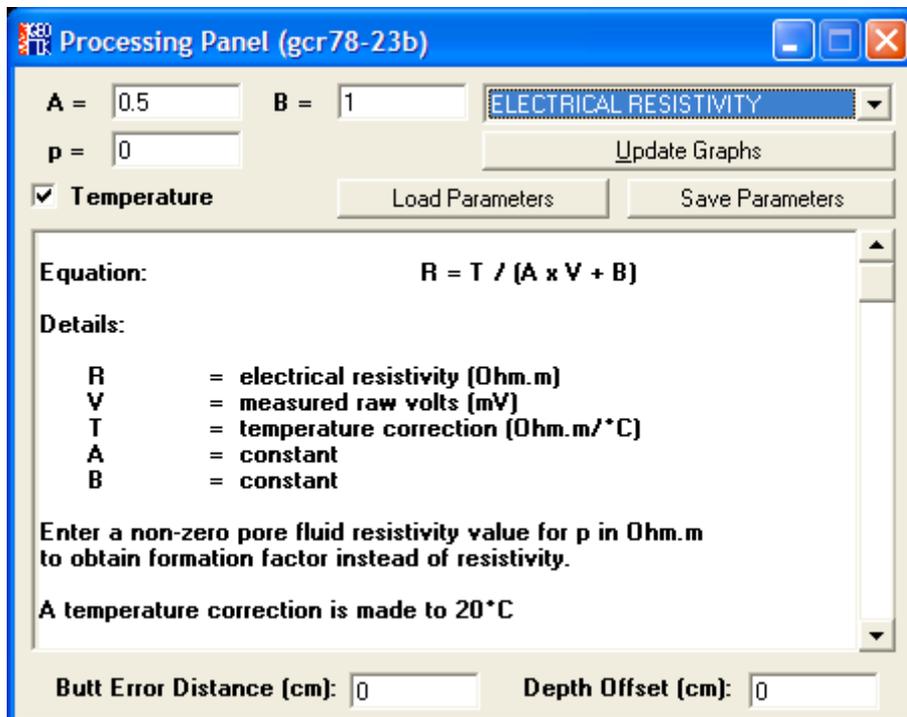


Figure 8-4. Electrical Resistivity processing panel.

Using resistivity data it is possible to obtain an independent estimate of porosity by using Archie’s theory relating in-situ electrical conductivity of sedimentary rock to its porosity and brine saturation. The relationship is defined as:

$$C_t = C_w \phi^m S_w^n$$

where:

C_t	=	rock or sediment conductivity
C_w	=	saturating fluid conductivity
ϕ	=	porosity
S_w	=	saturation
m	=	cementation exponent
n	=	saturation exponent

This can be rearranged for resistivity:

$$R_t = \frac{R_w}{\phi^m S_w^n}$$

The exponent m has been observed near 1.3 for unconsolidated sands, and is believed to increase with cementation. Common values for this cementation exponent for consolidated sandstones are $1.8 < m < 2.0$. The saturation exponent n is usually close to 2.

It is possible to better estimate the exponent m by using a Pickett plot, a plot of a resistivity measurement on the log x-axis versus a porosity measurement on the log y-axis. Points of constant water saturation (S_w) will plot on a straight line with negative slope of value m .

9 - Colour Spectrophotometry

Background

Electromagnetic radiation is characterized by its wavelength (or frequency) and its intensity. When the wavelength is within the visible spectrum (the range of wavelengths humans can perceive, approximately from 380 nm to 740 nm), it is known as “visible light”. Most light sources emit light at many different wavelengths; a source’s spectrum is a distribution giving its intensity at each wavelength. Although the spectrum of light arriving at the eye from a given direction determines the colour sensation in that direction, there are many more possible spectral combinations than colour sensations.

Colour is the visually perceived property corresponding in humans to the categories called red, yellow, green, blue and others. Colour derives from the spectrum of light (distribution of light energy versus wavelength) interacting in the eye with the spectral sensitivities of the light receptors. Colour categories and physical specifications of colour are also associated with objects, materials, light sources, etc., based on their physical properties such as light absorption, reflection, or emission spectra. Typically, only features of the composition of light that are detectable by humans are included, thereby relating the psychological phenomenon of color to its physical specification.

The familiar colours of the rainbow in the spectrum include all those colors that can be produced by visible light of a single wavelength only, the pure spectral or monochromatic colors. The table below shows approximate frequencies (in terahertz) and wavelengths (in nanometres) for various pure spectral colours. The colour table is not a definitive list but a common list identifies six main bands: red, orange, yellow, green, blue, and violet. Newton’s conception included a seventh colour, indigo, between blue and violet – but most people do not distinguish it, and most colour scientists do not recognize it as a separate colour; it is sometimes designated as wavelengths of 420–440 nm. The intensity of a spectral colour may alter its perception considerably; for example, a low intensity orange-yellow is brown, and a low intensity yellow-green is olive-green.

Colour	Wavelength Range (nm)	Frequency Range (THz)
Red	~700-630	~430-480
Orange	~ 630-590	~ 480-510
Yellow	~ 590-560	~ 510-540
Green	~ 560-490	~ 540-610
Blue	~ 490-450	~ 610-670
Violet	~ 450-400	~ 670-750

Quantifying Colour

The colour of an object depends on both the physics of the object in its environment and the characteristics of the perceiving eye and brain (sensor). Physically, objects can be said to have the colour of the light leaving their surfaces, which normally depends on the spectrum of that light and of the incident illumination, as well as on the angles of illumination and viewing. Some objects not only reflect light, but also transmit light or emit light themselves which also contribute to the colour.

As a result of all the factors affecting colour it can be very difficult to quantify. Various people have devised methods, often using complex formulas, for quantifying color and expressing it numerically. These methods attempt to provide a way of expressing colors numerically in the same way that length or weight might be expressed. For example, in 1905 the American artist A. H. Munsell devised a method for expressing colors which utilised a great number of paper color chips classified according to their hue (Munsell Hue), lightness (Munsell Value), and saturation (Munsell Chroma) for visual comparison with a specimen color. Later, after a variety of further experiments, this system was updated to create the Munsell Renotation System, which is the Munsell system presently in use (see Figure 9-1). In this system, any given color is expressed as a letter/number combination (H V/C) in terms of its hue (H), value (V), and chroma (C) as visually evaluated using the Munsell Colour Charts.

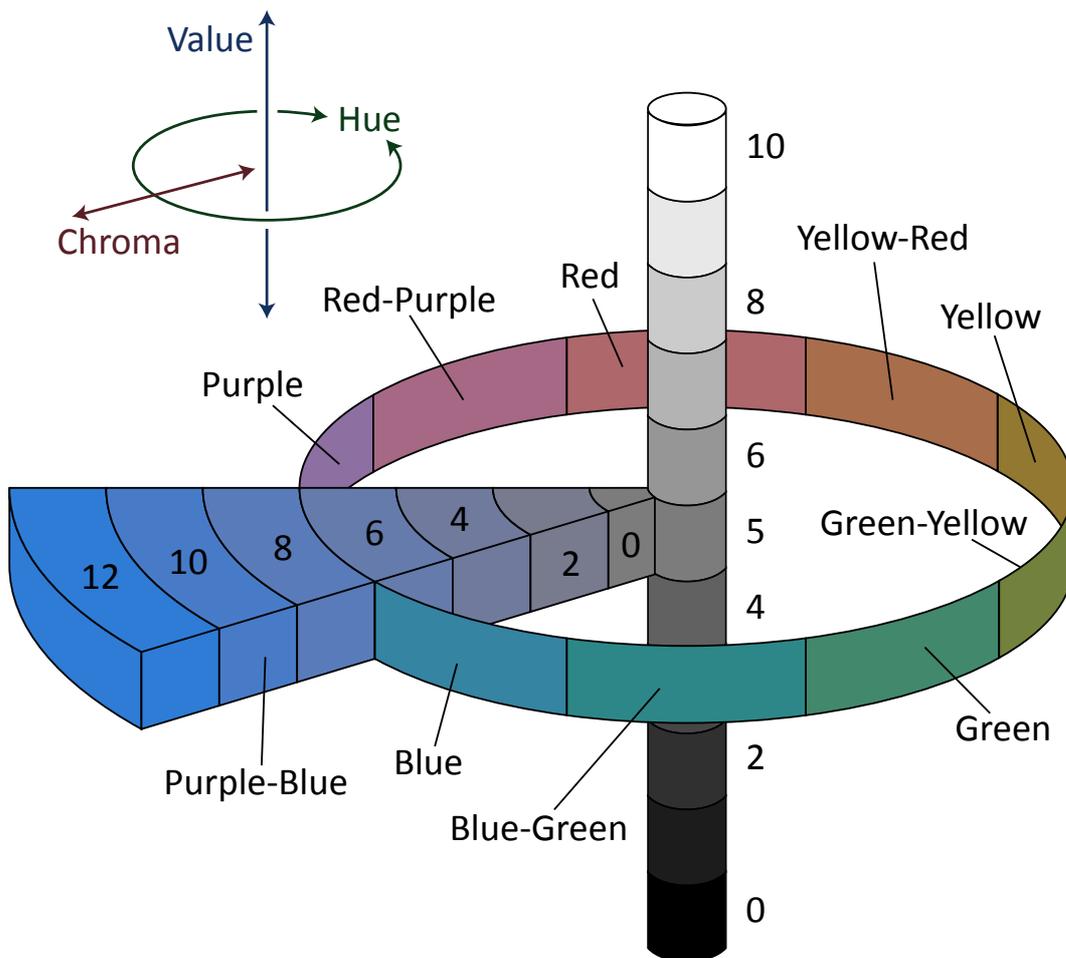


Figure 9-1. The Munsell Colour System.

Other methods for expressing color numerically were developed by the Commission Internationale de l'Eclairage (CIE, an international organization concerned with light and color). The two most widely known of these methods are the Yxy color space, devised in 1931 based on the tristimulus values XYZ defined by CIE, and the L*a*b* colour space, devised in 1976 to provide more uniform color differences in relation to visual differences. Colour spaces such as these are now used widely.

The CIE XYZ colour space was deliberately designed so that the Y parameter was a measure of the brightness or luminance of a colour. The chromaticity of a color (see Figure 9-2) was then specified by the two derived parameters x and y, two of the three normalized values which are functions of all three tristimulus values X, Y, and Z:

$$x = X / X + Y + Z$$

$$y = Y / X + Y + Z$$

$$z = Z / X + Y + Z = 1 - x - y$$

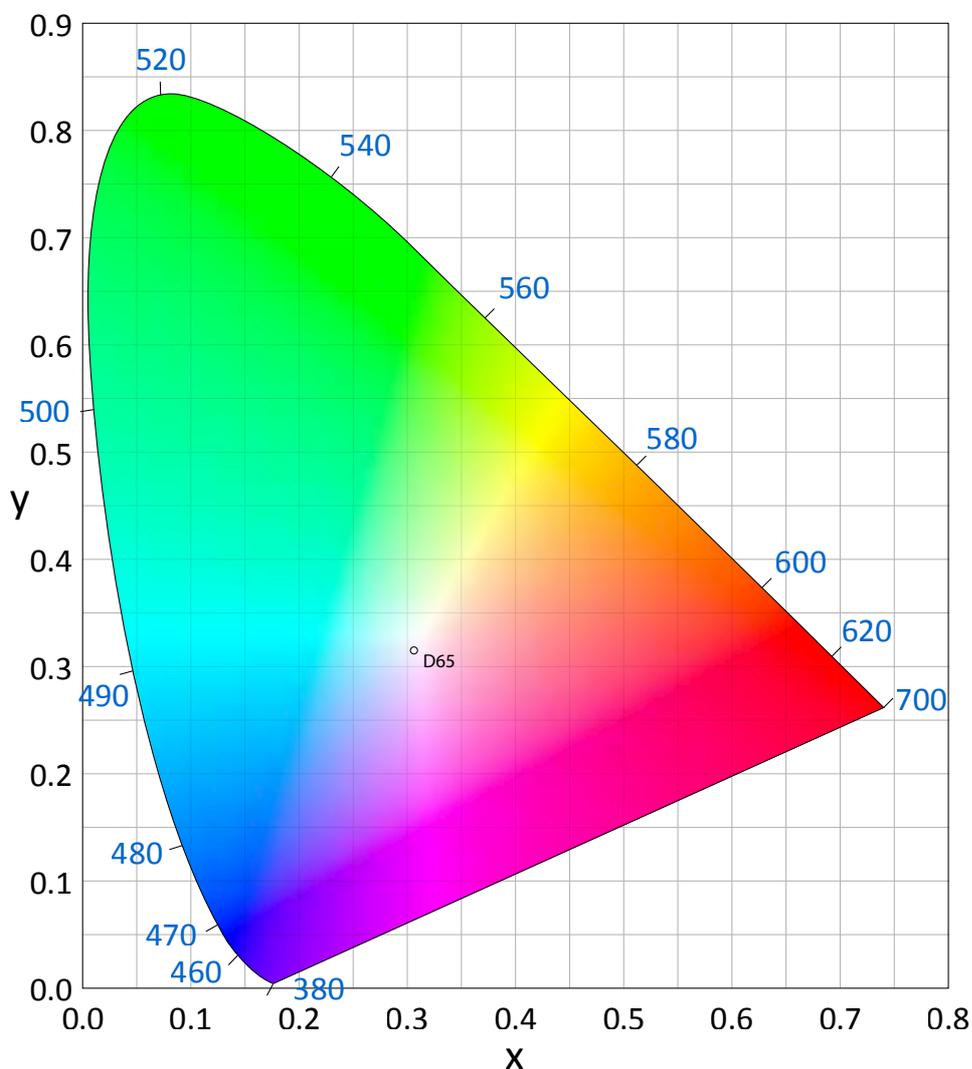


Figure 9-2. The CIE 1931 color space chromaticity diagram. The outer curved boundary is the spectral (or monochromatic) locus, with wavelengths shown in nanometers.

Observing Colour

The tristimulus values depend on the observer's field of view so to eliminate this variable the CIE defined the standard (colorimetric) observer. Originally this was taken to be the chromatic response of the average human viewing through a 2° angle, due to the belief that the colour sensitive cones resided within a 2° arc of the fovea. Thus the CIE 1931 Standard Observer is also known as the CIE 1931 2° Standard Observer. A more modern but less-used alternative is the CIE 1964 10° Supplementary Standard Observer.

The standard observer is characterised by three colour matching functions $\bar{x}(\lambda)$, $\bar{y}(\lambda)$ and $\bar{z}(\lambda)$ which can be thought of as the spectral sensitivity curves of three linear light detectors that yield the CIE XYZ tristimulus values X, Y, and Z. $\bar{x}(\lambda)$ has a high sensitivity in the red wavelength region, $\bar{y}(\lambda)$ has a high sensitivity in the green wavelength region, and $\bar{z}(\lambda)$ has a high sensitivity in the blue wavelength region (see Figure 9-3).

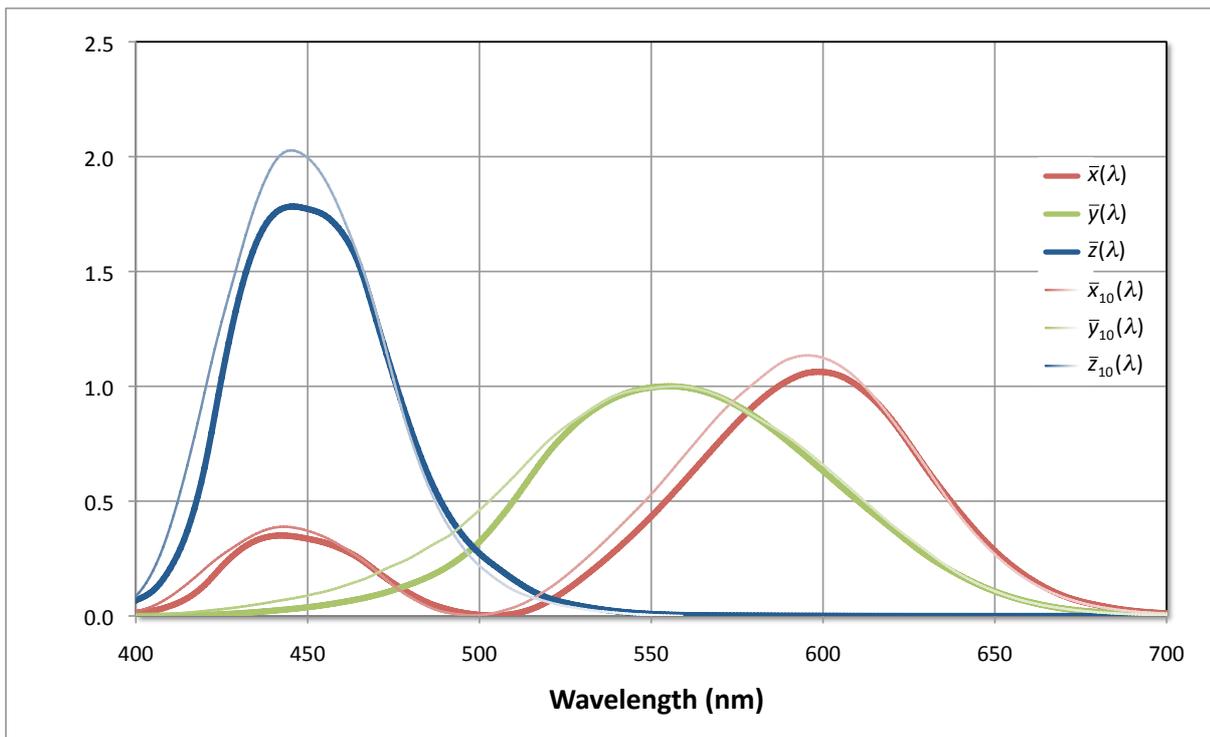


Figure 9-3. CIE 2° and 10° Standard Observer colour matching functions.

Illuminant Definition

The tristimulus values are also dependent on the spectral output of the light source or illuminant. As with observers the CIE developed a set of standards for illuminants. Originally (in 1931) there were three (A, B and C) but these were found not to be very representative of natural light and so in 1967 another series was introduced (the D series; D50, D55, D65 and D75). D65 corresponds roughly to a mid-day sun in Western / Northern Europe hence it is also called a daylight illuminant. Variations in the relative spectral power distribution of daylight are known to occur, particularly in the ultraviolet spectral region, as a function of season, time of day, and geographic location. D55, for example, is a better representation of daylight in equatorial regions.

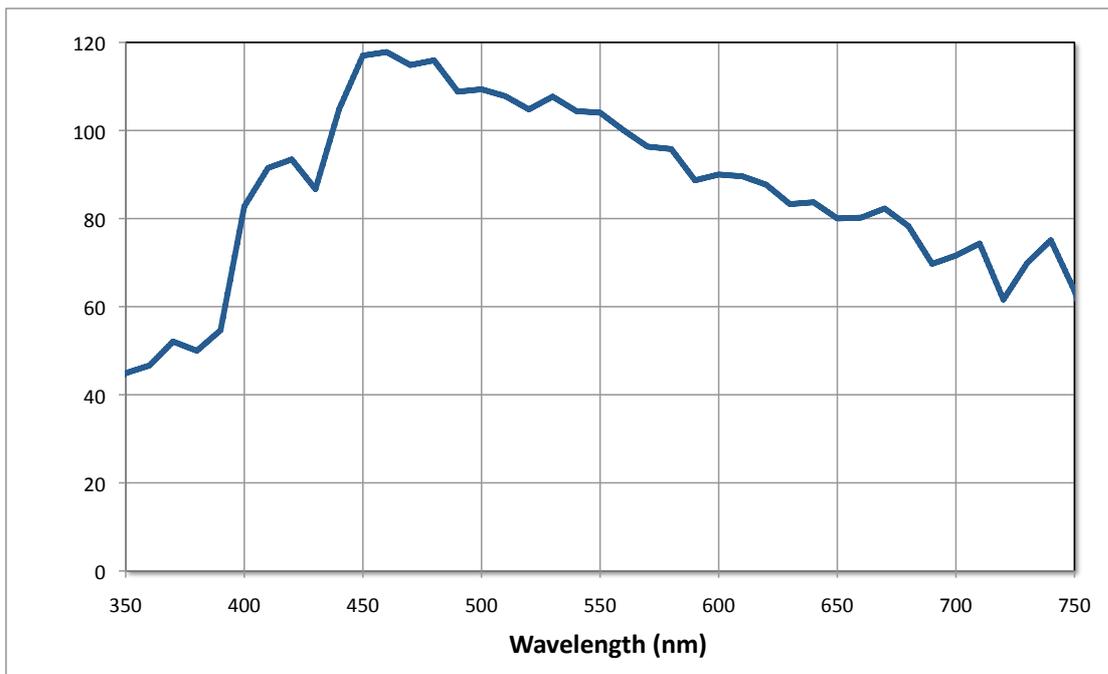


Figure 9-4. The CIE D65 illuminant spectral power distribution.

The CIE chromaticity coordinates of D65 are $x=0.31271$, $y=0.32902$ using the 2° standard observer and can be plotted on Figure 9-2. Normalising for relative luminance, the XYZ tristimulus values are $X=95.04$, $Y=100.00$, $Z=108.88$. Since D65 represents white light its co-ordinates are also a white point corresponding to a correlated colour temperature of 6504 Kelvin (K). The name D65 suggests that the correlated colour temperature (CCT) should be 6500 K, this discrepancy is due to a revision of the constants in Planck's law after the definition of the illuminant. This affects all CCTs and therefore all standard illuminants.

Measuring Colour

Colour can be measured using the tristimulus method where the light reflected from the object to three sensors is filtered to have the same sensitivity $\bar{x}(\lambda)$, $\bar{y}(\lambda)$ and $\bar{z}(\lambda)$ as the human eye and thus directly measures the tristimulus values X, Y, and Z. Colorimeters work in this way.

The spectrophotometric method utilises multiple sensors to measure the spectral reflectance of the object at each wavelength or in each narrow wavelength range. The instrument's microcomputer then calculates the tristimulus values from the spectral reflectance data by performing integration as shown below.

$$X = K \int_{\lambda_0}^{\lambda_x} S(\lambda) \bar{x}(\lambda) R(\lambda) d\lambda$$

$$Y = K \int_{\lambda_0}^{\lambda_x} S(\lambda) \bar{y}(\lambda) R(\lambda) d\lambda$$

$$Z = K \int_{\lambda_0}^{\lambda_x} S(\lambda) \bar{z}(\lambda) R(\lambda) d\lambda$$

where:

$$K = 100 / \int_{\lambda_0}^{\lambda_x} S(\lambda) \bar{y}(\lambda) d\lambda$$

$S(\lambda)$ = Relative spectral power distribution of the illuminant

$R(\lambda)$ = Spectral reflectance of specimen

The raw data from a spectrophotometer is the spectral response from which data can be converted into other colour spaces. For example, the XYZ tristimulus values can be converted into $L^*a^*b^*$ using the following algorithms.

$$L^* = 116 (Y / Y_n)^{1/3} - 16$$

$$a^* = 500 [(X / X_n)^{1/3} - (Y / Y_n)^{1/3}]$$

$$b^* = 200 [(Y / Y_n)^{1/3} - (Z / Z_n)^{1/3}]$$

where:

X_n , Y_n and Z_n = tristimulus values of a perfect reflecting diffuser¹

If X/X_n , Y/Y_n or $Z/Z_n < 0.008856$ then:

$(X / X_n)^{1/3}$ is replaced by $7.787 * (X / X_n) + (16/116)$

$(Y / Y_n)^{1/3}$ is replaced by $7.787 * (Y / Y_n) + (16/116)$

$(Z / Z_n)^{1/3}$ is replaced by $7.787 * (Z / Z_n) + (16/116)$

¹ ASTM E308-01, 2006. Standard Practice for Computing the Colors of Objects by Using the CIE System. ASTM International, West Conshohocken, PA, www.astm.org.

Other colour spaces such as RGB, $L^*C^*h^*$, Hunter Lab and Munsell can be reported rather than the spectral data either through calculation or look up tables.

Specular Component

Light reflected from a surface has two components, specular reflection (or gloss component) and diffuse reflection. Light which reflects at the equal but opposite angle from the light source is the specular component and light scattered in many directions is the diffuse component. The sum of the two components is the total reflectance.

For objects with shiny surfaces, the specular reflected light is relatively strong and the diffused light is weaker. On rough surfaces with a low gloss, the specular component is weak and the diffused light is stronger. When a person views a blue plastic object with a shiny surface at the specular angle, the object does not appear to be as blue. This is because the mirror-like reflectance from the light source is added to the colour of the sample. Usually, a person looks at the colour of the object and ignores the specular reflection of the light source. To measure the colour of a specimen in the same manner that it is viewed, the specular reflectance must be excluded and only the diffuse reflectance must be measured. The colour of an object can appear different because of differences in the level of specular reflectance.

Sometimes it is useful to separate these components and take measurements with the specular component included (SCI) or the specular component excluded (SCE). Different lighting geometries or optical traps can be used to separate the SCI and SCE measurements.

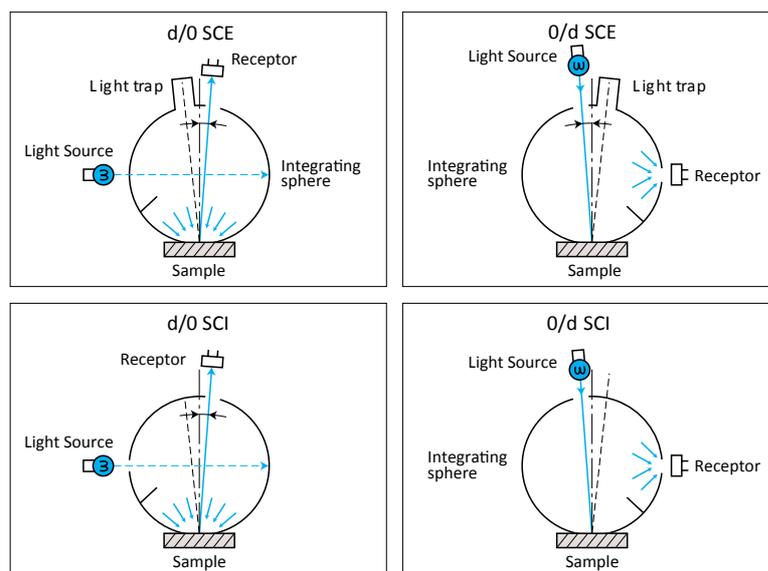


Figure 9-5. Different measurement geometries of an integrating sphere for measuring SCI and SCE spectra. The *d/o* optical geometry illuminates the sample diffusely and detects the light at the normal direction (*o* degrees). The *o/d* optical geometry illuminates the sample at the normal angle (*o* degrees) and collects the light reflected in all directions

Operating Principle

A truncated hollow sphere (the ‘integrating sphere’) is placed on the core surface to be measured. An integrating sphere is a spherical device with internal surfaces coated with a white material such as barium sulfate so the light is uniformly diffused. A light source within the sphere illuminates the sphere and the sample through the open aperture and the multiply-reflected light is split into its spectral components at the detector. The Konica-Minolta CM2600d spectrophotometer uses the *d/8* measuring geometry (the light reflected from the sample surface is received by the detector at an angle of 8° to the normal of the sample surface) and xenon lamps to provide the illumination.

The CM2600d detector collects light in 10 nm increments from 360 nm to 740 nm, thus providing complete spectral data in the visible wavebands (400-700 nm) with small extensions into the ultraviolet (360-400 nm) and infrared (700-740 nm) regions. The diffraction grating creates a Gaussian distribution of wavelengths, centred on

the reported value with a 10 nm width at half maximum. Therefore, in practice, the reported value at 360 nm contains photons from 355 to 365 nm with a contribution (about 30%) from wavelengths both larger and smaller.

By using 2 different lighting positions inside the sphere the system can measure both the diffuse 'back scattered' spectrum and the specular 'reflected' spectrum (see Figure 9-6). Two data sets are collected, one with both the backscatter and the specular reflection (SCI) and one with the specular reflection subtracted (SCE). To obtain spectral data into the UV region another light source (without a UV cut off filter) is used inside the sphere. Consequently when a user takes a measurement, 3 separate flashes are observed, one from each of the 3 light sources.

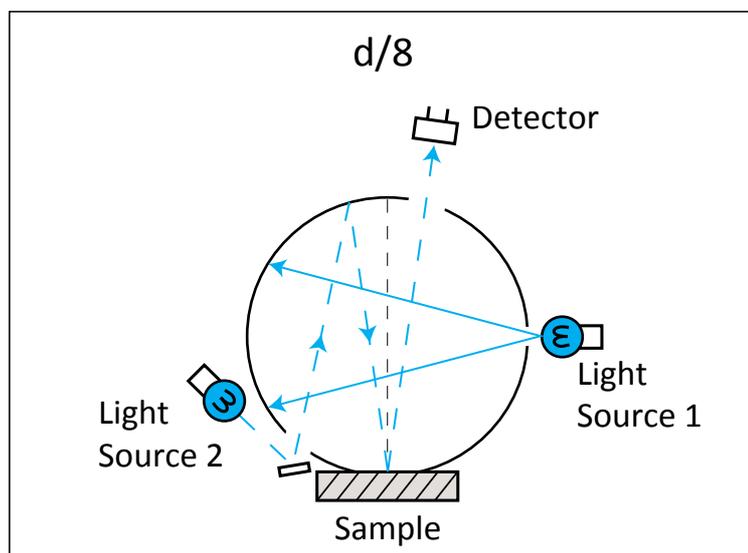


Figure 9-6. The two light source geometries used during measurement. Light source 1 is the diffused illumination used to measure SCI. Light source 2 is used to measure the amount of specular reflection to be subtracted from the SCI measurement to give SCE. UV measurements are made by using part of light source 1 without a UV cut off filter.

The spectrophotometer has a target mask to take measurements from different areas of sample. On the CM2600d these are called the MAV and SAV masks which must be installed manually. There is a measurement area selector switch on the side of the instrument that indicates to the instrument which mask is installed. The SAV mask is the smaller of the two at 3 mm diameter and the MAV mask is 8 mm diameter.

Setting Up

Ensure that the required mask (MAV or SAV) is installed and that the measurement area selector switch is set accordingly. The power and RS232 connector at the rear of the instrument should be connected and the power switch set to on (I). The device should be allowed to warm up before making any calibrations or measurements. No measurements can be made using the spectrophotometer until a series of calibrations have been made. These calibrations can be started either by using the controls on the spectrophotometer (see manufacturers manual) or by using the controls available through the MSCL software - from the spectrophotometer section of the configuration panel click on **[Show Setup]**.

A zero calibration must be performed without anything in the path of the light from the instrument and this will remove the effects of stray light in the measurement chamber. A white calibration is started when the spectrophotometer is sat in the white calibration plate provided. The reflectance levels of the white calibration plate are stored in the spectrophotometer and are used in conjunction with the white calibration data to compute a correction factor to ensure reliable calibrated data are collected. If at any point the power is disconnected from the spectrophotometer then the white and zero calibrations will be lost and must be repeated.

The spectrophotometer is mounted on an arm extending from the vertical (Z) motor assembly. It has a small amount of counterbalanced free travel to accommodate changing core thicknesses so that as little weight as possible is applied to the surface of the split core during measurements. It is important to ensure that the

spectrophotometer does not obstruct the core, i.e. there is sufficient travel on the Z motor during logging to bring the sensor clear of the core surface and that its counterbalanced travel is free.

The sediment surface should be covered and the measurements made as soon as practically possible after the core has been split (or the surface cleaned) because the colour of the core will change as a result of drying and because of chemical changes occurring when exposed to air (oxidation). It should be noted that using cling film can affect the measurements especially if the film is not smoothly laid on to the core surface.

The MSCL software sets up the spectrophotometer to report its data as if illuminated with the D65 illuminant and observed by the CIE 1931 2° standard observer.

Calibration and Operation

When the colour spectrophotometer is enabled in the Settings File, a new subpane will appear in the Setup pane of the MSCL software.

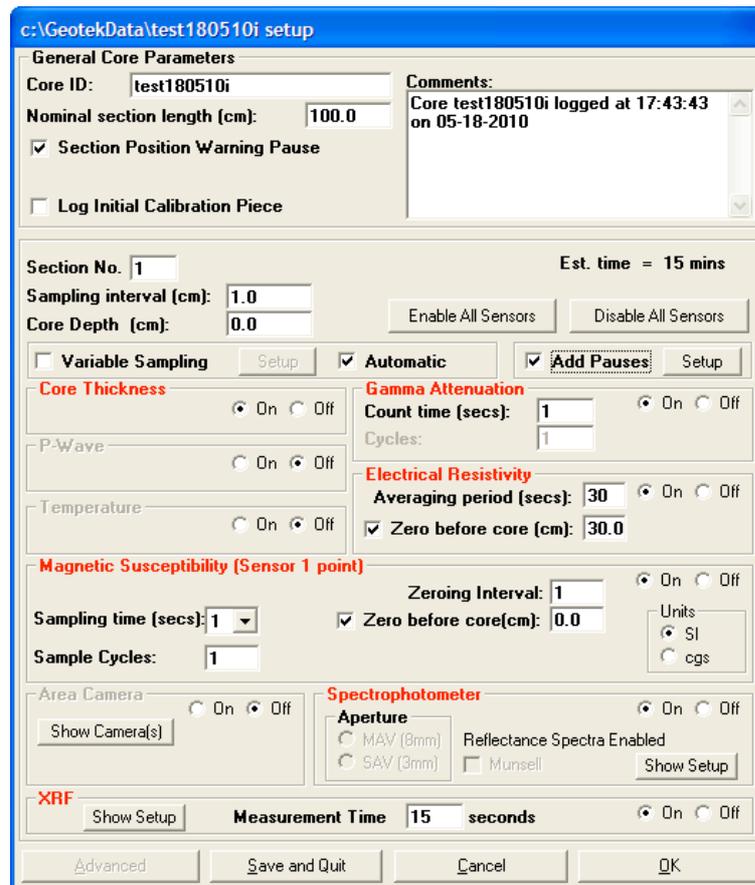


Figure 9-7. The Setup pane, showing the Spectrophotometer sub-pane. User must choose MAV or SAV (aperture size) and whether Munsell data should be collected.

Choosing “Munsell” gives Munsell colour output, and requires a complete second colour measurement. If the spectrophotometer is the rate-limiting step in logging, adding Munsell colour measurement will double the time required. However, if other long measurements are being collected, e.g., 10-second magnetic susceptibility with the point sensor, adding Munsell colour will not affect the logging time.

Before logging, the user will be prompted to calibrate the spectrophotometer unless the calibration has been performed recently. (As the calibration is housed in the instrument itself, if the spectrophotometer is switched off, it must be recalibrated.) Instructions appear on the screen, telling the user to first manually raise the spectrophotometer with the Z-axis-motor for the zero calibration, and then to lower the spectrophotometer onto the white calibration circle provided by Minolta. These calibrations are kept internally in the spectrophotometer and applied to the data before it is sent to the MSCL.

Once logging has begun, the spectrophotometer data is shown in three windows: the raw data display, the processed data display, and the spectrophotometer data display. In the Raw Data Display, the spectrophotometer data in the visible region (400-700nm) is plotted as average reflectance at each sample point.

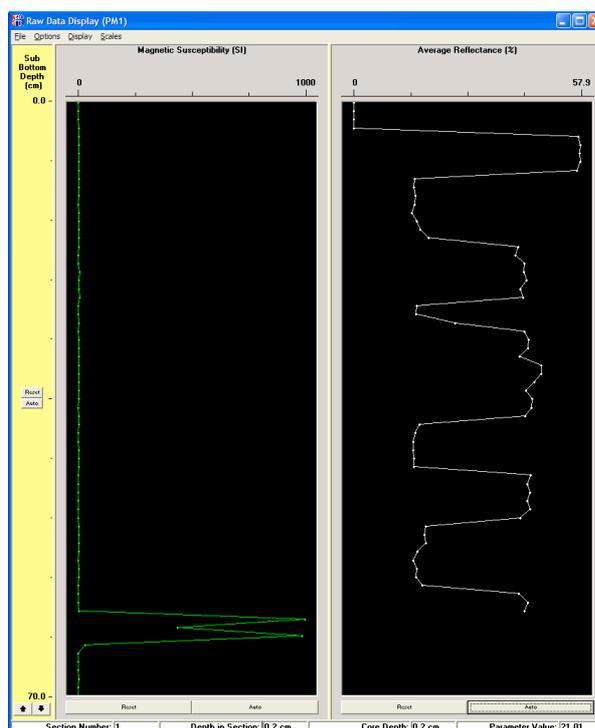


Figure 9-8. The Raw Data Display, with Average Reflectance from the colour spectrophotometer shown on the right.

In the Processed Data Display the spectra are divided up into three bands (nominally red, green, and blue) and the average reflectance in each of these three bands is plotted. The definition of the three bands can be modified by the user in the Processing Panel.

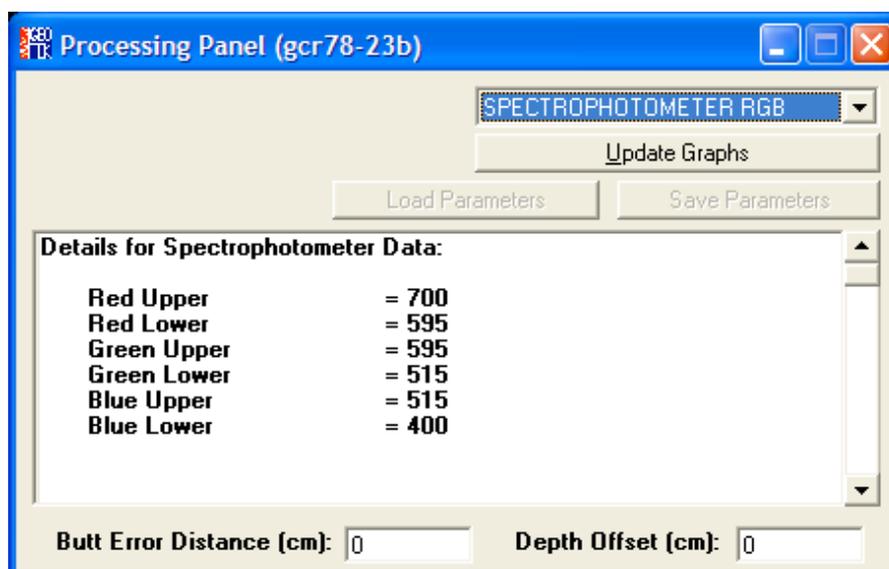


Figure 9-9. Spectrophotometer processing panel window.

The MSCL Spectral Data Display pane contains the spectra, the RGB data shown in the Processed Data Display, a simulation of the core, and colour in the L^* , a^* , b^* space. All of the plots except the spectral data can be shown or hidden.

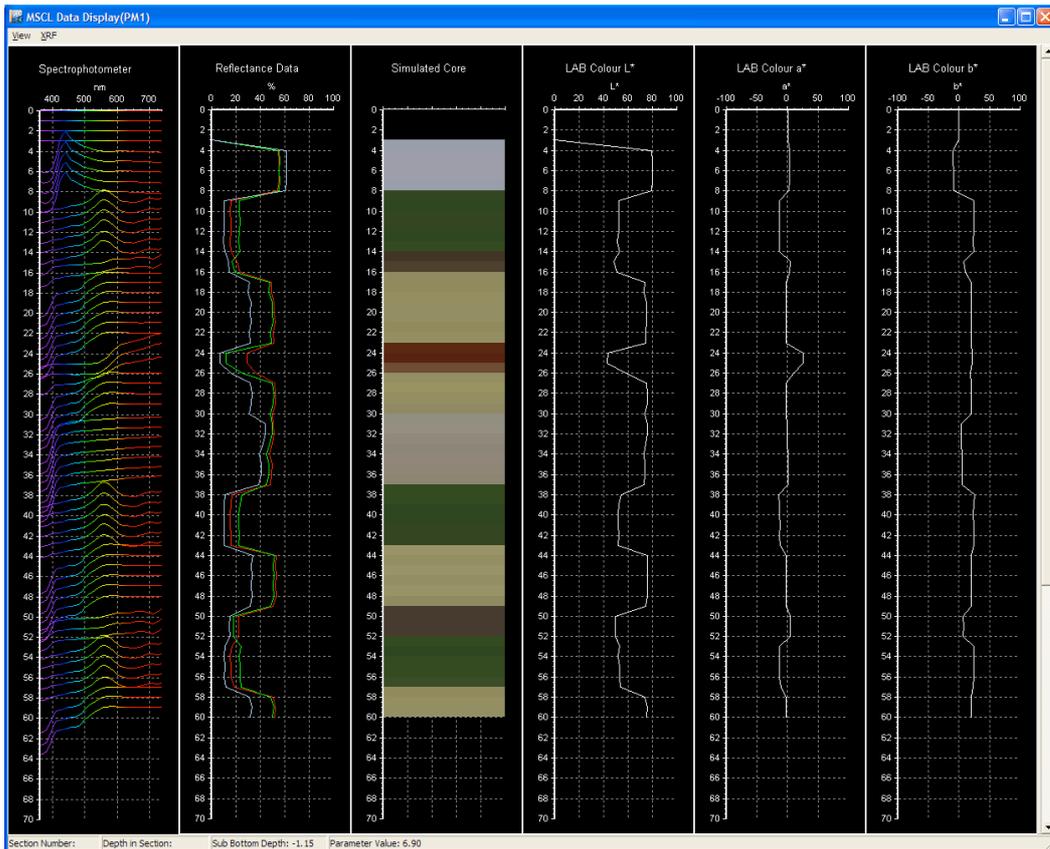


Figure 9-10. Spectrophotometer data display.

Right-clicking on the plots will bring up contextual menus. The contextual menu for the spectrophotometer data allows control of the number of spectra plotted and whether they are plotted in colour; these parameters will affect the refresh speed of this window.

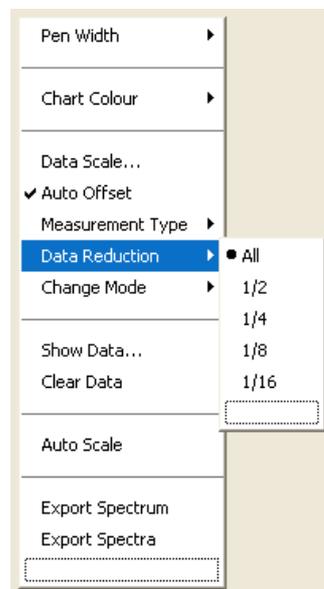


Figure 9-11. Spectral data contextual menu.

Spectral Data

The collected spectra are plotted at the depth they were taken. The vertical scale for the spectrum itself is arbitrary and can be exaggerated. By default, the zero for the vertical axis of the spectrum (zero reflectance) is set at the same level as the depth at which the spectrum was collected. For ease of viewing, the spectrum can be distributed around the depth of collection.

Reflectance Line Chart

The Reflectance Line Chart shows the spectra data in three user-definable bins. The default values for these bins are 595-700 nm, 515-595 nm, and 400-515 nm (red, green, and blue, respectively). These values can be modified by the user and can even overlap; however, the names will always be red, green, and blue.

Reflectance Block Chart

The Reflectance Block Chart is a colour image of the core as viewed by the spectrophotometer. The core colour can be displayed as a strict RGB image or a 'real' RGB image that more closely reproduces how a human eye sees colour.

Data Processing and Output

There is very little data processing in the MSCL software for the colour spectrophotometer. All data calibration is performed within the colour spectrophotometer, using the zero and white calibrations, so the MSCL software receives processed data. The user can specify the spectral bands to combine for red, green, and blue (RGB) data.

MSCL raw data files containing spectrophotometer data have a column of average reflectance data. The data range from 0-255, and only the visible bins of the spectrophotometer data are averaged (400-700 nm).

MSCL processed data files containing spectrophotometer data have columns for Munsell Value, CIE colour (L^* , a^* , b^*), XYZ colour; red, green and blue as defined in the processing panel (0-255); and each spectrophotometer bin (0-255).

Spectra can also be output from the contextual menu in the MSCL Data Display (see Figure 9-11), which is useful when single spectra are needed quickly.

Chapter 9 Appendix. ASD LabSpec 2600 Vis / NIR Spectrometer

Background

The LabSpec 2600 Spectrometer measures the optical energy that is reflected by, absorbed into, or transmitted through a sample. Optical energy refers to a wavelength range that is greater than the visible wavelengths, and is often called electromagnetic radiation or optical radiation.

With accessories, various set-ups, and built-in processing of the optical energy signal, the LabSpec Spectrometer can measure:

- spectral reflectance,
- spectral transmittance,
- and spectral absorbance.

Fiberoptic Collection of Reflected/Transmitted Light

Optical energy is collected through a bundle of specially formulated optical fibers, precisely cut, polished, and sealed for extremely efficient energy collection. The fibers themselves are of low OH composition providing the maximum transmission available across the wavelength range of the instrument.

Inside the LabSpec® Spectrometer

The fiber cable delivers the collected optical energy into the instrument, where it is projected onto a holographic diffraction grating. The grating separates and reflects the wavelength components for independent measurement by the detectors.

Visible/Near-Infrared (VNIR)

The Visible/Near-Infrared (VNIR: 350-1000 nm wavelength) portion of the spectrum is measured by a 512-channel silicon photodiode array overlaid with an order separation filter. Each channel (or detector) is geometrically positioned to receive light within a narrow (1.4 nm) range. The VNIR spectrometer has a spectral resolution (full-width half maximum of a single emission line) of approximately 3 nm at around 700 nm.

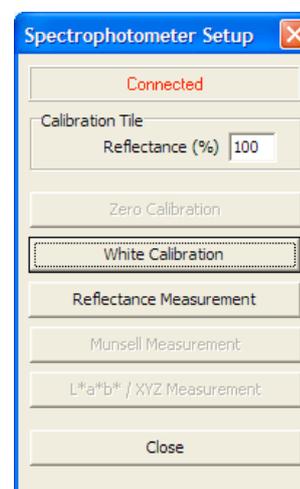
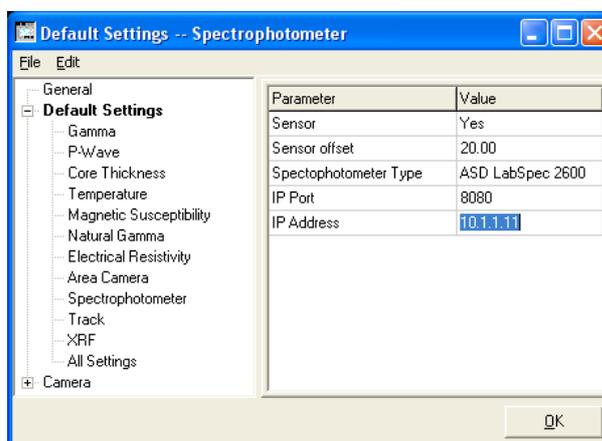
Each detector converts incident photons into electrons. This photocurrent is continually converted to a voltage and is then periodically digitized by a 16-bit analog-to-digital (A/D) converter. This digitized spectral data is then transmitted to the instrument controller for further processing and analysis by the controlling software.

The 512-channel array permits the entire VNIR spectrum to be scanned in parallel at 1.4 nm wavelength intervals. A single sample can be acquired in as little as 17 ms.

Near Infrared (NIR) or Short-Wave Infrared (SWIR)

The Near-Infrared (NIR), also called Short-Wave Infrared (SWIR), portion of the spectrum is acquired with two scanning spectrometers:

- SWIR1 for the wavelength range of 1000 nm to 1800 nm.
- SWIR2 for the wavelength range of 1800 nm to 2500 nm.



The SWIR scanning spectrometer has one detector for SWIR1 and another for SWIR2. This is different from the VNIR spectrometer that has an array of 512 detectors. The SWIR spectrometer collects wavelength information sequentially rather than in parallel.

Each SWIR spectrometer consists of a concave holographic grating and a single thermo-electrically cooled Indium Gallium Arsenide (InGaAs) detector. The gratings are mounted about a common shaft which oscillates back and forth through a 15 degree swing. As the grating moves, it exposes the SWIR1 and SWIR2 detectors to different wavelengths of optical energy. Each SWIR spectrometer has ~600 channels, or ~2 nm sampling interval per SWIR channel. The spectrometer firmware automatically compensates for the overlap in wavelength intervals.



Like the VNIR detectors, the SWIR1 and SWIR2 detectors convert incident photons into electrons. This photocurrent is continually converted to a voltage and is then periodically digitized by a 16-bit analog-to-digital (A/D) converter. This digitized spectral data is then transmitted to the instrument controller for further processing and analysis by the controlling software.

The grating is physically oscillating with a period of 200 ms. It performs a forward scan and a backward scan, resulting in 100 ms per scan. This is the minimum time required for any SWIR samples, or full-range samples.

Setting Up

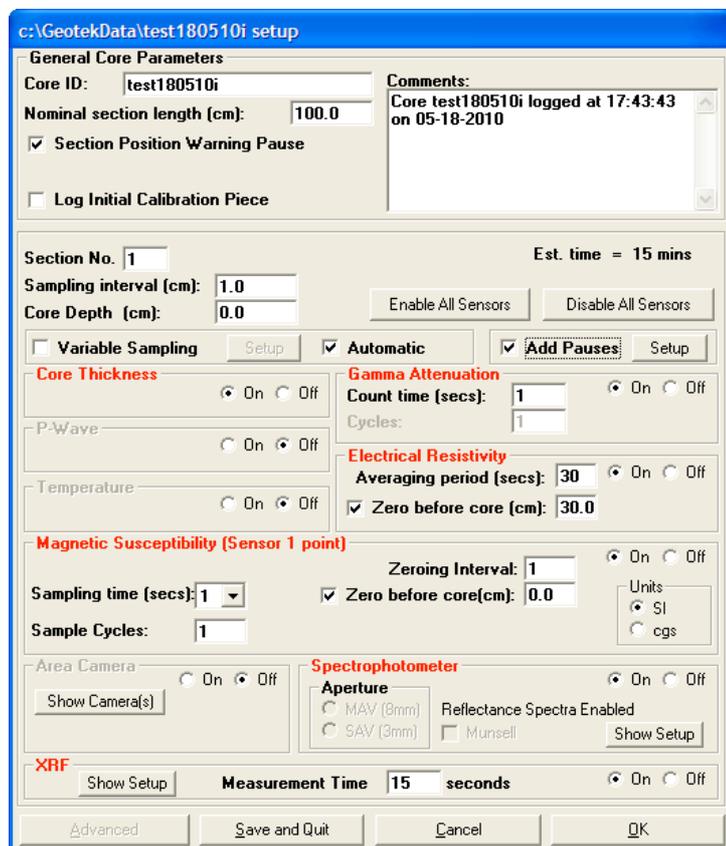
Ensure that the sensor array is correctly mounted onto the sensor arm and can freely move in the vertical orientation. The fibre optic cable and power connector should be connected to both the sensor array and to the main unit. From the main unit you should also connect the supplied shielded ethernet cable to the correct ethernet card on the computer. Finally the ASD power supply should be connected. The LabSpec Spectrophotometer uses input power to be 12 VDC (60 W). It does not contain an internal power supply to convert AC voltage to DC, nor does it have internal batteries.

The fiberoptic cable should never be stored with a bend of less than a 5" diameter for long periods of time.

The network interface that the spectrophotometer is connected to should be configured so that the IP Address is in the same range or subnet as the spectrophotometer. The same subnet means that the first three octets of the IP address (xxx.xxx.xxx.____) match the spectrometer and the computer. Nominally the ASD has the IP address 10.1.1.11, and the computer will be configured on that interface manually to the IP address 10.1.1.10.

Once everything has been connected correctly the easiest way to configure and test everything is working is by using the Test Panel in the Utilities software.

- I. Start the Utilities software and wait for the message that the electronics is connected.
- II. Select the **[Window] [Settings]** menu item.
- III. In your currently selected settings,

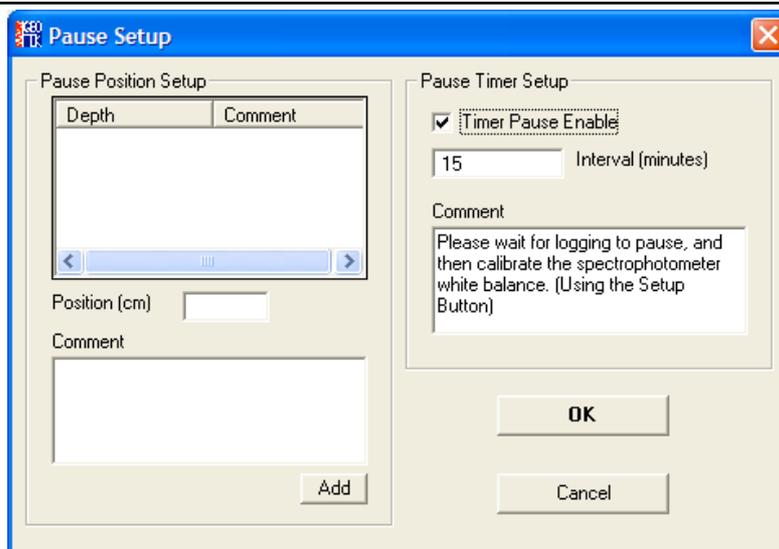


indicated in the bold font, expand and display the Spectrophotometer settings.

IV. Make sure the **Sensor** parameter is set to Yes.

V. Change the **Spectrophotometer Type** to ASD LabSpec 2600 if it is not already.

VI. Change the **IP Port** to 8080 and the **IP Address** to 10.1.1.11, unless the default network for the Spectrophotometer has been changed.



VII. Make sure the **Sensor offset** is correctly defined according to its position on the track.

You can now close the settings window. The next stage is to test the spectrophotometer is working within the Utilities software.

I. Select the [**Window**] [**Test Panel**] menu item.

II. Click on the [**Spectrophotometer**] button.

III. The Spectrophotometer Setup panel will be displayed as below:

Before taking measurements with the spectrophotometer there is a requirement to take a white calibration using the supplied Spectralon tile. Spectralon has the characteristic of being nearly 100% reflective within the wavelength range of 350 nm to 2500 nm. A Spectralon white reference scatters light uniformly in all directions within that wavelength range. Please see the ASD manual for handling instructions.

When you click on the [**White Calibration**] button you will be prompted by a further dialog to place the spectrophotometer on the while calibration tile.

Once the tile is in place click [**OK**] to continue with the calibration process.

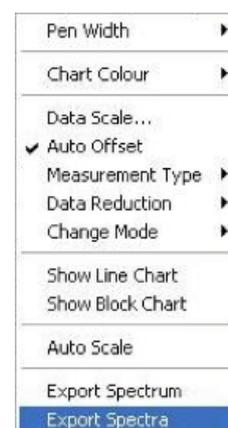
The whole operation will take around thirty seconds, and both a white calibration and a dark offset will be taken automatically. The calibration procedure, should be repeated approximately every 15 minutes while the instrument is warming up; thereafter, every hour or so is sufficient.

The LabSpec Spectrometer should be re-calibrated for:

- Light changes.
- Temperature changes.
- Whenever accessory probes are changed.

The reflectance levels of these calibration operations are stored in memory whilst the software is running. Should you restart the software, or for example move from the Utilities software to the MSCL software the operation should be repeated as the stored data will be lost.

You should now be able to click the [**Reflectance Measurement**] button and see a display of the reflectance values on a chart. If you have taken a measurement of the



calibration tile you should values around the 100 mark. You may need to adjust the vertical axis of the chart to see this properly by clicking on the axis itself.

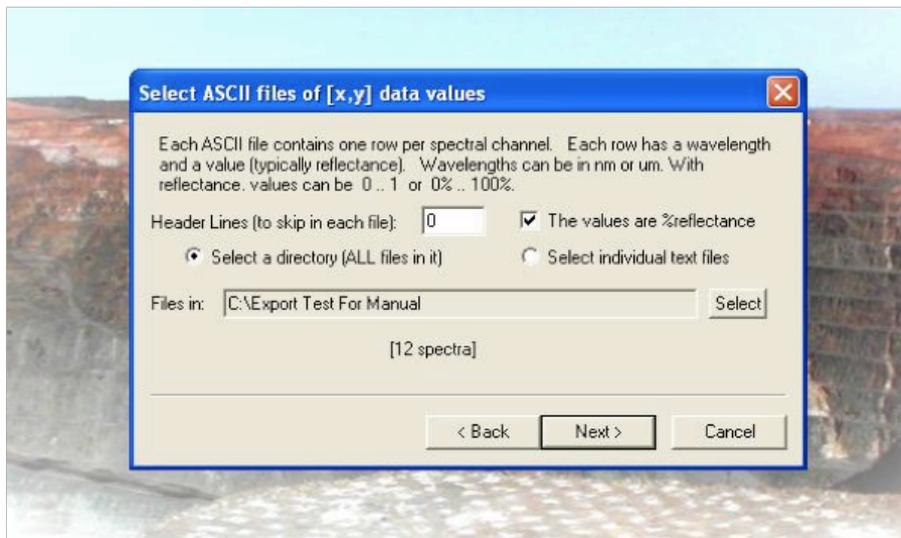
If everything is working as expected you can now close the Utilities software and move on to logging in the MSCL software.

Logging

- Setting up the ASD spectrophotometer during logging is exactly the same process as in the Utilities software.
- Firstly go through the standard process of logging a new core, by selecting **[Log New Core]** from the main menu.
- On the core setup dialog make sure the Spectrophotometer sensor is enabled.
- Click the **[Show Setup]** button and calibrate the spectrophotometer as per the instructions above.
- Close the Spectrophotometer Setup panel and any related windows.

Trying to continue logging with the Spectrophotometer enabled but not calibrated will produce a warning and a calibration will be required before proceeding.

Should you wish you can also enable the **[Add Pauses]** functionality. This will allow you to set a pause interval in either time or distance where you can re-calibrate the spectrometer.

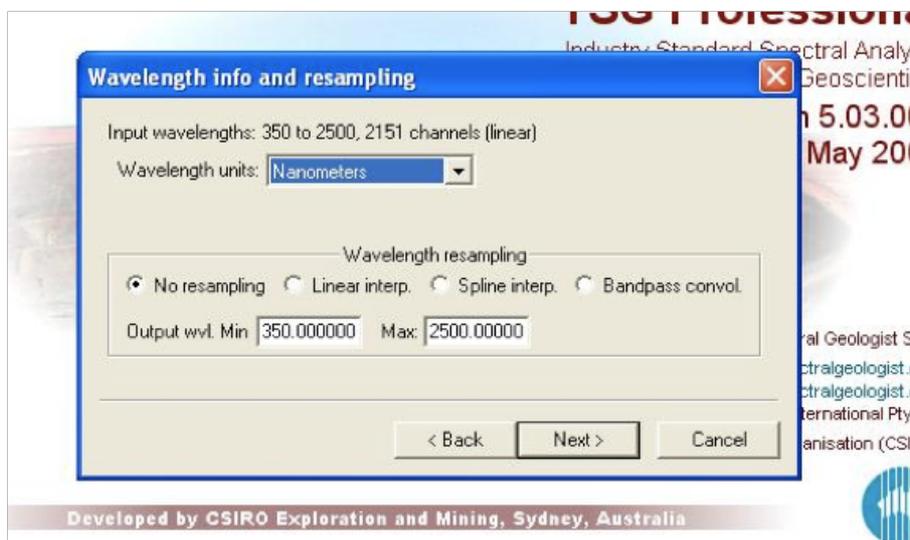


- Check the Add Pauses check box.
- Click on Setup.
- Add a new distance pause by entering a position and comment, if required, on the lefthand side of the dialog.

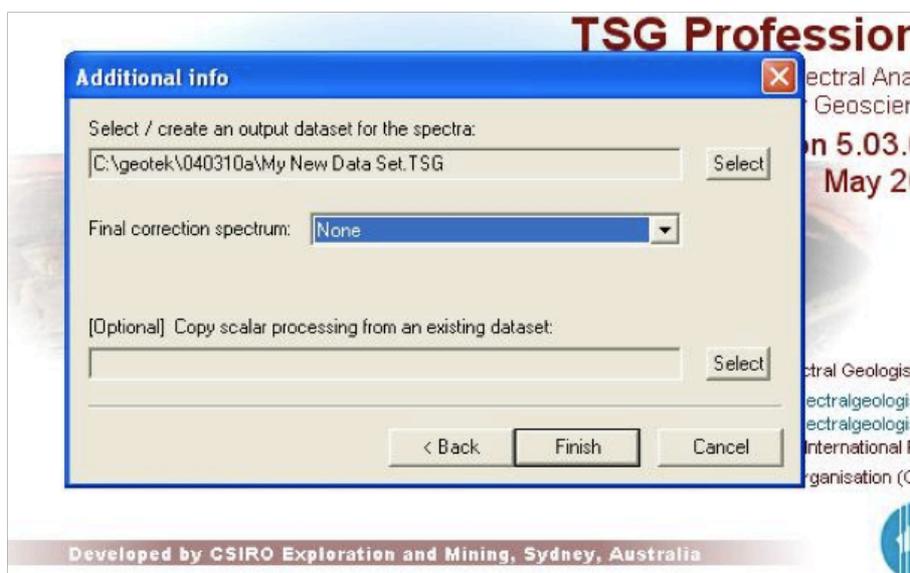
- Add a time interval pause by checking the box, entering a time interval and any comment you wish to appear when the interval occurs. This is by default pre-filled with a message to re-calibrate the spectrometer.

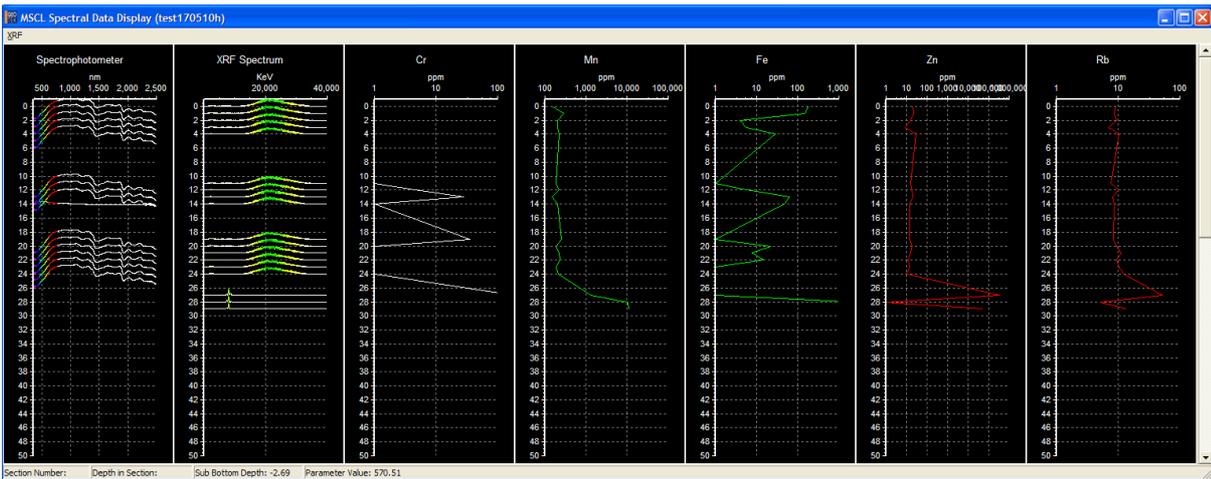
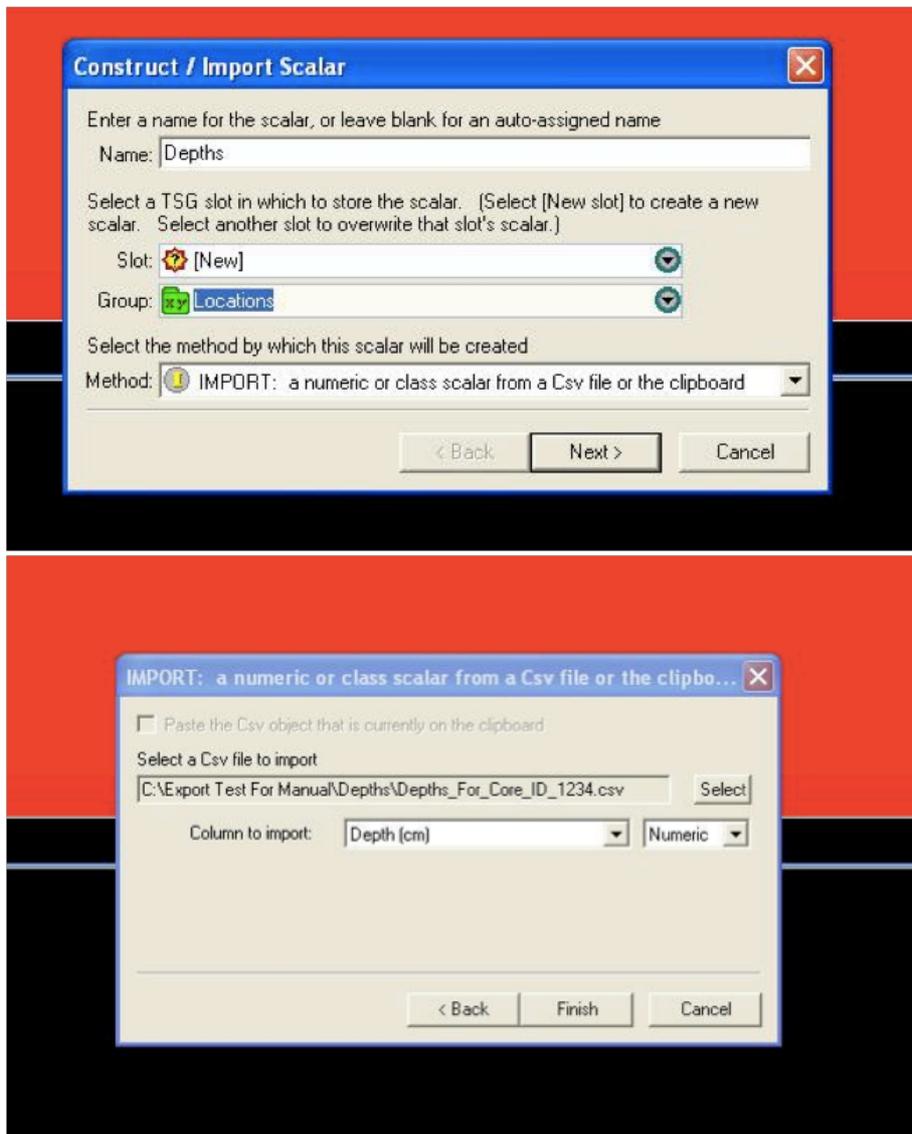
Data Display

During logging the incoming spectrometer data will be displayed in a variety of formats. Firstly in the Raw Data Display window an average reflectance of the visible part of the spectrum, from 400 nm to 700 nm will be plotted. In the Processed Data Display window an RGB plot also of the visible part of the spectrum will be displayed.



Finally the actual spectra of each data point will be displayed in the MSCL Spectral Data Display in a separate window.





The spectra is displayed centered around the data point depth with a height according to a configurable data scale. This scale along with a number of other settings, charts and export options can be selected by right clicking on the Spectrophotometer chart.

Exporting Data to Spectral Geologist

After logging infrared spectral data or loading previously logged data find the MSCL Spectral Data Display (as shown above) window in the MSCL software. Place the mouse over the Spectral Data Display window and right click, a popup menu will appear. Select the **[Export Spectra]** option, a message box will appear to confirm your selection. See right.

The user will now be prompted to enter text that will be prefixed to each exported data file. See figure to the right.

Select a folder to place the exported files and press **[OK]**. When the export is complete, a message saying that exporting has been completed will appear. Click **[OK]** to dismiss the dialog.

In the folder selected in the last step a file will be created for each measurement. Each file (.txt extension) will be prefixed with the core ID you entered followed by the depth of the measurement in millimetres. Each exported measurement file will contain two columns, the first one is the wavelength in nanometres and the second is the reflectance as a percentage. Also in the export folder will be a sub folder containing the depths file. This file will be prefixed with "Depths_For" followed by the core ID. This file has a .csv file extension and will contain one column.

Having produced the data files the Spectral Geologist application can be started. Follow the instructions laid out below to get the data into Spectral Geologist.

- I. Select **[File]** and then **[New]** from the Spectral Geologist main menu.
- II. In the dialog box that appears select "ASCII files of [x,] pairs (any wavelength range)" in the Format drop down box and click next.
- III. Another dialog box will appear. This offers different options for importing the data. See the figure below. The options to select are:
 - A. Header Line (to skip in each file) set to zero.
 - B. Check the box for 'The Values are %reflectance'.
 - C. Select the "Select a directory (All files in it)" option
 - D. Press the Select button and select the folder you exported the data to in step 4
- IV. Click **[Next]** to continue.
- V. A dialog for Wavelength info and re-sampling will be displayed. You should make the following selections:
 - A. Make sure that the wave length units is set to Nanometers.
 - B. No resampling option is set to No.
- VI. The correct settings are shown below. Click **[Next]** to continue.
- VII. The additional info dialog box will appear. Press the **[Select]** button in the top right hand corner and select a location for your new TSG file.
 - A. For the Final correction spectrum select none.
 - B. The correct settings are shown in the screenshot below.
- VIII. Click **[Finish]** button to continue.
- IX. The reflectance data has now been imported, the next step is to associate depth data with the reflectance data. This can be done by importing the depth scalar. From the main menu select **[File] | [Import > Scalar from CSV...]**.
- X. The Construct / Import Scalar dialog should now be displayed.

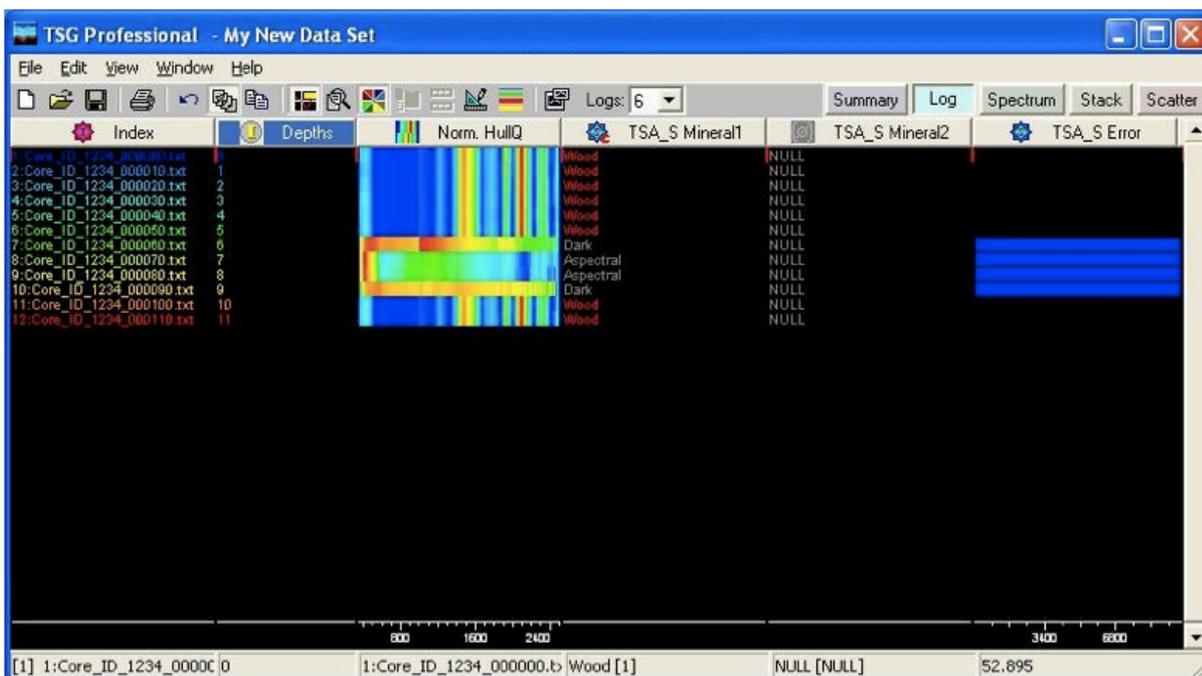
- A. In the box label name enter “Depths”
- B. The box label slot should be set to New.
- C. Pull down the list in the “Group” box and select “Locations”
- D. The Method box should already be set to IMPORT
- E. Click [**Next**] to continue.

XI. The import dialog box will appear, press the [Select] button on the right hand side. Browse to the export directory used in the previous steps, in this folder there should be a depths sub directory . Select the csv file in the depths directory.

XII. The column to import will display “Depth (cm)” and Numeric after the depth file is selected.

XIII. Click [**Finish**] to continue.

The import of data into Spectral Geologist is now completed. The measurements have been linked with depth data. This allows plots of mineral identification vs depth data (see below).



10 - X-ray Fluorescence (XRF) measurements

Background

X-ray fluorescence (XRF) spectrometry is a nondestructive method used to measure elemental abundances. X-ray photons excite electrons in the sediment, which release characteristic X-ray energies for each element as they relax. The amount of an element present is quantified by measuring the intensity of these characteristic emissions. XRF spectrometry is one of the few nondestructive techniques that can provide chemical information directly from core surfaces.

XRF measurements on the Geotek MSCL are made using an Olympus Innov-X handheld XRF spectrometer. This sensor is mounted on an arm connected to the vertical slide, allowing it to be moved up and down to contact the surface of a core. For more information on the Olympus Innov-X spectrometer or its use in a handheld mode, please refer to the manufacturer's manual included with the instrument.

Operating Principle

In XRF spectrometry, high-energy primary X-ray photons are emitted from a source (in this case, an X-ray tube) and strike the sample. The primary photons from the X-ray tube have enough energy to knock electrons out of the innermost (K or L) orbitals. Vacancies in inner electron shells are very unstable. An electron from an outer orbital (L or M) will “drop down” into the newly vacant space in the inner orbital, creating a more stable electronic configuration. As the electron from the outer orbital (higher energy) moves into the inner orbital (lower energy), it emits a “secondary” X-ray photon related to this energy difference. This phenomenon is called fluorescence. The secondary X-ray produced is characteristic of a specific element. The energy (E) of the emitted fluorescent X-ray photon is determined by the difference in energies between the initial and final orbitals of the individual transitions. Typical spectra for energy-dispersive XRF spectrometers (such as the Innov-X handheld units) appear as a plot of Energy (E) versus Intensity (I).

Modes

The Olympus Innov-X XRF spectrometers (models Alpha and Delta) measure using different beam conditions and different spectral analysis algorithms, depending on the type of sample and the objective of the measurement. Spectrometers destined to be used with the Geotek MSCL are usually set up with each of three different modes: Mining, Mining Plus, and Soil.

Mining Mode

Mining mode uses a single beam of 40 kV to perform a measurement. The spectrum is analyzed using the method of fundamental parameters, where the software assumes that certain elements are present in the sample and iteratively fits a model to the data. This type of modeling works well when analyzing a sample with high concentrations of elements of interest. Users can apply their own calibration to adjust for matrix effects.

Mining Plus Mode

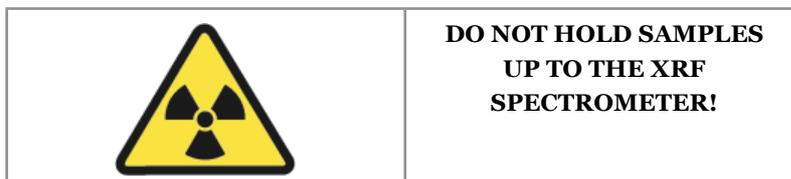
This is similar to Mining mode, except that the spectrometer performs two measurements in succession: one 40 kV measurement and one 15 kV measurement. Each of the spectra is subjected to modeling using the method of fundamental parameters. This mode is the most appropriate for measuring the overall composition of a rock or sediment.

Soil Mode

Soil mode is fundamentally different from mining mode, as it assumes that the elements of interest are relatively heavy, relatively dilute, and in a matrix of light elements. This is the most sensitive mode for measurement of metals in geological materials. Soil mode can use any combination of three beam conditions: 40 kV, 40 kV (filtered), and 15 kV. Each beam condition is best for specific elements, and only the beams the user requires need be used. Elements are calibrated individually and calibrations are assumed to be linear, and the user can adjust the calibration for different matrices. To account for loss of photons in the matrix, the spectra are first normalized to the Compton scattering peak

Before Logging with the XRF

- Ensure that the XRF spectrometer moves freely up and down on its mount, and is not obstructed by cabling.
- If split core is wet or sticky, cover with plastic wrap. If light elements (Mg, Si) are being measured, the thinnest plastic wrap possible (e.g., Kapton®) will provide the best data.
- **Caution:** X-rays are emitted by the spectrometer where it touches the core.



All measurements and calibrations should be performed with the XRF spectrometer resting flat against the sample, with shielding in place. When the XRF is making a measurement, a warning pane will appear on the screen.



Figure 10-1. X-ray warning pane.

Innov-X Software and XRF Controller

The Geotek software interfaces with the Innov-X Delta software to collect measurements. There are some settings on the XRF that can only be controlled from the Delta software: most notably, XRF test duration. The user will need to open the Delta software to make these changes prior to running the Geotek software.

- Open the Delta PC software. It will connect to the XRF spectrometer.

- If the Delta handheld software is running on the instrument, it must be closed. Click **[Close Device App]** to stop this program and allow the Delta PC software and the Geotek software to communicate with the spectrometer.
- Click **[Start]** to start the Delta PC software.
- Log in to the Delta PC software with the username “admi” and the password “1234”.

To set the testing times, click **[Mode]** and choose the desired mode. Click **[Set Up]** and the test time tab will appear. Change the maximum times for each beam, choose the end criteria (real time or live time), and click **[Save]**. Soil mode also has the choice of turning on or off each of the three beams, which is useful if there are only a few elements of interest.

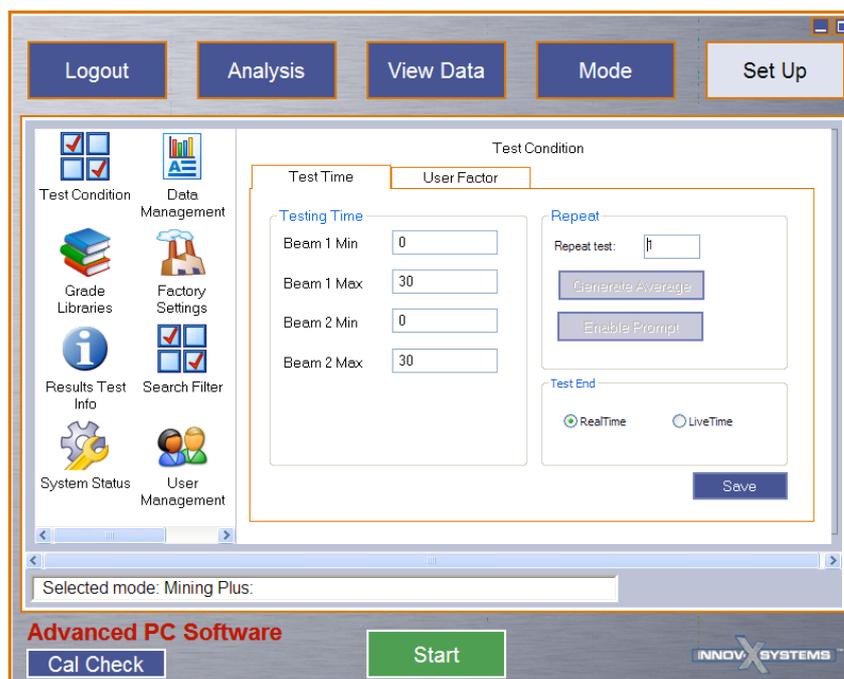


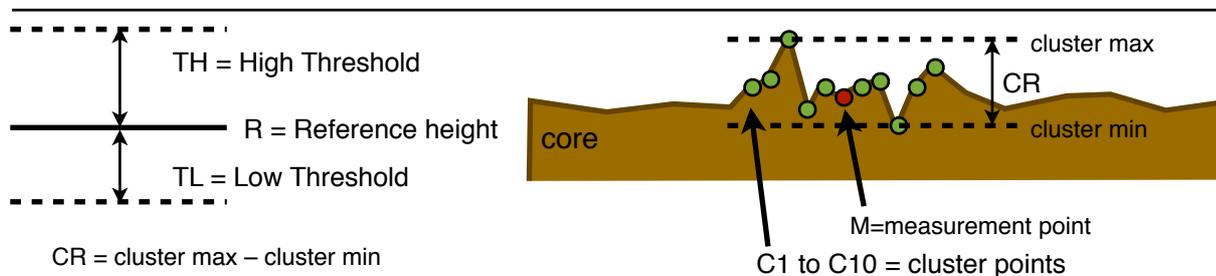
Figure 10-2. MSCL sensor setup window.

XRF Setup

Surface Roughness XRF Rejection Criteria

The MSCL contains settings to allow rejection of sample points on the basis of surface roughness. This prevents the XRF from making measurements (and ejecting unnecessary X-rays) when there are large gaps or depressions in core. As the laser passes each provisional XRF sampling location, it takes a series of closely-spaced distance measurements (cluster points). If these measurements show a hole in the core, or a high point that might puncture the XRF window, or simply a very rough surface that will allow scattering of X-rays, an XRF measurement will not be taken. If other measurements were to be taken at that location (e.g., magnetic susceptibility, colour spectrophotometry), those measurements are also cancelled.

The High Threshold, Low Threshold, and Cluster Range Max are the parameters for the rejection criteria for XRF data. The thresholds are relative to the reference height (the core stop). The Cluster Range Max is the maximum variation allowed within a sampling region (1 cm). The Cluster Interval sets the distance between laser cluster measurement points.



If any laser measurement > R+TH

OR

If any laser measurement < R-TL

OR

If CR > Cluster Range Max

then REJECT sample

Figure 10-3. XRF laser measurement rejection criteria.

Standardization

Before logging, a calibration must be performed. To do this, place the stainless steel standardization coin on the core stop. Go to **[Setup], [Sensor Setup], [XRF Setup]**. In the Position Control pane, select **[Move To]** “XRF Standardization”. The XRF spectrometer will place itself on the standardization coin. Click **[Standardize]** to calibrate the detector. The XRF Setup is also a good place to set the Abort Threshold (below).

Abort Threshold

To avoid taking XRF measurements when the XRF window is not fully covered by a sample, Geotek has implemented a count rate abort threshold. This threshold should be set before using the XRF on core, especially cracked or broken core, or core with a very uneven surface. To set the threshold, position the XRF on an average piece of core. Select “Off” under Abort Threshold. Make a manual measurement using the same mode that will be used for logging, and set the threshold either as absolute CPS (counts per second) or by typing in a percentage value, which will be applied to the last measurement (last beam of the last measurement) to calculate the threshold.

NOTE: when using a multi-beam mode, different beams will have different count rates. Monitor these different count rates and set the threshold accordingly.

Set Mode

Click **[Show Setup]** in the XRF section of the MSCL Setup Panel to see the XRF controller when configuring a core logging session. From here, choose the desired mode.

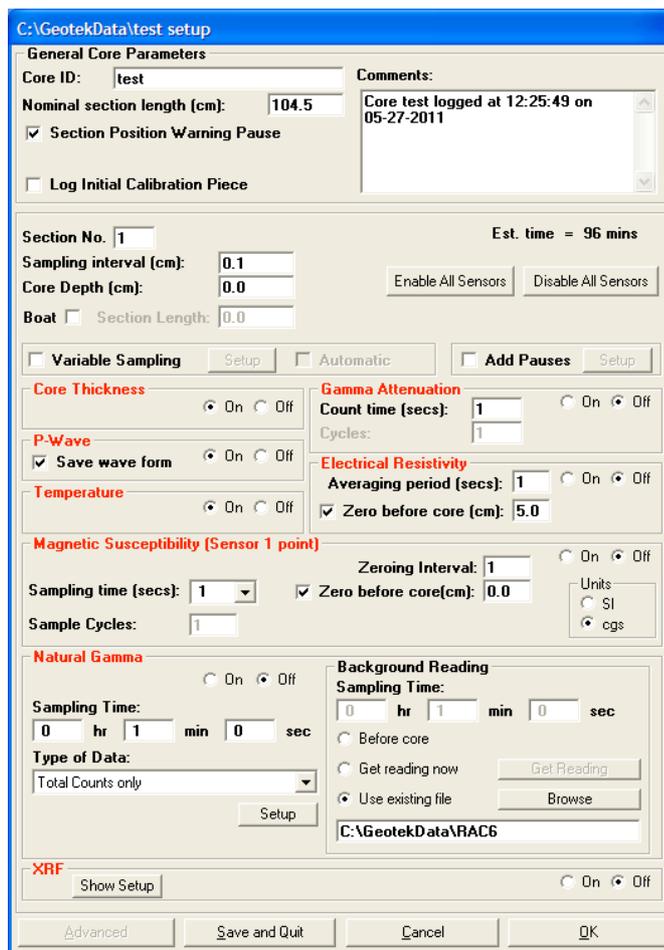


Figure 10-4. Setup pane for new core section showing XRF setup button.

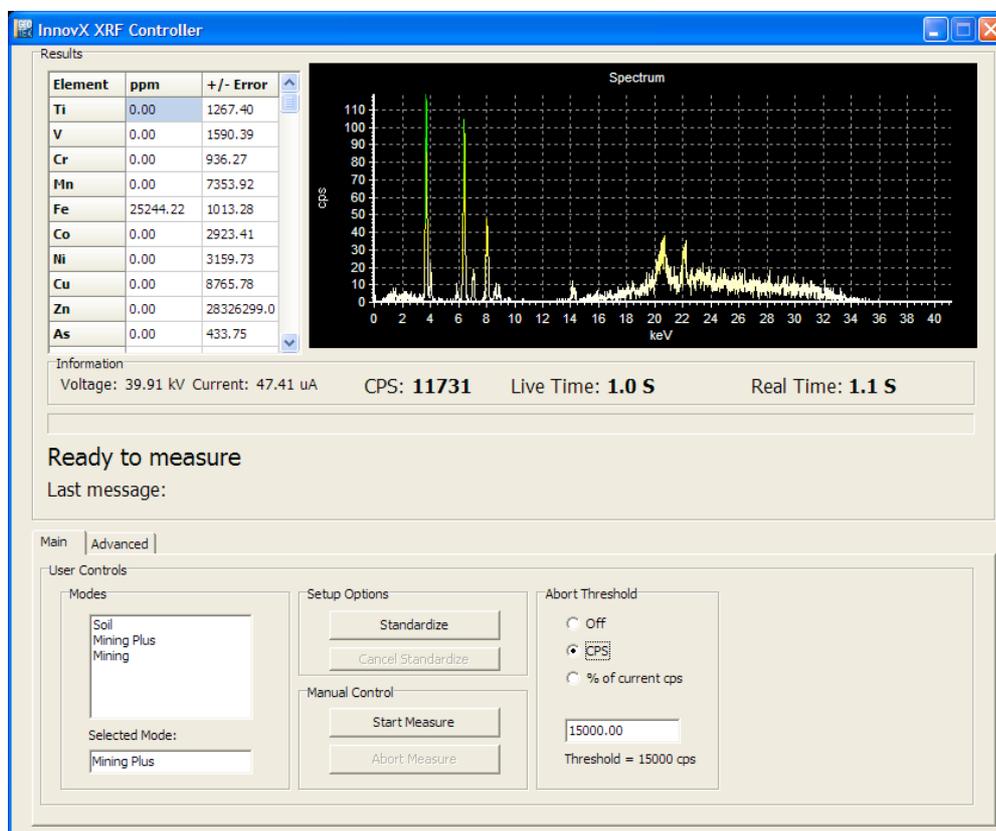


Figure 10-5. XRF controller window.

Data Display

Data is displayed as elemental abundances in ppm (parts per million). The elemental abundances come directly from the Olympus Innov-X software, which processes the spectra and returns elemental data.

Data for each point is continuously displayed in the XRF Controller Pane as it is acquired, including the raw XRF spectrum. This window can always be accessed from the XRF menu in the MSCL Data Display.

Data is plotted in the MSCL Spectral Data Display along with data from the colour spectrophotometer, if installed.

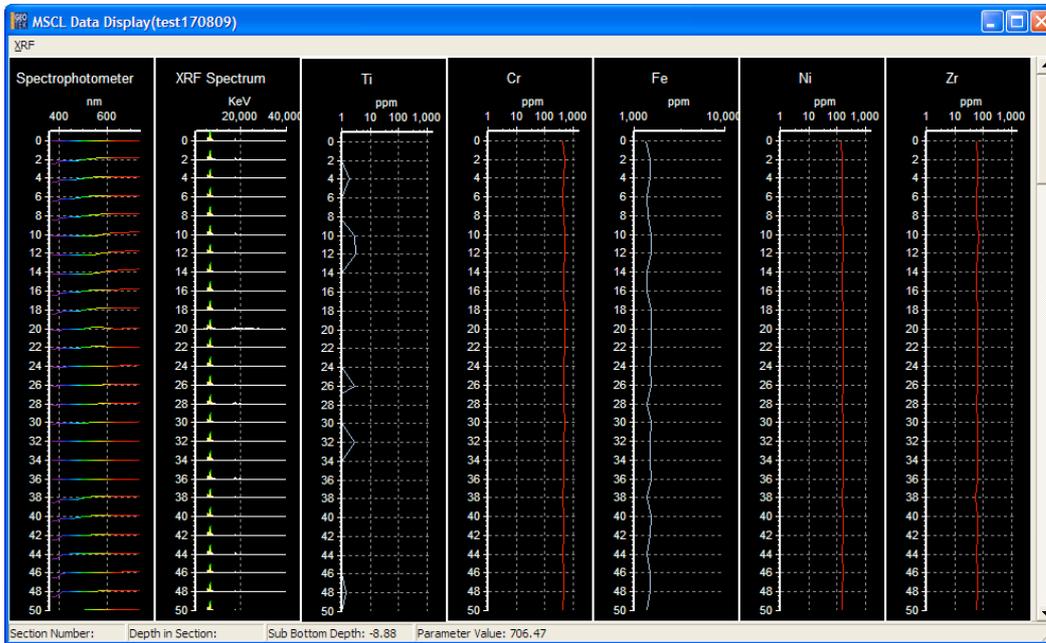


Figure 10-6. MSCL Spectral Data Display showing, from the left, spectrophotometer data, XRF spectrum and elemental concentrations.

For each XRF measurement point, the spectrum is displayed. The spectral window supports zooming for detailed inspection. Single elements can also be plotted in the Elements to Plot window accessed through the [XRF] menu. To hide or show all single element plots, select Hide Element Chart in the [XRF] menu.

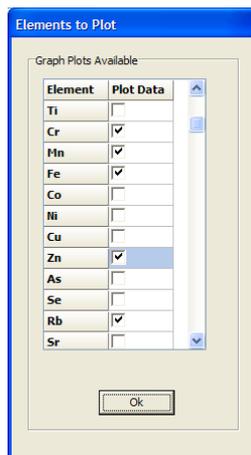


Figure 10-7. Elements to Plot window.

XRF data is also presented as total counts in the MSCL Raw Data Display. Total X-ray counts gives an indication of data quality.

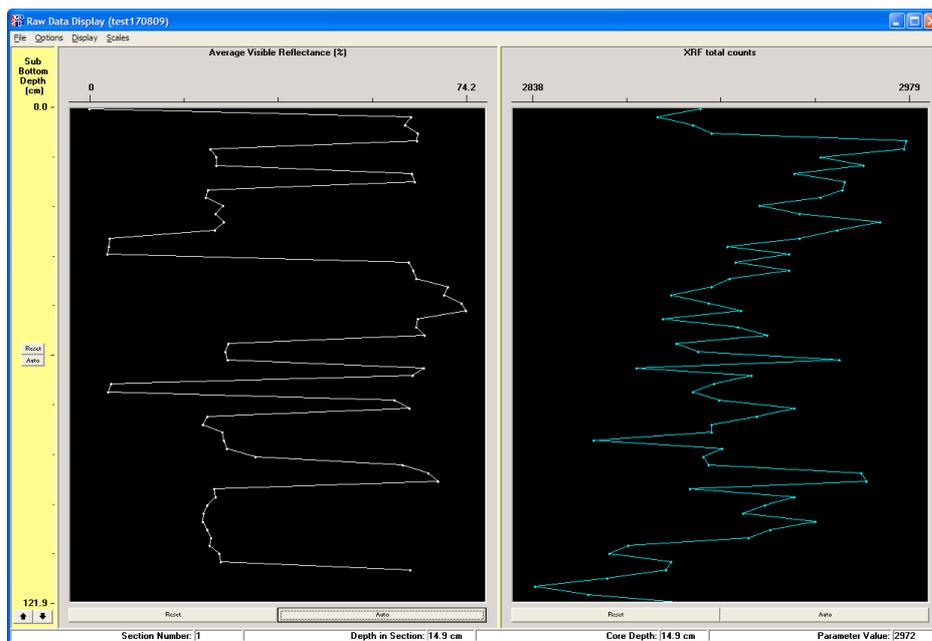


Figure 10-8. MSCL software Raw Data Display.

Data Export

XRF data is exported with both raw MSCL data and processed MSCL data. Raw MSCL data includes XRF total counts along with an option to export spectral data (ASCII file, wavelength bins vs. counts per second). Processed MSCL data includes elemental abundances for each element calibrated in the analyzer, plus the calculated uncertainty.

Calibration and Processing

Calibration of the instrument takes place at the Innov-X factory, and no processing of XRF data is required in the Geotek MSCL software. Uncalibrated elements must be added by sending the analyzer back to Innov-X.

The Delta handheld XRF allows the user to adjust the calibration performed by Innov-X. This can be important when measuring samples with very different matrices. In the Delta software, each element in a mode has an associated “user factor” that can be adjusted by the user.

11 - Natural Gamma Measurements

Chapter Overview

This chapter explains the calibration and operational procedures for the Geotek natural gamma measurement system. It provides some background information on natural gamma measurements in rocks and sediments, but users should also familiarise themselves with other sources of information. It is important that the user follows these protocols to ensure that the data obtained is accurate and of the highest quality. The user must understand how the system works if the user wishes to depart from the normal operating protocols and procedures so that the implications of the departure are to be fully appreciated.

Background

Gamma Rays

Gamma rays are electromagnetic radiation given off by an atomic nucleus during the spontaneous decay of an unstable element (radioisotope). These waves are characteristically at frequencies between 10^{19} and 10^{21} Hz (wavelengths between 10^{-9} and 10^{-11} cm). A gamma event corresponds to the transition from one state to another of lower energy and the emission of a photon with energy equal to the difference between the two states. The energy (E) is related to the wavelength (λ) and frequency (ν) as given below. The energy is expressed in electron volts (eV).

$$E = h * \nu = h * (c / \lambda)$$

where:

c = velocity of light
h = the Planck constant

Gamma rays have energies of the order of keV and MeV.

Sediment and Rock Radioactivity

The elements that constitute the Earth, both stable and unstable (radioactive), were formed in very extreme environments. The present day conditions on Earth are not suitable for the formation of these elements and therefore only elements that are stable or have a decay time greater than or equivalent to the age of the Earth are found here.

The naturally occurring radioisotopes with sufficiently long lives and that produce significant amounts of gamma rays are; potassium (^{40}K) with a half life of 1.3×10^9 years; uranium (^{238}U) with a half life of 4.5×10^9 years; and thorium (^{232}Th) with a half life of 1.4×10^{10} years. Minerals that fix K, U and Th, such as clay minerals, are the principal source of natural gamma radiation. K, U and Th are known as the 'primeval' emitters.

Potassium disintegrates to give Argon (^{40}A) which is stable. The decay spectrum of potassium therefore contains one peak.

Uranium and thorium decay is more complex as both disintegrate to give a series of daughter isotopes, only some of which are gamma ray emitters. These include thallium (^{208}Tl), actinium (^{228}Ac), bismuth (^{214}Bi) and lead (^{214}Pb). The principal gamma ray emissions from these decay steps and their relative intensities are listed in the table below.

It is important to note that it is assumed secular equilibrium has been reached. This means that the intermediate daughter isotopes decay at the same rate as they are produced by the parent isotope and the relative proportions of parent and daughter remain constant. Most equilibrium problems occur with the uranium series in recent or recently exposed deposits. Starting from pure uranium it takes approximately one million years of undisturbed decay to reach secular equilibrium.

Parent	Nuclide	Energy (MeV)	Emissions per 100 Decays of Parent	
^{40}K	^{40}K	1.461	11	
^{232}Th	^{228}Ac	0.210	4	
	^{212}Pb	0.239	43	
	^{224}Ra	0.241	5	
	^{208}Tl	0.277	3	
	^{212}Pb	0.300	3	
	^{228}Ac	0.339	12	
	^{228}Ac	0.463	5	
	^{208}Tl	0.511	8	
	^{208}Tl	0.583	31	
	^{212}Bi	0.727	6	
	^{208}Tl	0.860	4	
	^{228}Ac	0.911	27	
	^{228}Ac	0.964	5	
	^{228}Ac	0.969	16	
	^{228}Ac	1.588	3	
		^{208}Tl	2.615	36
^{238}U	^{226}Ra	0.186	3	
	^{214}Pb	0.242	6	
	^{214}Pb	0.295	19	
	^{214}Pb	0.352	37	
		^{214}Bi	0.609	46
	^{214}Bi	0.768	5	
	^{214}Bi	0.934	3	
	^{214}Bi	1.120	15	
	^{214}Bi	1.238	6	
	^{214}Bi	1.378	4	
^{214}Bi	1.408	3		
^{214}Bi	1.730	3		

Parent	Nuclide	Energy (MeV)	Emissions per 100 Decays of Parent
	²¹⁴ Bi	1.765	16
	²¹⁴ Bi	2.204	5

Use of Natural Gamma Data

Natural gamma measurements have three purposes:

- I. core/core and core/borehole correlation
- II. evaluation of clay/shale content
- III. abundance estimates for K, U, Th

The first item and to some degree the second item can be achieved by measuring bulk emissions (total counts) of the material. Elemental analysis is a much more complex process requiring spectral data acquisition and much longer sampling times.

Natural Gamma Measurements

The well logging industry uses a relative unit standard known as the GAPI (Gamma ray, American Petroleum Institute), sometimes abbreviated to API. This scale is defined at a calibration pit at the University of Houston which consists of three zones of specific mixtures of K, U and Th, two of low activity and one of high activity. A GAPI is defined as 1/200 of the deflection measured between the high and low activity zones in the calibration pit. Limestones have readings of 15-20 GAPI while shales vary from 75-150 GAPI although in highly radioactive shales readings of 300 GAPI are known.

The Geotek Natural Gamma sensor system cannot be calibrated in the calibration pit and therefore measurements are presented in counts per second (cps). This unit is dependent on the device (i.e. detector geometry) and the volume of the material measured.

Natural Gamma Total Counts

Total counts refers to the integration of all emission counts over the gamma ray energy range between 0 and 3 MeV. This radiation is, as detailed above, primarily emitted from three isotopes, ⁴⁰K, ²³⁸U and ²³²Th, and their decay products. If the purpose of the measurements is to obtain total counts, i.e. for core-core correlation, a reasonable precision can be obtained on relatively low counting times (minutes per sample). This allows cores to be logged in limited time schedules.

Natural Gamma Spectrometry

The GEOTEK natural gamma logger acquires 1024 channel spectral data which may be used for calculating elemental yields for K, U and Th. The radiation spectra of rocks and sediment are composed of a number of peaks at discrete energy levels corresponding to gamma emissions from isotopes in the three primeval series.

These peaks can be degraded in three different ways:

- I. Compton scattering in the sediment, between the core and the detector and in the detector and shield structure itself.
- II. pair production in the sediment and the detector (at energies above 1.02 MeV).
- III. an intrinsic broadening of the peaks by the detector itself.

This results in a large background in the spectrum that is added to by low intensity discrete emissions from the ²³⁸U and ²³²Th series which are indiscernible from the scatter.

The aim of natural gamma spectrometry is to determine the components of spectra, discrete peaks and portions of the background, in order to effectively estimate the abundance of K, U and Th.

Acquiring data for spectral analysis will require significantly longer counting times than total count sampling for a comparable precision (hours per sample).

Analysing Spectra

The Schlumberger method for analysing gamma radiation spectra involves division of the spectrum into five discrete energy windows. Two windows cover the low-energy region which include the energy range of gamma rays resulting from pair production and Compton scattering as well as lower energy emissions from the Th and U series. The three remaining windows cover the high energy region including the three main peaks; ^{208}Tl at 2.62 MeV (from the ^{232}Th family); ^{214}Bi at 1.76 MeV (from the ^{238}U family) and ^{40}K at 1.46 MeV. It is important to consider the low energy window as much improved results can be obtained.

Schlumberger use a calibration pit in Clamart, France for their natural gamma spectrometry (NGS) downhole tool from which they gain their calibration coefficients (A_i , B_i and C_i) in the following equation:

$$W_i = A_i * \text{Th} + B_i * \text{U} + C_i * \text{K} + r_i$$

where:

$$W = \text{count rate from window } i \text{ (1-5)}$$
$$r_i = \text{statistical error factor}$$

The equations are solved by minimising r^2 which is the sum of all r_i^2 .

The Schlumberger windows are defined as follows:

- Window 1: 0.20-0.50 MeV
- Window 2: 0.50-1.10 MeV
- Window 3: 1.10-1.59 MeV
- Window 4: 1.59-2.00 MeV
- Window 5: 2.00-3.00 MeV

Measurement Constraints

Any natural gamma measurement requires the acquisition of a zero-background spectrum. The resulting spectrum must be subtracted from the measured spectrum of a core sample to remove any environmental radiation effects within the measurement window. This type of background should be differentiated from the peak baseline which is often referred to as background (see Figure 15.1).

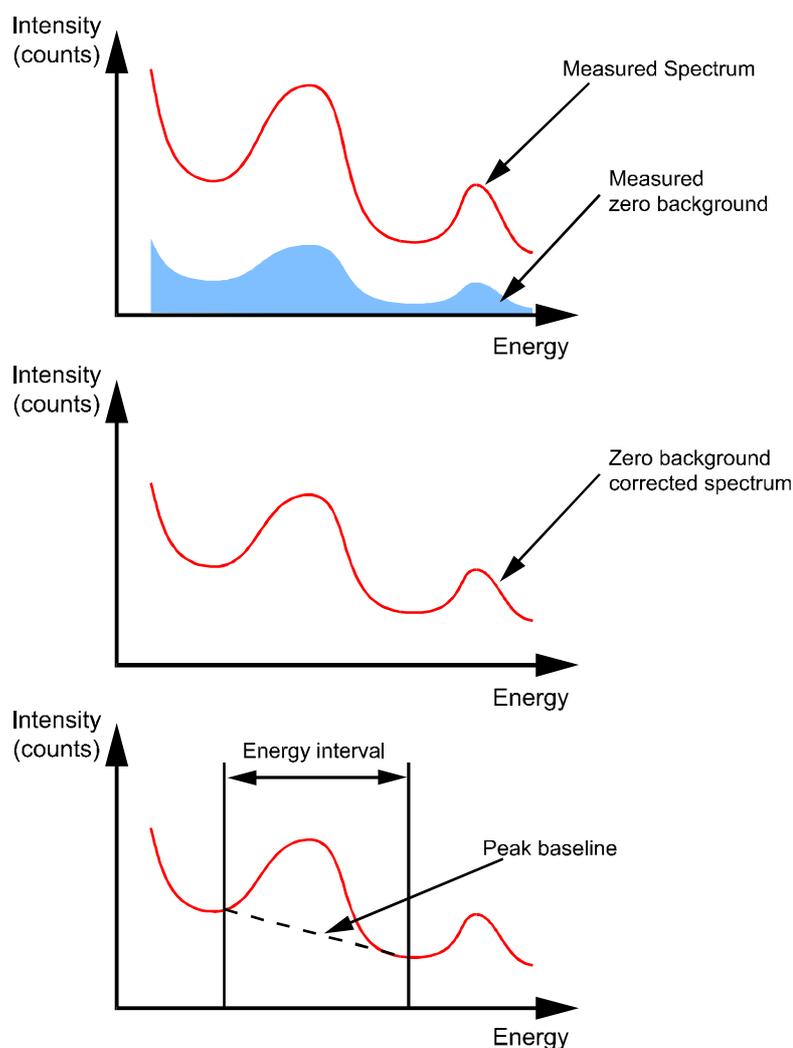


Figure 11-1. Differentiation of zero background and peak baseline.

Physical System

The components of the natural gamma system are mounted on a separate stand positioned between the magnetic susceptibility section and the LH track section. The mechanical arrangement is mounted on an adjustable plate similar to that used for the main sensor stand in horizontal mode. This plate can be raised or lowered to accommodate differently sized cores. Mounted in a central position is a large lead cube into which the two detectors are mated and through which the core is moved.

The central lead cube provides a radioactively 'quiet' area for measurements to be taken in. For ease of assembly the cube is split into several pieces which can be bolted together. Two lead inserts are placed in either end of the core hole to adjust the diameter to fit the cores being logged (see Figure 15-2). Into the centre of the complete assembly a plastic sheath (in two parts) is placed. This acts to prevent any contamination of the core liner and the lead housing (the sheath is easy to clean).

To put the system together, start by attaching the horizontal support legs to the aluminium frame supported by the wooden legs. Locate the horizontal plate (with the detector clamps and the spacer for the lead housing bolted on) on the adjustable plastic supports and ensure that the plate is seated in a level stable position (see Figure 15-2). Once the plate is in place put the detector housings into the clamps and secure them, leaving enough room in the centre to position the lead cube (do not tighten yet as some adjustment will be required).

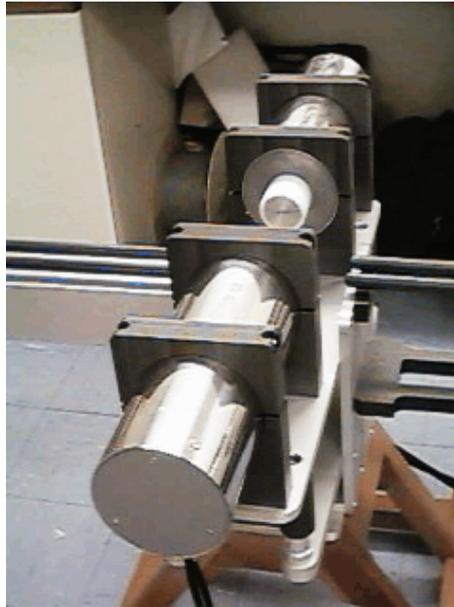


Figure 11-2. Horizontal plate and detector housing in place for natural gamma measurements.

Now the lead cube can be put into its place. Be very careful as it is extremely heavy. At least two people will be required to lift and position it. Place the housing centrally on the plastic spacer. The position should be adjusted to allow cores to move freely through the centre hole (Figure 15-3).

	<p>THE LEAD SHIELDS ARE VERY HEAVY: MIND YOUR BACK!</p> <p>USE GOOD STRONG HANDS NOT YOUR FEET!</p>
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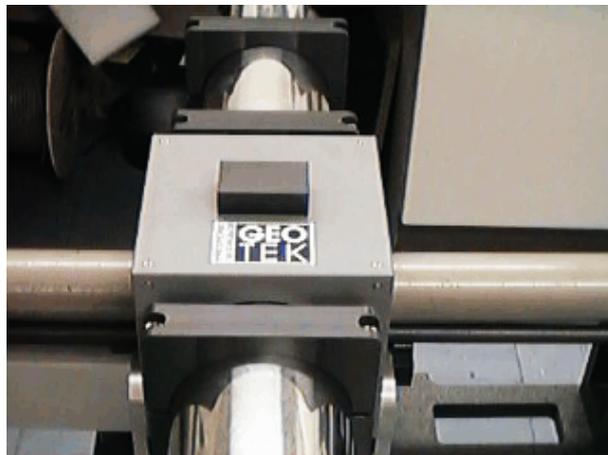


Figure 11-3. Lead cube in position allowing the core to move easily through.

Natural Gamma Sensors

The sensor itself comprises at least two 2" x 2" or 3" x 3" NaI(Tl) detectors housed in 6" diameter lead shields. A detector comprises a NaI(Tl) crystal optically coupled to a photomultiplier tube and connected to an integrated bias base and MCA. Emitted gamma rays hit the NaI(Tl) crystals which produces a pulse of light which then strikes the photomultiplier tube producing a small electrical current to give a voltage pulse. The peak height of the voltage pulse is related to the energy of the gamma emission which is recorded by the multi channel analyser in one of 1024 channels. Older systems will have Aptec MCAs on ISA cards installed inside the PC and the latest system will have Target/ICx scintiSpec MCAs connected via a USB to the PC.

Measurement Philosophy

Multiple detectors are used in order to increase the recorded signal level because natural rocks and sediments have very low natural radioactivity, so combining data collected with multiple detectors improves the data quality. The system provided by Geotek makes the use of multiple detectors relatively easy. The sensor suite is controlled through the software interface that allows collection of stabilised spectra, meaning that each detector and MCA pairing is calibrated using known isotopes at specific energy levels.

Calibration and Operation

The Geotek MSCL software provides features for continuous logging of sediment cores. The natural gamma logging protocols have been integrated into the existing Geotek software.

The Geotek software enables the user to log an entire core at fixed sampling intervals and for specified count times. Since accurate natural gamma measurements require long count times, this enables the user to set up a core to be logged for a period of several hours or days without the need for user intervention.

Please Note: Some versions of the Geotek software acquire data by communicating with the WinTMCA programs referred to later in this chapter. When running the Geotek MSCL program, do not close any WinTMCA windows that are automatically opened, however, they may be minimized.

Energy Calibration

MSCL systems with natural gamma detectors are delivered with energy calibration standards. These calibration standards are naturally occurring materials obtained from the International Atomic Energy Agency (IAEA) in Austria (IAEA-RGK-1, Potassium Sulfate, IAEA-RGTh-1, Thorium Ore and IAEA-RGU-1, Uranium Ore). More details of these materials can be found on the IAEA web site - <http://curem.iaea.org/catalogue/RN/index.html>. These samples provide emission peaks at various energies as detailed in the table in the first section of this chapter.

The energy calibration of each detector should be monitored, as they may drift over time and may need recalibration. The potassium sample can be used for quick monitoring of existing calibrations as it has an easily identifiable single peak at 1460.75 keV. When this peak has deviated significantly from the known energy, the detectors should be recalibrated. If the user is acquiring total counts only, this deviation can be over $\pm 5\%$ and remain acceptable, but if the natural gamma spectra are being analysed for K-U-Th, the deviation should remain less than $\pm 2\%$.

Brightspec Detectors/bMCA Calibration (Newer MSCLs)

Users should check the calibration of the natural gamma detectors with one or more standard peaks using the bMCA interface, which is part of the MSCL Utilities program and accessed by choosing Window --> Test Panel and selecting [**Natural Gamma**]. To check the calibration, collect a ^{40}K spectrum and move the cursor (red line) to the ^{40}K peak by dragging or selecting [**Move Cursor Here**] from the contextual menu. If the peak is properly labeled, the calibration is good and should not be changed.

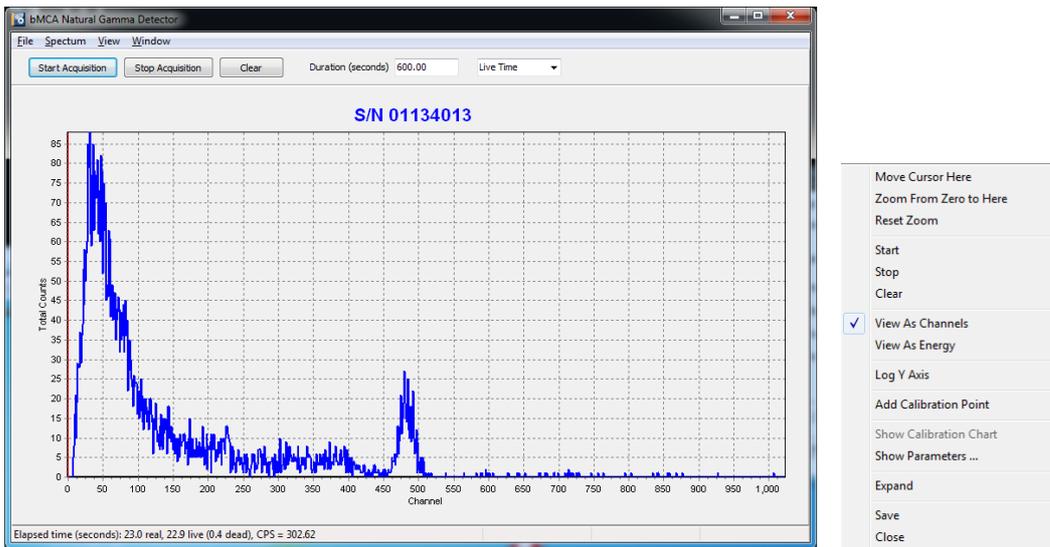


Figure 11-4. bMCA Natural Gamma Detector pane & contextual menu (right-click).

If recalibration is necessary, acquire a new spectrum using a calibration standard. Move the cursor (red vertical line) to the center of a peak. Suggested peaks are presented in **bold** in the table of natural radionuclides. Zoom into the peak or change from linear to log scales as necessary to center the cursor on the peak. Select **[Add Calibration Point]** from the contextual menu to bring up the Add Calibration Point pane.

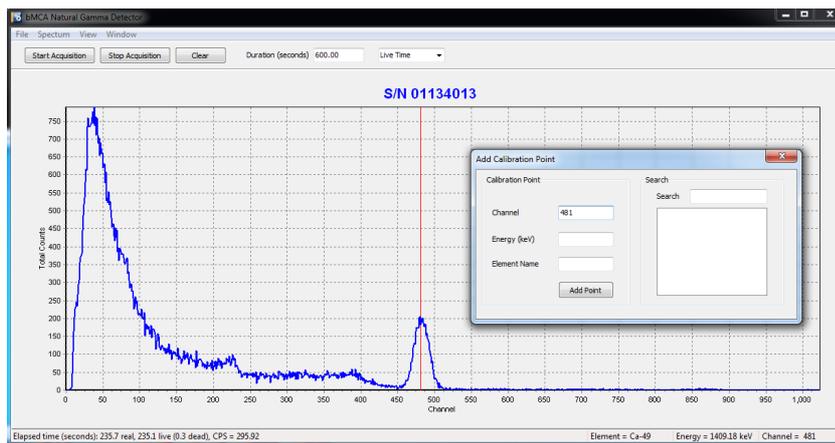


Figure 11-5. bMCA Natural Gamma pane with cursor on ⁴⁰K peak and Add Calibration Point pane open.

Begin typing the nuclide of interest into the Search field. A list of nuclides will appear on the right; choose the proper energy from the list by double-clicking, and then **[Add Point]**.

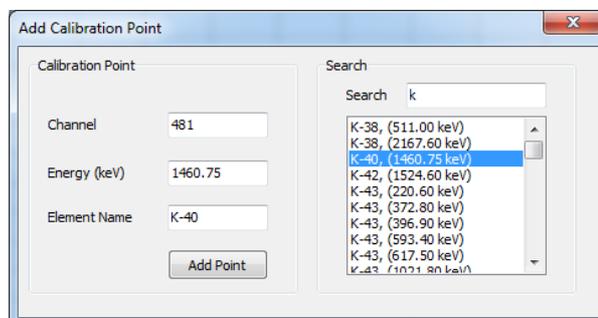


Figure 11-6. Add Calibration Point pane.

The NG Calibration pane will appear. This pane can also be displayed by selecting **[Show Calibration Chart]** in the contextual menu. Figures 11-7 & 11-8 show addition of ²⁰⁸Tl and ²¹⁴Bi peaks to the calibration chart. Note that the highest energy point may not display on the calibration graph, but is used in the calibration line. When

all desired calibration points have been collected, click **[Set Calibration to These Values]**. Calibration is complete and this calibration will be used by the MSCL software during core logging.

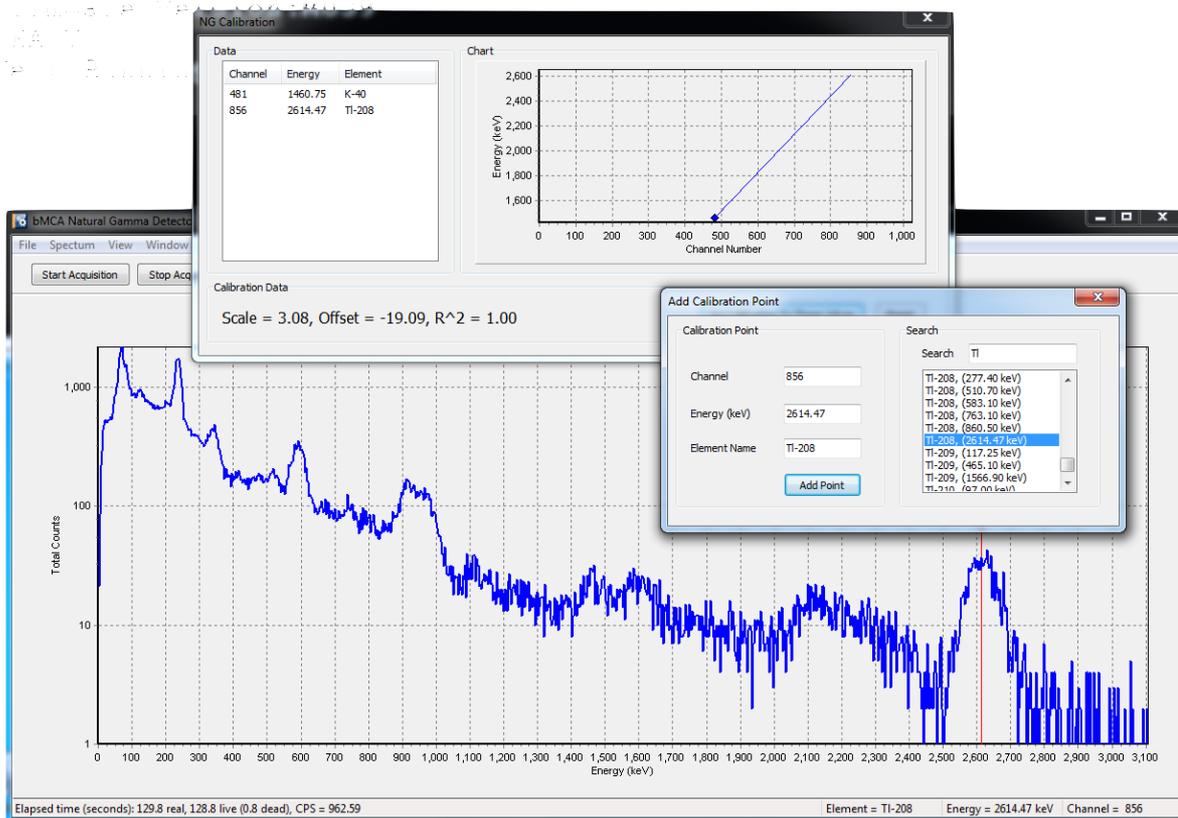


Figure 11-7. bMCA pane showing ^{232}Th spectra with cursor on ^{208}Tl peak, Add Calibration Point pane, and NG calibration pane.

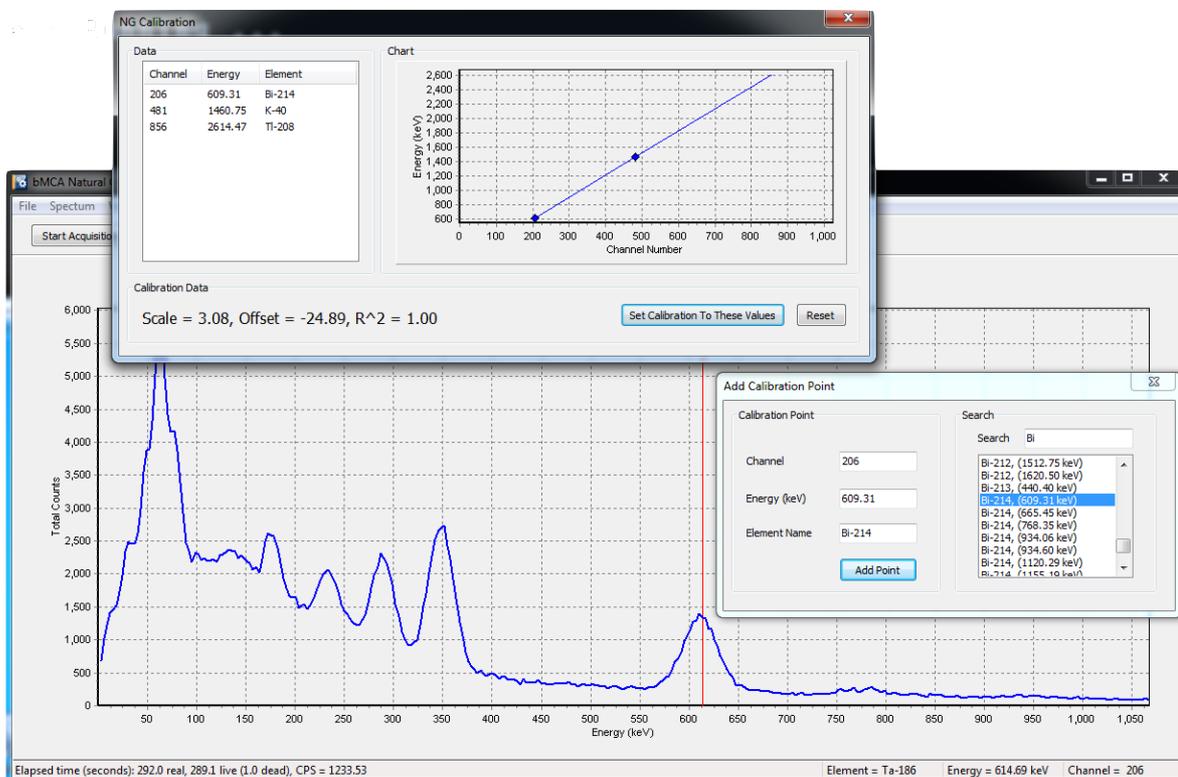


Figure 11-7. bMCA pane showing ^{238}U spectra with cursor on ^{214}Bi peak, Add Calibration Point pane, and NG calibration pane.

The Parameters pane can be accessed from the contextual menu. Users should not change any of the factory settings for the detectors unless asked to do so by Geotek staff.

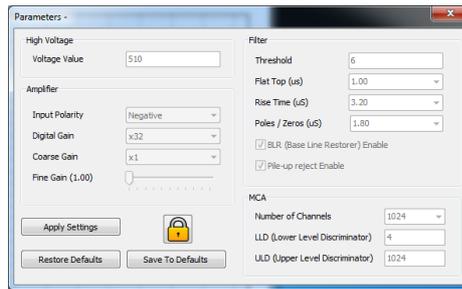


Figure 11-8. bMCA Parameters pane.

Scintispec Detectors/WinTMCA Calibration (Older MSCLs)

Users should check the calibration of the natural gamma detectors with one or more standard peaks using the WinTMCA program. To check the calibration, collect a spectrum and click on a known peak (e.g., ^{40}K). If the peak is properly labeled and centered on the label line, the calibration is good and should not be changed. If recalibration is necessary, find a known peak and enter the channel number corresponding to the peak in the Energy Calibration pane (Spectrum --> Energy Calibration). The channel number corresponding to the cursor line can be found in the lower left corner of the graph, or double-click on a peak to add it to the table. Next, click in the "Value" field and begin typing the nuclide of interest. A list of nuclides will appear on the right; choose the proper energy from the list by double-clicking. One or more channel/energy pairs can be entered. When finished, click **[Fit]** and then **[Set]**. If the calibration has been changed in WinTMCA, the Setup file must be updated in the Geotek software.

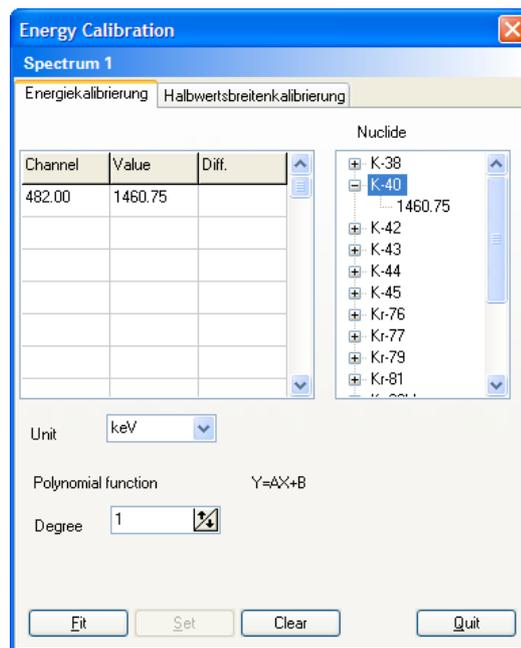


Figure 11-9. WinTMCA Energy Calibration pane.

In order to acquire calibrated data using the Geotek MSCL software, this calibration information and more must be passed back to the WinTMCA program before data acquisition. These "setup" files contain important information for each detector such as detector voltage, stabilisation peak (if any) and calibration data that ensure the detectors acquire good data. The Geotek software keeps a setup file, which can be updated as necessary by using the **[Setup]** button in the Natural Gamma subpane of the Logging Setup pane or in the Utilities Natural Gamma Test Panel. To use this **[Setup]** button, calibrate in WinTMCA and leave the WinTMCA program open after calibrating. Navigate in the MSCL or Utilities software to the Natural Gamma **[Setup]** button. When the **[Setup]** button is clicked, the Geotek software retrieves the relevant settings from the WinTMCA program, and the user can save these settings to the Geotek natural gamma setup file with the **[Save]** button.

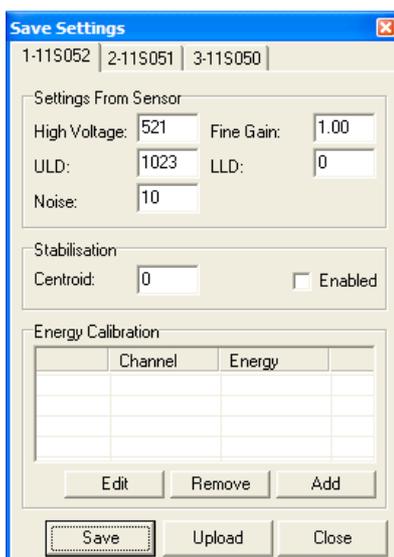


Figure 11-10. Natural Gamma Save Settings pane.

File Structure

For each core logged, the MSCL software will create a directory bearing a name entered by the user to represent the core. All data files created for the core will be placed in that directory.

Data files relating to natural gamma created by the Geotek software comprise:

File Type	Name Format
Geotek binary raw data file	*.dat
Geotek raw ASCII file	*.raw
Geotek processed ASCII file	*.out
WinTMCA spectrum file	*.spc

The Geotek MSCL software automatically creates a raw data file (*.dat) bearing the core name chosen by the user. This file contains the total counts per second recorded by the detectors at each sample point, as well as the configuration information for the core, including sampling interval, sample time, and processing parameters. The counts per second data stored in this file may be exported from the Geotek MSCL software as tab-delimited text files either of raw counts per second (*.raw) or processed counts per second (*.out).

If the user chooses to acquire spectral data as well as total counts per second, then the spectral data is saved as WinTMCA spectral file format (*.spc), containing header and setup information and is stored in text format. The data from each detector is saved in the WinTMCA spectral file format (*.spc). A spectral file is created for each detector and each sample point. The files are saved in the core directory with the following name format:

sssdxxxx.spc

Here sss refers to section number, d refers to detector number and xxxx gives the depth in section of the sample point in millimetres. For example, file 00120045.spc would contain the spectral data acquired by detector 2 for section 1 at a depth of 45 mm. If the spectral data is for a background reading then the data is saved in a file of the format bkgnd_XXXX.spc where xxxx indicates the detector serial number. For example, bkgnd_06L319.spc would contain the background spectrum for detector serial number 06L319.

Natural Gamma Logging Setup

Select 'On' in the Natural Gamma box of the logging configuration panel (see Figure 15-4). The user must enter or select the relevant settings for logging natural gamma at this point using the various text entry boxes and selection boxes.

Sampling time

Enter the time you wish to count for natural gamma in hours, minutes and seconds in the text boxes provided, underneath ‘Sampling Time’. The time you enter represents live time, that is, the actual time the detectors will be actively detecting. The total time elapsed for each acquisition may be greater than the specified live time due to detector effects (pulse pile up for example). You can also specify at what stage to take the background. You can make the software take a background reading before the core reaches the sensor or prompt the software to get a reading immediately or use a background acquisition that you collected earlier (with this option you must select the files containing the background spectra).

Type of Data

Under ‘Type of Data’ select either “Total counts only” or “Spectral data with counts”, depending on whether you want to record the full spectral data for the core or just the total counts per second.

The “Spectral data with counts” option collects data from all detectors from each sample point and manipulates the data into a single spectrum file (*.spc) with data from each detector combined and with the background data removed. Each spectrum file is labeled as the core depth in millimetres. It also retains the intermediate spectral files (*.spc) from each detector at each sample point. This allows the user to conduct their own manipulations of the spectral data using their own methodology. Files are named as **sssdxxxx.spc**, explained above.

The “Total counts only” option collects only the total gross counts from each detector and records this as a standard data set in the MSCL data file (*.dat). This data can be processed to remove the total background counts and the outputted to an ASCII file as with other MSCL data sets. The total counts data is collected in the energy range 0-3000 keV.

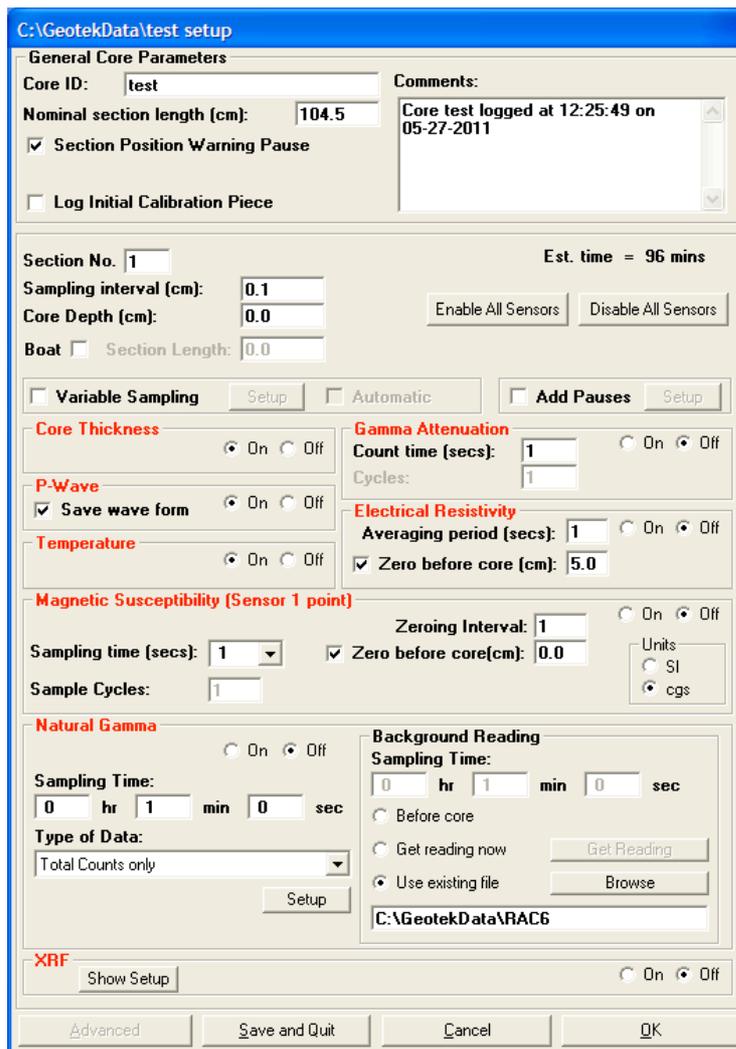


Figure 11-11. Logging setup pane, with Natural Gamma subpane.

Background Reading

A background reading must be taken in order to correct the data for the ambient levels of radiation. The user can collect a background reading as part of the automated logging procedure, the **[Before Core]** option, collect a background reading immediately (**[Get Reading Now]**) or use a reading already collected and stored (**[Use Existing File]**). The background reading should be taken whilst there is a non-radioactive sample of similar density to the sediment being logged. This means that the scattering of background radiation through the central lead cube (and the radiation from the check sources to different detectors, on older systems) will be constrained to the same levels as during core logging. Background readings should be taken for at least five to ten times longer than data acquisition. The user can also choose to take data without background subtraction (option not shown in figure above).

Natural Gamma Logging

Start Logging

Once the user has completed the configuration panel then the software will prompt the user to setup the track in the same way as during normal logging. The Logger Control Panel will appear and guide the user through this process. See Chapter 14 for more details of the MSCL software.

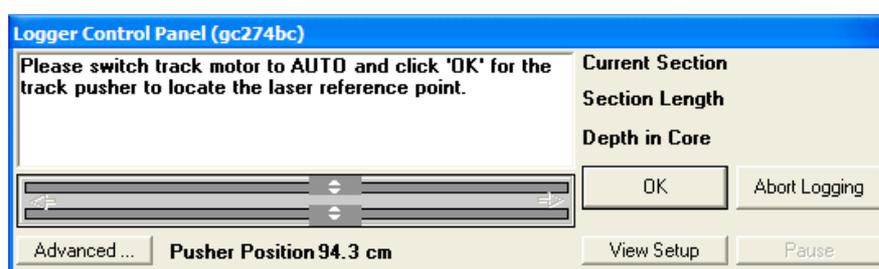


Figure 11-12. Logging Control Panel. The user is guided through the process of setting up the track through this interface.

When the track has been setup, the core section has been placed on the track and the user has clicked on **[Begin Logging]** the configuration panel will reappear as confirmation of what the user has selected – settings can be changed at this point. Click **[OK]** and the system will start logging.

During Logging

While natural gamma acquisition is in progress, a window will appear in the bottom left of the screen showing the amount of time left for natural gamma acquisition at the current sample point.

If you do not wish to see this window minimise it. Closing the window will interrupt the acquisition. However, if you wish to interrupt the current acquisition, click the **[Stop]** button. The data acquired on the detectors up to that point will be saved just as for a completed sample point and the logging software will go into pause mode.

If you wish to pause the logging without interrupting data acquisition at the current sample point, click the **[Pause]** button on the logger control panel. The acquisition for the current sample point will continue until completed, after which the logging software will go into pause mode.

During logging, a raw data display appears, giving the gross counts per second recorded at each sample point. This number is an average of the count rates for each detector, and does not include a subtraction of the background counts per second. The raw counts per second data can be exported to an ASCII file as with other MSCL data. The spectral data are stored as specified by the user in the Configuration Panel (Figure 15-4).

Ending Logging

The user can end logging at any stage by clicking on **[Abort Logging]** in the middle of a section or **[End Logging]** at the end of a section.

Data Processing and Output

Total Counts

To view the processed counts per second, select 'Process Data' from the 'Options' menu in the raw data display window. The numbers displayed in the processed data display represent the raw counts per second minus the background counts per second, where the latter are taken from the background files for the core. The value of background counts per second may, however, be altered in the processing panel. The processed counts per second may be exported in an ASCII file format.

Spectral Data

The spectral data are saved to a text file with the extension .SPC or .TXT. In either case, the internal structure of the file is the same. Header information includes the length (number of channels) realtime (seconds), livetime (seconds), start and stop date & times, and the calibration coefficients for the detector. Generally calibrations are linear: "c" is the linear coefficient and "d" is the constant in the linear equation. The spectrum follows the words "SpectrumText :" with eight values per line, separated by commas. Values are total counts per channel in order of channel number.

The user can manipulate .SPC files using WinTMCA as required using the WinTMCA software (manual in C:/geotek/installers/scintiSPEC/Documentation/WinTMCA32_manual.pdf) or any program that can open text files.

Chapter 11 Appendix: Stabilizing Detectors with Check Sources

Older detectors (Aptec) can benefit from using check sources to stabilize the spectra. The stabiliser works by monitoring the position of the energy peak selected for stabilisation and adjusting the detector gain to maintain the peak position. The stabilised spectrum is recorded in a preset energy range (for natural gamma measurements this should be 0 to 3 MeV). When used in a temperature controlled room the Target/ICx scintiSpec MCAs can be operated without stabilisation.

On older systems, two sources were provided for energy calibration of each of the detectors. These are two gamma emitting isotopes, providing 5 peaks of known energy which can be used for energy calibration and subsequent collection of stabilised spectra. The isotopes are ^{133}Ba (giving three identifiable peaks) and ^{60}Co (giving two peaks); the energies of these peaks are known and are shown in the table below.

Isotope	Peak	Energy (keV)
^{133}Ba	1	81.01
	2	302.71
	3	355.86
^{60}Co	1	1173.23
	2	1332.51

The calibration sources should be kept in a safe place. Although they are designed to be handled do not carry them around for long time periods and do not put them in any pockets where they can be forgotten.

If the system is to be used in a temperature stable room then the calibration isotopes may not be required for the stabilisation process because there is no observed drift over time with temperature. This has the advantage of removing any effects of the check sources from the final sample spectra that is used for any analysis.

12 - Core Thickness

The thickness or diameter of the core is measured as the distance between the active faces of the two PWTs. This is achieved by mounting a laser distance transducer (DT) on each of the PWT mountings. Each DT is coupled to the moving PWT bracket at the rear end of each transducer. In this way each DT precisely follows the movement of each PWT. In practice the core thickness is measured with reference to a known thickness and it is the deviation from that reference thickness that is recorded.

The 2 DTs are wired together in such a way that equal movements in the same direction produce no change in reading. Only real changes in total offset are recorded.

Setting up

The upper P-wave transducer is free to move approximately 25 mm in the motor driven housing. The movement in the housing is measured using the upper laser distance transducer. The lower P-wave transducer is spring loaded in the lower housing and is free to move approximately 15 mm which is measured by the lower laser distance transducer. The output of the two laser distance transducers provides the core diameter deviation reading in the MSCL Utilities software. The actual core diameter (thickness) is a function of both the core thickness deviation and the position of the upper motor housing.

During the automated logging procedure the user will be prompted to insert a reference piece between the transducers. It is important to make up reference pieces (from aluminium or plastic) that closely correspond to the size of core being logged.

For Whole cores:

Make a round bar, approximately equal in diameter (within 1 mm) to the nominal (outside) core liner diameter.

Split cores:

Make a semi-cylindrical piece to simulate the sediment or rock with the nominal or anticipated average core half-width. Fit this piece into a short length of split core liner.

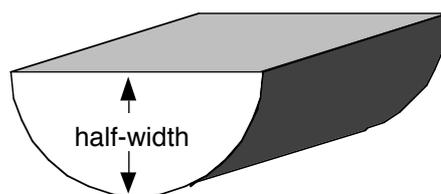


Figure 12-1. Core half width.

Split core logging (vertically arranged transducers)

- In this logging mode the vertical motor moves up and down between successive measurements. To ensure that the automated zeroing and measurement procedure works correctly during logging it is essential to carefully follow the set up procedure described below (in the latest version of the MSCL Software the user is prompted through this procedure for both split and whole cores).
- Put the "Auto/Manual" switch to "Manual" and the motor select switch to "Motor Z". Using the manual motor control raise the upper transducer to ensure that it is clear of the reference piece.
- Place the appropriate reference piece on the rails between the P-wave transducers. The reference piece must have a precisely known thickness. This thickness is entered in the "Processed Data Display" as the "Reference Core Thickness" value in order to accurately compute core thickness.

- Manually adjust the lower transducer housing so that the spring-loaded P-wave transducer is touching the lower part of the reference piece and adjust the upper housing so that it is approximately mid-way in its travel. This can be confirmed by watching the LCD core diameter deviation display (on MSCL serial numbers 1 through 38), observe the maximum and minimum readings and adjust so that the reading is approximately mid-way.
- Raise the motor so that it is well clear of the core

Whole core logging

With the reference piece in place, manually adjust the position of both P-wave housings transducer so that the P-wave transducer is approximately mid-way in its travel

Secure the position of the housings and leave in this position.

Use the test panel in the Utilities software (see Chapter 13) to check that the core thickness recorded is in agreement with the LCD (on MSCL serial numbers 1 through 38). Small differences can occur but it should be noted that the computer value is more accurate.

Calibration and Processing

The thickness of the sediment in the core is an important component parameter in the calculation of many logs. It is measured using the 2 laser distance transducers. In the case of whole cores the outside diameter of the core is measured and the sediment thickness is calculated by subtracting 2 * the liner wall thickness. In the case of split cores the half diameter of the core is measured and the sediment thickness is calculated by subtracting 1 * the liner wall thickness.

To ensure that the computer collects the correct number it is necessary to calibrate the digital output as follows.

The analogue voltage from the transducers is digitised in the electronics. Select 2 suitable round calibration bars of know diameter (with a difference in diameter of about 20 mm). Adjust the relative positions of the P-wave transducer housings such that both pieces can be placed between the transducers with them in contact.

Select [**Core Thickness**] from the test panel in the Utilities program. In the Logger Terminal panel a continuously updated display will show the digital value of core and the computed value of displacement (e.g. AD = 3130 Displacement = 6.17 mm). Secure the housings and place the smaller calibration piece between the transducers and note the AD value. Remove the smaller calibration piece and insert the larger piece and note the changed AD value.

The computed value of displacement $DISP(mm)=AD* DISP(scale)$

where $DISP(scale)$ is the value entered in the settings file. Typically this value will be about 0.002

Calculate $DISP(scale)$ using the difference between the two AD values collected above and $DISP$ (the difference in diameter of the 2 calibration bars in mm). Enter the new value into the settings file and check that the correct value of displacement is shown when the test is run again.

This calibration should not change over time as it is a function of the hardware in the MSCL electronics.

Core Thickness Data Processing

Having calibrated the displacement transducers the raw data provides the deviation in diameter between a reference piece of known thickness and the actual thickness at any point. The sediment thickness (which is the real parameter required) is therefore calculated using the following equation:

$$X = RCT - W + CTD/10$$

where:

X =	sediment thickness (cm)
RCT =	reference core thickness (cm)
W =	total liner wall thickness (cm)
CTD =	core thickness deviation (raw data, mm)

This equation is shown in the Sediment Thickness processing panel as shown below.

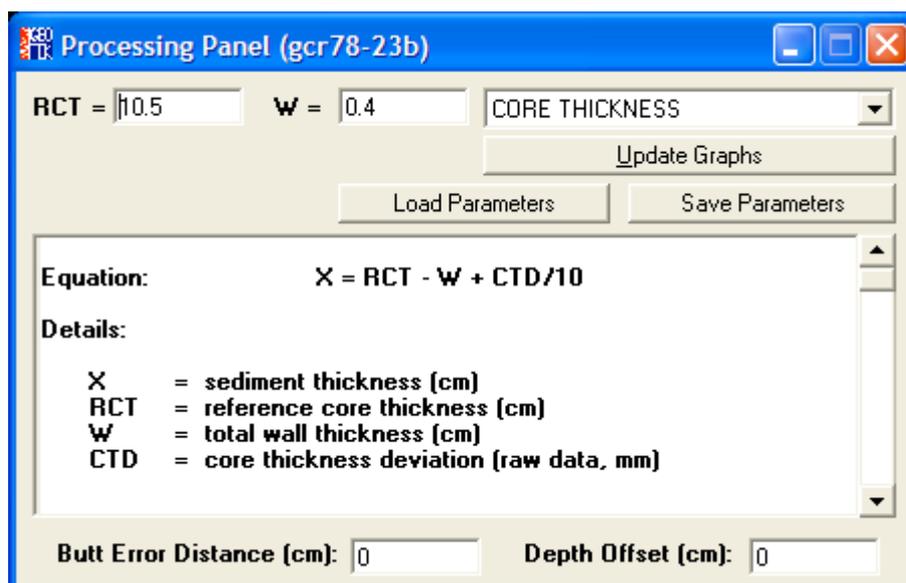


Figure 12-2. Core thickness processing panel.

The user enters the values of RCT and W in the boxes provided. Note that for whole cores $W = 2 * \text{liner wall thickness}$; whereas for split cores $W = 1 * \text{liner wall thickness}$. Having followed the above procedures the correct values of core thickness will be recorded, displayed and used to calculate other important parameters (e.g. P-wave velocity and gamma density).

13 - Temperature

A standard PRT (platinum resistance thermometer) probe is used to measure temperature. The probe is connected to a long flying lead that can be most conveniently inserted into the end of each core section as it is loaded onto the RH section. It is most important for accurate velocity measurements in sediments because velocity changes by approximately 3 m/s per °C. The temperature measurements are also used to calculate accurate electrical resistivity.

To test the thermometer place it in a beaker of water at a known temperature and use the test panel in the Utilities software (see Chapter 13) to check that the reading is accurate.

Calibration

The analogue voltage from the PRT probe/electronics is digitised through the electronics. When **[Temperature]** is selected from the test panel a continuously updated display is provided in the terminal window; for example:

```
AD = 10136      Temperature °C = 16.35
```

The output from the temperature probe is proportional to temperature. Therefore, to calibrate the temperature probe the user must obtain 2 AD readings (A_1 and A_2) at two known temperatures (T_1 and T_2). This is most easily done by inserting the probe in a beaker of water with a calibrated thermometer. The scale (S_t) and offsets (O_t) for the temperature probe must be entered in the 'settings file' and then the temperature output will be correct. This can be checked by observing the temperature reading when the temperature test is running.

$$\text{Temp} = \text{AD} * S_t + O_t$$

To calculate S_t & O_t use the following relationships:

$$S_t = (T_2 - T_1) / (A_2 - A_1)$$

$$O_t = T_1 - A_1 * S_t = T_2 - A_2 * S_t$$

This calibration should not change over time as it is a function of the hardware in the MSCL electronics.

14 - MSCL Software

Chapter Overview

This chapter provides detailed information on the different aspects of the main application program for the MSCL. It is aimed at the new and regular user who requires further detailed information on how the software operates.

The MSCL operating software is Windows™ based. It is a user-friendly application that can be configured to operate with all Geotek logging systems. If you are still using an older version, newer versions can be downloaded from the Geotek website. The main software controls the data acquisition process, stores the data, and presents the raw data graphically in real time. The user can also view and edit graphical processed data in real time and change the processing algorithms if required. Although data is normally presented graphically on the screen, tables of raw and processed data can be viewed and exported to other applications for further processing and for presentational purposes.

The same application can also be used to view and process previously collected data (old data).

In addition to the main operating and processing application there is an associated utilities program which is described in detail in Chapter 14. This enables the user to run tests of individual sensor systems and to set important configuration parameters specific to the users system. There is also a terminal mode option that enables the advanced user to edit/modify the software in the microprocessor.

The descriptions of the software in this chapter relate to the latest version of MSCL hardware so users without the latest hardware modifications should be aware of the protocols to be followed that are specific to a particular system. The most notable differences to the procedures described here are those relating to the laser detect system and how that affects the setting of the reference position.

Running the program

Click on **[Start]**, **[Programs]**, **[Geotek MSCL]**, **[MSCL x.y]** (where x.y is the version number)



Figure 14-1. Main Menu panel.

The Main Menu will appear as below providing the five menu items:

[Log New Core]

[Relog Old Core]

[View Old Data]

[Settings]

[Exit] (exit from application)

Log New Core

This is the normal starting position from the main menu when the user begins to log a core for the first time.

Enter new filename: The “Enter New Filename” panel will then be displayed. This prompts the user to enter the new core name and select the destination for the data to be logged. The last core logged is shown as a guide.

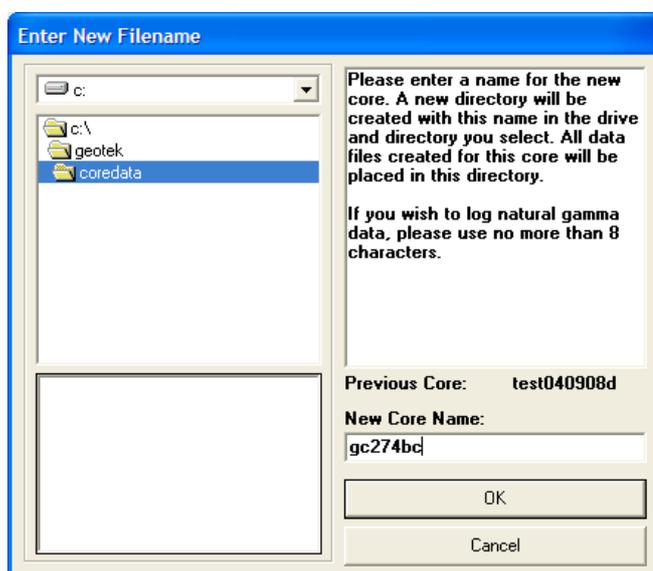


Figure 14-2. Enter new filename panel.

It is suggested that the user uses the following file structure:

C:\geotek\coredata\coredirectoryname

This is the directory in which all data relating to this core will be stored. Note that raw data is stored in a binary format and has the extension **.dat** after the filename. These data files can only be read by the application program. ASCII data files (which can be exported to other applications) of both raw and processed data can be created as described later.

Once selected the user should click **[OK]**.

If the filename you have chosen already exists you will be warned that the filename is already in use and that if you continue the old data will be deleted. Once the file name has been chosen the user will be presented with the configuration panel (see below).

Relog Old Core

This option should be chosen from the main menu if the program had to be stopped for any reason whilst a core was in the process of being logged but had not been completed. This option may be required under the following circumstances.

- Logging was aborted because of an operator error: e.g. a core section was logged out of order or the wrong way around.
- The user wishes to use a different logging configuration.
- A power failure or computer error occurred during logging.

After selecting **[Relog Old Core]** from the main menu the “Select Data File name” panel will be displayed. The user should select the file relating to the old core and click **[OK]**.

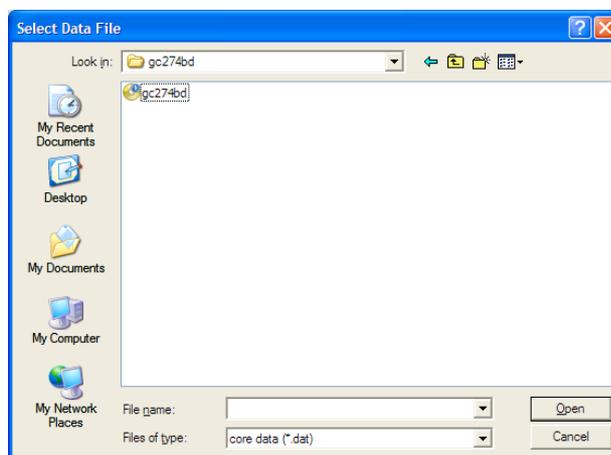


Figure 14-3. Select Data File (relog old core).

The “Raw Data Display” will then appear together with an information panel relating to the selected core that will help the user to select which section he/she wishes to restart the re-logging process.

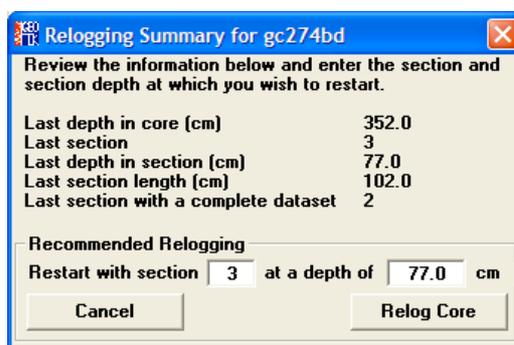


Figure 14-4. Relog old core panel.

WARNING

.....
**NEW DATA WILL OVERWRITE ANY DATA FROM CORE SECTIONS AFTER
 AND INCLUDING THE SECTION BEING STARTED FROM**

The user should decide at which core section and at what depth in that section that logging should begin and enter these values in the boxes provided. Click **[Relog Core]** when ready.

Logging will then resume in the normal manner.

The user will be asked to reset the reference position and zero the vertical motor if necessary before being asked to place the appropriate core section on the track.

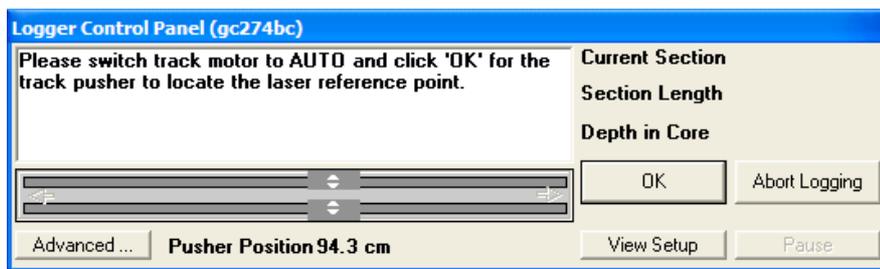


Figure 14-5. Logger control panel (set ref. point).

It is most important that the length of the section should match exactly the value as recorded previously. If in any doubt the user can look up the previously recorded by core length by using the **[View Setup]** button in the Logger Control Panel. Logging will then continue in the normal manner.

View Old Data

This option enables the user to view data sets collected and to process/reprocess the data. It enables data files to be created for export to other applications for either further processing or for presentation.

All the user must do is to choose from the Filename panel the core that he wishes to view. The raw data for that core will then be displayed.

Configuration Panel

The configuration panel appears between sections during the course of logging cores or when viewed by the user when **[View Setup]** on the logger control panel is clicked.

It enables the user to define exactly how each core section should be logged and when viewing old data enables the user to determine how the logging process was carried out. Within the panel the user can define which parameters are logged and at what spatial intervals. Note that different parameters can be logged at different spatial intervals. Below is a description of each box available to the user.

Figure 14-6. Configuration panel.

The configuration panel is split into 2 sections:

General Core Parameters: which refer to the complete core and

Sensor Parameters: which refer to the individual sensors and can only be edited between sections.

General Core Parameters

Core ID

This is the core identification label. As a default it is set as the same as the filename that the user chooses in the filename panel, but can be edited by the user. The core ID also acts as a security check because this name is

written inside all the data files and hence if the filename is accidentally changed then its identification can still be established.

Comments

This is a simple text box in which the user can enter or edit comments regarding the core being logged at almost any time during the logging process. It enables notes to be kept regarding the core that is being logged which can be seen when the data is being viewed at a later date.

Nominal section length

Each core section is pushed through the sensors to the left. When the core pusher reaches the reference position it automatically moves to the right enabling the user to insert the next section. The distance that the pusher moves to the right is set by the 'nominal section length'. Normally this can be set as 150 or 100 cm (depending on what length the core sections are normally cut). However, if the sections are of variable length then this parameter can be changed each time a new section is loaded. When the pusher moves to the right, to enable the next core section to be loaded, it moves the nominal section length plus 2 cm to provide room to load the section easily and to allow for the fact that each section may not be cut to the exact length.

Section Position Warning Pause

This will enable the feature of the software that checks the progress of sections along the track and when a section reaches a predetermined position the software will pause. A window will also appear showing the section positions on a diagrammatic track.

Log Initial Calibration Piece

The protocols for calibration are discussed in a separate section. However, it may often be desirable to use a calibration piece to check that the sensor systems are functioning correctly at the beginning of each core. If the box is clicked then the software assumes that the first section placed on the track is a calibration section. Note that its length is determined automatically (see below). As with the "logging before core" facility (see above) the data obtained from the calibration section is assigned a negative sub-bottom depth and is distinguished on the graphical display by the use of a different colour.

Sensor Parameters**Section No.**

The number of the next section to be loaded onto the track is displayed in this box. If a calibration section is to be logged first then it will read 'cal'. Note that the software always assumes that core sections are logged in order starting with section 1.

Sampling Interval

This number is set by the user and determines the distance between successive sampling points along the core. If variable sampling has not been selected (see below) then all selected parameters will be measured at this sampling interval. The number can be set to within 1 mm. However, the user should note that some sampling intervals are much more time efficient than others because of the spacing of the sensor systems. The sensors are normally spaced at multiples of 2 cm apart from each other. Consequently it is advisable to use the following sampling intervals for maximum time efficiency; 0.1, 0.2, 0.5, 1.0 or 2.0 cm.

Core Depth

The user can enter the real depth for the top of any section as it is logged. This real depth value is used to populate the Edit Depths table accessible from the processed data display (see below) and when activated will plot the data from each section at the depth entered here. By default the depth at the bottom of the previous section is automatically entered.

Variable Sampling

If this box is selected the user can choose different sampling intervals for each sensor selected. This is a valuable facility when the user is balancing the time taken to log a core with the resolution required from different sensors. The set-up button is activated when variable sampling is selected and when clicked the Variable Sampling Set-up panel is displayed (Figure 14-7).

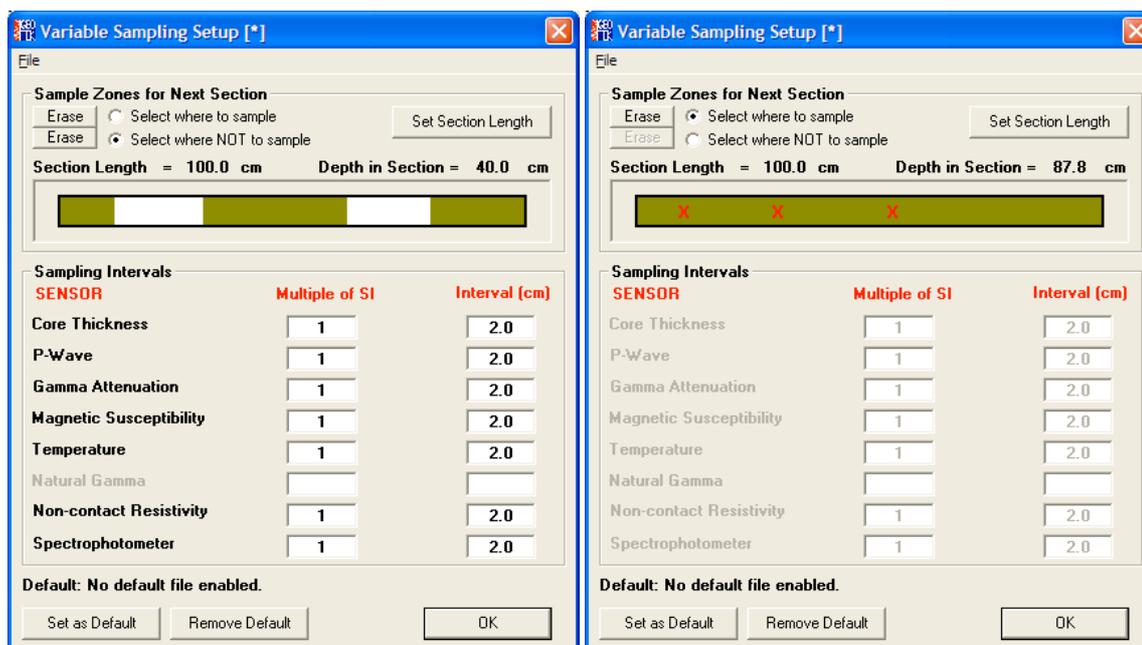


Figure 14-7. Variable sampling Setup panel.

The “sample zones” section at the top of the panel allows the user to select areas of the core in which no data are to be collected or discrete points for data collection. The section length is set as the nominal section length by default but this can be changed using the **[Set Section Length]** button. It is best to set the section length greater than the actual section length. To define a skip zone click the mouse at the start or end position using the numeric display for a position guide and release the mouse button at the other end. To set the skip-zone the user must then click in the brown coloured area. A dialogue box will appear prompting the user for precise start and end points. After clicking **[OK]** the skip sample zone will be set and become white in colour. Alternatively the user can select discrete points at which to take readings. The user must click approximately where a sample should be taken and a dialogue box will appear prompting for an accurate position. Click **[OK]** and a red cross will appear at the selected position.

To define a skip zone at the end of the section then the user should set the section length longer than the section itself and define a skip-zone from the start point required all the way to the end the section. The software will then set the skip-zone to the end of the section as measured by the logger.

The lower sampling intervals area shows the sensors that are available and have been selected.

When variable sampling is selected the sampling interval (SI) set in the configuration panel becomes the minimum sampling interval available for any sensor. All other sampling intervals are multiples of this minimum sampling interval. In this way the time efficiency for the logging process is optimised. The sampling interval for any sensor is set either by selecting and editing the “Multiple of SI” or selecting and editing the “Interval (cm)”. If the interval chosen is not an exact multiple the nearest exact multiple will be substituted. When the selection is complete click **[OK]**.

It is possible to define a variable sampling regime for each section by choosing where or where not to sample and then selecting **[Set as Default]**, the chosen regime will then be used for all subsequent sections after the user has saved the sampling template to a variable sampling file (*.vsf). The feature can be disabled by clicking **[Remove Default]**.

Sensor Selection

The remainder of the panel shows the sensors available. The available sensors are defined by the logger settings facility (see Chapter 15). Available sensors are shown in red with the offset from the reference position shown in a tool tip if the mouse is held over the sensor name. If a sensor is unavailable then it is shown in grey and that part of the panel is inactive. Any available sensor can be turned on or off simply by clicking on the adjacent buttons. Some sensors also require further settings information and the user can define these sensor specific parameters in

the boxes provided as described below. Note that the settings used are applicable to the 'Section No' displayed and can be changed for other sections if required.

Gamma attenuation 'Count Time' is the time in seconds for which gamma photons are counted at each sampling point. Note that the precision with which gamma density is measured improves with longer count times but the overall logging time increases. A compromise value must be chosen which is described in greater detail elsewhere. A sensible minimum practical count period for most applications is probably 4 seconds.

In the Magnetic Susceptibility panel either a point sensor or a loop sensor can be used (as set in the settings file). The 'Sampling Time' should be set the same as the setting on the Bartington MS2 meter. Note that on the Bartington meter the sampling interval is given in Hz; so 1 Hz is equivalent to 1 s and 0.1 Hz is equivalent to 10 s. The user should also set the units used (SI or cgs) to be the same as set on the Bartington meter. If the sensor is a loop then the user should also set the distance before the core that the loop is zeroed. Typically this should be about 10 cm.

In the Electrical Resistivity panel the user should also set the distance before the core that the sensor is zeroed. Typically this should be about 10 cm.

For the Spectrophotometer the user should set the target mask used (MAV or SAV) and choose is Munsell colours are to be acquired as well as the colour spectra. The **[Show Setup]** button gives access to the calibration features of the spectrophotometer (see Figure 13-10) and allows test measurements to be made.

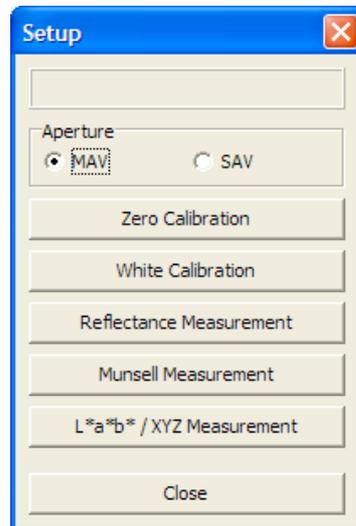


Figure 14-8. Spectrophotometer setup window.

Once the user has completely defined how the first section is to be logged by editing the configuration panel then under normal circumstances the user should click **[OK]**. However, if it is required to save the set-up, but to quit the application, then click **[Save Changes + Quit]**. The filename and configuration parameters will appear as defaults the next time the application is opened. If **[Cancel]** is chosen then all changes will be lost. Note that this configuration panel can be viewed at any time during the logging process to enter comments in the text box or simply to review the information that has been entered.

Logger Control Panel

This panel is used to control the logging process once the configuration panel has been completed. Within this panel the user is informed about the current status of the system and is prompted to perform actions by messages in the central panel. When it is first activated communications are established with the microprocessor. The user is prompted by messages to start the logging process.

Zeroing the Vertical Slide/Motor

It is necessary at the beginning of logging a new core to ensure that the computer 'knows' the position of both the main core pusher and the vertical motor.

Assuming that the displacement transducers have already been calibrated (see Chapter 12) then all the user should do is place the reference piece between the correctly positioned transducers and click on the **[OK]** button as instructed.

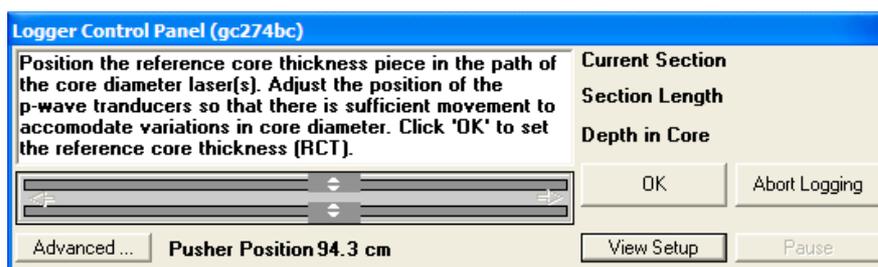


Figure 14-9. Logger control panel (zero vertical motor).

At this stage the Excursion Distance panel will appear:

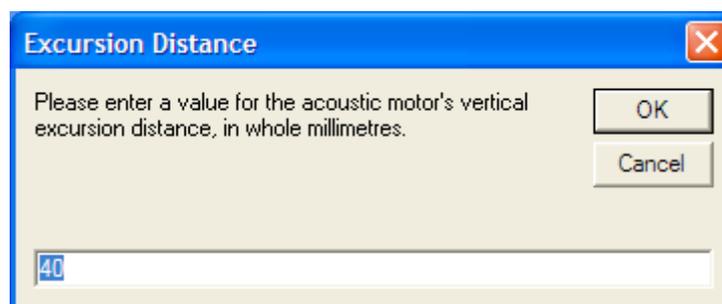


Figure 14-10. Excursion distance panel (vertical motor).

The user should enter the vertical excursion distance and click **[OK]**. The transducer housing will then automatically move up to its rest position with the upper P-wave transducer, MS point sensor and spectrophotometer (if fitted) clear of the core.

Note that this procedure can be recreated at any time during the logging process by clicking **[Advanced...]** in the logger control panel. The **[Set Zero]** option will then be available.

A micro switch limits the maximum vertical motion of the P-wave transducer, in its housing. This protects the core from being damaged by the upper P-wave transducer. In normal operation this limit switch will not normally activate (even with quite rough surfaces if the auto adjust feature (see next section) is on. If it does activate for any reason then the positional reference of the transducers will be lost and the user must 're-zero' the vertical slide as described above.

Locate Reference Point

It is necessary at the beginning of logging a new core to ensure that the computer 'knows' the position of both the main core pusher and the vertical motor. After setting the RCT the next message to appear is to set the track reference point.

The user should follow the instructions and switch the track motor to Auto and click **[OK]**. The pusher will then move to the left until the laser detect system detects the pusher. The pusher will then move to the right and start moving to the left in 0.1 mm increments to accurately position itself. To reduce the time this takes the user can manually move the pusher close to the laser detect system.

It is possible to bypass this procedure by using **CTRL-S** from the keyboard. However if the user does this he should check that the actual position of the pusher is the same as that shown by the logger control panel. This can be done by using the manual control to move the pusher to the position shown in the panel and then returning to 'Auto' control, or by using the Advanced Panel to set the track position in the software.

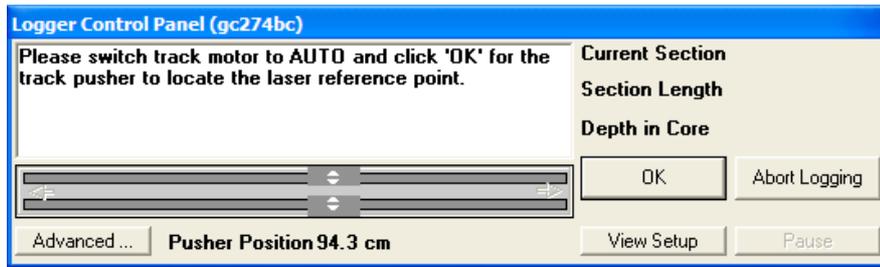


Figure 14-11. Logger control panel (set ref.).

Core Pusher Scroll Bar

The next message to appear is

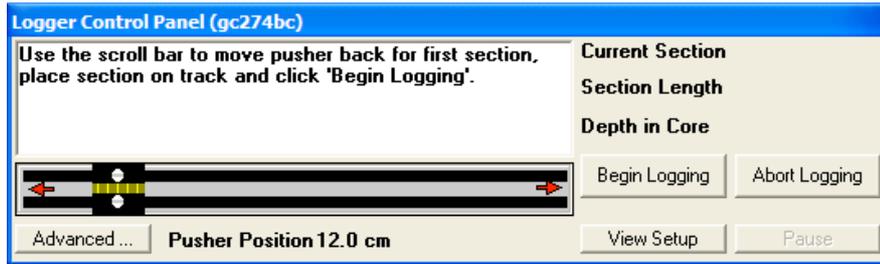


Figure 14-12. Logger control panel (scroll bar and nudge pusher).

The horizontal core pusher scroll bar represents the pusher on the rails; the exact position at any time is shown numerically beneath the scroll bar. The pusher can be moved in this automatic mode either by:

- I. Clicking on the end arrows. This moves the pusher in 2 mm increments.
- II. Dragging the pusher along the scroll bar to a set position. To 'pick up' the pusher click anywhere on the scroll bar (apart from on the pusher itself) and hold down the button. Drag the pusher to the required position and release the button.

There is sometimes a short delay before the pusher moves as an acceleration routine is computed.

Using the above controls the user has complete control of the pusher from the screen and should move the pusher back to a distance just greater than the length of the first or calibration section. If a mistake is made then the user can press the **ESCAPE** key while the mouse button is still pressed down and the pusher will stay in its original position. Position the LH edge of the core such that the laser detect system is not obscured. Note also that the length of the RH track section is set as a parameter in the settings file (see Chapter 13).

Note: Ensure that the motor is put in the "Auto" position prior to moving the pusher with the scroll bar. Failure to do this will mean that the microprocessor loses its reference position and the logging process must be re-started from the beginning.

Begin Logging

Assuming that all the pre-logging checks have been made and that the sensor systems are suitably calibrated then logging can begin. Click the **[Begin Logging]** button in the Logger Control Panel and the configuration panel will be displayed again. This enables a final check on all the settings to be made before logging begins. Final changes can be made or comments added at this stage. Click **[OK]** when ready and the logging process will begin.

The Logger Control Panel will remain active (showing when the data is being acquired) until at least 2 data points have been obtained. The panel also provides continuous information on the status of the logging process; Current Section No., Section Length, Depth in Core and Current Sample No.

When the logging process has begun the "Raw Data Display Panel" will appear showing the graphical representation of the data as it is collected. For a full description of the features and options in the raw data panel.

When the pusher reaches the reference position it will automatically check its position using the laser detect system and return to the nominal core length position (plus 2 cm). The user will then be prompted to place the next section on the track and can click **[Continue]**.

Pause, Abort and End Logging

During the logging process the user can pause the complete operation by clicking **[Pause]** on Logger Control Panel. Logging will pause after the next set of data has been acquired. The user then has the choice to either click **[Abort Logging]** from the Logger Control Panel or to click **[Continue]**.

The logging process will continue until:

- I. It is aborted (as described above)
- II. The user clicks **[End Logging]** or **[Abort Logging]** on the Logger Control Panel. Note that this option is only available between sections or when the logging operation is paused.
- III. The Maximum Core Length (as defined in the 'Edit Configuration Parameters' panel) is reached.
- IV. The section designated as the last section has moved past the last sensor.

The Advanced Panel

The **[Advanced...]** button on the Logger Control Panel is only active when the pause button has been activated or between core sections and brings up the Advanced Panel (see Figure 13-15). This advanced panel enables the user to;

- I. recover from inadvertent mistakes made during logging
- II. change certain settings
- III. test/adjust sensor systems without disrupting the logging process

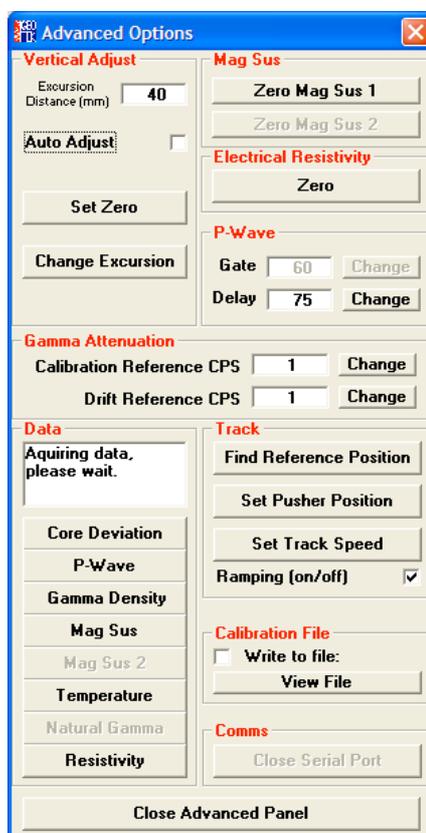


Figure 14-13. The Advanced Panel.

Horizontal/Vertical Adjust

This region of the panel refers to the adjustable sensors, namely the P-wave transducers, the displacement transducers and the Magnetic Susceptibility Point sensor. If the vertical motor is checked in the settings file then the software assumes that the logging is taking place vertically through either a whole core or a split core and the region of the advanced panel is labelled Vertical Adjust. Otherwise the software assumes the transducers to be 'looking' horizontally through a whole core and the region of the advanced panel is labelled Horizontal Adjust.

The excursion distance (*i.e.* the distance the motor moves up away from the core between successive readings) is shown in the top box. This value is normally set at the beginning of the logging process but can be altered at any time the logging process is paused by accessing the advanced panel and clicking on the **[Change Excursion]** button.

The zero position of the transducers is set at the beginning of the logging procedure but once again this can be altered at any time the logging process is paused by accessing the advanced panel and clicking on the **[Set Zero]** button.

If the **[Auto Adjust]** box is checked then the vertical motor will make adjustment in its rest position to accommodate any major changes in core thickness (>5 mm). In this way there is no chance of the slow but large changes in thickness causing the transducers to reach the end of their maximum travel.

Warning: If there are large gaps in the core the Auto Adjust' feature will attempt to find a core sample at the bottom of the liner and will lose its reference position/and or crash into the core when it encounters core after the gap. If in any doubt do not check this box as under most circumstances it is not necessary.

Data

This region of the panel enables the user to command any of the sensors to acquire data outside the main logging program simply by clicking on the appropriate button. The retrieved data is displayed in the top dialogue box. It operates in a similar mode to the 'Test Panel' in the MSCL Utilities program except that it is not continuous it simply collects a single data value.

Mag Sus

This enables the user to zero the MS meter at any stage during the logging process.

Electrical Resistivity

This enables the user to zero the Electrical Resistivity meter at any stage during the logging process.

P-wave

This enables the user to change the values of gate and delay (displayed in micro seconds) at any time during the logging process. The initial values are taken from the values provided in the settings file. Note that the values in the settings file are not altered by changing the values in the Advanced options panel and hence when a new core is logged the values will revert to those saved in the settings file. Note also that this region is active only if the 'Software Gate and Delay' in the settings file is activated. This should always be yes on MSCLs serial #39 through 103 and higher as on these systems the thumbwheel switches for these functions have been removed. On MSCL serial #104 and above the Gate is no longer required.

Gamma Attenuation

This enables the user to change the values of the calibration reference and the drift reference counts per second values used to correct the gamma attenuation data for drift. Note that the values in the settings file are not altered by changing the values in the Advanced options panel and hence when a new core is logged the values will revert to those saved in the settings file.

Track

This enables the user to re-synchronise the software with the track pusher in the event that there has been a problem e.g. the user had the switch in manual mode when it should have been in auto or if the pusher met an obstruction during logging and the motor stalled. **[Find Reference Position]** should be clicked when the user has manually moved the pusher to the reference point. **[Set Pusher Position]** should be clicked when the user

wishes to synchronise the pusher with the logging program. Note for the logging program to continue to operate correctly the pusher position must be set at the position shown in the Logger Control Panel. The **[Ramping]** check box turns the automatic motor ramping routines off. **[Set Track Speed]** allows the user to change the speed of the track motor.

Calibration File

This enables the user to write test information to a file at any time during the logging process. If the **[Write to file]** box is checked then data collected by clicking in the Data panel or the Mag Sus region can be written to a separate file which can be used later during data processing. The user can choose how it is written as a dialogue box appears before being written to file. It will be particularly useful for correcting any drift that occurs in the magnetic susceptibility and attenuated gamma data sets. The file can be viewed by clicking the **[View File]** button and can be found in the core directory with the same name as the core-ID and a *.cal extension.

Comms

The **[Close Serial Port]** button closes the serial port being used by the program enabling another program to use the serial port if needed (e.g. the MSCL Utilities program).

Section Positions

The section positions window appears when the user selects this option in the configuration panel. This window shows a diagrammatic track and the progress of sections along it.

From the right of the window sections appear in yellow as they are logged (see Figure 13-16). The solid white line represents the track reference point, the start of the light green area the last sensor on the track and the end of the dark green area defines the point at which the system will pause when the start of a section reaches it. All of these positions are defined in the track settings (see Chapter 13).

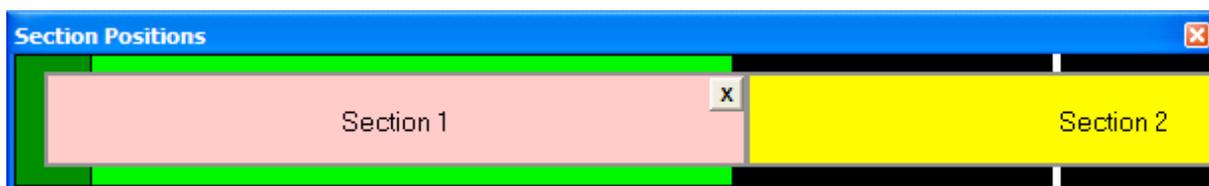


Figure 14-14. Section positions window.

If a section has finished being logged (*i.e.* the bottom has entered the light green area) then section colour will change to blue indicating that it is safe to remove the section from the track. If the section is not removed in software then the system will pause logging when it reaches the end of the dark green area.

Once the top of a core section enters the dark green area the section will turn red to indicate that action will soon be required. Obviously it is important the the section has finished being logged but once this has happened the user can move the mouse over the section and click on the **[X]** that appears. The software will then assume that the section has physically been removed from the track.

Graphical Data Displays (Raw & Processed)

The graphical displays of data can be viewed either while the data is being collected or subsequently when viewing old data. This section describes the facilities for viewing and manipulating data. Raw and processed data are displayed during logging, but the user may also review and process/reprocess data from the files of previously logged cores. A full description of the features available within the data display panel is given in the following sections.

Raw Data Display

The raw data display panel appears automatically when logging cores or when old data is selected. It consists of a series of columns that plots the various raw data collected against a vertical depth scale. Raw data is the primary data collected from the different sensors. For example; core diameter deviation, P-wave travel time and attenuated gamma counts per second. An example of a typical raw data display is shown in Figure 13-17.

The size of the panel can be changed in the normal way by either clicking on the buttons in the top RH corner or by dragging on the bottom LH corner or on the sides of the panel. Unlike the processed data the raw data cannot be edited or modified in any way.

On line information:

Along the bottom edge of the display a series of parameters provides the user with on-line information. This information refers to the position of the cursor arrow on the screen. The parameters are:

[Sect] refers to the section number. For example [2 of 6] means that the arrow is located within data collected in Section 2 and there are a total of 6 sections of data available.

[Depth] refers to the depth in the current section. For example 83 cm means that the arrow is located at a position 83 cm down from the top of the current core section.

[SBD] refers to the Sub-Bottom Depth. For example, 3.27 m means that the arrow is located at a position 3.27 m down from the top of the core (top of section 1).

[Val] refers to the value of the parameter. For example if the arrow is located in the Attenuated Gamma column and Val = 17560 then this means that the value of gamma counts at the position of the arrow is 17560 CPS.

This interactive row of data relating to the position of the mouse arrow is very useful when examining data in relation to the core itself. For example from the data obtained the user may wish to either visually examine the core in the area of interest or take a sub sample for other analysis. All that is necessary is to point to the area of interest and the on-line information will provide the use with the information required to locate the region with an accuracy of better than 1 mm (depending on the scale at which the display is shown).

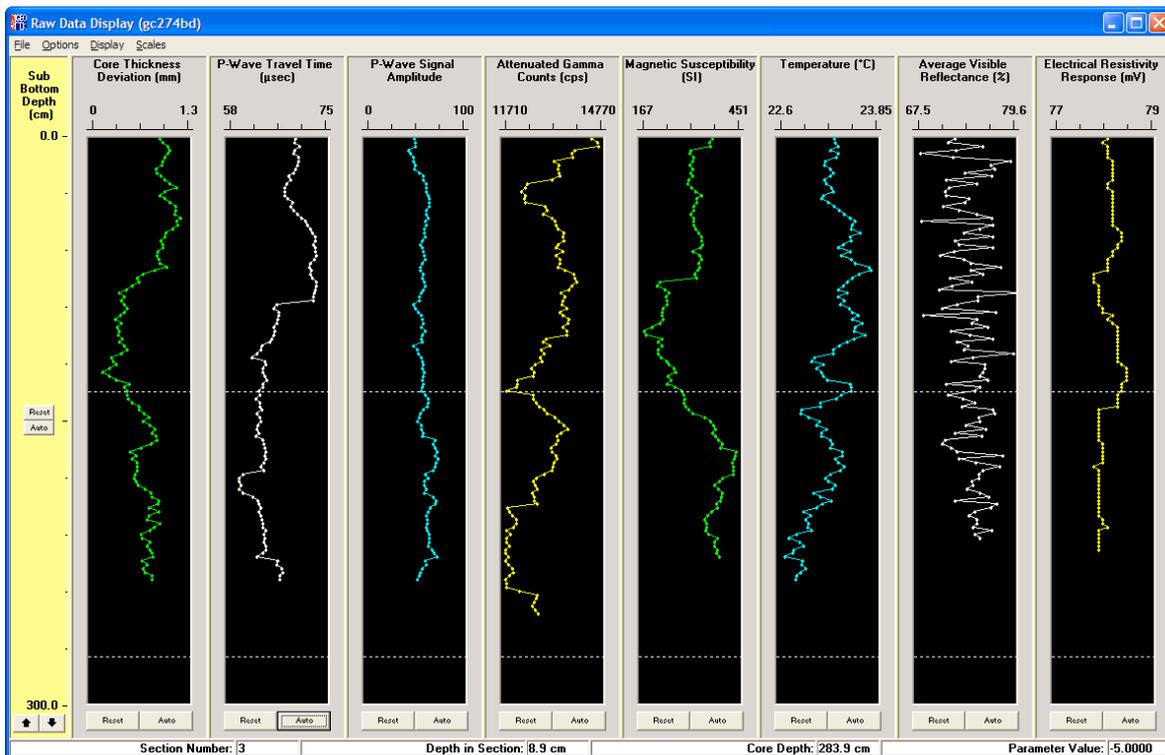


Figure 14-15. Raw data display panel.

Processed Data Display

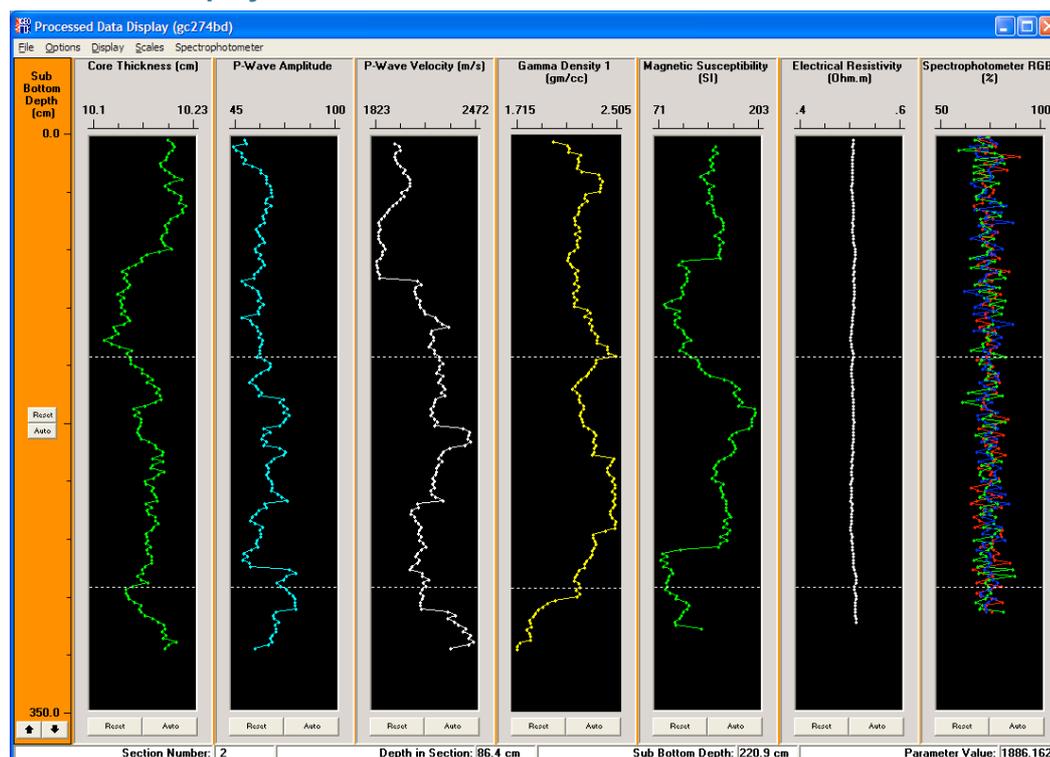


Figure 14-16. Processed data display panel.

The processed data display is accessed from the raw data display from the pull down menus by choosing **[Options - Processed Data]**. It consists of a series of columns that plots the calculated processed data against a vertical depth scale. Processed data is calculated from the raw data and calibration constants entered by the user (see Chapters 5 to 11). An example of such a display is shown in Figure 13-18.

This panel is very similar to the raw data display in the options available with one or two exceptions that are detailed later in this chapter. Unlike the raw data the processed data can be altered by changing the processing parameters or can be edited to remove bad data points.

At the bottom of the panel there is a line of parameters providing on line information which relate to the position of the mouse arrow on the screen in the same way as with the raw data display.

Changing Scales

When the graphical data display panels first appear they are presented at the scales last saved as default values (see later in this section). This format can easily be changed by the user in a number of ways.

Auto Scaling

To adjust the scales to fit the data available click on the **[Auto]** button in any of the individual graphs or on the sub-bottom depth scale. When **[Scales - Auto Scaling - Include deleted points]** is chosen the auto scaling function either includes or excludes the deleted points depending on the users selection

Clicking on the axis

To adjust either the vertical sub-bottom depth scale or any of the horizontal sensor parameter scales simply click on the axis of the scale to be changed. A dialogue panel will appear as shown in Figure 13-19.

This prompts the user to insert new Minimum and Maximum values as required. Click **[OK]** when ready and the graph or graphs will be re-plotted at the new scale. Note that changing the sub-bottom depth scale effects all the graphs whereas changing the sensor parameter scales only effects the parameter of interest.

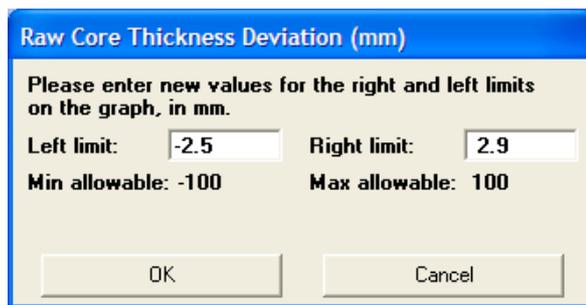


Figure 14-17. Change graph axis panel.

Zooming using the Mouse

An alternative method for looking in detail at one particular data set is to zoom within the data set of interest. To do this the user must place the arrow at one corner of an imaginary box, which encloses the data of interest. Click and drag the mouse over the area of interest (an active box will appear to guide you). When the selection has been made release the mouse button and click inside the drawn box. To cancel the operation click outside the drawn box. The graph will be re-drawn according to the box you have selected. Note that this operation changes both the sensor parameter scale in the chosen box and the Sub-Bottom depth scale. Consequently any other parameters that are displayed will also be re plotted according to the new sub-bottom depth scale.

Scrolling data

By clicking on the **[Up]** and **[Dn]** arrow buttons at the base of the Sub-Bottom Depth scale the user can scroll rapidly through the complete data set. The rate at which the scrolling occurs depends on the range between Min. and Max. depths. Note that when the maximum sub-bottom depth exceeds 1000 cm then the scale changes from cm to metres.

Setting default scale values

To make the current limits on the graphs the default for that display, the user must select **[Scales_Set Current As Default]**.

When the user subsequently changes these scales they can be reset by the following commands:

[Scales_Reset All Scales]: which returns both the sub-bottom depth scale and the parameter scales to the default value.

[Scales_Reset Vertical Scale]: which returns only the sub-bottom depth scale to the default value (leaving the parameter scales unchanged).

Alternatively the user can click on the **[Reset]** button at the bottom of each graph which will return the parameter scale of that graph only to the default value. Note that the default scale values last set will be the scale values saved and used when the file is reopened. Scales can also be changed by using the pop up menu that is enabled by right clicking over the graph with the mouse.

Display

Clicking on **[Display]** provides a list of the available graphs.

To select which graphs are displayed the user simply clicks to turn them on or off. Alternatively click on **[All]** to display all the graphs available. If there are more graphs available than will fit in the window the software will automatically limit the number of displays but will start with the first graph selected.

To view a single data set the user can simply click on the title above the appropriate graph. This will expand the graph to fill the available window. To return to the multi-graph display use the **[Display]** menu.

A pop-up menu can be used to access the commands in this menu item. This is accessed by right clicking inside a graph frame with the mouse.

File_Create ASCII File

To create an ASCII file of either raw or processed data (for export into another application) select **[File_Create ASCII File]**. A dialogue box will appear prompting the user to name the file and its destination. Note that the default convention for ASCII files is:

Raw Data - corefilename.raw

Processed Data - corefilename.out

The content of the ASCII file is identical to that viewed by using the Table command.

Options_Plot Style

By default the graphs consist of plots with lines only. By selecting **[Plot Style]** the user can choose either lines or points or both. Points can be very useful when viewing in detail a small number of data points but note that the screen refresh rate is much slower when large number of points are used. In both the raw and processed data displays the user can now choose the size of the data points displayed (three choices 1,2, or 3).

Options_Show Section Breaks

It is often useful when viewing the graphs to be able to distinguish where the breaks between each section are. To do this select **[Options_Show Section Breaks]** and a light broken line will be shown horizontally on all graphs at the section break positions. Select **[Options_Show Section Breaks]** again to turn the lines off.

Options_Show Hidden Points

This option can be used to show the points deleted by the user (in the Processed Data Display). These are shown in purple dots.

Options_Correlation Line

It can also be useful when viewing a number of graphs to be able to correlate accurately between different graphs. The **[Options_Correlation Line]** command draws a light red line horizontally across all of the graphs. To adjust the line up and down use the **U** and **D** keys on the keyboard. Select **[Options_Correlation Line]** again to turn the line off.

Options_Table

To view the data being displayed graphically (either in the raw or processed graphical displays) select **[Options_Table]**. A table of data will be generated which is identical in content to the files that are created using the **[File_Create ASCII File]** command. An example of a data table is shown in Figure 13-20.

The user can [page up] or [page down] using the buttons provided. Alternatively to start the table from a depth other than zero, type a value in the 'Start Depth' text box and press **ENTER**. Use the scroll bar to look through the data as required.

Sub-Bottom Depth (m)	Section	Depth in Section (cm)	Core Thickness Deviation (mm)	P-Wave Travel Time (µsec)	P-Wave Signal Amplitude	Attenuated Gamma Counts (cps)	Magnetic Susceptibility (SI)	Temperature (°C)
0.000	1	0.00	-0.01	32.31	0.1962	123	-0.5	24.1
0.020	1	2.00	-0.03	46.43	0.1420	126	-0.2	24.1
0.040	1	4.00	-0.02	33.60	0.1715	116	-0.2	24.1
0.060	1	6.00	0.02	47.44	0.1558	116	-0.2	24.1
0.080	1	8.00	0.05	35.59	0.1702	128	-0.2	24.1
0.100	1	10.00	0.04	47.20	0.1638	145	-0.3	24.1
0.120	1	12.00	0.03	39.44	0.1596	142	-0.4	24.1
0.140	1	14.00	0.03	34.21	0.1584	132	-0.5	24.1
0.160	1	16.00	0.02	39.20	0.1263	138		24.1
0.180	1	18.00	0.03	33.97	0.1463	137		24.1
0.200	1	20.00	0.03	48.72	0.1874	131		24.1
0.220	1	22.00	0.07	34.22	0.1046	143		24.1
0.240	1	24.00	0.07	34.94	0.1098	156		24.1
0.260	1	26.00	0.06	32.29	0.1092	164		24.1
0.280	1	28.00				130		
0.300	1	30.00				127		
0.320	1	32.00				132		

Figure 14-18. Raw data table panel.

Options_View Setup

To view the configuration panel of the core being logged or viewed select **[Options_View Setup]**. To look at the set up parameters for different sections enter the required section number in the Section Number box. The comments box can be edited at any time even when viewing old data.

Editing Data (processed data only)

Hiding points

Data points can be hidden from the processed data display and the associated output file 'Filename.out'. Click on the processed graph to be edited and drag a box around the points to be hidden. The points inside the box will appear highlighted. To hide these points, click inside the box while holding down the **SHIFT** key. To cancel the operation click outside the box. A warning message will appear to confirm your actions. Hidden points will not be plotted and they are replaced in the data table with the label "DELETED". In the exported processed data file, hidden points are replaced with empty cells.

Replacing hidden points

Points that have been hidden using the above process can be replaced. Click and drag a box on the graph of interest across the area where the points are missing. To replace hidden points click inside the box while holding down the **CTRL** key. To cancel the operation click outside the box. A warning message will appear to confirm your actions.

Saving a record of hidden points

When closing the processed data display the user is prompted to save a record of the points hidden such that when the data is loaded in the future the data points remain hidden. The record of hidden points is stored in a file in the core directory (with the same name as the core-ID) with a *.del extension.

Edit Depths

In the processed data display the user is able to shift the data up and down the depth scale using the Edit Depths feature. After selecting **[Options_Edit Depths]** a dialogue box will appear that has two columns, one labelled 'Original Depth' and the other 'New Depth'. By default the original depth column will be filled with the tops of each section and the new depth column with the 'Real SBD' as entered in the setup panel when the core section is put onto the MSCL. All depths should be entered in centimetres. The two radio buttons elect which set of data to use on the plots.

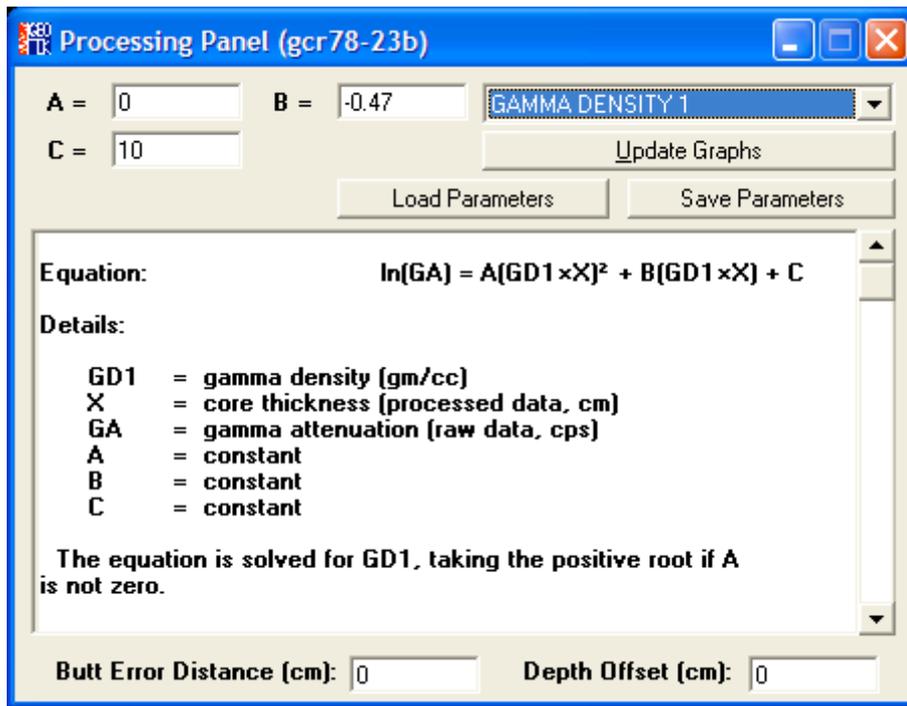


Figure 14-20. Gamma density processing panel.

Within each panel the governing equation is displayed together with a short-form explanation. At the top of the panel there are text boxes which can be edited by entering the correct calibration constants. A detailed explanation of all the processing panels is given in Chapters 5 to 11.

In all the processing panels there are 2 text boxes at the bottom of the panel that relate to the depth calculation. The Butt Error Distance refers to the thickness of the core end caps. Obviously the core is longer by the accumulated error of the end caps and the user can correct for this error by assuming that all the end caps have a constant thickness. If a value is entered then any data that falls in the end-cap thickness is deleted from the processed data set and the sub-bottom depth is adjusted accordingly. The Depth Offset value refers to the estimated real depth of the top of Section 1. Obviously if the top of Section 1 has a depth of zero then 0 should be entered in this box.

To re-plot the data according to the values entered in the processing panel select [**Update Graphs**].

The [**Load Parameters**] and [**Save Parameters**] buttons can be used to load and save sets of processing parameters. The parameters are viewed and can be edited in a dialogue box as shown in Figure 13-23. The files are saved with a *.pro extension.

Processing Parameters

Sediment Thickness
 RCT = 10.5 W = 0.4

Magnetic Susceptibility
 A = 1 B = 0
 Den = 1 LD = 0

P-Wave Amplitude
 A = 1 B = 0

Fractional Porosity
 MGD = 2.65 WD = 1.026

P-Wave Velocity
 PTO = 18.05 T = 20
 S = 0 D = 0

Electrical Resistivity
 A = 0.5 B = 1
 ρ = 0

Gamma Density 1
 A = 0 B = -0.47
 C = 10

Save Parameters Cancel

Figure 14-21. Save/Load processing parameters. All the parameters are shown and are user editable.

Other Displays

As sensors have been added to the MSCL extra features and displays have been added to the MSCL software interface.

Spectral Data

The spectral data from the spectrophotometer is displayed in a separate window as shown in Figure 13-24. On initial display only the spectra are displayed but it is possible to view a line and a block chart of the data. See Chapter 10 for discussion of XRF data display options.

The collected spectra are plotted at the depth they were taken with, by default, the zero point for the vertical axis (zero reflectance) set at the same level as the depth at which the spectrum was collected. The vertical scale for the spectrum itself is arbitrary but can be exaggerated and distributed around the depth of collection for ease of viewing. A right click on the spectrum chart will bring up the following options in a contextual menu:

- I. Data Scale - Spectrophotometric data is plotted at an arbitrary scale. Use the Data Scale option to increase or decrease the vertical exaggeration.
- II. Auto Offset - The default setup for the spectrophotometric data places zero intensity for each spectrum at the depth of collection. Auto offset centres the spectrum around the depth at which it was collected, making the graph easier to read.
- III. Measurement type - This option allows you to specify which of the spectrophotometer measurement types is displayed: SCI, SCE, SCI cut, or SCE cut (SCI/SCE: specular component included/excluded; 'cut' truncates the ultraviolet region of the graph).
- IV. Data reduction - This option allows you to reduce the number of spectra displayed for improved performance or clarity. The data are not erased from the data file.
- V. Mode - Colour Display shows each data point plotted with the correct colour; Simple Display shows a single colour. Switching into Simple Display improves performance and should be used in combination with Data Reduction.
- VI. Show Line Chart - Displays the Reflectance Line Chart (see below).
- VII. Show Block Chart - Displays the Reflectance Block Chart (see below).
- VIII. Show Data - This shows the spectrophotometric data in the form of a table. This option should not be used while acquiring data, as it may slow logging considerably.

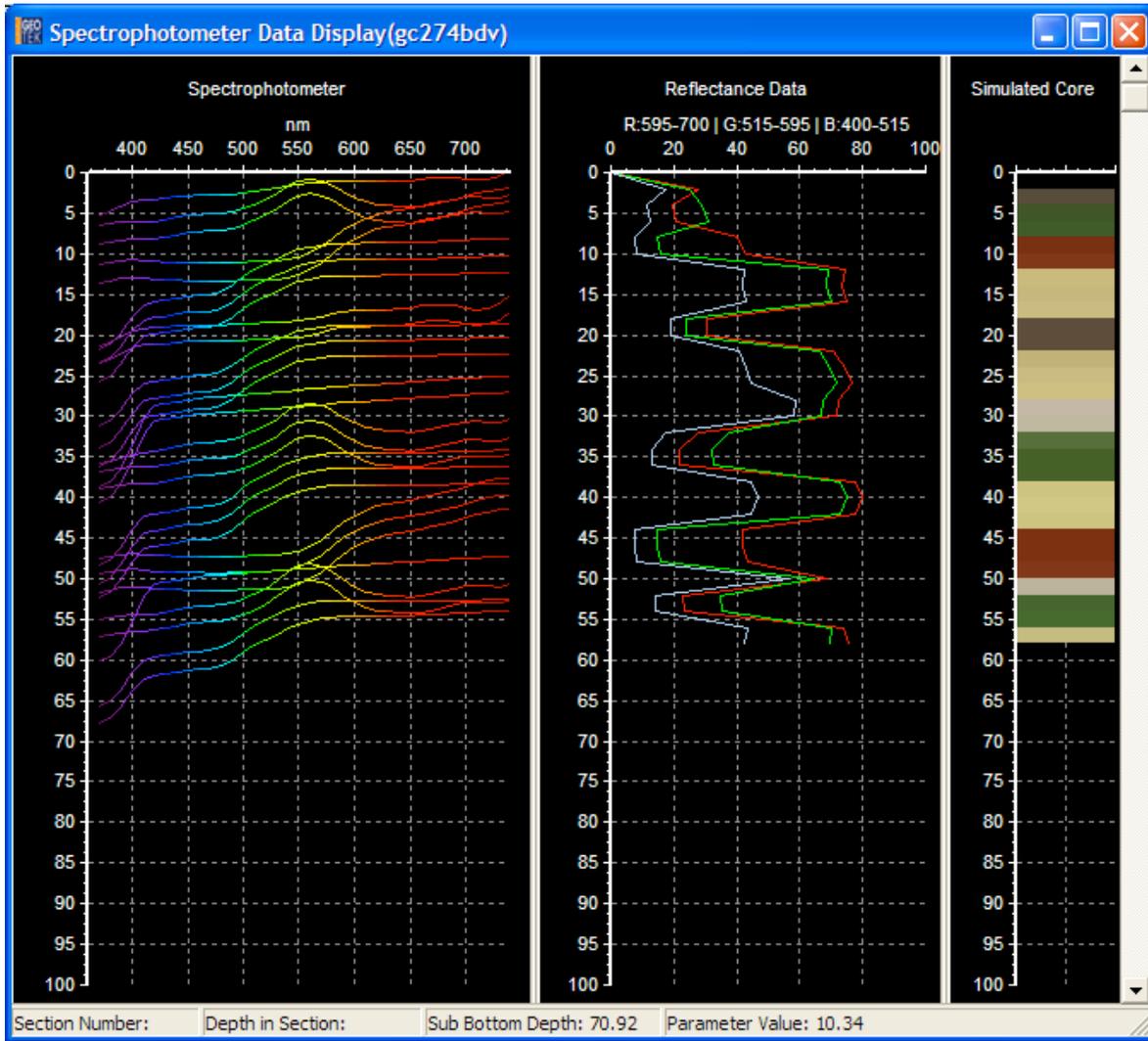


Figure 14-22. Spectrophotometer data display window.

Reflectance Line Chart

The Reflectance Line Chart shows the spectra data in three user-definable bins. The default values for these bins are 595-700 nm, 515-595 nm, and 400-515 nm (red, green, and blue, respectively). These values can be modified by the user and can even overlap; however, the names will always be red, green, and blue. A right click on the line chart will bring up the following options in a contextual menu:

- I. Pen Width - Select the width of the line connecting the plotted data.
- II. Chart Colour - Select between a white or black background.
- III. Show Red, Show Green, Show Blue - These menu items toggle the display of each line plot on and off.
- IV. Mode - Allows the user to select a triple plot of the colours defined by the sampling limits or a single plot of greyscale reflectance. Greyscale reflectance is calculated using the following algorithm and assumes that the sampling limits define red, green and blue.

$$\text{Greyscale (\%)} = 0.299R + 0.587G + 0.114B$$

- V. Show Points - Shows squares at each data point.
- VI. Show Sampling Limits - The range of the three bins (nominally red, green, blue) in nanometres is shown at the top of the line chart. These ranges are user-definable, and the ranges can overlap.

Reflectance Block Chart

The Reflectance Block Chart is a colour image of the core as viewed by the spectrophotometer. The core colour can be displayed as a strict RGB image or a 'real' RGB image that more closely reproduces how a human eye sees colour. A right click on the block chart will bring up the following options in a contextual menu:

- VII. Chart Colour - Select between a white or black background.
- VIII. Mode - This function switches between two colour modes: Real RGB and RGB. 'Real' RGB uses an algorithm to convert spectra to an RGB value based on work by Dan Bruton (<http://www.midnightkite.com/color.html>). RGB mode divides the spectrum into non-redundant bands.
- IX. Brightness - This option allows the user to brighten the block chart for ease of viewing.

P-wave Velocity Data

Two windows are used to display the P-wave velocity waveforms in addition to the line chart in the raw and processed data displays. One is a scope window that can be used to view the current signal and is described in Chapter 6. The second window contains a down-core plot of the collected waveforms in a colour raster display and is shown in Figure 13-25. The colour scale shows the range of signal levels and varies from yellow for large negative levels to dark green for large positive levels.

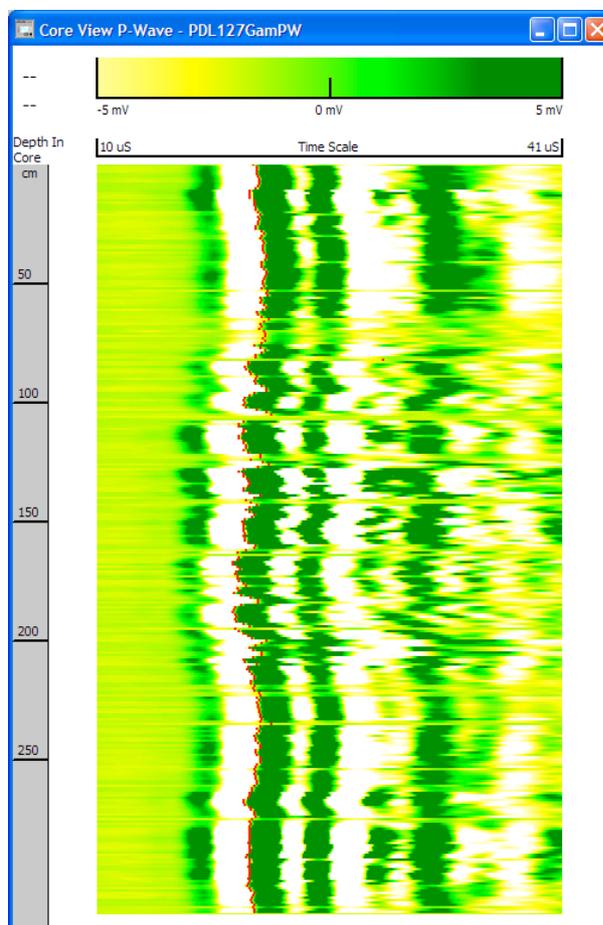


Figure 14-23. P-wave core view display.

15 - The PC, Hardware and Utilities Software

Chapter Overview

This chapter briefly describes the interaction between the host PC and the hardware. It describes the facilities available in the Utilities software which enable the user to perform a number of functions that are necessary to define and customise the MSCL and test the individual sensors.

Computer

All MSCL systems are supplied with a PC to host the MSCL and Imaging software as appropriate. These computers are installed in industrial 4U rack mount cases so that they can be mounted together with the other electronics associated with the MSCL. The specification of PCs and their components change over a very short time scale but Geotek endeavours to maintain a high standard and specification of parts whilst retaining backward compatibility for old MSCL and PC hardware where necessary. Typically the maximum amount of RAM will be installed in Geotek supplied computers so that the Imaging software has sufficient memory to acquire and manipulate the high resolution (and bit level) images. Two hard disk drives are usually installed and formatted together in a RAID 1 array such that in the event of a failure of one drive the PC can still operate as a RAID 1 array creates an exact copy (or mirror) of a set of data on two or more disks.

Hardware and Utilities Software

The Utilities software give the user access to the hardware controlling the MSCL giving an interface to the code on older Mk I systems and access to test facilities on both Mk I and II systems. An interface to the settings that describe a MSCL system is also provided although this is also a component of the MSCL and the Imaging software. Features and functions that are greyed out in the menus will not be applicable to the system version as defined in the settings.

Hardware Mk I - 8052 Microprocessor Based

The primary command software for the MSCL resides in a microprocessor (MP) unit that is in the main electronics rack. The MP is the Intel 8052AH BASIC, a version of the 8051 micro-controller with an on-board BASIC language interpreter. This system provides all the interfacing between the core logger and the PC, using a simple RS232 interface. Linked directly to the main MP board are the boards containing the A to D converters, the serial interface and the gamma counter board. The complete MP system forms an independent stack, supported over the main P-wave electronics board.

Software and Terminal Window

When the MSCL Utilities software is run an active terminal window appears (see Figure 14-1) that gives the user direct access (in terminal mode) to the MP software. This software is pre-loaded in battery backed Read Only Memory (ROM) and is automatically active when the system is switched on. The MP software has the identifying extension .i52 and if for any reason (e.g. battery failure) the software is erased from ROM then it must be reloaded.

To check that the i52 program is loaded in ROM turn the power off at the main electronics rack and run the Utilities program. Turn the main power on and observe the display in the terminal window. If a series of hexadecimal characters are scrolled within the display and end with an active cursor then the program is present in ROM and is now running.

If nothing happens then there is no program in ROM either because it has been deleted or because the back up battery has failed. To initialise the MP the space character (ASCII code 32) must be received through the serial port. If it receives any other character first, the microprocessor will not function and must be turned off before continuing. Press the space bar and the following message will appear:

```
*MCS-51(tm) BASIC v1.1*  
READY  
>
```

If this occurs then it confirms that there is no program in ROM .

ROM/RAM modes

The MP can operate in two modes; ROM mode (which is the default mode when switched on) or in RAM (Random Access Memory) mode. The MP will operate in whichever mode it is set. Program in ROM cannot be edited directly and are preserved, when the main power is off, by the backup battery as described above. Program in RAM can be edited directly but are lost immediately the power is turned off. Program can be transferred to and from ROM and RAM locations using the following commands:

ROM to RAM

To transfer software from ROM to RAM first ensure that the RAM memory is empty. Type **RAM (CR)** to ensure you are in RAM mode. Type **NEW (CR)** to clear the contents of RAM (this is important because the process only updates line numbers and corruption can occur if the memory is not empty. Revert to ROM mode by typing **ROM (CR)**. Then type **XFER (CR)** to transfer the code to RAM. This can be checked by going back to RAM mode (type **RAM (CR)**) and then typing **LIST (CR)**. A program listing will appear.

RAM to ROM

To transfer software from RAM to ROM first be sure that the program in RAM is the one you want to save. Ensure you are in RAM mode and Type **GOTO 30000 (CR)**. The code will be loaded into ROM and the progress can be viewed in the Terminal Panel. This process can take a few minutes depending on the size of the program.

File Transfer to and from the PC

To transfer a file from the PC to the MP the user should use the **[File_Upload to Micro]** command. A dialogue box will appear asking the user which file is to be uploaded. This process will place the program in RAM. Once you are sure this is the program you wish to keep it should be loaded into ROM as described above.

To transfer an I52 program from the MP to the PC the user must use the **[File_Download to PC]** command. A dialogue box will appear asking the user to name and define the location of the file. Note that it is the file from RAM that is downloaded hence if you are saving a program from ROM then you must first copy it to RAM before downloading to the PC.

If the user wishes to record the output from the MP during a terminal session then select the **[File_Output to File]** command. A file will be written in which the output is recorded.

Hardware Mk II - FPGA Based

In the most recent MSCL systems the electronics is based around a Spartan FPGA chip. The FPGA interfaces the PC and the MSCL sensors using a TCP/IP protocol. The connection between the PC and the FPGA is an ethernet link that also provides access to a serial server mounted in the 3U electronics rack giving access to third party sensors requiring an RS232 connection, the Minolta CM2600D spectrophotometer for example. The ADC inputs and high speed P-wave ADC input is controlled through the FPGA and data passed back to the PC.

The FPGA is similar to the old 8052 microprocessor based system in that there is some code that defines its operations and but is not interactive in the way that a microprocessor is. As a result of the the terminal window in the Utilities software acts only as a window to show the results of sensor tests. The **[File_Output to File]** can be used to record to file what is displayed in the terminal during any testing of sensors.

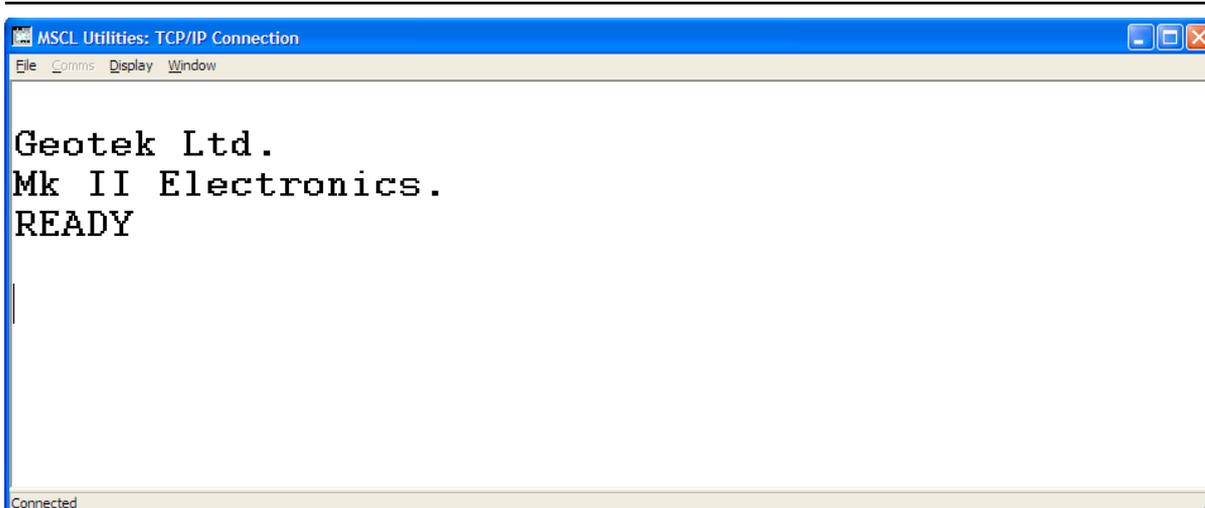


Figure 15-1. Logger terminal panel.

Display

This command enables the user to clear the display, change the background colour and change the font size on the display. Increasing the font is can be valuable when attempting to view numbers in the terminal window when the user is working at some distance from the screen.

Test Panel

The test panel enables the user to operate the track, vertical slide and all the sensor systems through the PC. In this way the user can test individual systems and monitor the output of the different sensors during set-up procedures. The test panel routines use the same software elements as the main application program and hence the test panel acts as a complete software and hardware test system. The Test Panel appears when [**Window_Test Panel**] is selected as shown in Figure 14-2.

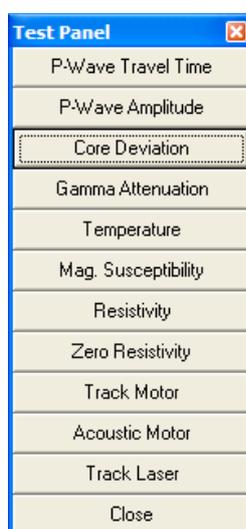


Figure 15-2. Test panel.

The configuration of the test panel depends on which sensors are available as defined by the active group of settings. To operate any test simply select the appropriate test box. The output of the test routine is displayed in the Terminal display panel. To stop the routine either select the box again or another box.

P-wave Travel Time: provides the travel time between the two PWTs in μs ; e.g. 50.05 μs .

P-wave Amplitude: provides the digital AD output together with the computed value which is obtained from the settings file parameters (scale and offset).

When testing either of the P-wave parameters the scope window will be displayed.

Temperature: provides the digital AD output from the PRT together with the computed value of temperature which is calculated from the settings file parameters.

Core Diameter Deviation: provides the digital AD output together with the computed value which is obtained from the settings file parameters.

Gamma Attenuation: When selected the user is prompted to enter a count time in seconds. The display then shows both the total counts and the CPS (counts per second) value.

Magnetic Susceptibility: When this box is selected ensure that the MS2 meter is in automatic mode (toggle switch in centre position). The value will be displayed which should be the same as that shown on the MS2 LCD.

Resistivity: provides the digital A-D output from the resistivity meter with the computed value or resistivity response that is calculated from the settings file parameters.

Zero Resistivity: zeroes the resistivity meter

Track (X) Motor: When this box is selected the user is prompted to enter a distance that the pusher will move. If a positive number is entered the pusher will move to the left and a negative number will cause the pusher to move to the right. The user can test the ramp routine by checking the box provided, ramping will only occur when the pusher moves to the right.

Vertical (Z) Motor: When this box is selected the user is prompted to enter a distance that the vertical slide will move. If a positive number is entered the slide will move down and a negative number will cause the slide to move up. The vertical motor will ramp up and down when the ramping check box is ticked.

Track Laser: Selecting this button displays if the track laser beam is broken or unbroken.

Logger Settings

Logger settings are a series of parameters that define the sensor and mechanical configuration of the logger as well as the calibration constants. It is essential that these parameters are set accurately to ensure that the main application operates correctly and provides accurate raw data. When **[Window_Settings]** is selected a settings panel is displayed as shown in Figure 14-3. The categories in the left hand pane of the settings window fall into four categories, the first two of which are always present, the latter two being optional depending the presence of a GeoScan system or the type of MSCL. In the right hand pane details of the item highlighted in the left hand pane are shown.

Category	Description
General	Identifies the settings group in use; the communication properties for the MSCL connected to the PC; options to include processing parameters and a time stamp on each data point in the processed data ASCII output.
Settings Group	Defines the setup and calibration constants for different configurations of the MSCL connected to the PC. There can be a number of these groups for different logging processes.
Camera	Defines the setup and calibration details for the GeoScan imaging system if installed (see Chapter 15 for details).
XY Table	Defines the setup of an XY(Z) table for the MSCL-XY(Z) systems - described in a separate manual.

The settings are stored in the Windows registry under the HKEY_CURRENT_USER section and SOFTWARE, GEOTEK and SETTINGS sub-sections. This is accessible through the RegEdit application of Windows but the user is advised not to use this method to access the MSCL settings. Settings can be imported or exported from the Settings panel using the **[File_Backup...]** and **[File_Restore...]** options. The restore option will prompt the user to select a file to restore from and whether the current settings should be overwritten. If the current settings are overwritten a backup is automatically made. Backed up files are stored in a file with a .mscl extension but are in a format that allows them to be loaded in and out of the Windows registry using the RegEdit application or by changing the file extension to .reg and double clicking on the file. This method of loading settings should be used with extreme caution as any settings already in the system will be overwritten and no backup option is available.

As a result of where the settings are stored in the Windows registry they are specific to a user account so if new user accounts are created on the PC or in the PC is linked into a corporate network domain any MSCL settings should be exported whilst logged in as the original user then imported when logged in as any other user wishing to use the MSCL.

General

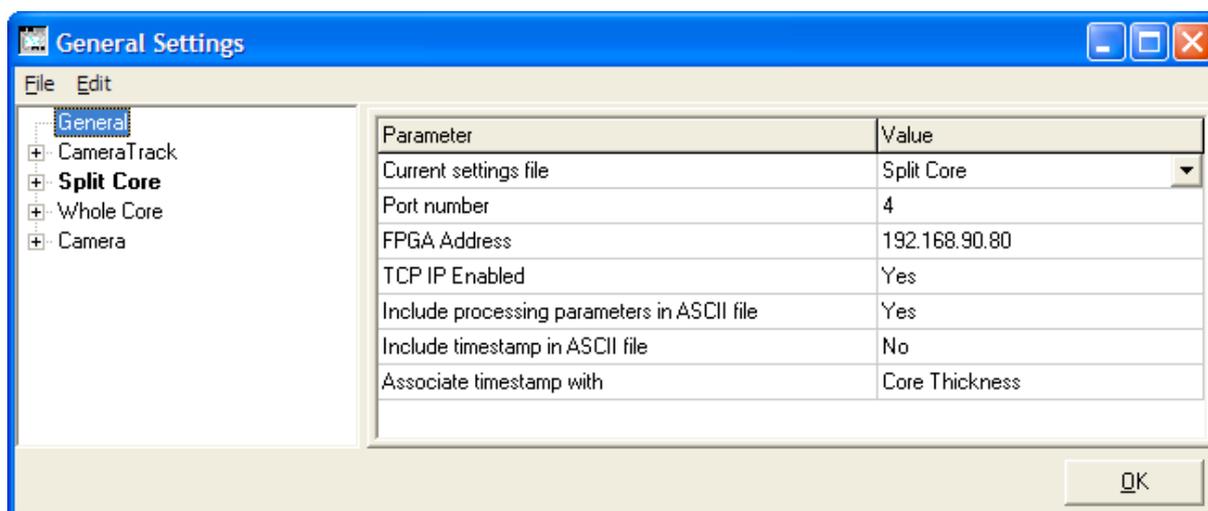


Figure 14-5. MSCL settings panel.

Under the General category the settings group to be used is defined, a drop down box of the defined settings groups (see below) can be used to select the relevant group. The communication with the MSCL electronics is defined and this can be either through an RS232 port on the PC or through a TCP/IP interface using an ethernet port on the PC. In the case of an RS232 port connection the TCP IP Enabled option should be set to 'No' and the COM (RS232) port used to connect to the MSCL electronics should be defined in 'Port Number'. For a TCP/IP enabled MSCL (FPGA based) the TCP IP Enabled option should be set to 'Yes' and the IP address used to communicate with the MSCL electronics should be defined in the FPGA Address field. By default this should be 192.168.90.80 and the Port Number set to 4.

Also within the General category the option to output the processing parameters (used to convert the raw data into geologically meaningful data) in the processed ASCII data file can be selected. By default this is set to 'Yes'. A time stamp for each data point can also be output in the processed ASCII data file. If required change the 'Include timestamp in ASCII file' option to 'Yes' and define the data set to associate the time stamp with using the 'Associate timestamp with' option.

Settings Groups

It is possible to create a series of different settings groups and select which group is operational at any time. To create a new group of settings click on **[File_New_Settings]** and an additional column will be created that has the same settings as the column on the far right. To delete an unwanted setting group click on **[File_Delete]** or right clicking on the group of settings and select **[Delete]**. Settings groups can be renamed by clicking on **[Edit_Rename]** or right clicking on the group of settings and select **[Rename]**.

Each settings group contains the details that define the sensor and mechanical configuration of the MSCL. This has been divided up into individual sensor or system sub-categories for easier management and each of the sub-categories are described below.

The sensor sub-categories all have a similar layout, the first two options define whether a sensor is present and if so what is its position along the track in cm (relative to the reference point of the track at the left hand end of the motorised RH track). Following these sensor specific options are displayed. If a sensor is not present and is set to 'No' in the first option then the parameters relating to it are automatically hidden.

Gamma Density

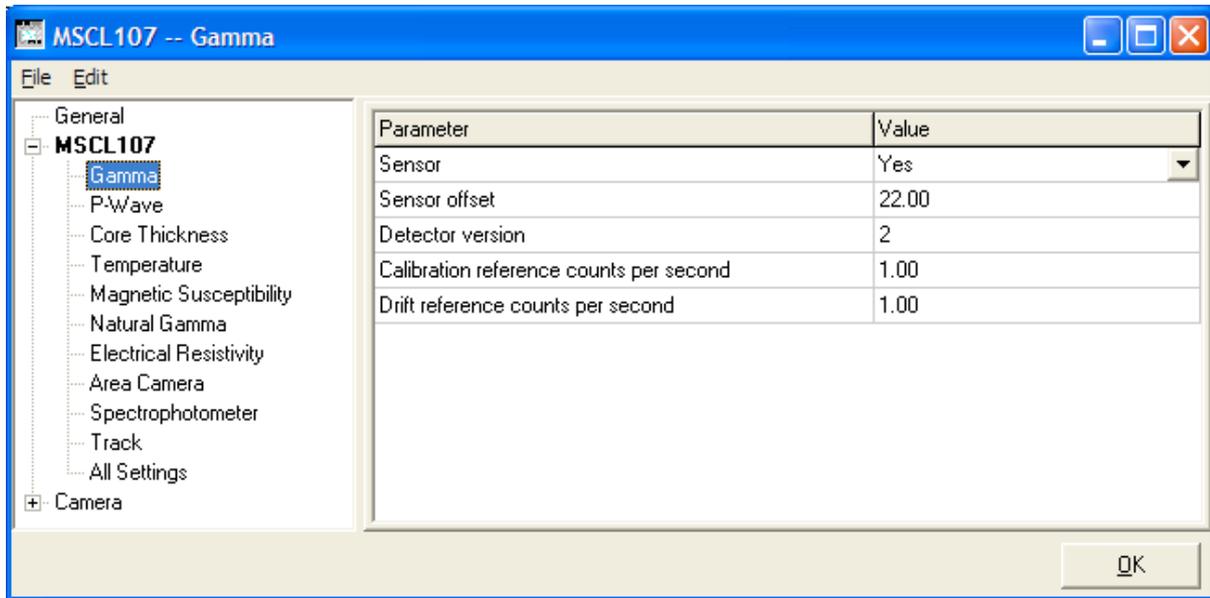


Figure 15-4. Gamma density settings.

Detector Version (1 or 2); 1 is the old system that uses the SD1 single channel analyser electronics in MSCL serial numbers 1 through 15 and 2 is the new system that uses the integrated detector and single channel analyser (MSCL serial numbers > 15)

Calibration and Drift reference counts per second; these are values that enable the user to correct for small amounts of drift which may occur with the gamma detector system without the need to carry out a complete re-calibration. The following calibration/drift correction protocol can be used. At the time of the main calibration the user should select a reference piece which ideally should be a block of aluminium with a thickness that provides a gamma count rate that is similar to the cores being logged. At the time of the calibration the user should measure the gamma count rate CPS in the reference piece. This value should be entered as the Calibration Reference in CPS (CR). Initially the Drift Reference (DR) in CPS is the same as CR. During the logging process the user may wish to check on any drift that has occurred by measuring DR again. The new value can be entered into the settings file before logging a new core. All measured values are corrected according to the ratio of DR/CR.

i.e. Corrected CPS = Measured CPS * DR/CR

The measured and corrected values are shown in the results when using the test panel. If there is no correction to be applied then ensure that the values of CR and DR in the settings file are the same. Note also that the values of DR and CR can only be changed before logging a new core not in the middle of logging a core.

P-wave

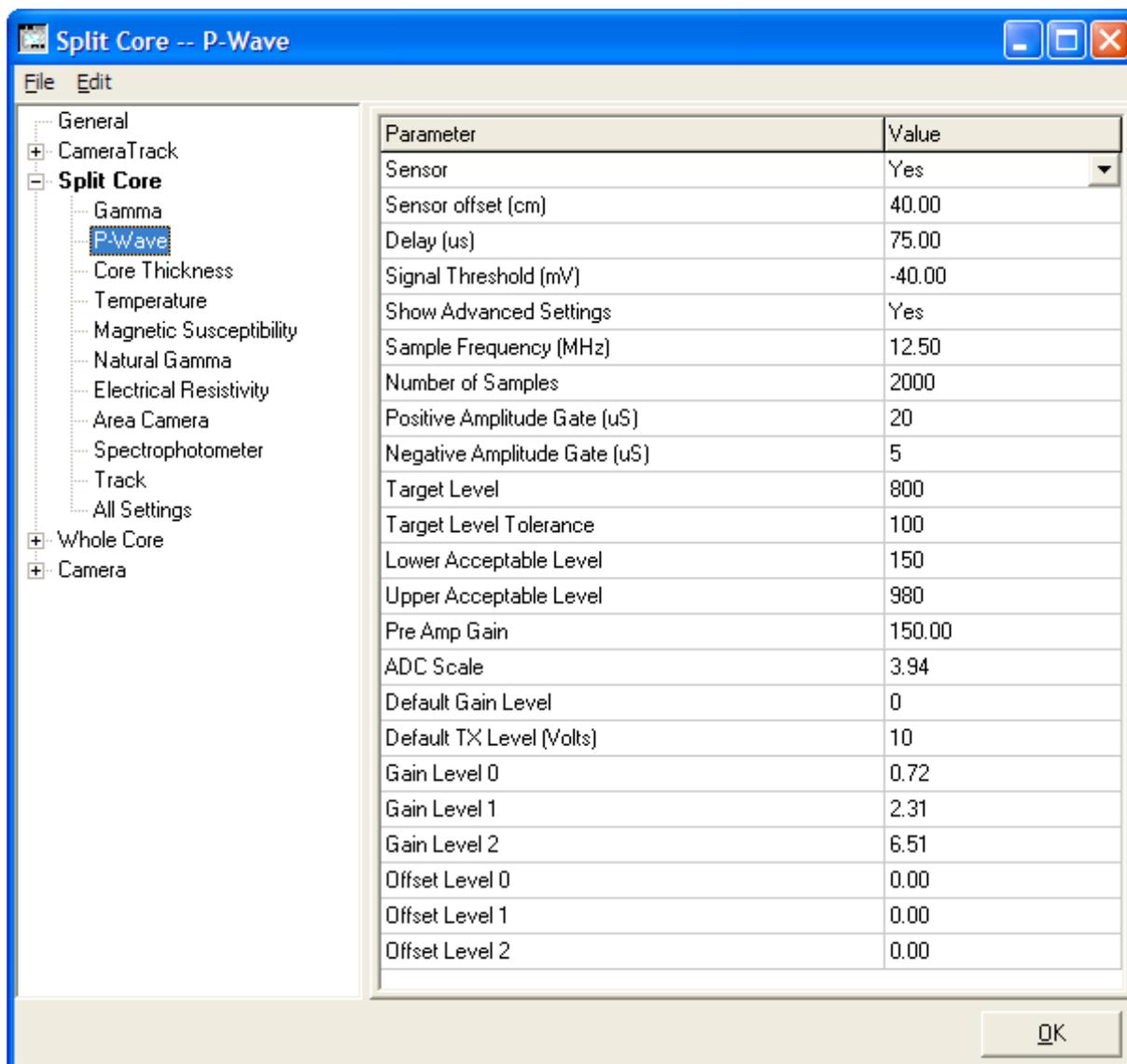


Figure 15-5. P-wave velocity settings.

There are a lot of settings relating to the P-wave velocity system but many of these are advanced settings and should not be changed by the user. All these settings refer to features that are discussed in Chapter 6 but their description is repeated here.

The 'Delay' defines the point in time (μs) at which the software should start its threshold detection. The 'Signal Threshold' defines the level that the signal must exceed (in mV) before the next zero crossing is picked for the P-wave timing.

The advanced settings can be hidden by changing the 'Show Advanced Settings' to 'No'. The 'Sample Frequency' defines the ADC speed (i.e. the rate of digitisation). 'Number of Samples' defines how many samples the digitiser should take at the rate specified in 'Sample Frequency'. The 'Positive and Negative Amplitude Gates' set the window for the calculation of P-wave signal amplitude. The 'Target Level' and 'Target Level Tolerance' define the optimal signal level (mV peak to peak) used in the automatic transmit and gain adjustments. The 'Lower and Upper Acceptance Levels' define the signal level (mV peak to peak) that the system will accept for a signal timing measurement before automatically adjusting the transmit and gain. The 'Pre Amp Gain' is the level of signal amplification close to the receiver. The 'ADC Scale' is used to convert the ADC bits into mV (mV/bit). 'Default Gain Level' is the level of variable gain applied when initialising a measurement or starting to log core. 'Default TX Level' is the starting transmit voltage used when initialising a measurement or starting to log core. The 'Gain

Levels 0, 2 and 2' define the amplification stages of the variable gain. The 'Offset Levels 0, 1 and 2' define any signal offset required when using the variable gain.

Core Thickness

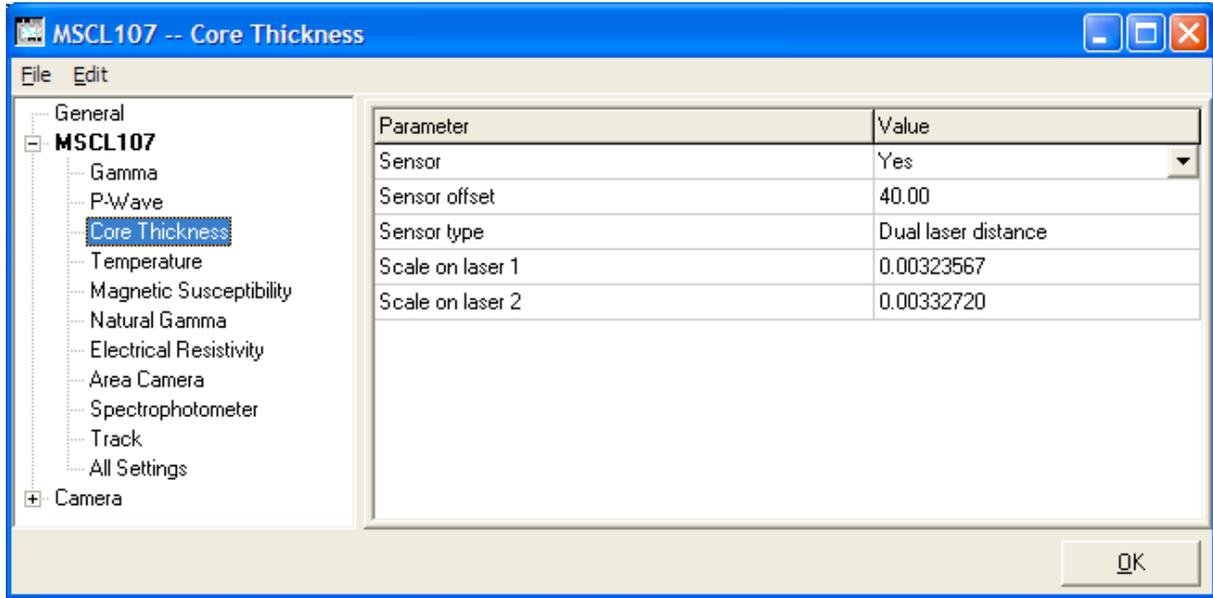


Figure 15-6. Core thickness settings.

The sensor type defines the sensor system installed, the three options being displacement transducers, laser distance or dual laser distance. For each of these options a hardware calibration is required to convert the voltage outputs from the sensors (through the ADC) into distance. In the case illustrated the scale (mm per bit) to convert the ADC output into mm is shown for each of the laser distance sensors. These values should not change over the lifetime of the MSCL and so should not be changed. However, should re-calibration become necessary the protocol for calibration is detailed in Chapter 10.

Temperature

The AD data channel for temperature data (4 or 7) is hardwired on individual systems and should not be changed.

A hardware calibration is required to convert the voltage outputs from the sensors (through the ADC) into temperature. To do this a scale ($^{\circ}\text{C}$ per bit) and offset ($^{\circ}\text{C}$) is defined as per the protocol defined in Chapter 11. These values should not change over the lifetime of the MSCL and so should not be changed. However, should re-calibration become necessary the protocol for calibration is detailed in Chapter 11.

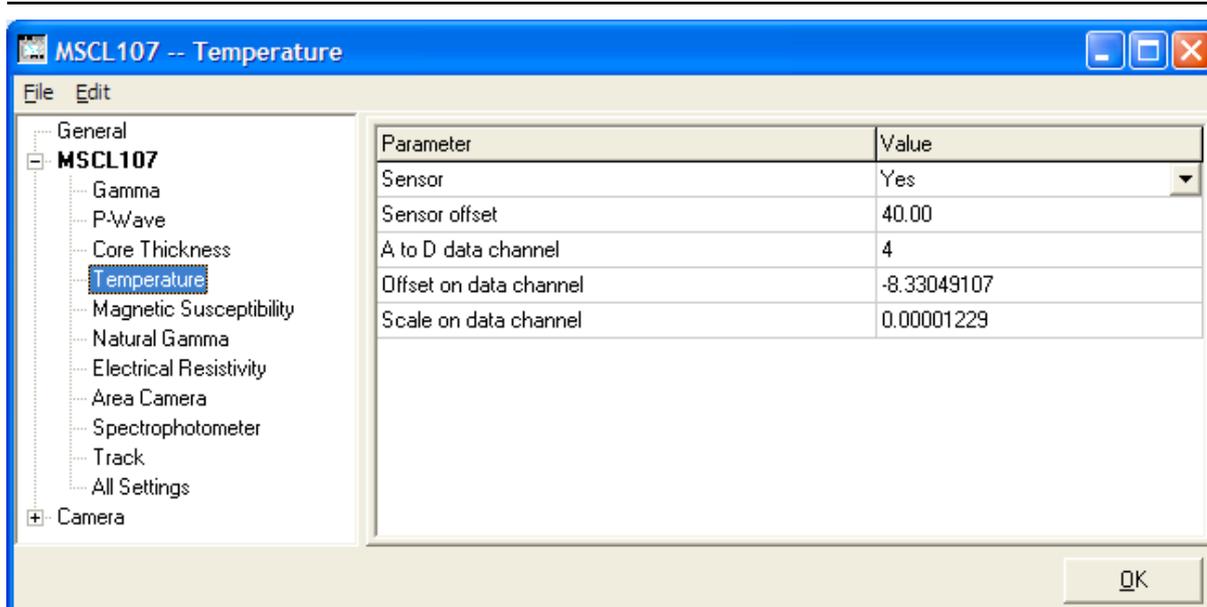


Figure 15-7. Temperature settings.

Magnetic susceptibility

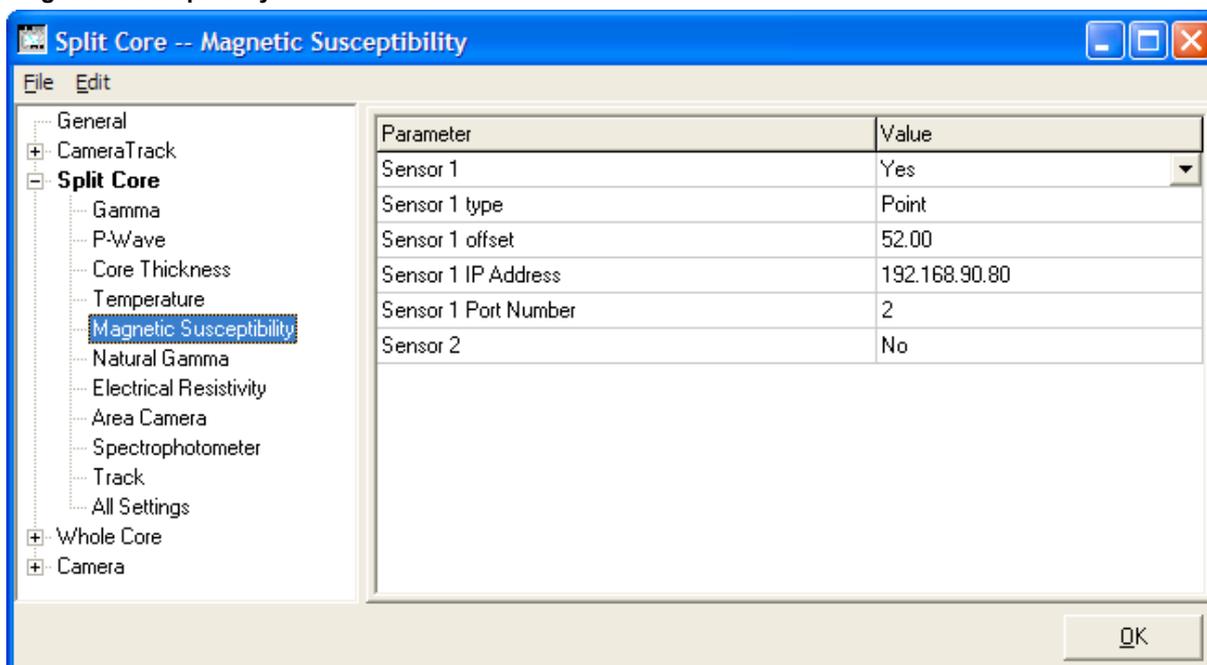


Figure 15-8. Magnetic susceptibility settings.

The MSCL-S system can be configured to have two magnetic susceptibility loop sensors installed and therefore options for Sensor 1 and Sensor 2 are available. The sensor type can be either 'Loop' (MS2C) or 'Point' (MS2E) and on TCP/IP enabled systems (see above) the 'IP Address' and 'Port Number' for communication to the magnetic susceptibility meter should be defined, the defaults for these being IP address '192.168.90.80' and port number '2'.

Natural Gamma

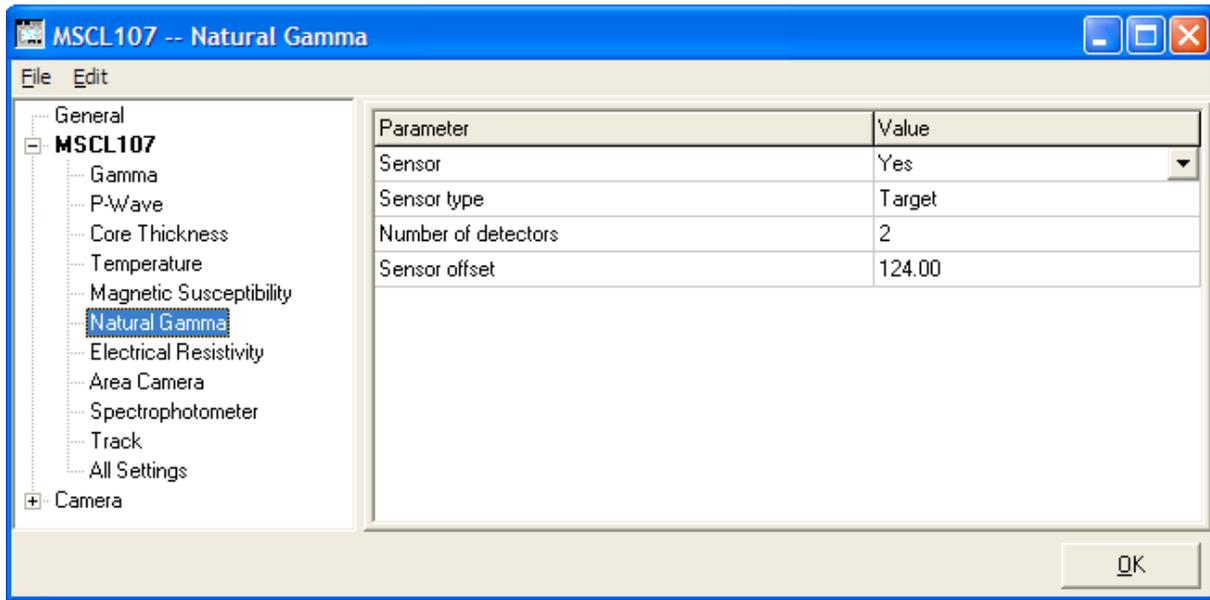


Figure 15-9. Natural gamma settings.

The settings for natural gamma are relatively straightforward and all that needs to be defined is the number of detectors installed and their type. There are two options for ‘Sensor type’ and these are ‘Aptec’ or ‘Target’, referring to the manufacturer of the multi-channel analysers installed. Aptec sensors have an ISA card in the PC for each detector and the Target sensors are connected to the PC via a USB interface.

Electrical resistivity

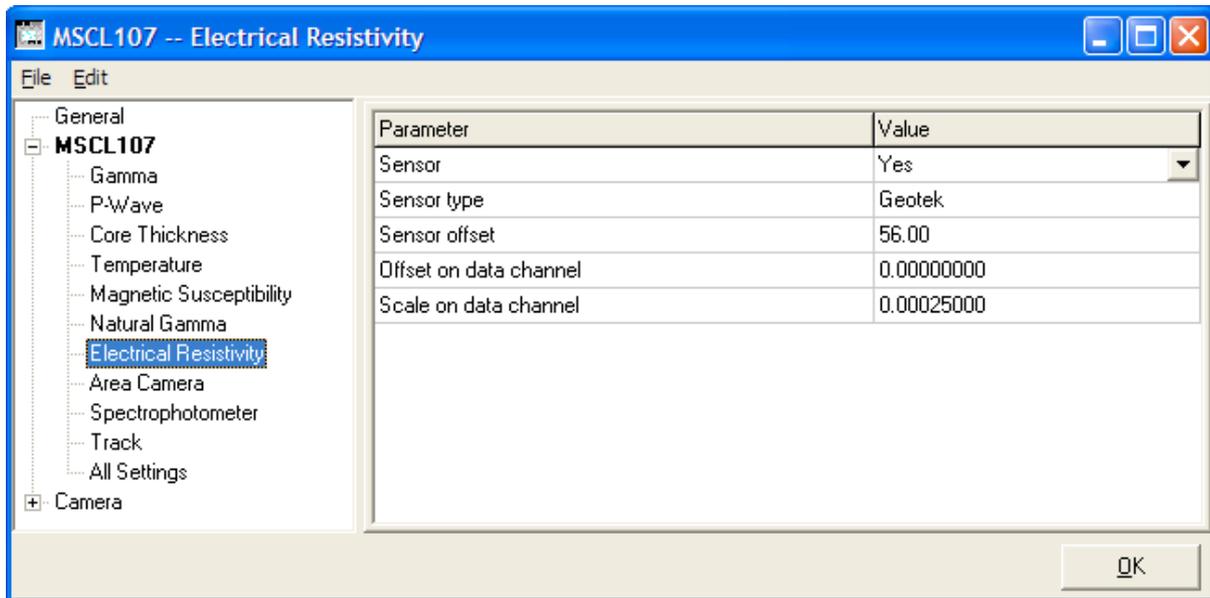


Figure 15-10. Electrical resistivity settings.

‘Sensor type’ defines the type of sensor installed and can be either ‘Geotek’ (for the standard Geotek NCR sensor) or ‘Geo-Instruments’ (for the Geo-Instruments conductivity sensor range). If the latter option is chosen the serial port that the Geo-Instruments sensor is connected to on the PC should be defined.

A hardware calibration is required to convert the voltage outputs from the sensor (through the AD converter) into millivolts sensor response. To do this a scale (mV per bit) and offset (mV) is defined. These values should not change over the lifetime of the MSCL and so should not be changed.

Area Camera

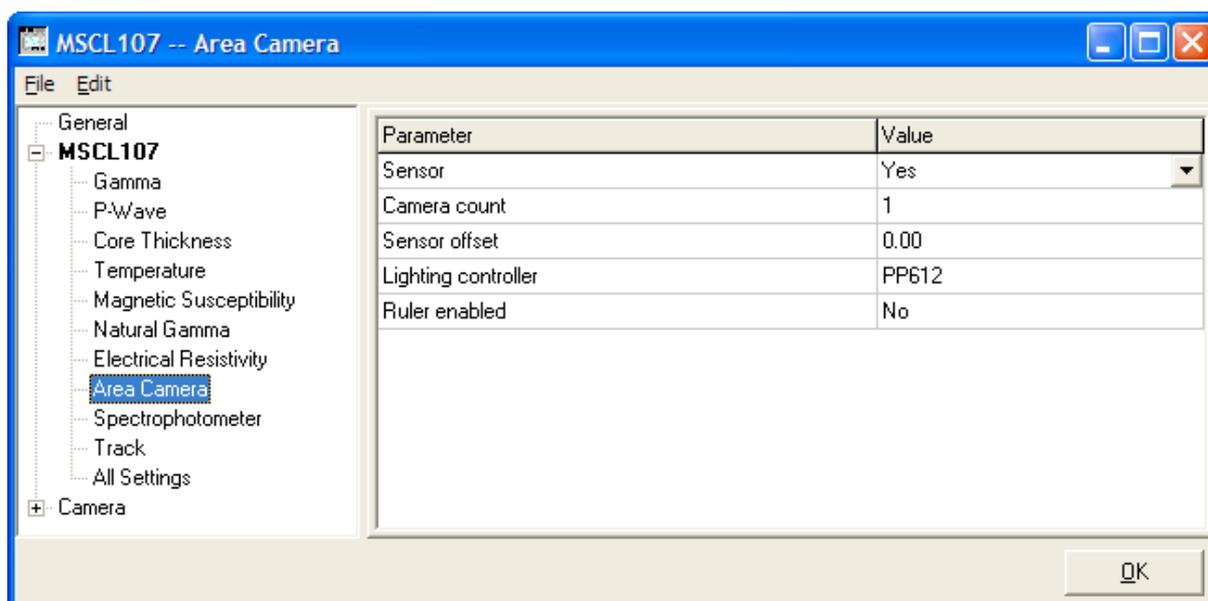


Figure 15-11. Area camera settings.

If an area camera system is installed the number of cameras should be defined in 'Camera count' and the type of lighting system in 'Lighting controller'. The 'Ruler enabled' option is set to 'Yes' then the images produced by the area camera(s) will have a ruler added to the left hand edge.

Spectrophotometer

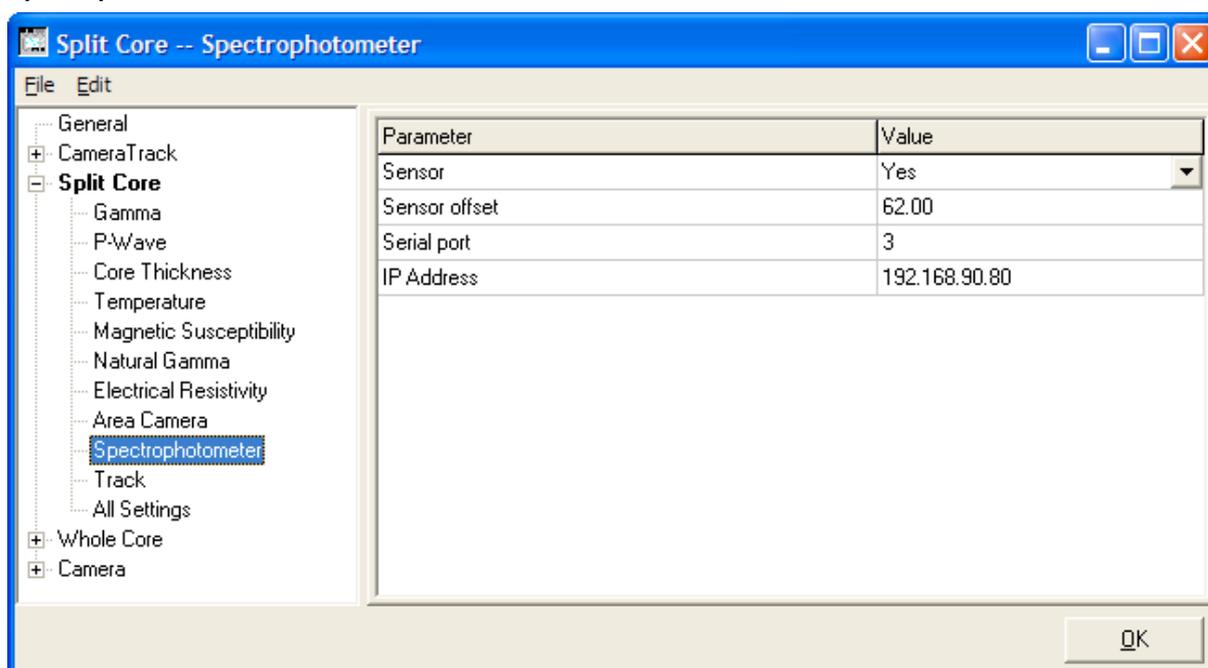


Figure 15-12. Spectrophotometer settings.

The spectrophotometer settings are very simple, on TCP/IP enabled systems (see above) the 'IP Address' and 'Port Number' for communication to the spectrophotometer should be defined, the defaults for these being IP Address '192.168.90.80' and port number '3'. If not TCP/IP enabled then the serial port that the spectrophotometer is connected to on the PC should be defined.

Track

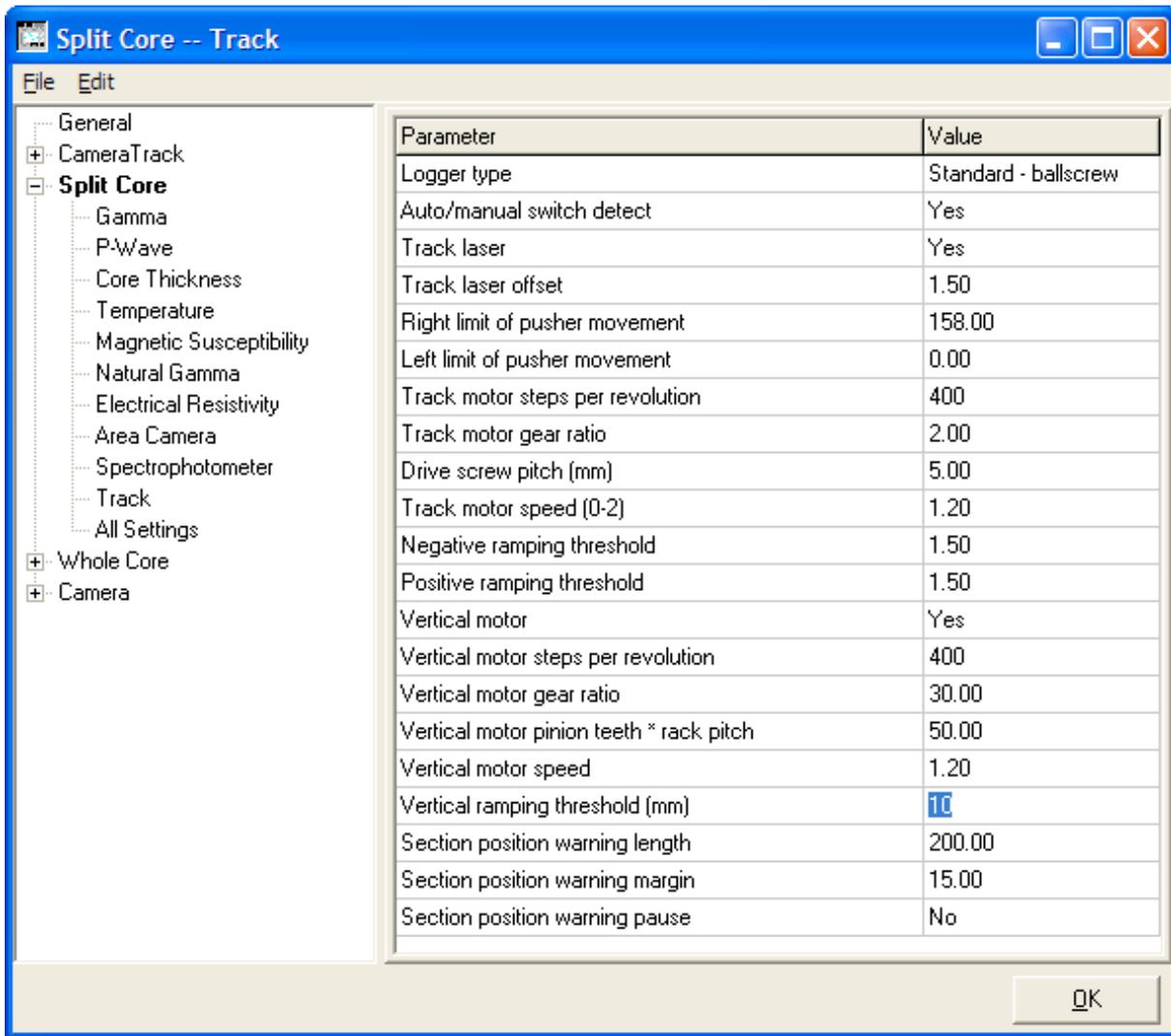


Figure 15-13. Track settings.

The settings under the track heading define the type of track system and the mechanical configuration of the stepper motors and how they attached to the MSCL. The ‘Track type’ defines the type of drive system and in so doing customises the MSCL software interface appropriately. The different types of system are ‘Standard’ - pusher system where pusher is restricted to RH box section; ‘Unrestricted pusher’ - pusher system where pusher moves through sensors; ‘Boat’ - where core is placed in core boat; ‘Moving sensors’ - where sensor move past stationary core; ‘Vertical’ – sensors move past vertical core; ‘Standard - ballscrew’ (as Standard but with ball-screw rather than a belt drive); ‘XY Table’ and ‘XYZ Table’.

‘Auto/Manual switch detect’ defines is the system is capable of detecting how the Auto/Manual switch controlling motor movement is set and prevents the user from inadvertently trying to control the motors under software control whilst the switch is set to Manual. This feature has been installed on all MSCL systems since serial number 39.

‘Track laser’ indicates if a track laser is present and ‘Track laser offset’ defines the distance of the laser to the right of the reference point of the track in cm.

The ‘Right limit of pusher movement’ and ‘Left limit of pusher movement’ set the limits of movement of the pusher (in cm) before hitting any of the limit switches. The left limit should be set to zero unless the track type is the ‘Unrestricted pusher’, ‘Boat’, ‘Moving sensors’, or ‘Vertical’ variety when the left limit should be set at the distance such that the core can pass the last sensor (or *vice versa*).

The next four parameters are used to define how the pusher moves along the track and are used to in the calculation of the number of steps that need to be sent to the stepper motors to move a certain distance. 'Track motor steps per revolution' is the number of steps needed to rotate the motor shaft by one turn - this is always 400. 'Track motor gear ratio' is the gear ratio between the motor shaft and the drive shaft or the track. On belt driven systems this gear ratio is normally 100 or 120 but on ball-screw systems it is 2. The 'Drive screw pitch (mm)' is the pitch of the ball-screw on more recent systems but on belt driven systems this setting is renamed as the 'Track motor pulley teeth * belt pitch (mm)' where the number of pulley teeth is usually 40 and the belt pitch 10 mm. The 'Track motor speed' defines the non-ramping speed of the pusher, this a relative measure and should be set at no more that 1.2 for ball-screw systems and 1.6 for belt driven systems. On servo motor driven systems such as the MSCL-V this speed can be increased significantly.

The 'Negative Ramping Threshold' and 'Positive Ramping Threshold' parameters set the distance above which the track motor will ramp

The vertical slide system is also driven by a stepper motor and so requires similar parameters to be defined. Firstly, 'Vertical motor' indicates if the vertical motor is used in this configuration (it may not be if the MSCL is set up in its horizontal sensor configuration. 'Vertical motor steps per revolution' is the number of steps needed to rotate the motor shaft by one turn - this is always 400. 'Vertical motor gear ratio' is the gear ratio between the motor shaft and the drive shaft or the track (normally 30 or 60) and 'Vertical motor pinion teeth * rack pitch' where the number of teeth on the pinion on the vertical slide 50 and the pitch of the teeth on the rack is 1 mm. The 'Vertical motor speed' sets the speed of vertical motor, a relative measure as with the track motor and is normally set between 1.0 and 1.6. 'Vertical ramping threshold (mm)' is the distance the Z motor will move before being ramped.

The last three parameters in the track sub-category relate to the section positions window in the MSCL software (see Chapter 14) that can be used to alert the user when core sections reach the end of the track. These parameters define how the sensor positions pause feature operates, the 'Section position warning length' is the distance (in cm) from the track reference point beyond which the core sections being logged must not pass; the 'Section position warning margin' is the distance (in cm) ahead of the 'Section position warning length' that when a core section passes into it will be highlighted in the section positions window in the MSCL software. The 'Section position warning pause' defines whether the section positions pause feature is enabled by default in the MSCL software.

All Settings

This sub-category lists the settings parameters in a complete list.

16 - GeoScan Digital Imaging

Technical Specification

GeoScan Colour Line-Scan Camera

The GeoScan colour line-scan camera is a 3 CCD device using 3 * 2048 pixel CCD arrays (1024 pixels in older versions of GeoScan). A standard Nikon mount lens fitting is used which enables the user to easily purchase and change lenses depending on the exact imaging requirements. This is an important consideration when considering focussing and depth of field issues. Light from the object passes through the lens and is split into 3 paths by the beam splitter to fall on the red, green and blue detectors which when combined reproduce a conventional colour image.

All CCD detectors are sensitive to light in the 400 to 950 nm waveband. However they are relatively insensitive to light at shorter wavelengths (400-500 nm - the blue end of the spectrum) than at the longer wavelengths of the visible spectrum wavelengths (600-700 nm - the red end of the spectrum). Consequently the blue channel is amplified more than the red and green channels.

To ensure that there is minimal overlap between the wavebands in the 3 channels (red, green and blue) for scientific applications, the light leaving each exit face of the splitter passes through a dichroic colour interference filter before falling on the detector which is located at the focal plane of the lens. The transmission characteristics of the filters used are illustrated in Figure 16-1 which clearly shows how the filters ensure true colour separation.

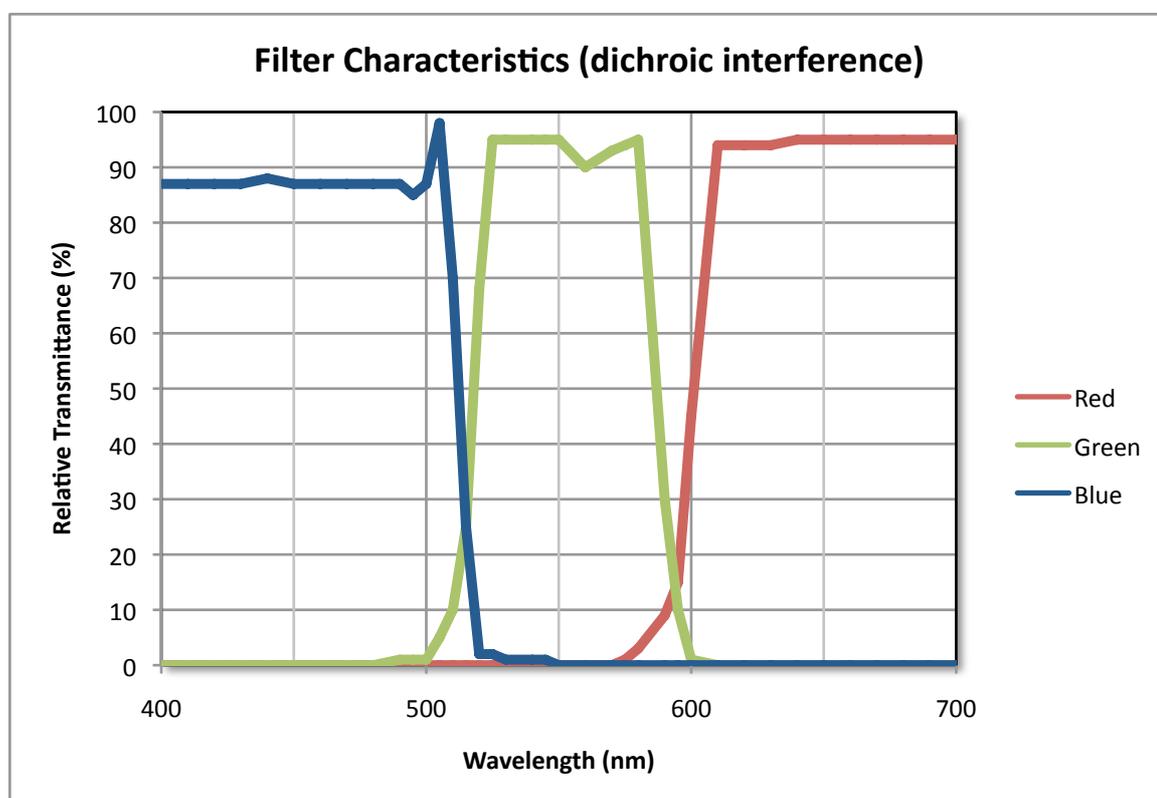


Figure 16-1. Dichroic interference filter characteristics.

This filter separation can be compared to a typical 3 CCD camera where normal dye filters are used as illustrated in Figure 16-2. Whilst the latter system response may give perfectly good images for viewing they will not enable any rigorous colour analysis to be performed because of the lack of true colour separation.

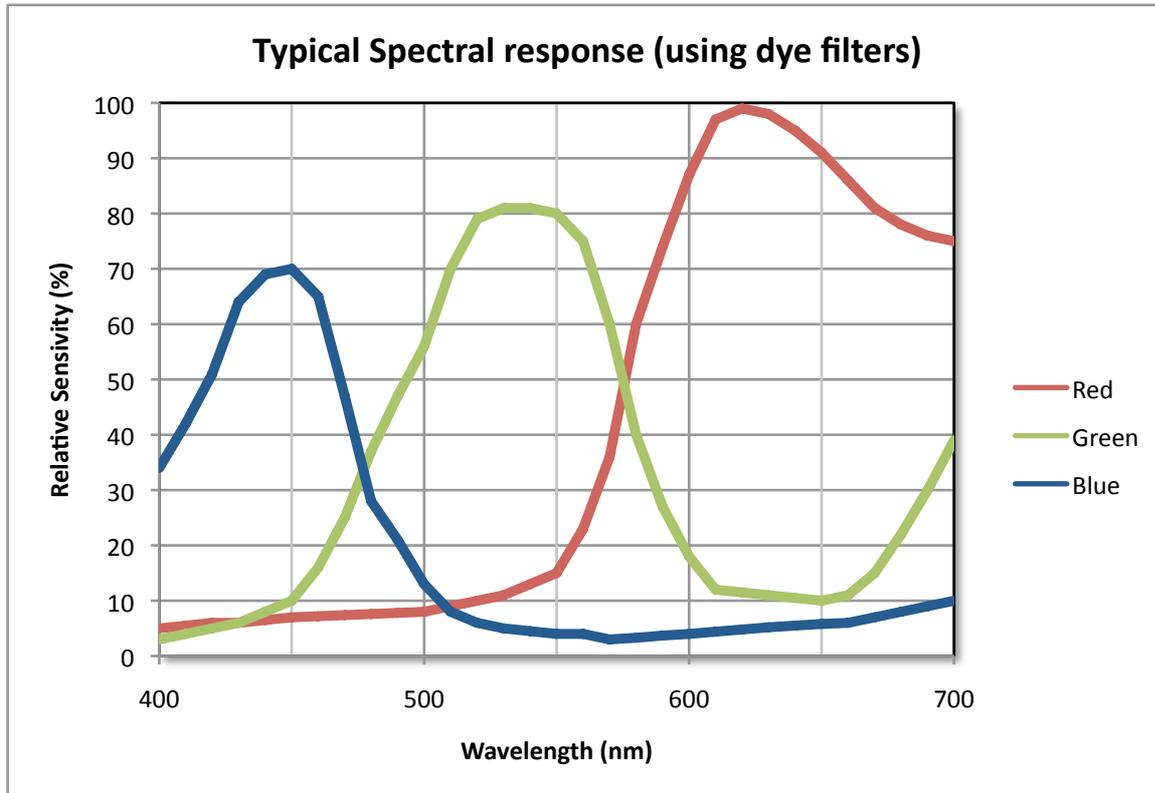


Figure 16-2. Typical response of a system using overlapping dye filters.

The 3 CCD sensors used have 2048 active elements each. A dark reference pixel is used which is electrically identical to the active pixels, but has been fabricated with an opaque layer over it. It is used to compensate for electrical drift within the sensor due to temperature variations. Each pixel is 14 μm square with a total active array length of 28.8 mm. The digitised data from the 3 sensors is 14 bits per channel and is multiplexed and transmitted in 16 bit streams to the PC via a GigE interface. Older versions of the GeoScan system transmit data in 8 bits per channel over an RS442 interface.

Synchronisation between the camera and the track is achieved by using the stepper motor pulses to trigger the line acquisition of the camera. Since each motor pulse corresponds to a fixed amount of track movement it can be seen that the camera images a line across the core at precise spatial intervals down the core. This means that there is no optical distortion from the lens in the down-core direction, an important factor for high-resolution studies. Motor speed defines the time between pulses and hence the integration period (exposure time). The software-controlled pulse divider allows the distance between scans, i.e. down-core resolution, to be defined. Camera data is transmitted to the PC interface card. Once in the PC the data is corrected for convergence, gain and offset.

A software convergence routine applies a correction that compensates for any minor mechanical differences between the 3 sensor arrays. This feature is particularly valuable when assessing the performance of the camera. In the event that the camera is subjected to excessive mechanical shock (it gets dropped!) the convergence routine would enable the user to assess the extent of any damage that had been sustained and, within limits, apply a software correction to the data. Offset correction ensures that the 3 channels are referenced to a true black level. This is achieved by measuring the signal level of the black reference pixel for each sensor. Gain correction compensates for pixel-to-pixel response variation, uneven lighting, and lens effects. Lenses tend to darken the edges of the field of view, an effect which becomes more pronounced with increasing aperture. To correct for all of these the camera images a white tile and a software gain correction is calculated for each pixel. This correction is then applied to subsequently acquired image data. The corrected data are stored in a BMP or TIFF format with

depth and calibration information stored in an associated metadata xml file that can then be read by the image replay software.

Geotek Visible Light Source

The GeoScan camera comes with a light specifically designed to illuminate cores. For normal RGB imaging, the Geoscan system uses white LEDs with spectral maxima at 460 nm and 565 nm (Figure 16-3). (Older light models use high frequency fluorescent lamps that produce light in 3 main wavebands, corresponding to the red, green and blue parts of the spectrum.) Two banks of LEDs, or two fluorescent tubes, are used to illuminate the core evenly from both sides of the image line. This provides a flooded illumination that minimises any shadow effects that could be caused from micro-topographic effects. The camera is arranged directly above the light and “looks” through a slot in the top surface of the light unit. Spurious reflections are eliminated by black anodising both the camera and light units.

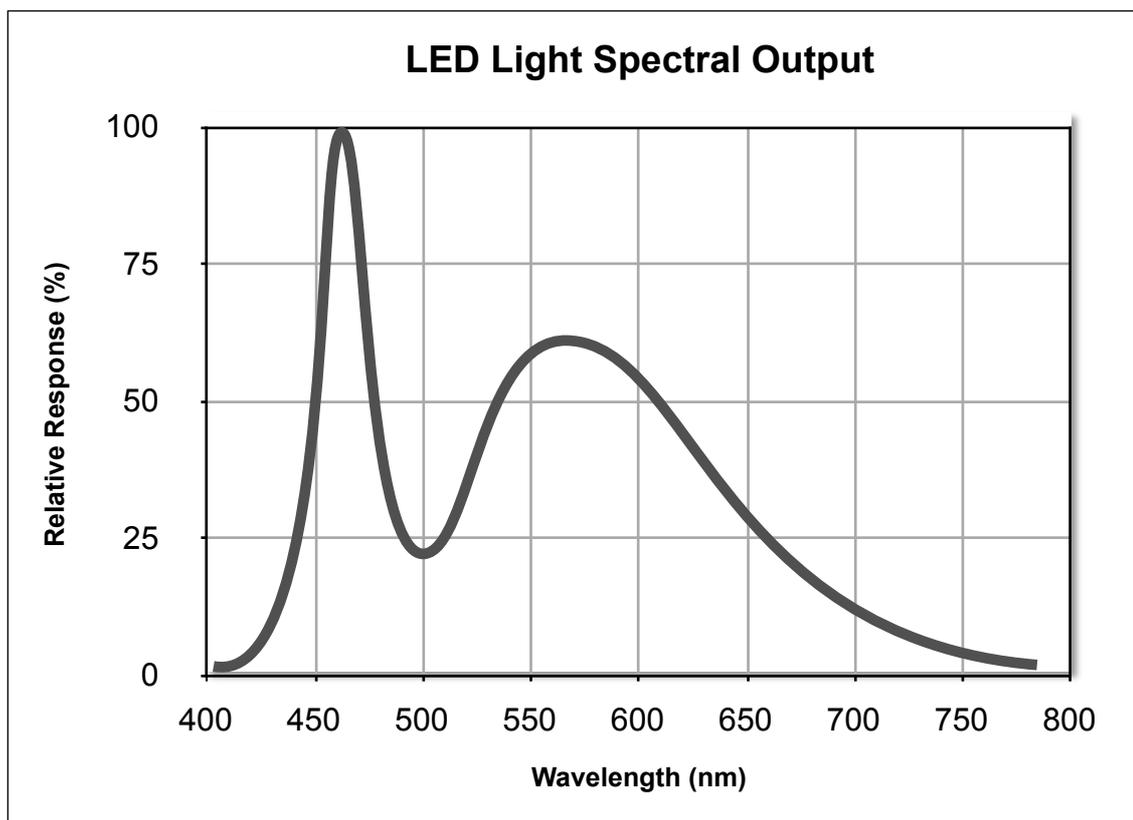


Figure 16-3. Output spectrum of LEDs used in Geotek lights.

Geotek Digital Imaging Software

Running the program

The Main Menu will appear as below providing the four menu items:

[Acquire Image]

[Camera Setup]

[About] (version information)

[Settings] (opens the settings window)

[Exit] (exit from application)



Figure 16-4. Main Menu Panel.

Acquire Image

This brings up the main track/camera control panel where the user enters the core sections to be logged and removes the core sections that have been logged. The options available are New, Edit, Delete, Show Log, Zero Pusher, Move Nominal Position and Begin Scan. Click Close Box (x) in the top right corner to exit.

This camera control panel shows an imaging queue at the bottom, where all core sections currently entered are shown.

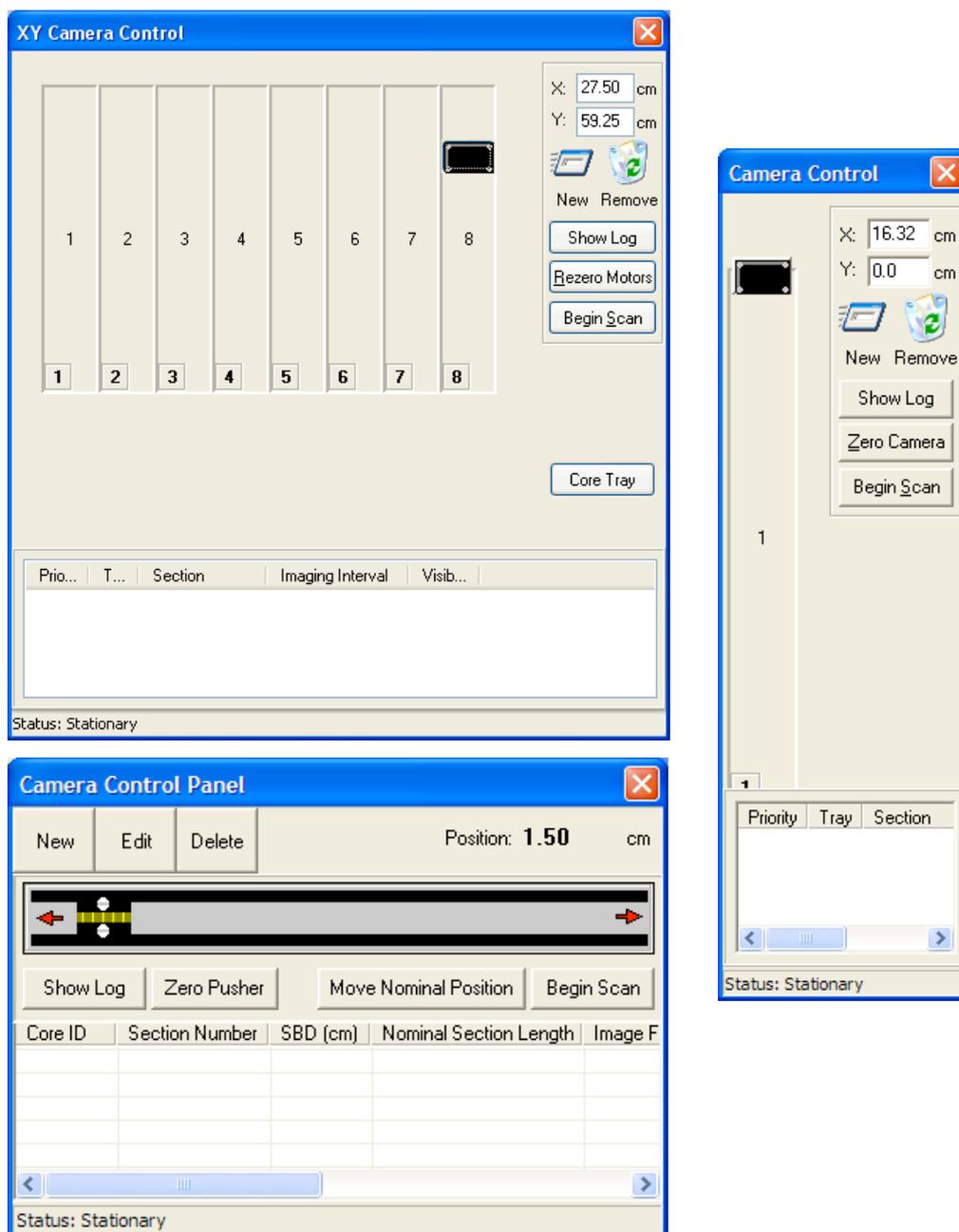


Figure 16-5. Camera control panels for the MSCL-XYZ (top left), MSCL-S (bottom left) and MSCL-XZ (right).

New (Core Section)

This adds a new core section to the imaging queue. Cores can be added at any time during the imaging process.

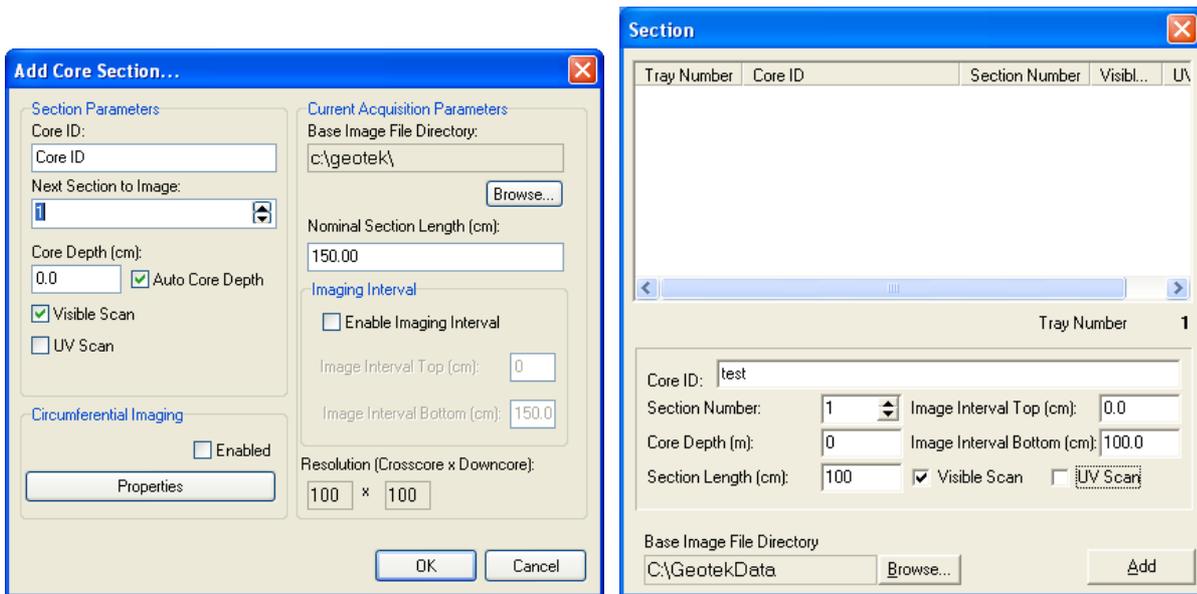


Figure 16-6. Add core section dialogue for the MSCL-S (left) and MSCL-XZ & MSCL-XYZ (right).

Most fields default to the last entry. Section Number defaults to the last entry plus one, and SBD (sub-bottom depth) Top of Section defaults to the last entry plus the length of the previous core section. The base image directory sets the directory structure where the image files will be stored. An Imaging Interval can be used to image a portion of a core section, rather than the entire section. The visible and UV checkboxes are only visible on systems where a UV option has been installed.

Edit (Core Section)

Allows the user to edit the section parameters already entered. Click on the section to be edited and then click on the edit button, or alternatively double click on the section in the list.

Delete (Core Section)

Allows the user to delete the section. Click on the section to be deleted and click on the delete button.

Show Log

This shows the entire log of imaged core sections and calibrations.

Zero Pusher

Finds the laser reference point.

Move Nominal Position

Moves the pusher to the nominal section length of the next section in the queue.

Begin Scan

Starts the track moving and collecting images. The image collection is tied to stepper motor pulses. Imaging of a section must be completed once begun, but imaging can be halted once a section has been completed by removing all other sections in the imaging queue. While scanning, core sections can be added and edited and the Log can be shown.

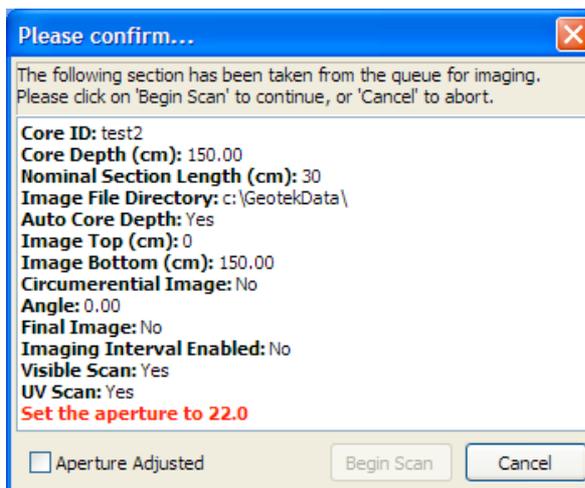


Figure 16-7. Begin scan panel.

An image of the core section being scanned is shown in a companion window. This image is scaled to the screen and is used for monitoring progress.

Core Tray (MSCL-XYZ only)

This option is available on the MSCL-XYZ to allow entire rock core trays or boxes to be laid on the MSCL-XYZ bed for imaging. When using rock core trays, the user can define the position of each channel of the tray.

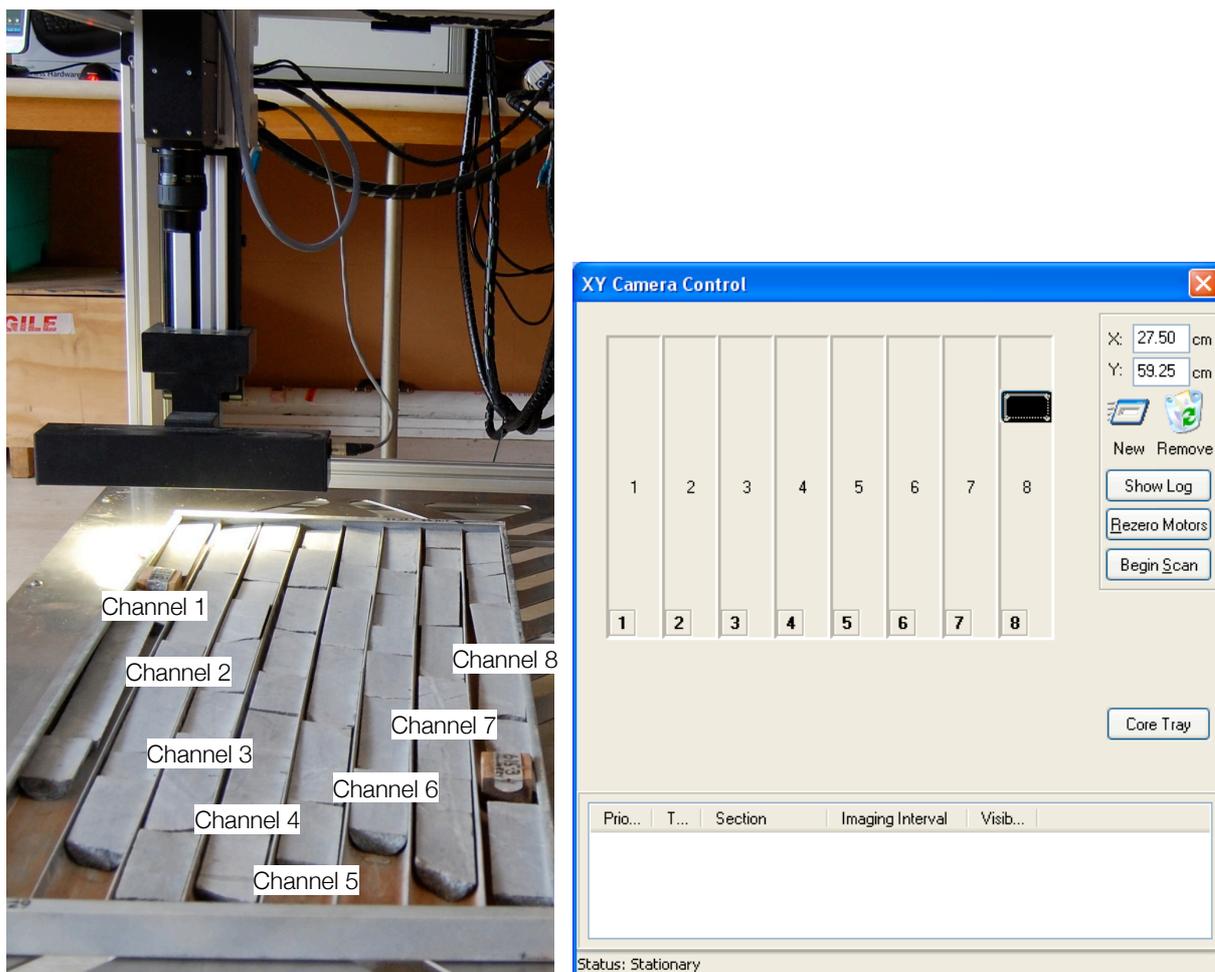


Figure 16-8. Example of .rock tray on MSCL-XYZ, showing labeled channels and corresponding MSCL-XYZ camera control.

Clicking on the [Core Tray] button brings up the “Core Tray Layout” pane. The position of each channel in the tray can be defined using this pane.

Before using the “Core Tray Layout” pane, first determine the location of each channel with respect to the MSCL-XYZ sensor head. Place the tray snugly against the registration bars on the MSCL-XYZ bed and click [Rezero Motors]. Using the software, move the camera over the exact center of the first channel (the leftmost channel). To find the first channel with the camera, make a black dot on a piece of white paper and place the dot at the top of the first channel. Using the scope display under [Basic Setup]-->[Set Focus] and the motor control arrows, move the dot to the center of the scope display. Read the X, Y position from the boxes at the top of the camera control pane. Measure the top of the rest of the channels with respect to the first channel.

In the “Core Tray Layout” pane, enter the X and Y position of the first (leftmost) channel and the channel length. If the channels are equally spaced, enter the space between each channel as the “Interval” and enter the number of channels in “Count”. Click [Auto Configure] to create a table showing the position of each channel. The channel information can be edited directly as well; click [Update] to apply the table edits to the tray layout on the “Camera Control” pane. Once a core tray layout has been defined, the layout can be saved for future use.

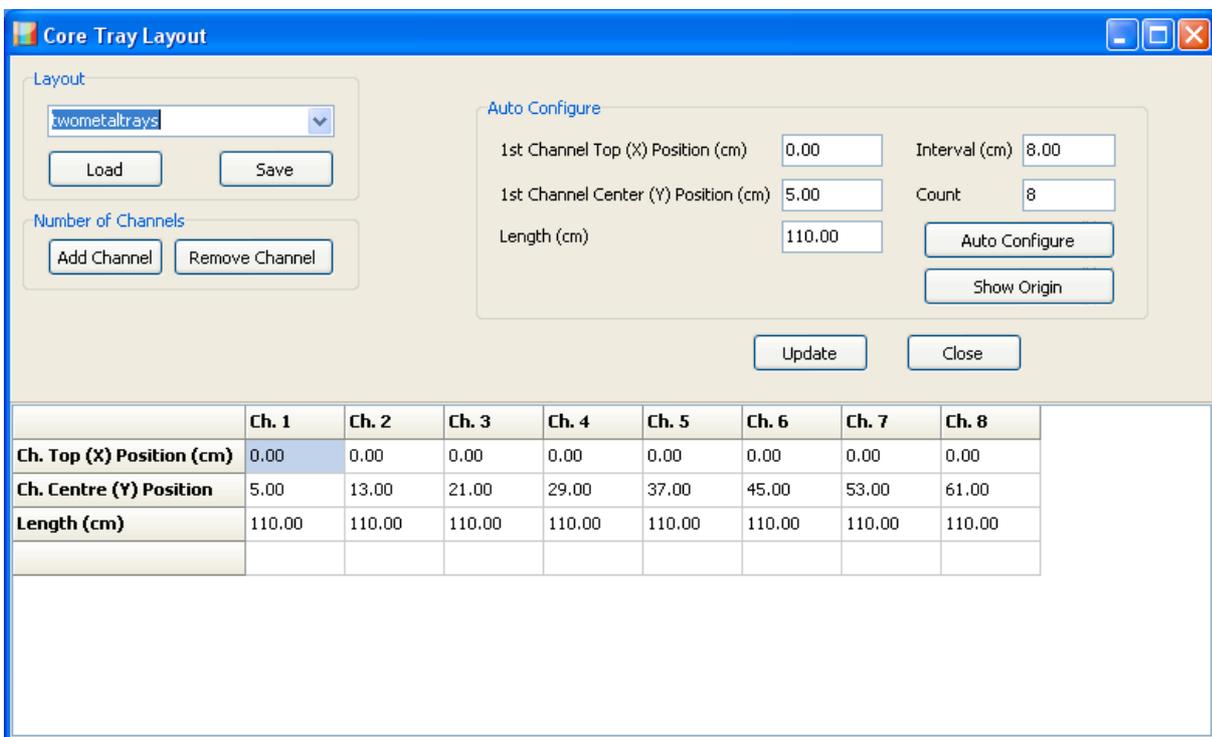


Figure 16-9. Core Tray Layout pane.

If the “Core Tray” button is missing, it means that Rock Tray Mode is not active. To activate Rock Tray Mode, in the settings, choose Tray Layout and select Use Rock Tray Mode-->Yes.

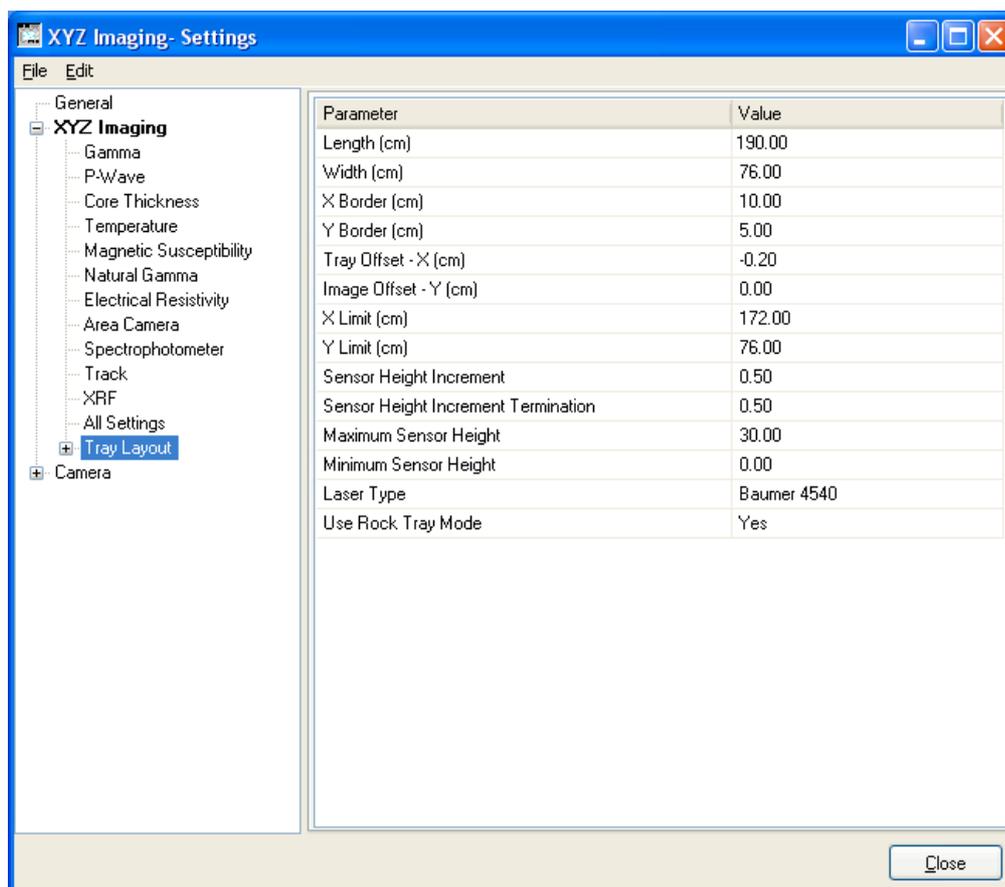


Figure 16-10. MSCL-XYZ settings showing Rock Tray Mode.

Basic Setup

This menu contains five options. The first three are procedures that may be used relatively frequently:



Figure 16-11. Basic setup menu panel.

When clicking on any of these options the user will see a track control panel appear and a camera scope display along with a specific dialogue to act as a guide through the procedure in question.

Camera Scope

The camera scope provides direct access to the data from the CCD sensors monitoring the output of all 2048 (or 1024) elements of each of the 3 CCDs (red, green, and blue). The window shows the output of the red, green, and blue channels on the bottom and the line-scan image (repeated for better visibility) at the top. The scope can be

resized if required (bottom right hand corner). Dragging an area on the scope from top left to bottom right can enlarge portions of the scope and corresponding line-scan view. Dragging in reverse, from bottom right to top left, will reset the zoom.

The **[Display Options]** menu allows customization of the scope. The options are:



Figure 16-12. Display options menu.

- All Colours: This forces the scope to display R,G & B channels.
- Show Red (Green, Blue): Toggles individual channels on and off
- Show XY Label: Displays the X (pixel No 1-2048) and Y value (0-100%) of any location on the scope.
- Resolutions: Set the number of pixels displayed across the scope.
- Show Image Frame: Shows yellow frame corresponding, in the horizontal, to the edges of the image (removing the permanently dark pixels at the left) and in the vertical to 0 and 255.
- Large Pixels: Doubles the size of the scope pixels on the screen for easy viewing.
- Dark Correction: Toggles the correction applied from the permanently dark CCD pixels to compensate for thermal noise and other environmental effects.
- B & W Calibration: Toggles the corrections applied to each pixel from the Black and White Calibration files.
- Reset Zoom: Returns the scope to full view. Areas can be enlarged by selecting and clicking. Maximum zoom is 20x in either dimension; if this value is exceeded zoom will not proceed.

Set Focus

This assists the user in focusing the camera in the plane of the split core surface using a focus bar (shown at bottom of window) and the RGB Scope window (see 2.4.1). Focusing should take place on a subject that is in the same plane as core sections to be imaged and has sharp transitions (edges). Aperture will affect the depth of field and the need for refocusing.

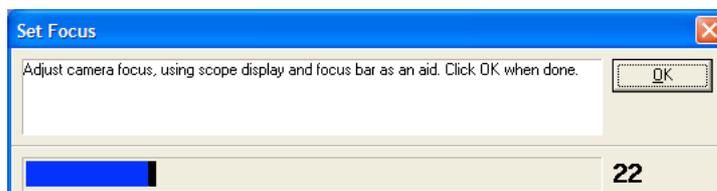


Figure 16-13. Set focus panel.

Colour Balance

This procedure writes calibration files containing the low and high calibrations for each element in the CCD. This ensures that all CCD pixels are scaled to the same black (minimum) and white (maximum) values. High calibrations are performed on a special white ceramic tile or a photographic calibration card. Choose a calibration standard that is similar in intensity to the surface being imaged. The RGB reflectance level of the tile or card should be entered into the Reflectance text box.

When preparing for the high calibration, the red, green and blue traces on the scope should be close to their maximum levels but not saturated (e.g., Fig. 16-11). It is recommended that the user leave the high calibration aperture the same as the scanning aperture and instead lower the light. Changing the aperture can produce line artifacts due to minor flaws and aberrations in the lens.

Before starting the calibration, ensure that the pusher is zeroed. Drag the pusher back (using the software), ready to move the calibration card past the camera at the core height. The software integrates a short distance across the tile or card to remove the effects of any dust on the tile.

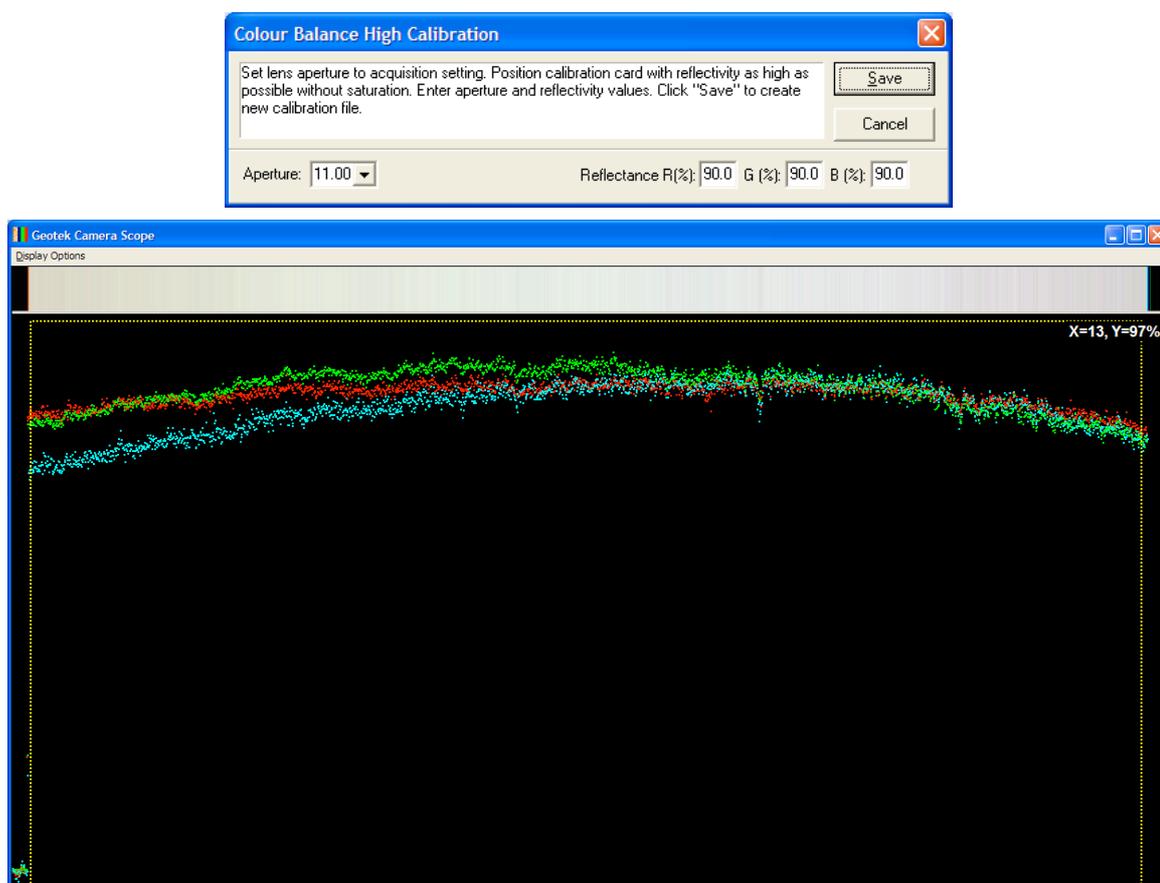


Figure 16-14. High calibration panel and scope display.

Low calibrations are performed with the lens cap on. Data is collected for few seconds and averaged. If the light height was changed for the calibration, it should be returned to the imaging height.

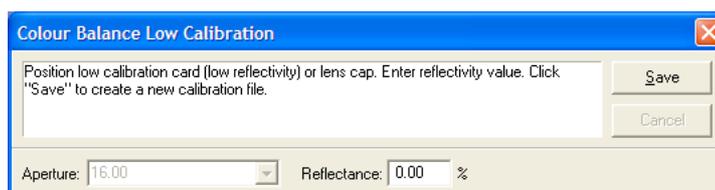


Figure 16-15. Low calibration panel.

The data from the two calibrations are stored in files (high.cal and low.cal.) in the c:\geotek directory.

Set Aperture

Writes the chosen Aperture value to the settings file. Aperture should be selected using the output of the RGB Scope such that the scope output is as large as possible without flattening at the upper values, indicating saturation of the CCD.

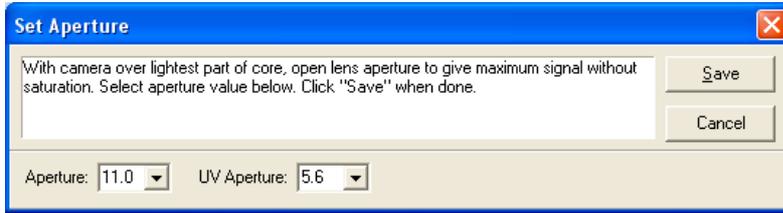


Figure 16-16. Set aperture panel.

Advanced Setup

This menu contains options that are likely to be used relatively infrequently and normally by experienced operators:

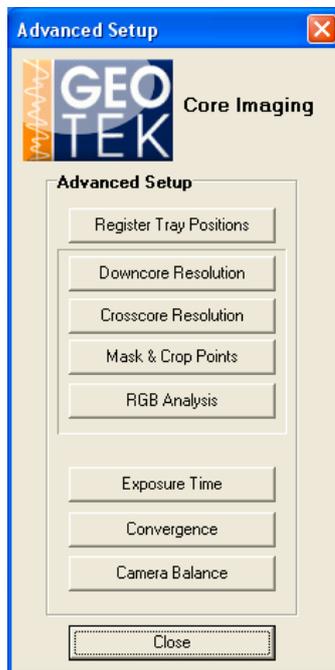


Figure 16-17. Advanced setup menu.

Down-core Resolution & Exposure Time

The down-core resolution is a function of a number of parameters but is controlled by the line acquisition rate as synchronised to the stepper motor. Consequently it is not a continuous variable but is a multiple of the smallest step distance. This is currently 0.00625 mm (1600 ppcm, pixels per cm) meaning that in theory the down-core resolution could be any multiple of 0.00625 mm. In the standard operational mode the down-core resolution will be set at 0.05 mm (200 ppcm). Default resolutions available are 100, 200 and 400 pixels per cm (equivalent to 100, 50 and 25 µm pixel size).

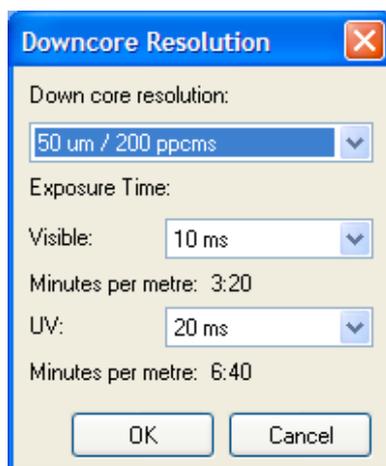


Figure 16-18. Selection of down-core resolution and exposure time.

The exposure time can be adjusted to improve the speed of image acquisition if the subject core is sufficiently light as when the exposure time is changed the aperture will also need to be changed to allow more or less light to hit the CCD arrays. Exposure time options are 5, 10 and 20 ms so halving the aperture size at each step means that the same amount of light will hit the CCD arrays for each exposure period.

The table below shows an example of how the exposure time and down-core resolution affect image acquisition time.

Resolution (μm)	Time to collect 1 m core image (minutes)		
	5 ms exposure	10 ms exposure	20 ms exposure
25	03:20	06:40	13:20
50	01:40	03:20	06:40
100	n/a	01:40	03:20

The exposure time can be varied from 5 to 80 ms for visible imaging and UV imaging. Geotek recommends that exposure time be set, generally, at 10 ms for visible imaging and 40 or 80 ms for UV imaging. There are interactions between exposure time and image resolution, so a few combinations of exposure time and image resolution are disallowed by the software.

Cross-core Resolution

The cross core resolution is controlled by the lens and the height of the camera above the object but of course is limited to 1000 pixels wide. If the full width were used then the cross-core resolution on a 9 cm wide core would be 0.09 mm (111 ppcm).

To reduce the cross core resolution to match that of the down-core resolution the user simply has to raise the height of the camera so that it is imaging a full 10 cm providing the 100 ppcm cross core resolution.

The software contains a feature to crop the additional image on either side of the core.

Since the cross core resolution depends on the distance between the camera and the object imaged, or practically, the camera height. The resolution is determined by placing something of known dimension under the camera at the height of the core surface.

To determine the cross core resolution the user should use the sliders and arrow keys in the control panel to move the left and right yellow lines on the scope to the known edges. Zooming in on the scope window can be helpful.

The user should enter the known distance (in cm) and the software will automatically calculate the full view and the cross core resolution.

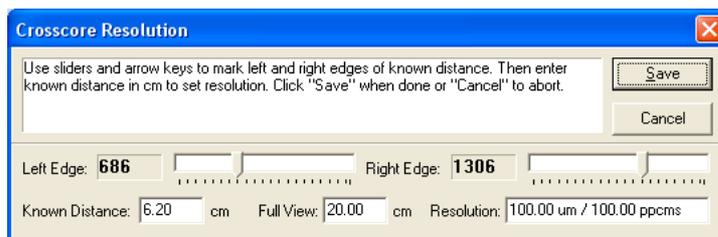


Figure 16-19. Cross-core resolution dialogue.

To set a predetermined cross core resolution (for example if the user wishes to adjust the camera so that the cross core resolution is the same as the down core resolution, *i.e.* 100 ppcm) then the user should follow the procedure below.

- Place an object of know width at the core surface level (say 5 cm wide).
- Enter 5 cm in the known distance and set the left and right yellow markers at a difference of 500 pixels (e.g. set the left edge at 200 and the right edge at 700). This will produce a resolution of 100 ppcm. Now adjust the camera height and focus so that the image fits exactly between the yellow marker lines. An iterative procedure of moving the camera, focusing and moving the object will be required.

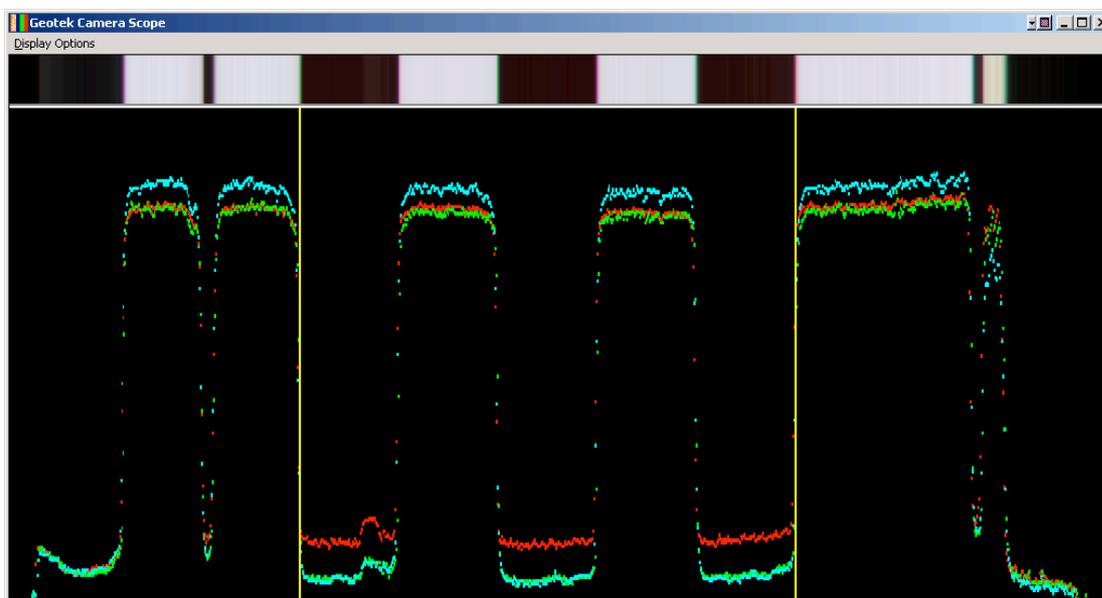


Figure 16-20. Setting the cross-core resolution using a known distance.

Mask and Crop Points.

This option allows the user to discard or mask data at the edge of the CCD array, for example if a particular cross-core resolution is required then this may leave parts of the image without any useful data in. There are two options, firstly a mask that allows the user to set a frame around the image in white, black or a shade of grey and secondly a crop that will physically crop the saved image width. The former option is useful for providing a neutral background to an image and the latter for reducing saved file size.

The mask shade can be modified using the slider bar (higher numbers represent lighter shades of grey) and the position of the mask at the left and right of the core is adjusted using the left and right edge slider bars (the live scope display will show these changes as the sliders are moved). The crop at left and right can be changed in the same way and if necessary can be disabled completely using the tick box.

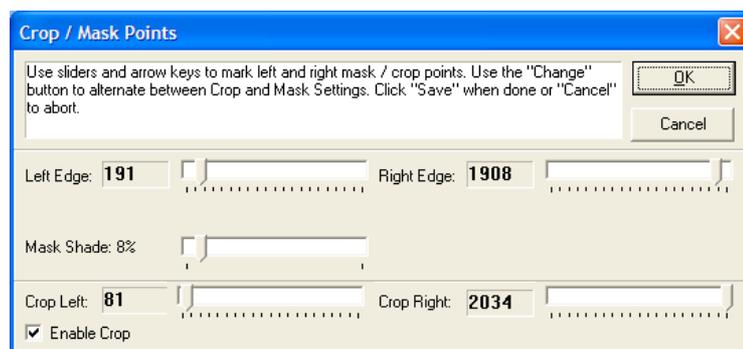


Figure 16-21. Crop and mask control.

Convergence (Cross- and Down-core)

There are two options available from this button, a live cross-core convergence as described below and a static cross- and down-core convergence.

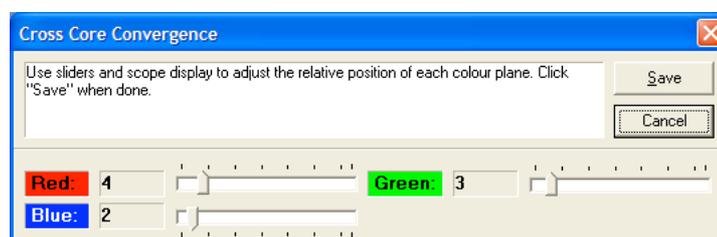


Figure 16-22. Cross-core convergence panel.

The static convergence utility allows the user to open a previously collected image and change the convergence values for either the cross- or down-core alignment. A line should be drawn on the loaded image across a black to white transition from which a scope like plot will be produced and on which the traces of red, green and blue can be moved into alignment. The alignment values can be saved for cross-core convergence and for each of the available down-core resolutions. It is important to note that the image to work from for this static correction should have no convergence applied – i.e. all convergences should be set to zero (this can be done in the settings file).

The live cross core convergence facility enables the user to check and adjust any y-axis misalignment in the 3 colour planes. To do this the user should view on the scope a black to white edge and observe the transition in each colour. They should of course occur at the same pixel number.

The user can adjust the position of each colour transition by using the colour sliders on the control panel. When correctly aligned they will appear as in Figure 16-21 below. When the convergence is not set correctly colour fringing around objects will be visible, the colour of which depending on the channels out of alignment. Some examples of colour fringes around a black object are shown in Figures 16-22 & -23.

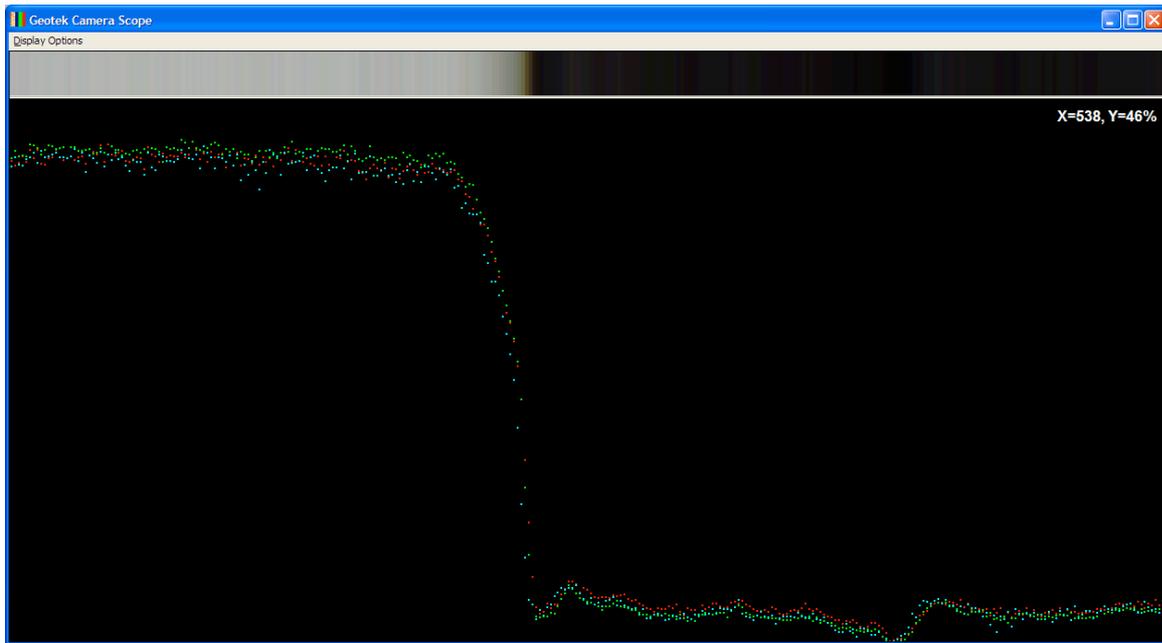


Figure 16-23. Good cross-core convergence.

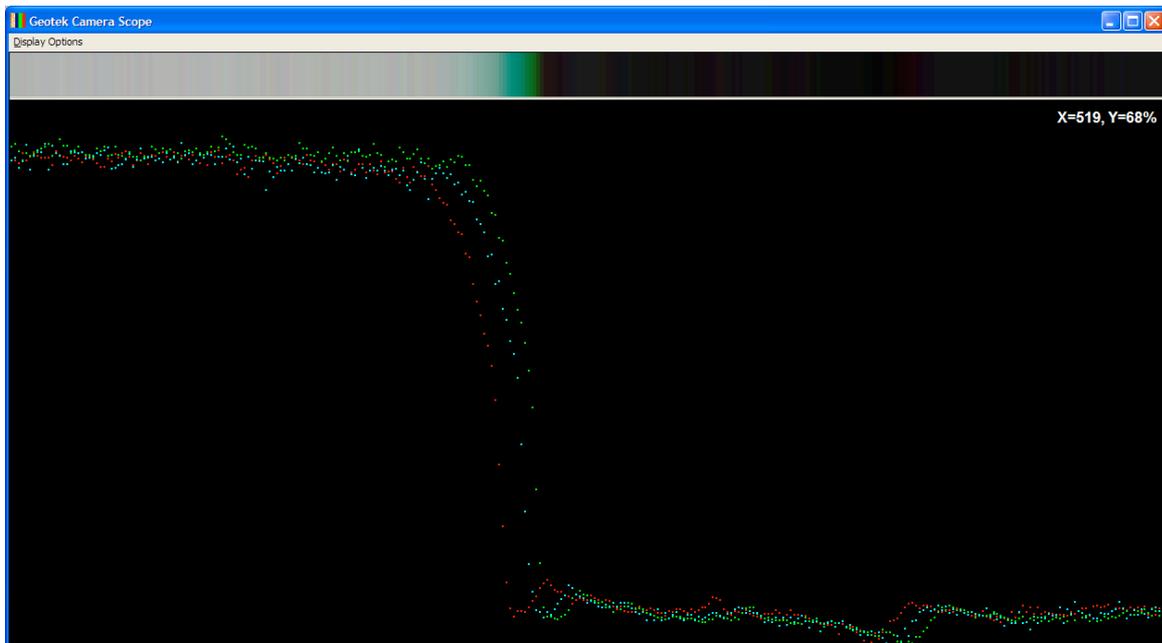


Figure 16-24. Poor cross-core convergence.

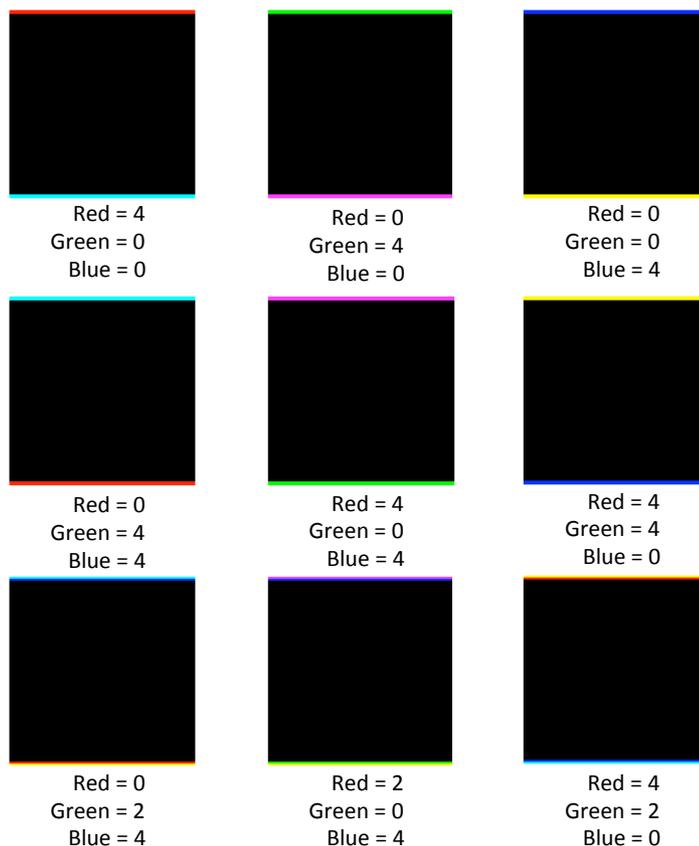


Figure 16-25. Examples of colour fringing with different channels and offsets.

Camera Balance

This procedure allows the user to modify the hardware analogue to digital converter settings of the GeoScan IV camera, adjusting the individual gains and offsets of each channel. These settings are factory set and should not be changed unless under advice from Geotek.

For communication between the software and the camera, the camera interface box should be connected to the PC using the supplied RS232 cable. Selecting the Camera Balance option without this cable connected will result in a communication error occurring.

It is important that both the camera and the light are given sufficient time to warm up. As with the colour balance you will need either the white calibration tile or the photographic calibration card.

Place the white calibration piece beneath the camera and adjust the aperture so that the red, green and blue traces on the scope are close to their maximum (indicated by the yellow box around the scope section of the screen) but do not exceed this level – i.e. become saturated.

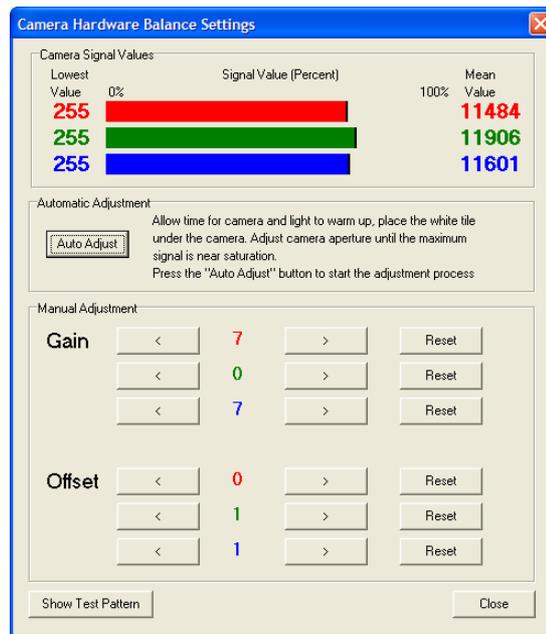


Figure 16-26. Camera Balance Dialog.

Click the Auto Adjust button to begin the process, and follow the prompts. This will take you through several steps where you will have to add and remove the lens cap.

The lower half of the dialog is concerned with manual adjusting the gains and offsets of each of the colour channels, however the Auto Adjust function will normally be sufficient to correctly balance the camera.

Image Data

The files created by the Geotek Digital Imaging software are in bitmap format (BMP) or tagged image file format (TIFF). Additional information is included in a associated xml file that is used by the Geotek image replay software. This metadata file includes calibration information (image aperture and white calibration aperture), resolution parameters (cross-core and down-core) and the relevant positional data (image top, length and width). Users should be aware that the image file and metadata file should always accompany each other if they are to be used in . The Geotek replay software will not be able to show images that have lost the associated xml file. The file structure that is used for the data files as stored in the core directory is illustrated below, there is a single image file per core section and an associated xml file.

im001_01.bmp & im001_01.xml for section 1

im002_01.bmp & im002_01.xml for section 2 etc.

There are no output functions available with the Geotek software but the widely used bitmap and TIFF format allows cross platform manipulation of the data, whilst retaining all the relevant colour depth and resolution data intact.

The images can be viewed alongside the data collected with the other sensors on the Geotek MSCL system using the standard software. The user should load in the core data and then, in the Processed Data Display, load the relevant core image (**[File_Load Image]**). The image will be displayed at the correct depth so that features and data can be compared. The profiles of red, green and blue reflectance can be extracted from the image and also displayed alongside the image and log data.

RGB Analysis

The data from the individual CCD sensors behind each of the dichroic interference filters can be automatically extracted from the image files immediately after acquisition. This process can be enabled or disabled and defined through the RGB Analysis option in the Advanced Setup Panel.

Where in the image that the strip of data is extracted from is defined by setting a left and right point from which the data will be extracted. There are two choices when generating RGB data and these are either sampling or averaging. Sampling will simply obtain a value from a line of data and the interval is defined by the resolution, whereas averaging will average a block of data as set by the Sample Interval value and can be enabled by checking the Average RGB values checkbox. RGB data will be extracted from the full length of the acquired image.

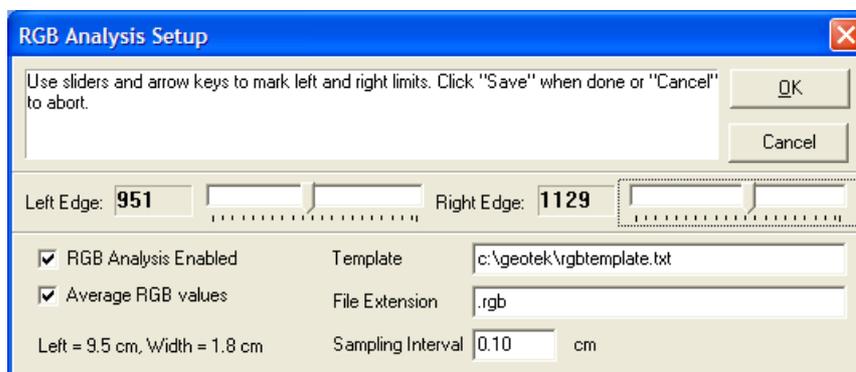


Figure 16-27. RGB Analysis Setup Dialog.

By default the final output is based around a template file called rgbtemplate.txt, which is stored in the c:\geotek directory. This template file contains xml style tags that define the final ASCII file that is saved to disk. The file rgbtemplate.txt can be renamed and its contents redefined using the xml tags shown the table below.

Standard Tags	RGB Tags
<filename/>	<rgb-left/>
<image-type/>	<rgb-width/>
<coreID/>	<rgb-top/>
<section-number/>	<rgb-height/>
<image-number/>	<rgb-interval/>
<physical-width/>	<rgb-average/>
<physical-height/>	<data> with </data>
<physical-top/>	<top/>
<pixels-per-scan/>	<red/>
<pixels-per-CM/>	<green/>
<horizontal-resolution/>	<blue/>
<calibration-aperture/>	
<image-aperture/>	
<pixel-width/>	
<scan-lines/>	

Inserting any of the above tags into the template file will cause them to be replaced with the relevant values on the final output. You need to make sure that the tag is exact else it will not get replaced.

The data gets placed into the file via a set of <data> tags. For example:

```
<data><top/> <red/> <green/> <blue/></data>
```

In the final output the <data> and </data> tags will disappear. Each line will have a 'top' value followed by calibrated Red, Green and Blue values each separated by a tab. By changing the template file and the data tags you can get the data in any format you wish. For example:

```
<data><top/>,<red/>,<green/>,<blue/></data>
```

will produce data that is comma separated.

The output file generated will be saved automatically, providing the RGB Analysis Enabled option is checked, into the same directory as the images with an .rgb file extension. The file extension can be defined using the File Extension option.

Camera Settings

Many of the camera parameters are controlled through the Imaging software but some are only accessible from the settings window (see Figure 16-27).

Camera

The 'Camera type' is defined as is the 'Camera offset', these are the version of Geoscan system (I through IV) and the position of the camera relative to the reference point of the track, note that this offset is to the right of the reference point.

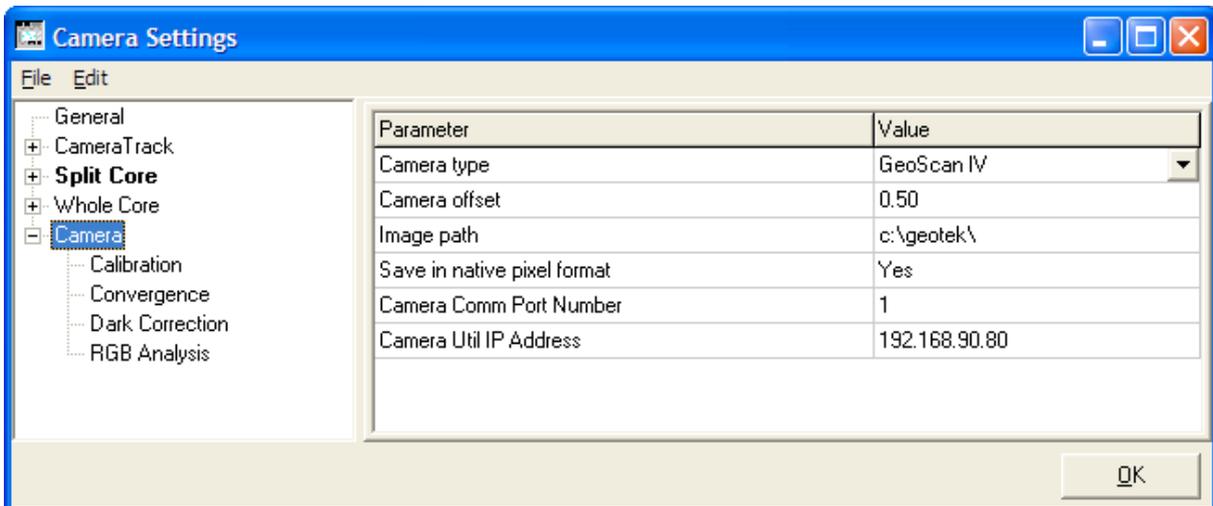


Figure 16-28. Camera settings.

The 'Image path' indicates where the core image directories will be stored, this is accessible through the Imaging software too (when adding a core section to be imaged, see Figure 16-6). The option 'Save in native pixel format' is available only when the GeoScan IV is selected as 'Camera type' and defines whether images are stored in a 16 (Yes) or 8 (No) bit format. 'Camera Comm Port Number' tells the software on what serial port to communicate with the camera for configuring the hardware ADC settings. On a TCP/IP enabled system this can be done using the Imaging software under Setup - Advanced Setup - Camera Balance. In this instance the IP address should be set to 192.168.90.80.

Calibration

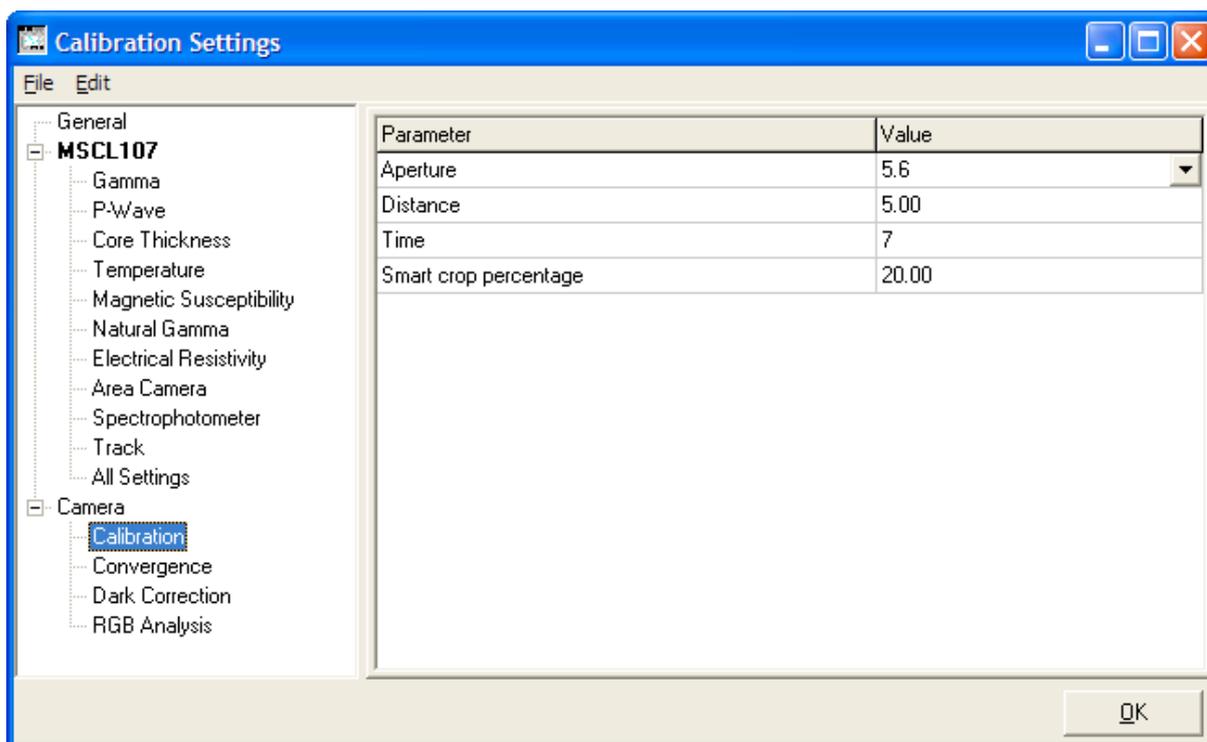


Figure 16-29. Calibration settings

The camera calibration settings group contains the last high calibration aperture level ('Aperture') - this parameter is updated by the Imaging software and does not need to be changed. The 'Distance' and 'Time' parameters define over what distance the pusher moves during calibration to remove the effects of any dust on the tile or calibration card and how long the calibration takes (this defines the number of averages used). If the calibration piece does not cover the entire viewing area of the camera it will cause the data outside of that area to be incorrectly calibrated. 'Smart crop percentage' determines the level below which the image will automatically be cropped. By default the smart crop percentage is at 20% which should be significantly different to the high calibration level although it can be adjusted if necessary.

Convergence

The down- and cross-core convergence parameters are stored in the 'Convergence' group. The cross-core convergence needs only one definition per channel but the down-core convergence should be defined for each resolution available. The parameters stored here are updated by the imaging software when setting the down- and cross-core convergence but can be overridden from this window. Care should be taken when changing these parameters from the settings interface.

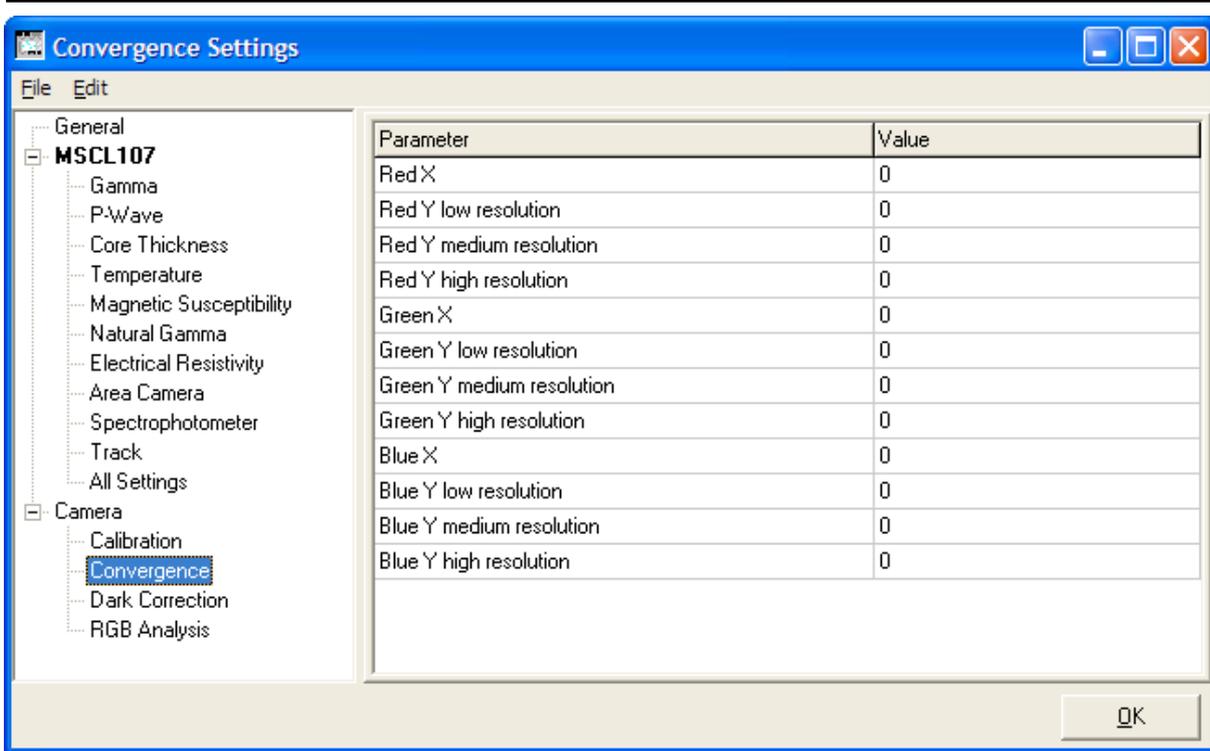


Figure 16-30. Convergence settings.

Dark Correction

The dark correction should not be enabled when using the latest version of the software as dark calibrations are used when imaging that account for the dark levels for each pixel in each CCD array. The dark level correction was originally made using blanked off pixels at the start of each array.

RGB Analysis

The parameters used for the analysis described above for extracting the red, green and blue values from images are defined here. These parameters can either be defined manually using the settings or more easily through the RGB Analysis option in the Advanced Setup Panel.

The analysis can be switched on or off using the 'Enabled' setting and the template file defining the output file is given in 'Template'. The file extension of the output file can be defined in 'File extension', by default this is set as .rgb and has a filename the same as the image from which the data was extracted.

Where in the image that the strip of data is extracted from is defined by setting the point across the image to start extracting data (the 'Left position', in cm) and the strip's 'Width' in cm. There are two choices when generating RGB data and these are either sampling or averaging ('Average' set to 'Yes' or 'No' respectively). Sampling will simply obtain a value from a line of data and intervals set by the resolution, whereas averaging will average a block of data as set by the resolution value (defined by 'Sample interval', in cm). RGB data will be extracted from the full length of the acquired image.

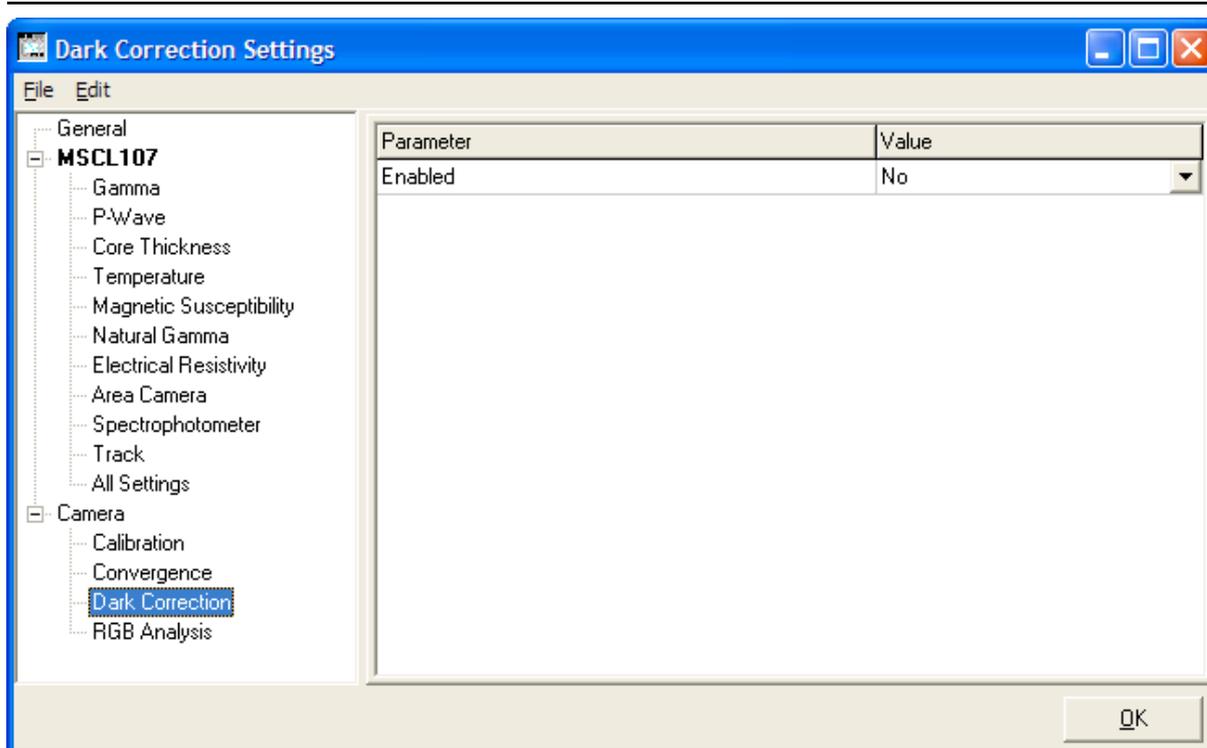


Figure 16-31. Dark correction settings.

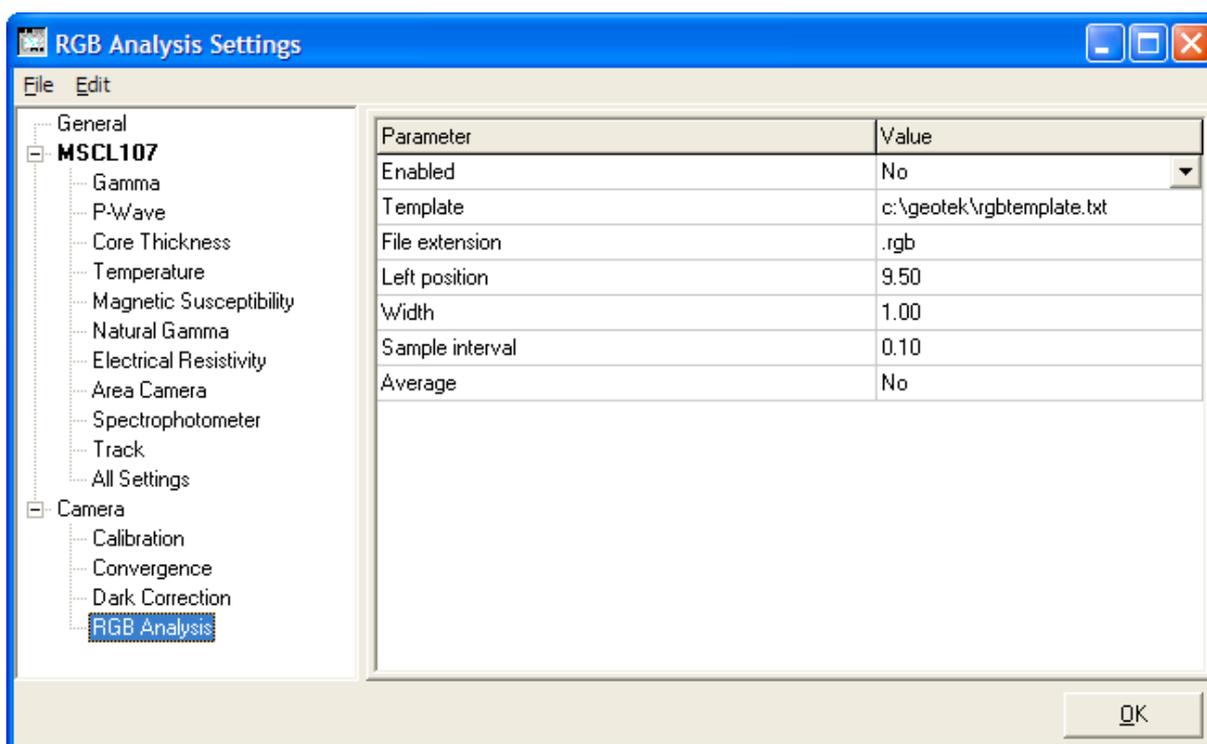


Figure 16-32. RGB analysis settings.

Ultraviolet Fluorescence Imaging

The Geoscan camera can be used to record images of visible fluorescence in cores using ultraviolet excitation. Crude oil fluoresces under ultraviolet light, as do some minerals. Using the Geotek UV light source and a dark room or covered imaging system, images of fluorescent material in core can be obtained.

Geotek Combination UV/Visible Light Source

Geotek produces a combination ultraviolet and visible light source. The ten high-power ultraviolet LEDs provide narrow-band ultraviolet radiation centred around 365 nm (full width half max approx 12 nm) and are shielded by a UG1 bandpass filter. The visible light LEDs are the same as used in the standard Geotek visible light source.

Each bank of LEDs, including the UV bank, can be angled by the user to provide optimal lighting. Each UV LED is individually controllable, and the two banks of white LEDs are each grouped into four separately controllable sets of lights.

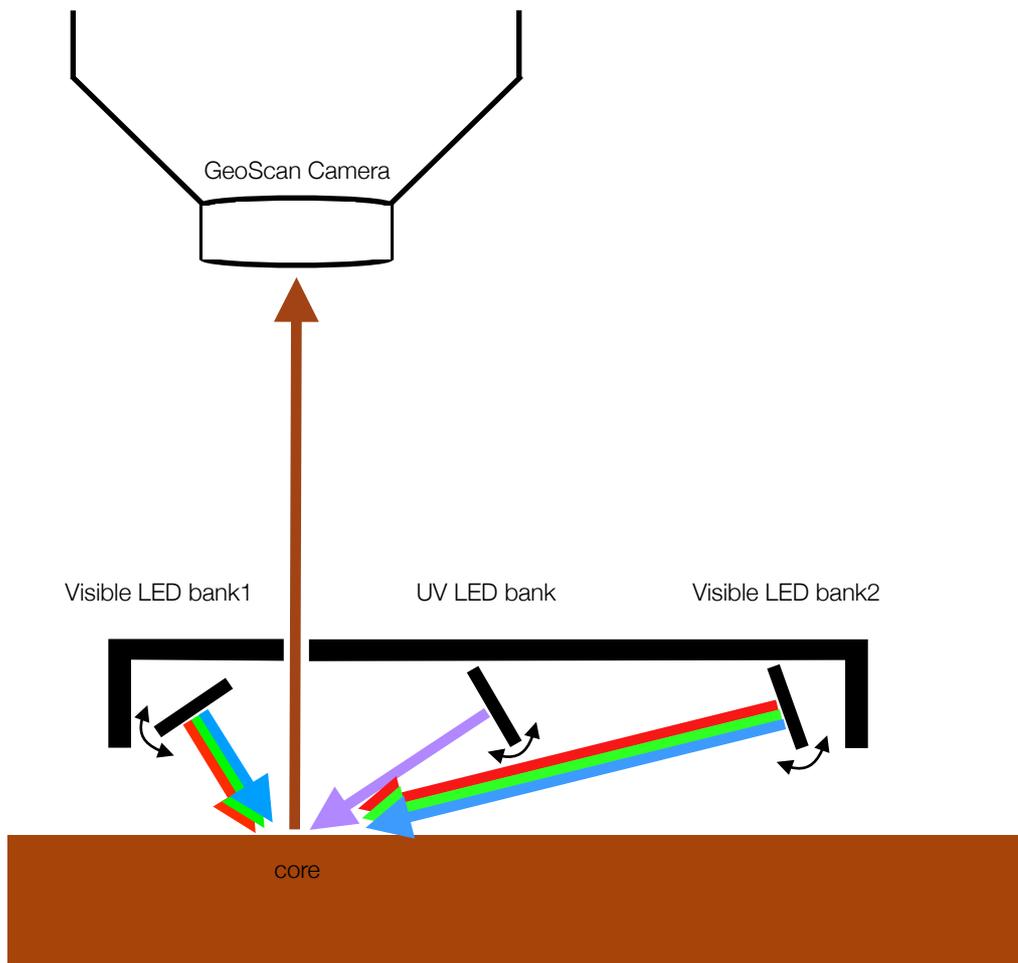


Figure 16-33. Diagram of Geotek combination UV/visible light source.

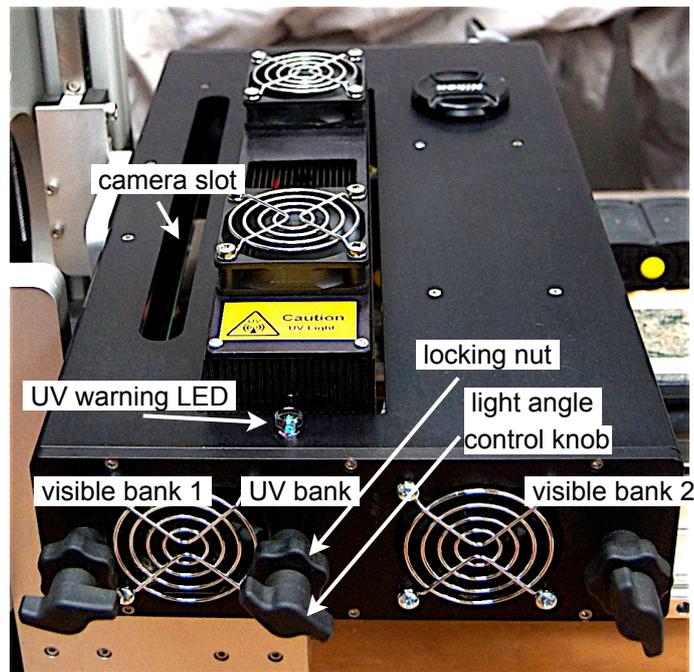


Figure 16-34. Picture of Geotek combination UV/visible light source as seen from the top.

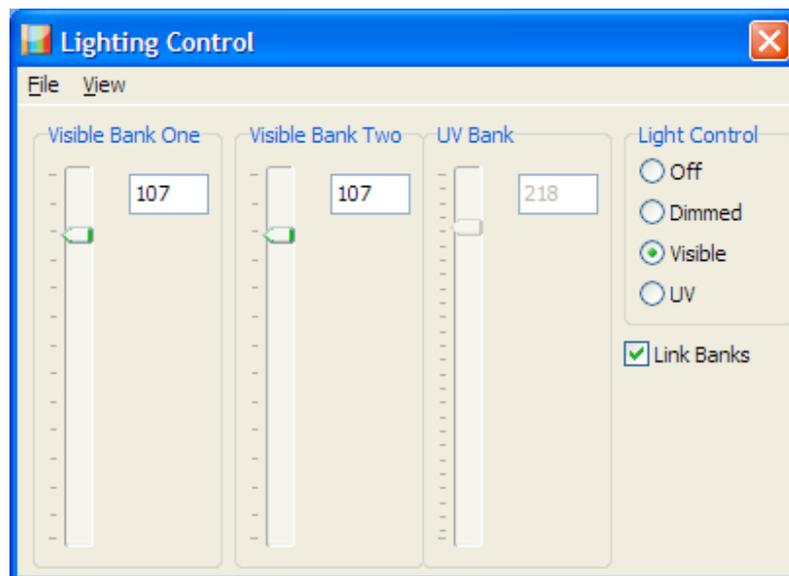


Figure 16-35. Simplified version of UV/visible light control.

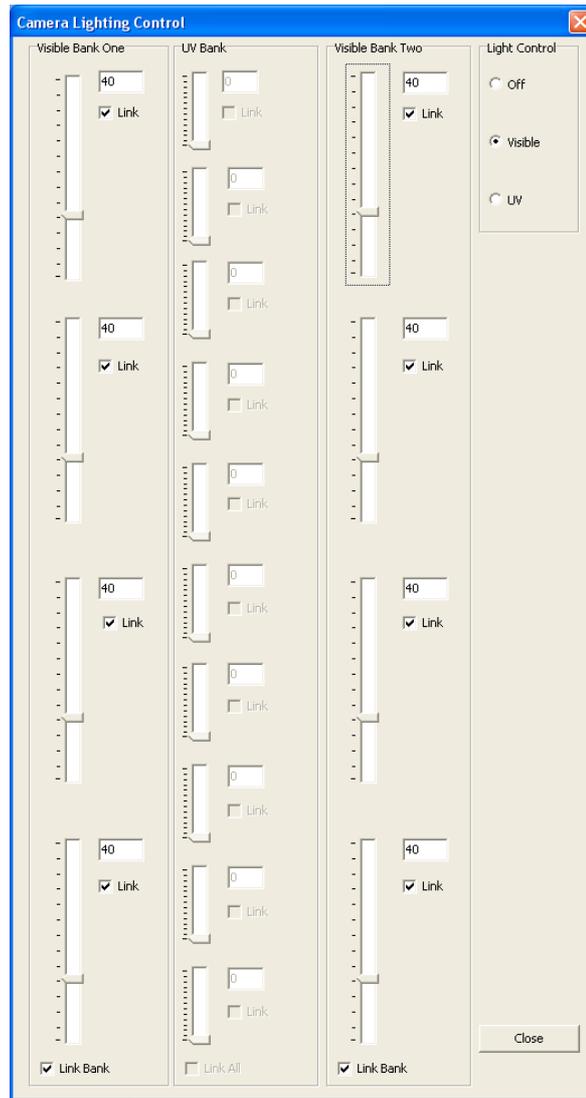
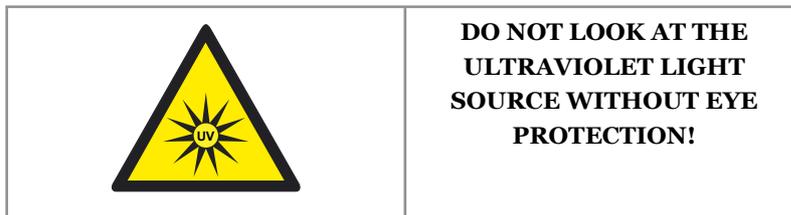


Figure 16-36. Geotek combination UV/visible light source control pane, showing intensity controls for groups of lights within banks. Light groups can be linked to one another so their intensities can be controlled together.

Ultraviolet Radiation Safety

No visible light is produced from the UV light source, so care must be taken to prevent eye damage by invisible ultraviolet rays. Wear protective goggles when using the UV light source.



A blue LED on the top of the light will illuminate whenever there is power to the UV lights, and a warning pane will be displayed on the screen.



Figure 16-37. UV warning pane.

The light can be controlled through the Geotek software. The software can switch the two sets of LEDs on or off, or adjust the intensity. This allows repeat visible and ultraviolet fluorescence imaging without user intervention.

Use of UV Data

Most laboratories use ultraviolet images in a qualitative mode, to see the location of fluorescent compounds and the co-occurrence of mineral phases or sedimentary strata. However, it is possible to perform more quantitative analysis with the data.

Because the GeoScan camera separates incoming light cleanly into red, green, and blue components, analogues to some standard chromatic parameters can be calculated directly from the camera output. Q 650/500, the intensity ratio between 650 and 500 nm, will have the same characteristics as the GeoScan red/blue ratio. QF-535, the ratio between 535-750 nm and 430-535 nm, will have the same characteristics as the ratio of (red + green)/blue. The user must experiment to decide how these parameters can be applied to their cores, and what scaling factors might be required.

Acquisition of UV images

Ultraviolet images are acquired in the same manner as visible images (see previous section on image acquisition). If the user wishes to automatically collect a UV image after a visible image, both the visible and UV boxes should be checked on the “Add Core Section” pane. After the visible image is collected, the system will prepare to collect an ultraviolet image. On the MSCL-XZ, the camera will move back to the top of the section, and the software will prompt the user if the aperture requires changing. On the MSCL-S, the pusher will move back, and the user must move the core section back. The software will also prompt the user to change the aperture if necessary.

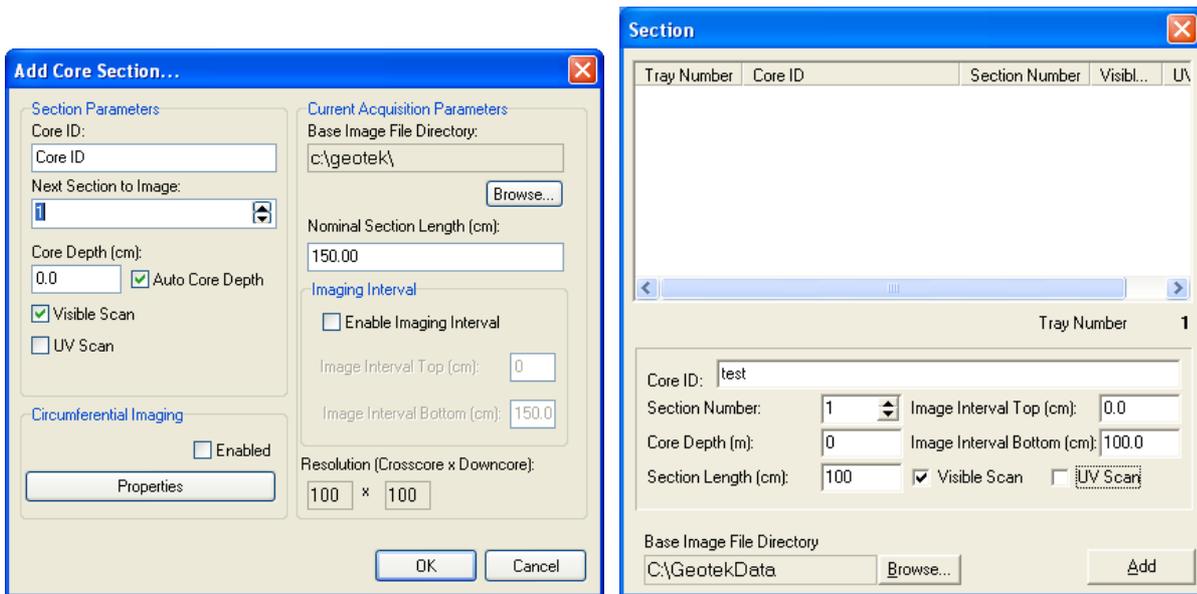


Figure 16-38. Add core section dialogue showing visible and UV checkboxes for the MSCL-S (left) and MSCL-XZ (right).

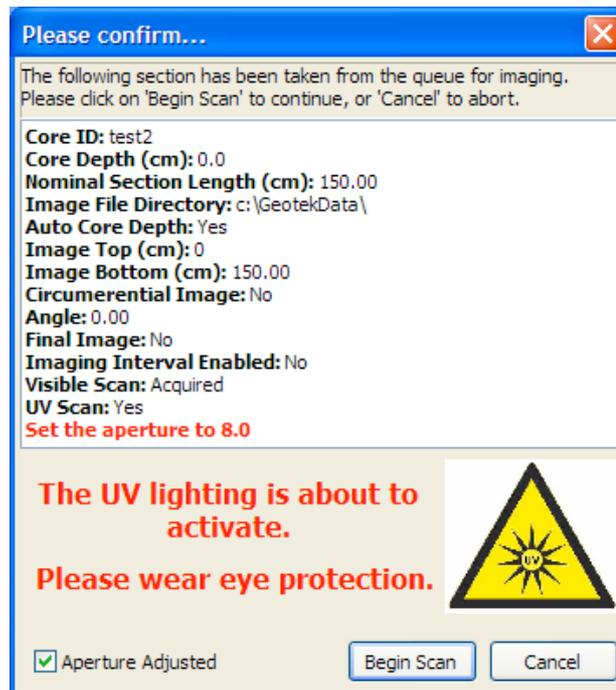


Figure 16-39. Prompt for user to change aperture and prepare for ultraviolet imaging.

Chapter 16 Appendix - Circumferential Imaging

Overview

To analyze structure in rock cores, it is best to visualize the core in an unwrapped mode. For example, a planar feature (such as a fault or vein) dipping through the core at an angle will appear as a sine wave in an unwrapped image, where the dip angle is simply a function of the amplitude of the sine wave and the diameter of the core.

An unwrapped image of a rock core can be obtained by computation from a static image. Computational unwrapping can now be performed on line scan images collected perpendicular to the long axis of the core with the GEOTEK Digital Imaging System. Two or more scans of the core, at different angles of rotation, can be corrected geometrically and stitched together using automated software techniques.

Computational unwrapping overcomes problems of image distortion caused by 'core tumbling' which can occur with less than perfectly cylindrical cores when unwrapping mechanically. The GEOTEK system overcomes these difficulties by imaging sections while the core is stationary in 2 or more individual passes. This gives the user complete control and enables high quality images (around 300 dpi) to be easily obtained on cores that are not perfectly cylindrical.

Calibrating Circumferential Imaging

In order to get the best possible images whilst running the Imaging software in circumferential imaging mode it is important to go through an initial geometry calibration process. During this calibration, the properties required for computational unwrapping are calculated. This calibration process should be repeated anytime the camera is moved, the resolution changed or lighting conditions changed.

ImageTools, Geotek's image manipulation application, is used for both the initial calibration and optionally as a tool to be used for greater control of the final image.

Creating the Calibration PDF

For calibration, a calibration chart is first generated with ImageTools. The calibration chart is specific to a core diameter.

- Start the ImageTools software.
- When the main window appears, click the [**Circumferential Imaging**] button in the right hand panel to open the Circumferential Stitching pane.

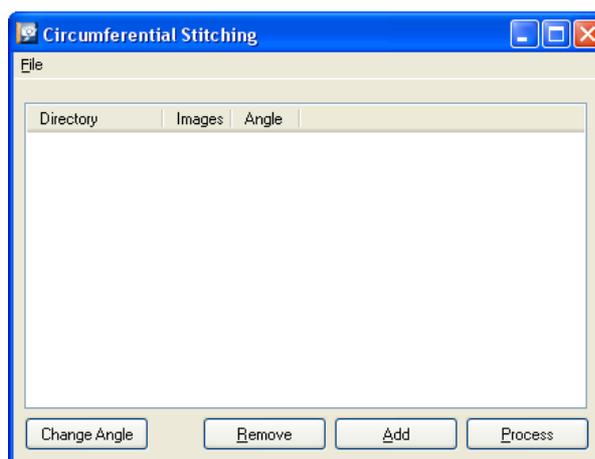


Figure 16A-1. Circumferential Stitching pane.

- From the File menu select the [**New Calibration PDF**] menu item or use the [**Ctrl+N**] shortcut. The Generate Calibration PDF dialog will be displayed.

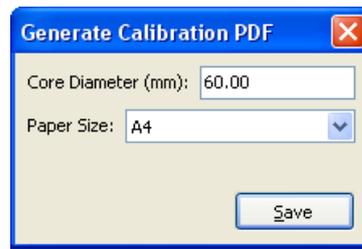


Figure 16A-2. Generate Calibration PDF dialog.

- Enter a core diameter value in millimetres and choose a suitable paper size from the drop down box.
- Click [**Save**] and choose a filename and directory for the file.

The paper size must be large enough to print the entire calibration sheet for the core diameter specified. When printing the PDF, ensure that it is printed at 100% size. An example calibration diagram is shown below.



Figure 16A-3. Calibration chart.

The calibration chart should be cut and then wrapped around a suitably sized liner or core with as much care as possible, paying particular attention to the alignment of the overlap.

Collecting Calibration Images

The calibration piece must now be imaged at various degrees of rotation using the Imaging software. Set up the camera on the calibration piece exactly as if it were a core. Setting the horizontal resolution is especially important, and a guide specific to the circumferential imaging calibration piece is included below. Please refer to Chapter 16 for the rest of the imaging setup process.

- Start the Imaging software.
- Select the [**Setup**] button.
- Select the [**Advanced Setup**] button.
- Choose the [**Crosscore Resolution**] option.
- In the Display Options menu make sure the option “Show Centre Line” is checked.

- Align the 0° line with the centre line of the scope.
- Drag the yellow lines, or use the scroll bars to align them to the 45° vertical lines.
- Enter the distance value as shown on the calibration chart into the known distance field.
- Click [**Save**] to store the resolution information.

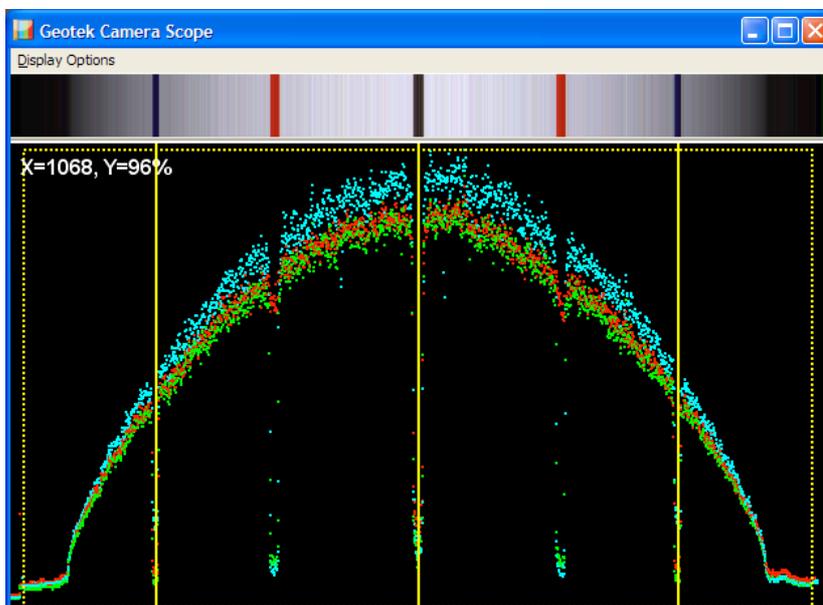


Figure 16A-4. Setting horizontal resolution.

It is normally easier to acquire images without the crop process enabled. This presumes that the camera is centered mechanically and avoids any difficulties in calculating an offset from the centre for each image.

- In the Advanced Setup panel select the [**Mask & Crop Points**] button.
- In the Scope Control Panel that appears make sure that the [**Enabled Crop**] option is unchecked.
- Make sure the mask position is outside the area of the core section, or set to the maximum positions for no mask.

Acquire a set of calibration images using the acquisition mode of the Imaging software. Ensure the Circumferential Imaging check box is checked (the Final Image box should be unchecked) and the Angle is set to 0.0. If the calibration section is much longer than the calibration chart, use Enable Imaging Interval to speed up the imaging process by only imaging the necessary interval.

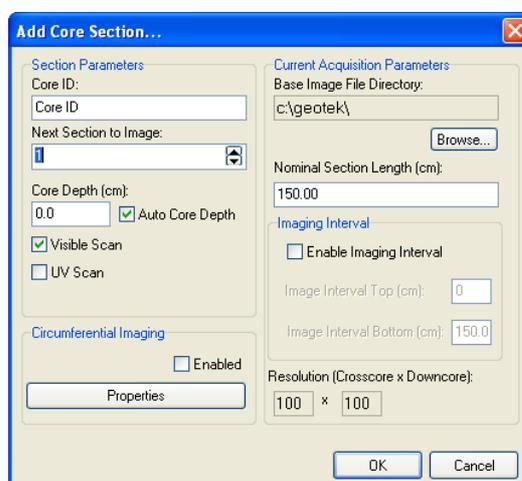


Figure 16A-5. Add Core Section pane, showing circumferential imaging checkbox.

Click the Circumferential Imaging [**Properties**] button. Set the Image Count to the number of images to be taken per rotation and the set core diameter in the Diameter field. Choose a 48 or 24 bit image. The other values will be iterated using Image Tools.

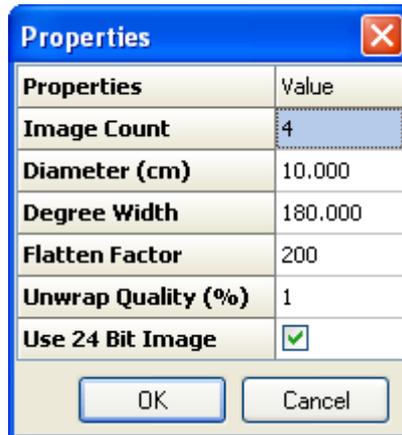


Figure 16A-6. Circumferential Imaging Properties.

Image the calibration section, with the first angle (0.0°) centered at the top of the section. Collect the rest of the images by repeating this process, with the core properly rotated. The Angle field in the Add Core Section pane will automatically increment. When the last image is reached, the Final Image checkbox will automatically be checked and an unwrapped, stitched image (not correct, at this stage in calibration) will be created.

Images are saved into a directory named with the Core ID, with subfolders for each angle. Degrees are reduced to their integer parts: the angle 90.5° will be saved in a directory called "90". (The metadata will still retain the angle value 90.5° .) The unwrapped, stitched image is saved at the top level, stored directly in the folder "CoreID".

Using ImageTools to Finish Calibration

- Start the ImageTools software
- Click on the [**Circumferential Imaging**] button in the right hand pane.
- In the dialog that appears click on the [**Add**] button.
- Select the parent directory which contains all the other angle directories. ImageTools will search the sub-directories for images. Alternatively, browse for each angle directly and add them each individually. (If these instructions are followed in order, there will be a reconstruction circumferential image under the parent directory called IM001_01.bmp. Remove this image from the parent directory before selecting the parent directory to avoid confusion.)
- The set of images just acquired should now populate the list. Click on the [**Process**] button to continue. The Circumferential Stitching pane will appear.

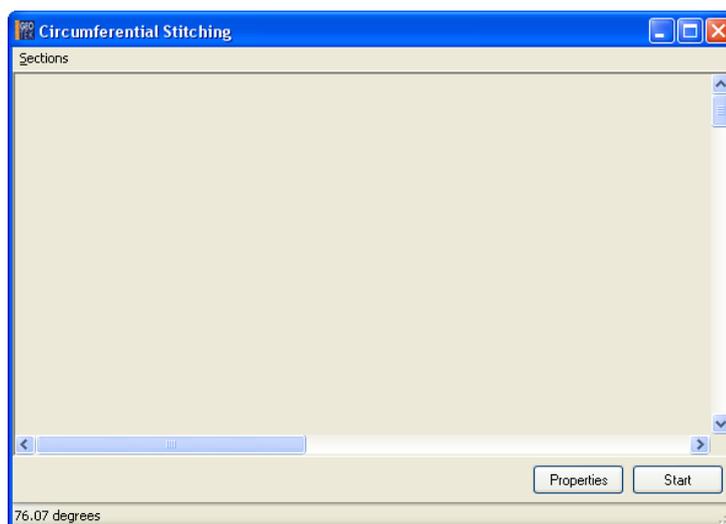


Figure 16A-7. Circumferential Stitching pane.

- To load the images and display the initial processed image, click the [**Start**] button in the bottom right hand corner.

The images will now begin to load and be processed into a final image that will appear in the window. Zoom into the image using the mouse wheel if desired. A progress bar will appear in the status bar at the bottom of the window. Any time any image operations occur, the progress bar will re-appear.

Adjust the various properties of the reconstruction to improve the quality of the final image.

- Click the [**Properties**] button at the bottom of the window. The properties dialog will appear.
- Check the “Show Angle Line” box. A set of vertical yellow lines will appear down the image.
- Change the Start Degree to 45.00 and click the [**Update**] button.

Nominally the image will start with 0° at the leftmost position of the image and 360° at the rightmost. By shifting the Start Degree for this calibration, the angle lines are all visible simultaneously.

The angle line markers will be drawn at the center of the images acquired (e.g., 0°, 90°, 180° and 270°). It is most often the case that the images will not be perfectly aligned with these markers. The Angle property can be used to adjust each image to compensate for this.

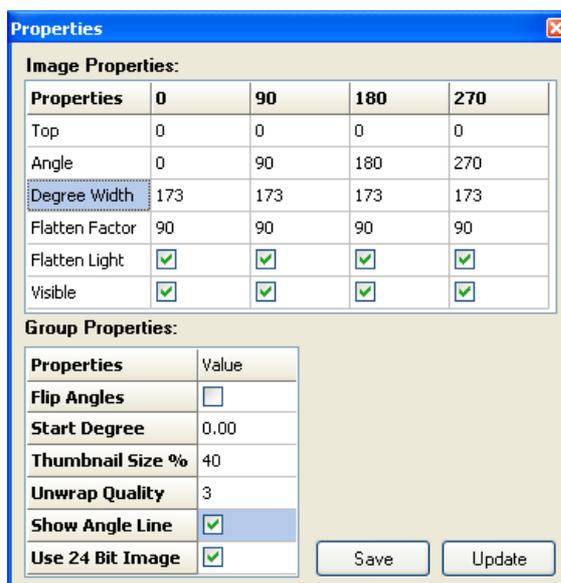


Figure 16A-8. ImageTools Circumferential Imaging Properties.

The properties dialog is divided into two lists. The first list is the individual Image Properties, where values can be adjusted on an image by image basis. The second list contains the Group Properties which apply to all the images as a set.

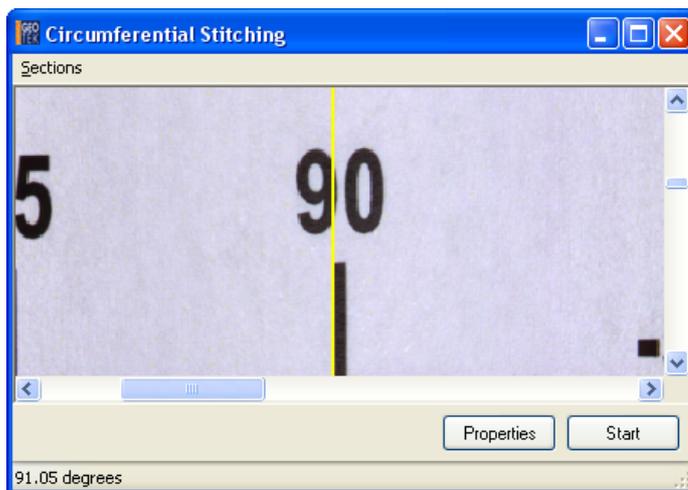


Figure 16A-9. Angle alignment.

In the figure above, the 90° yellow line is not consistent with the image. By hovering the mouse over the line, in the image the status bar will display the actual degree point where the 90 degree line is situated (in this example, 91.05°).

- Zoom into each angle marker (yellow line) and adjust the Angle property for each image to compensate for any offset to the angle in the actual image.
- Click on [**Update**] to apply the changes to the image. Iterate as necessary.

The vertical alignment of an image is a similar process although this time using the Top property of each image. If a particular image needs moving upwards you will need to subtract a value from current Top property, and add a value should the image need moving down. Top positions can be negative.

- Adjust the top value of single image to bring it into alignment with its neighbouring images.
- Click on [**Update**] to see the change
- Repeat for each image until all the images are vertically aligned.

If required, individual images can be hidden by unchecking the Visible property. This often helps in vertical alignment of images.

The Degree Width property is defined by how many degrees on the original image are visible. The starting value is approximate, and will need adjusting to produce the final image. In the figure below, the centre line is marked in 5° intervals. Use these markers to determine the original degree width values. On the full size version of this image it is possibly see up to the 80 degree marker on either size of the 0 line. So the degree width should initially be set to 160 degrees.

Though each image has a separate Degree Width value, due to the geometry of the camera, each image in a set should normally be set to the same value.

- Once the individual images have been examined, adjust the Degree Width values in each image in the Properties pane and click the [**Update**] button.

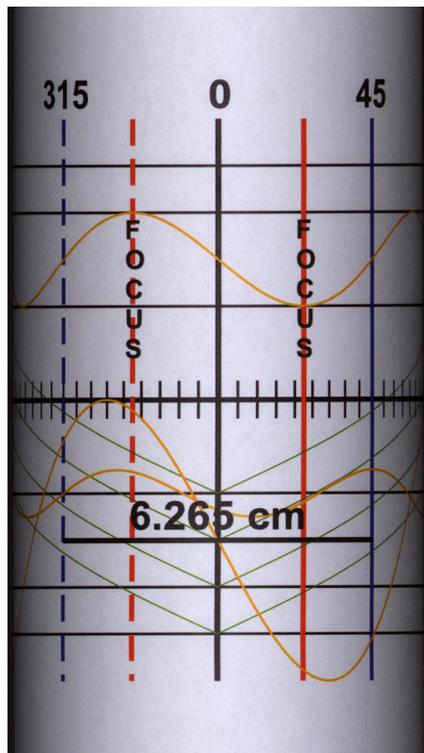


Figure 16A-10. Single calibration image.

You should now be able to see the effect that the degree width has on the image, reducing the degree width shortens the number of pixels that the individual image fills horizontally in the final image. Increasing the degree width has the opposite effect. The figure below shows three examples of the same portion of image, the first where the degree width value is too small and two separate 45° lines are visible, the second where the degree width is too large and the line has disappeared completely and the third where the degree width is set correctly.

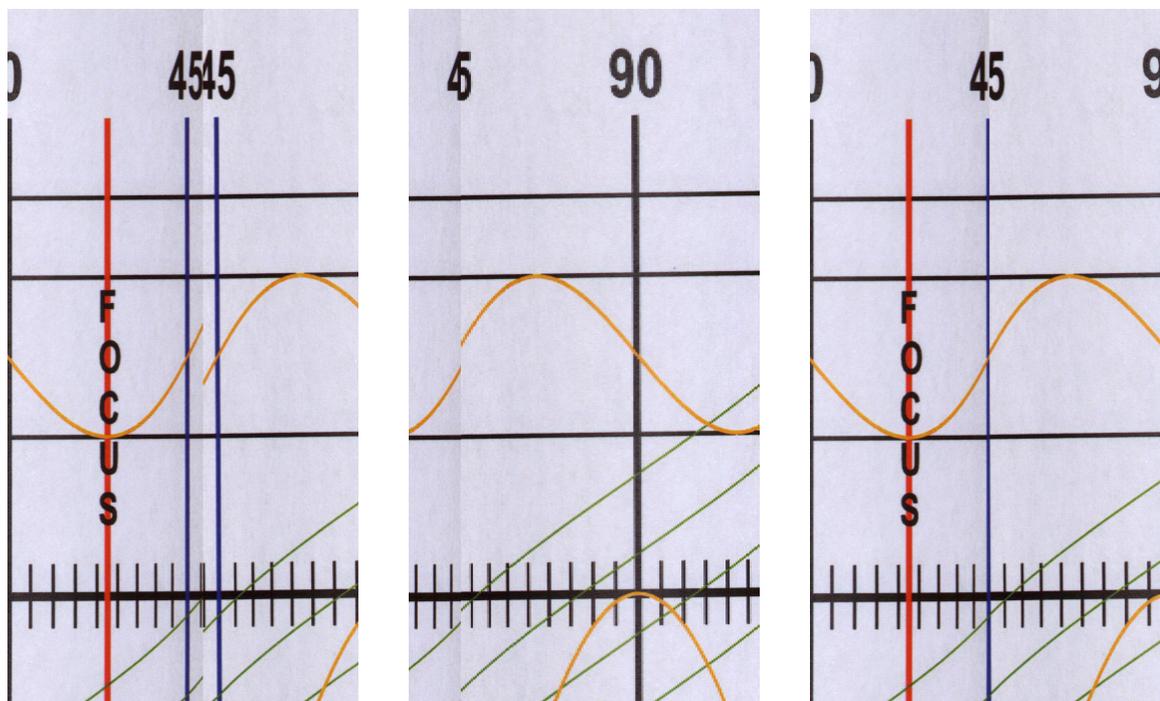


Figure 16A-11. Degree width examples.

The Flatten Factor property and Flatten Light checkbox applies a filter to the image to attempt to balance the light consistently across the image. The flatten factor is a percentage value and by default the value is set at 95%. Larger values will increase the brightness near the edges of the image. The Flatten Light checkbox disables the light flattening filter for the individual image if unchecked. The figure below shows an unwrapped image, before and after light flattening.

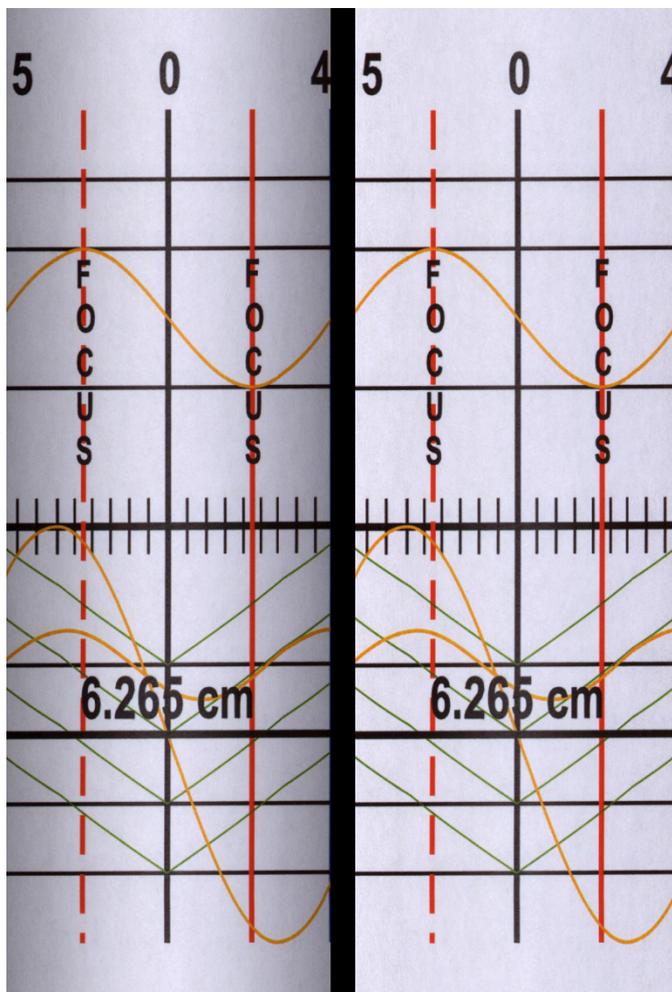


Figure 16A-12. Light flattening filter, before and after applying.

The Thumbnail Size group property controls the percentage size of the resulting image that is displayed in the Circumferential Stitching pane. Whilst adjusting parameters, it may be desirable to lower the resolution to speed up any image operations.

Unwrap Quality is a quality factor (1-20) which is used in the unwrapping algorithm. Larger numbers take longer to unwrap but the resulting geometry of the image is better. The effect is most noticeable on the diagonal lines of the calibration which take on a slightly S-shaped curve with lower values. Again whilst initially adjusting it may be advisable to leave this at 1 for speed.

Both thumbnail size and unwrap quality will have an effect on degree width, so when adjusting these values you may need to re-adjust the degree width value.

The Use 24 Bit Image property forces the resulting image to be 24-bit, 8 bits per colour channel. On a GeoScan III or earlier camera system this will make no difference. Only on the GeoScan IV system, which can save 48-bit images, will this option increase speed and reduce the file size of the final image.

To save the resulting image, click on the **[Save]** button in the Properties pane and choose a location, filename and format accordingly.

Circumferential Imaging

Using the property values iterated in Image Tools, collect a set of images for a core. Modify the core diameter property to accurately reflect the core if necessary, as this value is critical for the unwrap algorithm. The Imaging software will automatically generate an unwrapped image, which will be placed in the parent directory. Image Tools can be used to refine the unwrapping. Note that the Geotek Circumferential Imaging supports multiple sections, so the user must ensure that the correct section is chosen in the Circumferential Stitching pane.



Figure 16A-13. Raw and final unwrapped image.

17 - Getting the Best Data from Cores

Core Quality

When logging whole cores, only high quality cores where the liner is full of sediment will provide consistently good data. Figure 17-1 illustrates this problem in P-wave and gamma density logging.

This problem can be partially overcome by reorienting the P-wave and gamma sensor systems into a horizontal orientation (see Chapter 4).

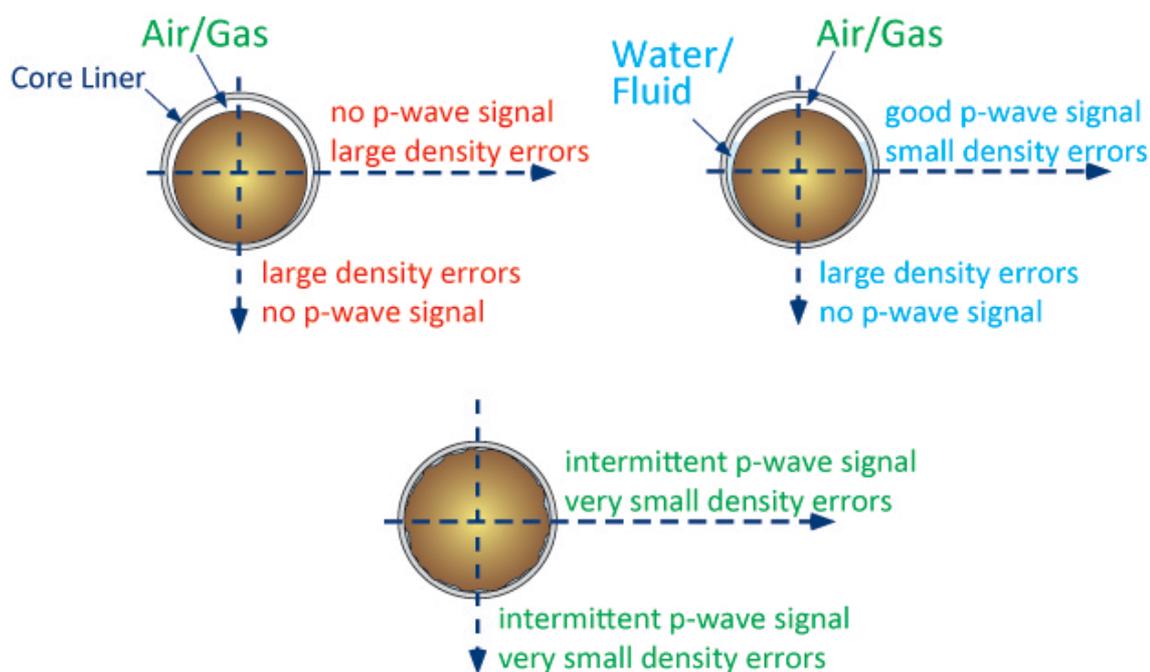


Figure 17-1. Horizontal vs. Vertical acoustic coupling.

Core Handling

It is important to recognise at the outset that the quality, and hence value, of core logs is to a large extent dependent on the physical quality of the cores being logged. No matter how sophisticated the individual measurement techniques are or how skilled the operator is, poor quality core will result in poor quality logs.

Log data quality is a function of:

- I. Quality of the recovered core.

Problems:

- A. Poor recovery and disturbed sediment cores.
- B. Disturbance to cores as a result of bad handling and storage.

Solutions:

- A. Use the correct coring equipment for the prevalent conditions, accounting for weather, operator skill and the ship's capabilities.
- B. Once a core is recovered treat it with care and ensure correct storage (i.e. the right way up and at the correct temperature).

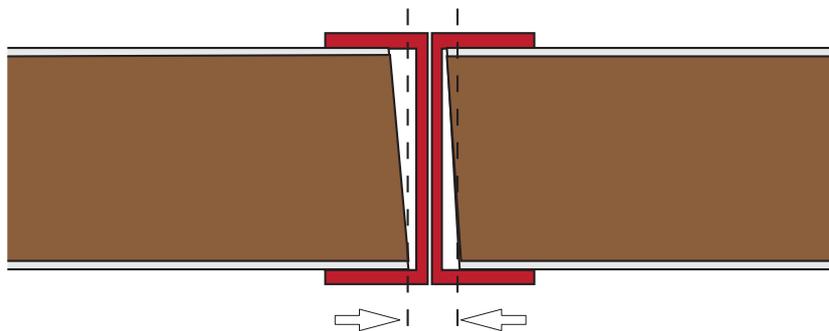
II. Core sectioning.

Problems:

- A. Errors in measuring section lengths and butt error distance (see Figure 17-2).
- B. Compounded length problems.

Solutions:

- A. Sections should be cut perpendicular to the core length.
- B. Adjacent sections should be oriented during sectioning and aligned during logging.



Butt Error Distance

Figure 17-2. Representation of butt error distance.

III. Core splitting.

Problems:

- A. Inconsistent core thickness and cross-sectional area.
- B. Poor sensor contact and variable thickness due to uneven core surfaces.

Solutions:

- A. Split the liner consistently and correctly align adjacent sections.
- B. Ensure that the core surface is as flat as possible.

IV. 4 - Liner quality.

Problems:

- A. Core liner that is not perfectly round.
- B. Variations in liner thickness.

Solutions:

- A. Use liners as soon as possible after purchase and ensure that adjacent sections are marked so that they can be aligned during splitting and logging.

- B. It is a fair assumption that liner thickness will not vary greatly although the user should be aware that these variations cause errors.

V. 5 - Corer endcaps (Figure 17-3).

Problems:

- A. Loss of acoustic contact for P-wave transducers with errors compounded by inaccurate core diameter measurements.
- B. Endcaps necessitate the use of a larger magnetic susceptibility loop.
- C. Endcaps increase the overall length of the core (1-2% depending on the care taken to ensure a good fit).

Solutions:

A, B & C. Ideally cores should be logged without endcaps, internal endcaps are a viable second choice (i.e. for soupy cores) and a third alternative is to make cut outs in the endcaps as shown in Figure 17-3. One solution, often employed, is simply to discard the data around the end caps. This is hardly satisfactory as the user could be discarding up to 10% of the data. Most users who adopt this technique normally find that the most interesting lithological boundaries occur within the end-cap region of each section!

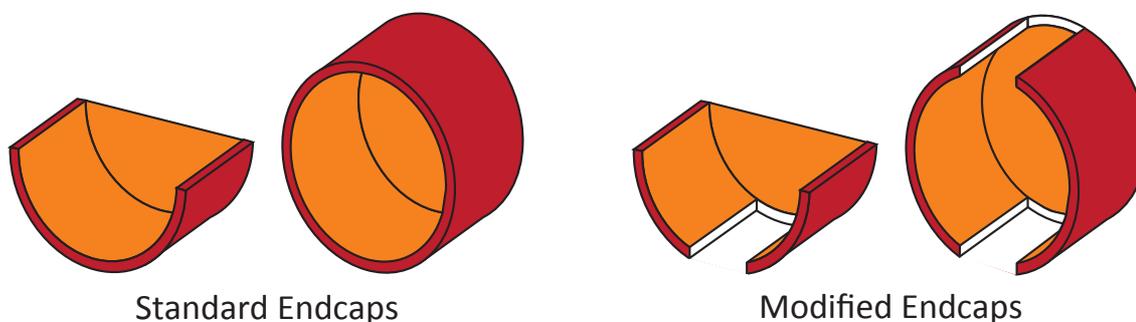


Figure 17-3. Cut away endcaps to improve quality of P-wave velocity and gamma density data.

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Appendix - MSCL-XZ Operation and Software

Chapter Overview

The MSCL-XZ is a moving-sensor single section core logger, optimized for benchtop logging of split cores. It can be fitted with a subset of the sensors available for the MSCL-S, including the magnetic susceptibility point sensor, the colour spectrophotometer, the near-infrared/visible spectrophotometer, and the X-ray fluorescence spectrometer. This appendix familiarizes the user with the MSCL-XZ system and software.

MSCL-XZ & MSCL-XYZ Systems

The MSCL-XZ has a sensor array which moves along the core and up and down off the surface of the core. The sensor array is moved by two stepper motors, which can be controlled from software or from the switches and knobs on the front of the MSCL electronics. The sensors in the array are counterbalanced if necessary so that they touch the core surface lightly.

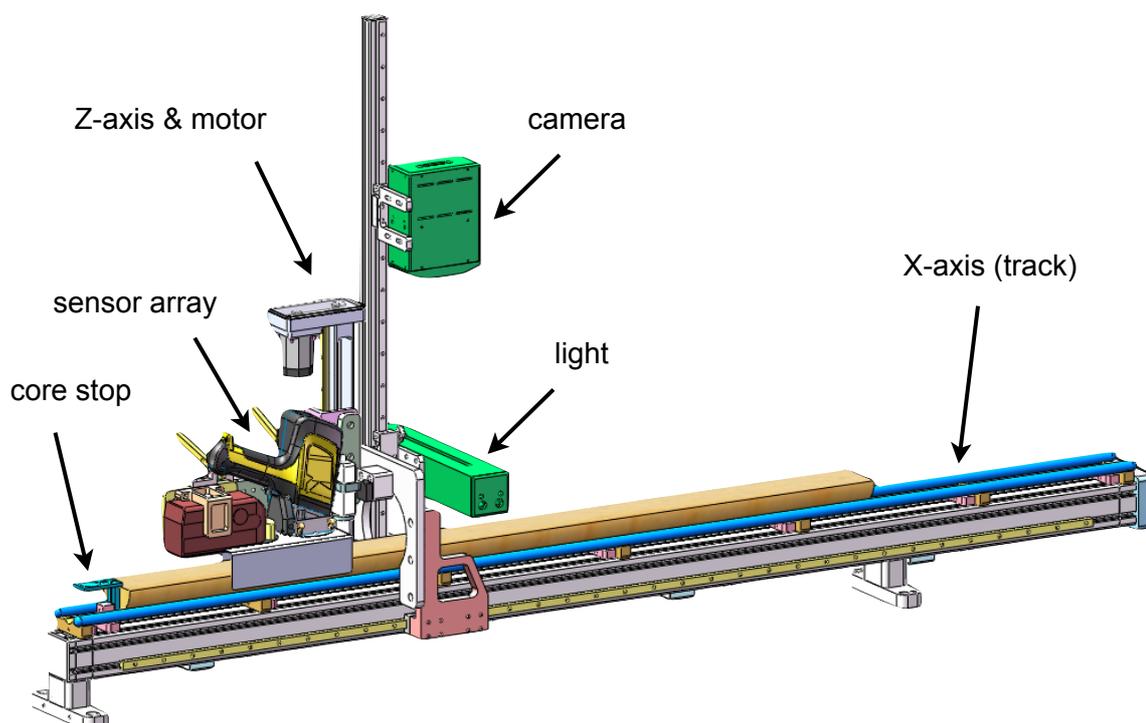


Figure APP-1. MSCL-XZ (electronics not shown).

Plastic rails hold a curved core section in place while measurements are being taken. The rails have two positions to accommodate wide or narrow core; see Chapter 4 for details of core diameters and instructions on changing rail position. At the left (or top) end of the track, a plastic core stop is fitted. This core stop must be set to the height of the core, and the software made aware of its location using the “Register Tray” option.

The MSCL-XYZ is essentially the same machine as the MSCL-XZ, with the addition of a third axis to allow scanning of multiple core sections or entire rock core boxes. The MSCL-XYZ's more robust Z-axis can also accept the natural gamma detector, which is not possible on the MSCL-XZ.

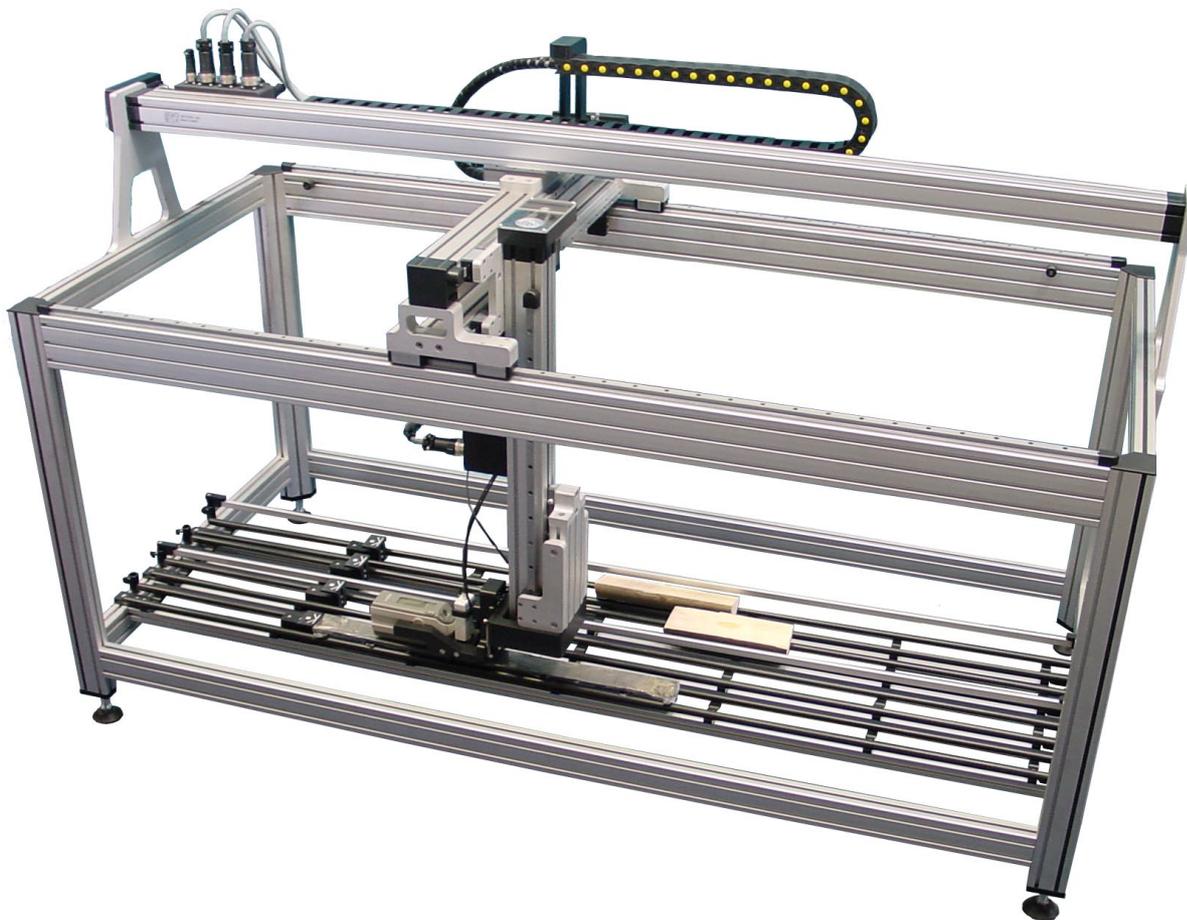


Figure APP-2. MSCL-XYZ (electronics not shown).

A Geoscan linescan camera may be fitted to the MSCL-XZ. The Geotek Imaging software is used to control the acquisition of images.

MSCL-XZ/XYZ Quick Start

User can follow this Quick Start guide if the MSCL settings are correct, the tray has been registered, and the XRF (if used) is ready to connect. Place the split core on the rails, with the top against the core stop. Cover the split core with plastic wrap to protect the core from the sensors and the sensors from the core.

Quick Sensor Setup

Open the MSCL-XZ software and select **[Setup]**, then **[Sensor Setup]**. Rezero the motors by lowering the sensor array near to the left end of the track (or the top left with the XYZ) using the manual knob or the software controls, and then clicking **[Rezero Motors]**. The sensor array will end up in the “Home” position.

Both the colour spectrophotometer and the handheld XRF require calibration before use (see Chapters 9 & 10 for details). To calibrate the spectrophotometer, select **[Spectrophotometer Setup]**, then **[Calibrate]**. Follow the instructions on the screen, calibrating first in air, and then on the white spectrophotometer calibration piece.

Connect to the XRF by selecting **[XRF Setup]** from the Sensor Setup pane. To calibrate (standardize) the XRF, place the stainless steel calibration disk on the core stop. Click **[Move To]** and select “XRF Standardize”. Once the XRF is on the calibration disk, click **[Standardize]** in the XRF Controller pane.

Logging Core

To begin logging core, return to the main menu and select **[Log New Core]**. Add a new core section in the Position Control pane by dragging the “New” icon to the tray. In the New Section pane, enter a Core ID and the section length. If using the XRF, click the **[Setup]** button and select the desired XRF mode. Click the checkboxes by the sensors to be used and click **[OK]**.

The screenshot shows the 'New Section [Tray 1]' dialog box with the following details:

- General Core Parameters:** Core ID (empty), Nominal Section Length (cm): 150.00, Comments (empty text area).
- Section Parameters:** Section Number: 1, Section Length (cm): 100.00, Core Depth (cm) (at section top): 0.00, Missing Samples (Top (cm): 0.00, Bottom (cm): 0.00, Sample (cm): 100.00), Out of sequence, update depths? (checkbox unchecked).
- Sensor Parameters:** Sampling Interval (cm): 2.00, Enable All Sensors (button), Disable All Sensors (button), Variable Sampling (checkbox unchecked, Setup button), Pauses (checkbox unchecked, Setup button).
- Laser Profiler:** Offset: 0.00.
- Magnetic Susceptibility:** Offset: 4.00, Sampling Time (secs): 1, Zero: Zero every reading, 1, Units: SI (selected), cgs (radio button), On (checkbox checked).
- Spectrophotometer:** Offset: 24.00, Reflected Spectra (checkbox checked, Setup button), Munsell (checkbox checked), On (checkbox checked).
- XRF:** Offset: 10.00, Setup button, On (checkbox checked).

Buttons at the bottom: OK, Cancel.

Figure APP-3. New Section pane.

In the Position Control pane, click **[Begin Log]**. Logging will commence and the Data Display pane will appear. Graphs can be rescaled by clicking on an axis. Each graph has a contextual menu (right-click) to adjust details of the display (see next section for further explanation). Data can be exported from the File menu in the Data Display pane.

MSCL-XZ/XYZ Software

Main Menu

The main menu has three options: Log New Core, Setup, and Load Previous Data.



Figure APP-4. MSCL-XZ Main Menu.

Log New Core Position Control Pane

Selecting Log New Core brings up the Position Control pane.

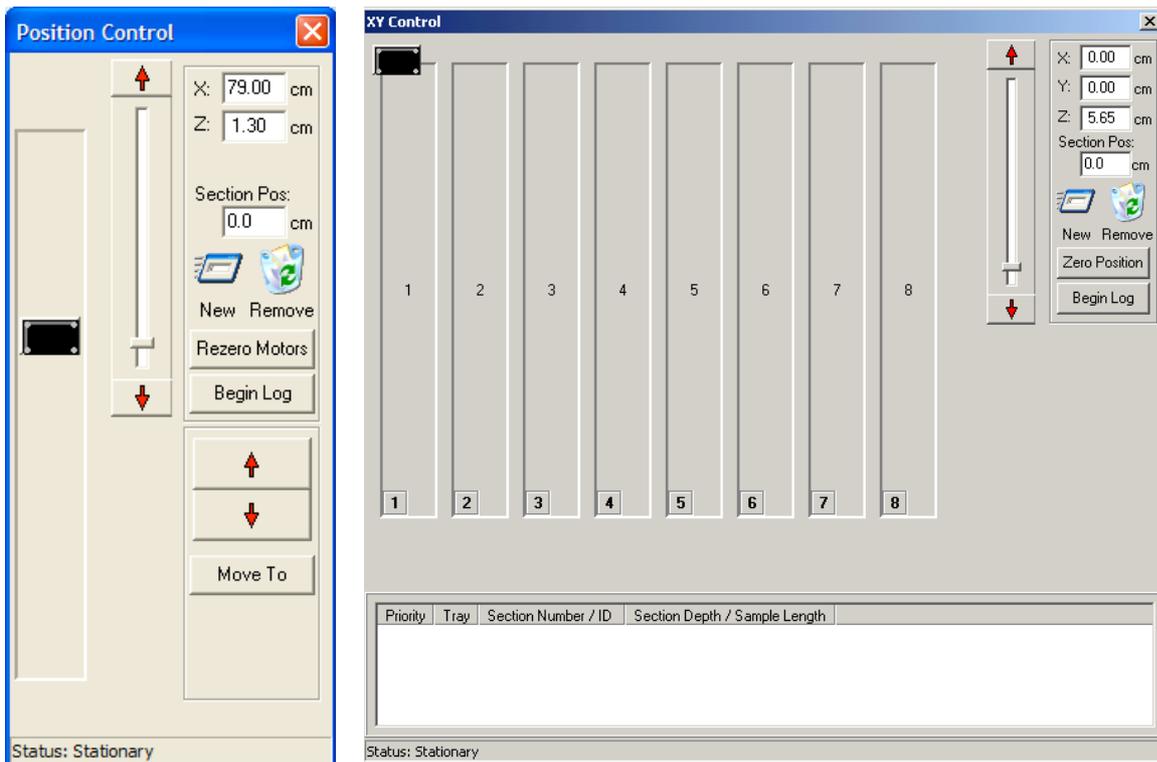


Figure APP-5. Log New Core Position Control pane for MSCL-XZ and MSCL-XYZ.

The long rectangles are a representation of the each tray on the XZ or XYZ track, and the black rectangle is a representation of the sensor array. Clicking and dragging on the sensor array rectangle will cause the sensor array to move along the track (Shift-drag is required in the MSCL-XYZ software). The slider in the top middle of the pane controls the height of the sensor array. Arrows on either end of the Z-axis slider or to the right of the pane for the X-axis (XZ) allow precise movements of 1mm (10mm if holding the shift key). The X, Y and Z values show the position of the sensor array in the XYZ coordinate system.

Clicking [**Rezero Motors**] allows the MSCL to determine where the sensor array is in the XYZ coordinate frame. Ensure the sensor array is in a low position near the top of the track (all the way to the left) before rezeroing.

Clicking on **[Move To]** brings up a submenu with choices “Home” or “XRF Standardize”. The “Home” position is at the top end of the track, at the sensor ride height. The “XRF Standardize” position is on the core stop.

Add a new core to the track by clicking on the New icon and dragging it to the track representation. An unlogged core is shown by red hash marks. Double-clicking on the core representation brings up the Core Setup pane. When a core is logged, it turns yellow and can be removed by dragging it to the Remove icon.

During core logging, the depth of the sensor array is shown in the “Section Pos.” field.

New Section Pane

The New Section pane has three subpanes requesting information about the core and where measurements should be made: General Core Parameters, Section Parameters, and Sensor Parameters. Below these three subpanes are subpanes for each of the sensors on the instrument.

The screenshot shows the 'New Section [Tray 1]' dialog box with the following fields and controls:

- General Core Parameters:** Core ID (text field), Nominal Section Length (cm): 150.00 (text field), Comments (text area).
- Section Parameters:** Section Number: 1 (text field), Section Length (cm): 100.00 (text field), Core Depth (cm): 0.00 (text field), Out of sequence, update depths? (checkbox), Missing Samples (table with Top, Bottom, Sample columns).
- Sensor Parameters:** Sampling Interval (cm): 2.00 (text field), Enable All Sensors (button), Disable All Sensors (button), Variable Sampling (checkbox), Pauses (checkbox), Setup (button).
- Laser Profiler:** Offset: 0.00 (text field).
- Magnetic Susceptibility:** Offset: 4.00 (text field), Sampling Time (secs): 1 (dropdown), Zero: Zero every reading (dropdown), Units: SI (radio), cgs (radio), On (checkbox).
- Spectrophotometer:** Offset: 24.00 (text field), Reflected Spectra (checkbox), Munsell (checkbox), Setup (button), On (checkbox).
- XRF:** Offset: 10.00 (text field), Setup (button), On (checkbox).

Figure APP-6. New Section pane.

General Core Parameters contains a Core ID field, a Nominal Section Length field, and a Comments field. The Core ID is also the filename, and cannot be edited once the first section has started logging. The Nominal Section Length is the default length that will appear in the Section Length field (in the Section Parameters pane). Comments can be added to at the beginning of any section.

Section Parameters contains a Section Number field, a Section Length field, a Core Depth field, and a Missing Samples box. The section number should be entered in the Section Number field; the method of section numbering is important to the software, which assumes that the core has been cut into sections, section 1 at the top and then numbered continuously downward. The Section Length should be measured and entered; this will be the logging length. Core Depth is the depth of the top of the section; this can be either in the core or in the formation, as the user chooses. The checkbox below Core Depth, titled “Out of sequence, update depths?”, should be checked if logging a section either out of order or with an unknown depth. The MSCL software will assign a temporary depth to the section based on the section number and the nominal section length. If a section is out of

order--for instance, sections 1 & 3 have been logged, but not 2--the MSCL software will notice when section 2 is logged, and assign proper depths to section 3. The missing samples box allows the user to account for core material that no longer exists. This record is useful for curatorial purposes, as it allows the curated top of section and section length to be entered even though not all the section may be logged.

Sensor Parameters contains a Sampling Interval field, buttons to Enable or Disable All Sensors, and a Variable Sampling checkbox. The sampling interval is the distance between each sample point down the core. If the Variable Sampling box is checked, the Variable Sampling pane will appear (see next section).

Each sensor has a subpane, containing any user-editable parameters for each and a checkbox to turn the sensor on or off (with the exception of the laser profiler, which is always on). The sampling time must be chosen for the magnetic susceptibility point sensor as well as the choice of measurement system (SI or cgs); ensure that these are the same settings as on the Bartington meter in the MSCL-XZ electronics. The frequency at which the meter zeroes itself is also adjustable. For the spectrophotometer, the user can choose to collect reflected spectra and/or Munsell colour values. For both the spectrophotometer and the XRF, there are small colored dots indicating the status of the sensor. Green dots show that the sensor is ready to make measurements. If the dots are red or yellow, click the appropriate **[Setup]** button for the sensor to rectify the situation (see Spectrophotometer Setup pane and XRF Controller pane, below).

Variable Sampling Pane

Variable sampling can be used to choose different sampling intervals for each sensor selected, or to define areas that should or should not be measured. This is a valuable facility when the user is balancing the time taken to log a core with the resolution required from different sensors or the quality of different parts of the core.

Users can choose either where to sample or where NOT to sample a given section. If the “where to sample” button is clicked, the user can click on the representation of the core in the variable sampling panel and a red “X” will appear. A window pops up, asking the user to confirm or refine the measurement depth. As many “where to sample” points can be defined as necessary.

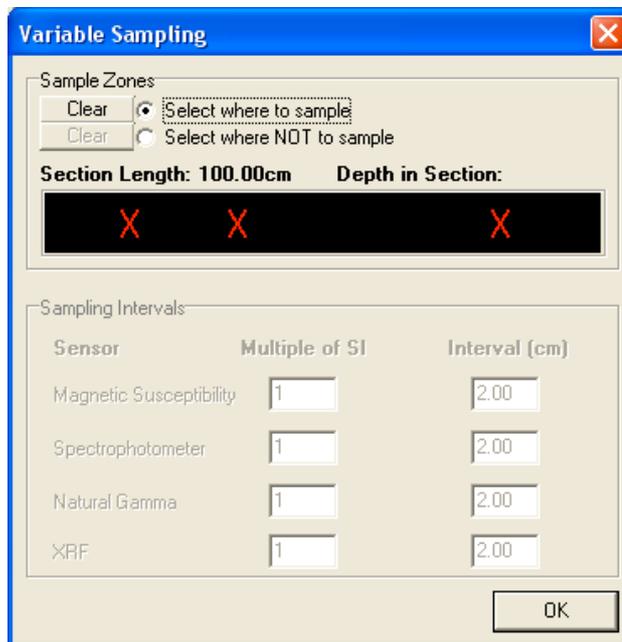


Figure APP-7. Variable Sampling pane: where to sample.

The “where NOT to sample” option allows users to skip regions of the core. To define a skip zone, click on the core representation at the depth the skip zone should start, and drag to the end of the skip zone. The zone will turn red. Click on the red zone to accept or adjust the start and end depths, and the skip zone will turn blue.

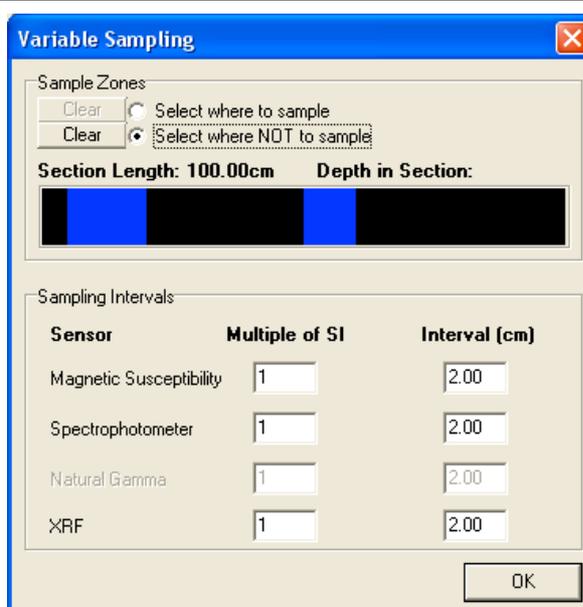


Figure APP-8. Variable Sampling pane: where NOT to sample.

When “where NOT to sample” is selected, the software allows some sensors to be used less frequently than others. The sampling interval (SI) set in the New Section pane is the minimum sampling interval available for any sensor. All other sampling intervals are multiples of this minimum sampling interval. The sampling interval for any sensor is set either by selecting and editing the “Multiple of SI” or selecting and editing the “Interval (cm)”. If the interval chosen is not an exact multiple the nearest exact multiple will be substituted. When the selection is complete click [OK].

Data Display Pane

The Data Display pane shows graphs of all the data collected. These graphs are updated in real time. Data are plotted for the each sensor on the MSCL. The scale can be changed on the graphs by clicking on the relevant axes, or by right-clicking on the graphs to display a contextual menu with Autoscale and Autoscale Depth options. Zoom in on graphs by clicking and dragging down and to the right; zoom back out by clicking and dragging up and to the left.

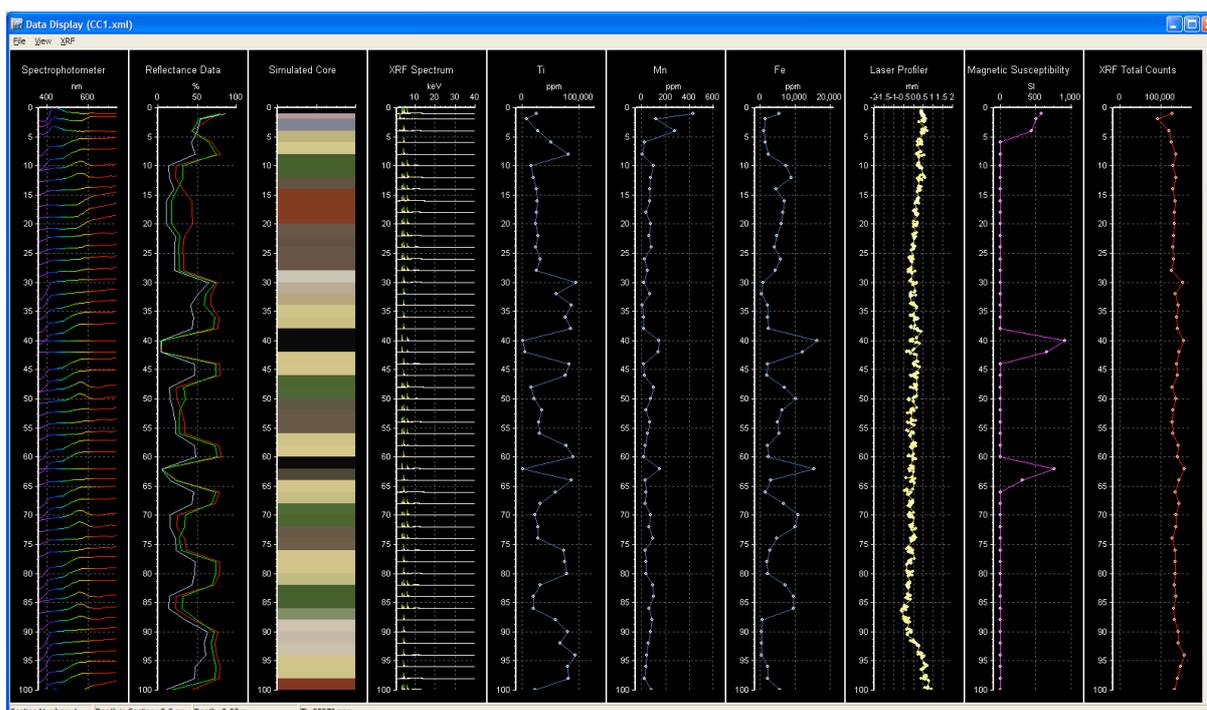


Figure APP-9. Data Display pane, showing spectrophotometer, XRF and magnetic susceptibility data.

The spectrophotometer data includes the spectra, RGB data as line plots, a simulation of the core, and colour in the L*, a*, b* space. All of the plots except the spectral data can be shown or hidden. Right-clicking on the plots will bring up contextual menus. The contextual menu for the spectrophotometer data allows control of the number of spectra plotted (data reduction) and whether they are plotted in colour (change mode); these parameters will affect the refresh speed of this window.

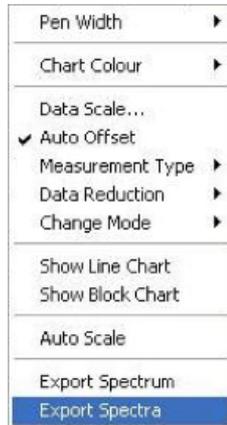


Figure APP-10. Spectrophotometer spectral plot contextual menu.

For each XRF measurement point, the spectrum is displayed. The spectral graph supports zooming for detailed inspection. Single elements can also be plotted in the Elements to Plot pane accessed through the [XRF] menu. To hide or show all single element plots, select Hide Element Chart in the [XRF] menu.

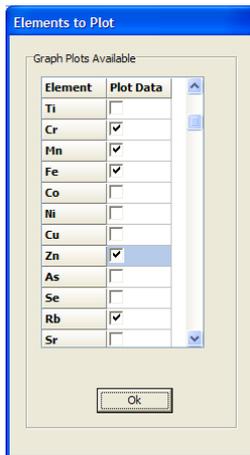


Figure APP-11. Elements to Plot pane.

Setup

The Setup menu has four options: Sensor Setup, Register Tray Positions, Settings, and Close (back to main menu).

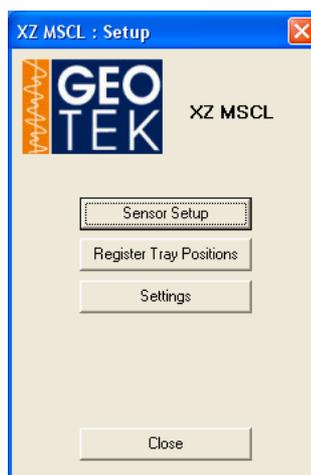


Figure APP-12. MSCL-XZ Setup Menu.

Sensor Setup

There are four options in the Sensor Setup menu: Spectrophotometer Setup, Mag Sus Setup, XRF Setup, and Back (to Setup menu).



Figure APP-13. Sensor Setup Menu.

Spectrophotometer Setup

The Spectrophotometer Setup pane allows the user to calibrate the spectrophotometer and to make individual measurements. The correct aperture should also be set in this pane. To calibrate the spectrophotometer, click on the **[Calibration]** button and follow the instructions on the screen. The zero calibration is performed first and requires that the spectrophotometer have at least 10cm of air below it. The white calibration is performed next and the user must hold the white spectrophotometer calibration piece under the sensor.

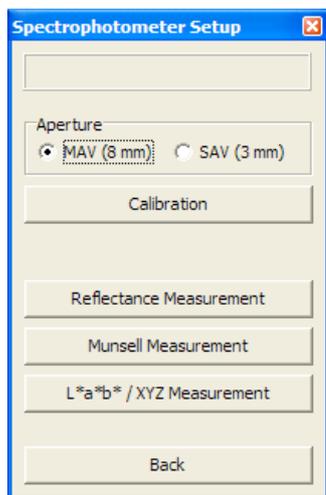


Figure APP-14. Spectrophotometer Setup pane.

Clicking on [Reflectance Measurement] causes the unit to take a reading and display the spectrum. Munsell or numerical color measurements can also be made.

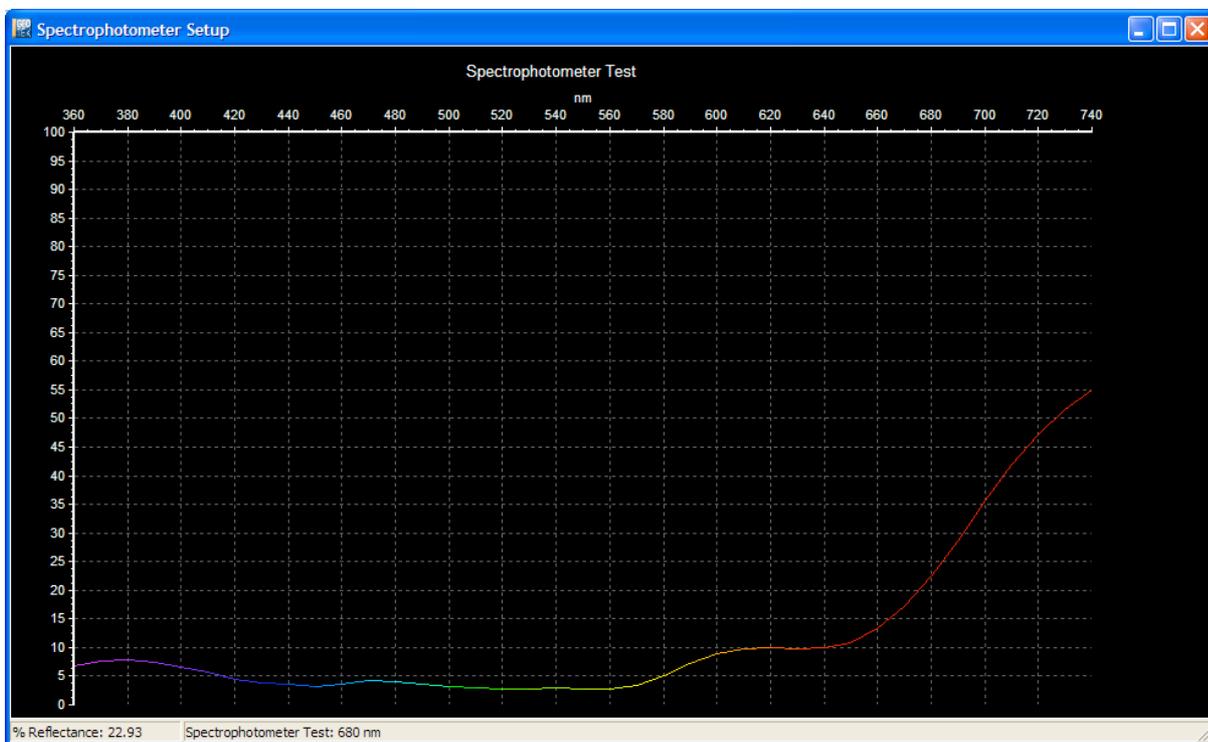


Figure APP-15. Spectrophotometer Setup graph.

Magnetic Susceptibility Setup

The Mag Sus (magnetic susceptibility) Setup pane allows the user to zero the magnetic susceptibility sensor and take a manual reading. This can be used with the check piece to ensure the magnetic susceptibility sensor is still within specifications.

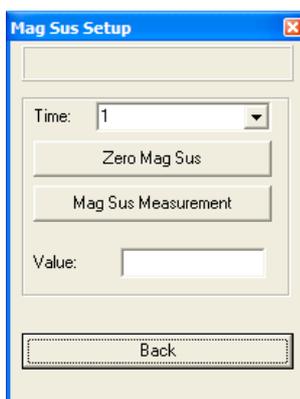


Figure APP-16. Mag Sus (magnetic susceptibility) Setup pane.

XRF Controller

The XRF Controller pane displays all the information and settings regarding the XRF. The top of the pane gives information about the current measurement being made or, if idle, the last measurement made. There is a list of element concentrations, a spectrum (rescalable with a zoom box), and measurement conditions. Below these data are the status of the XRF spectrometer and any messages.

The User Controls subpane allows the user to choose the XRF measurement mode and the abort threshold. The Abort Threshold is an important parameter to set for both safety and data quality and should be set for each core: see Chapter 10 for instructions.

The XRF Controller also has buttons for standardizing the XRF spectrometer (using the stainless steel calibration disk) and making single measurements.

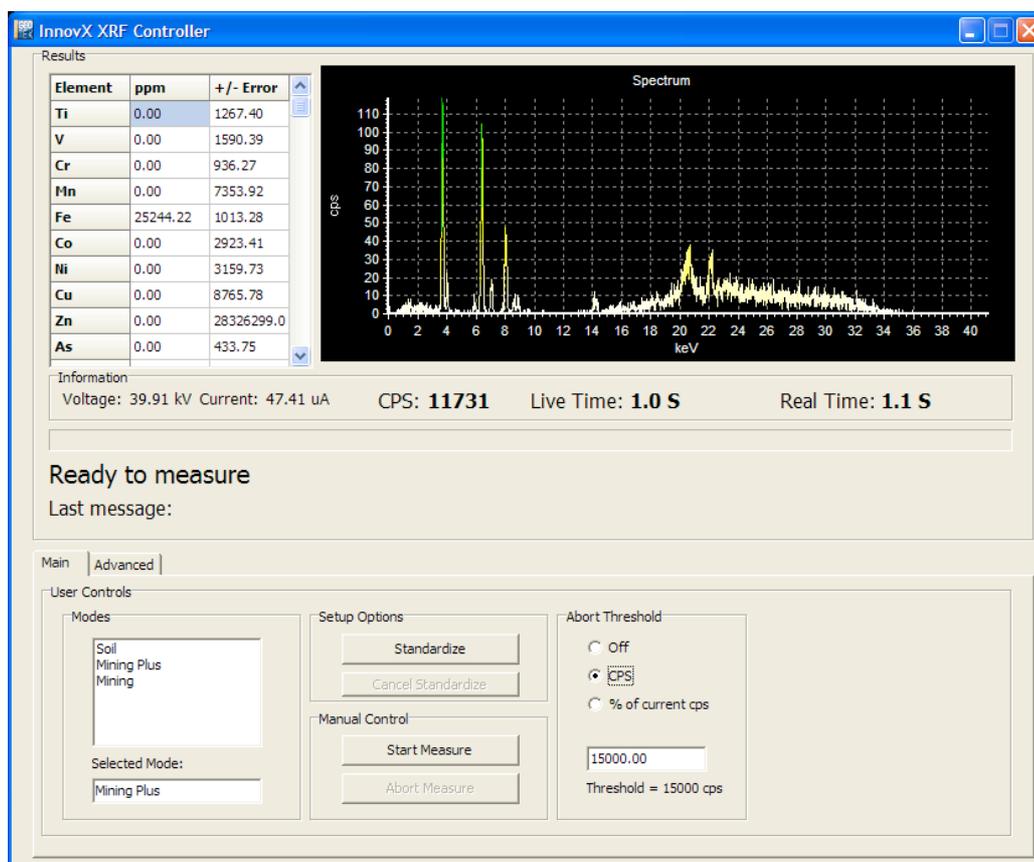


Figure APP-17. XRF Controller pane.

Register Tray

Before core is logged, the exact location of the core must be known. The core stop is used for this purpose, and both its location along the track (X position) and its height (Z position) are important. The user should set up the core stop at the height of the core to be logged. Any time the X or Z position of the core stop is altered, the Register Tray option should be used.

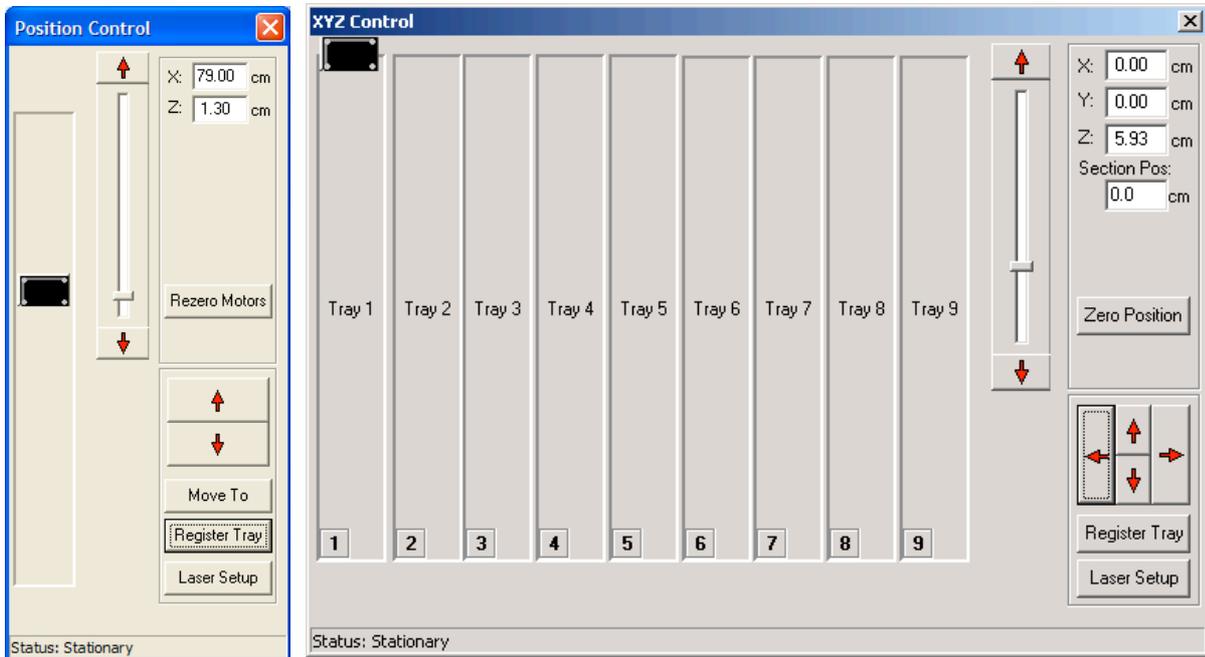


Figure APP-18. Position Control pane with Register Tray options (MSCL-XZ & MSCL-XYZ).

Tray registration is done using automatic software routines that locate distinguishing features on the core stop. To register the tray, click **[Register Tray]** and follow the on-screen instructions:

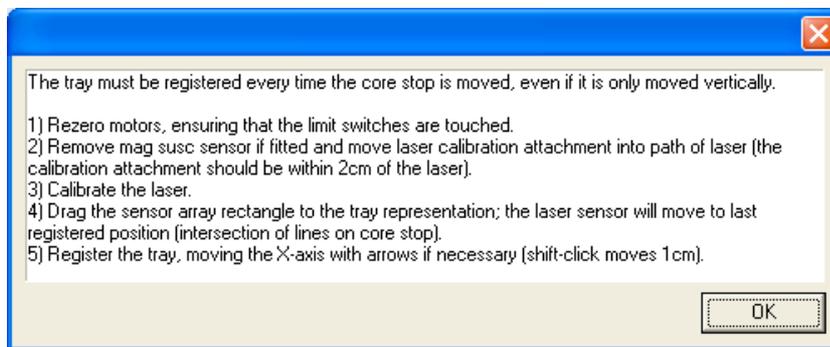


Figure APP-19. Register Tray instructions.

Settings

Many of the MSCL-XZ settings are similar to the MSCL-S settings detailed in Chapter 15. Settings that are unique to the MSCL-XZ are in the Tray Layout Settings.

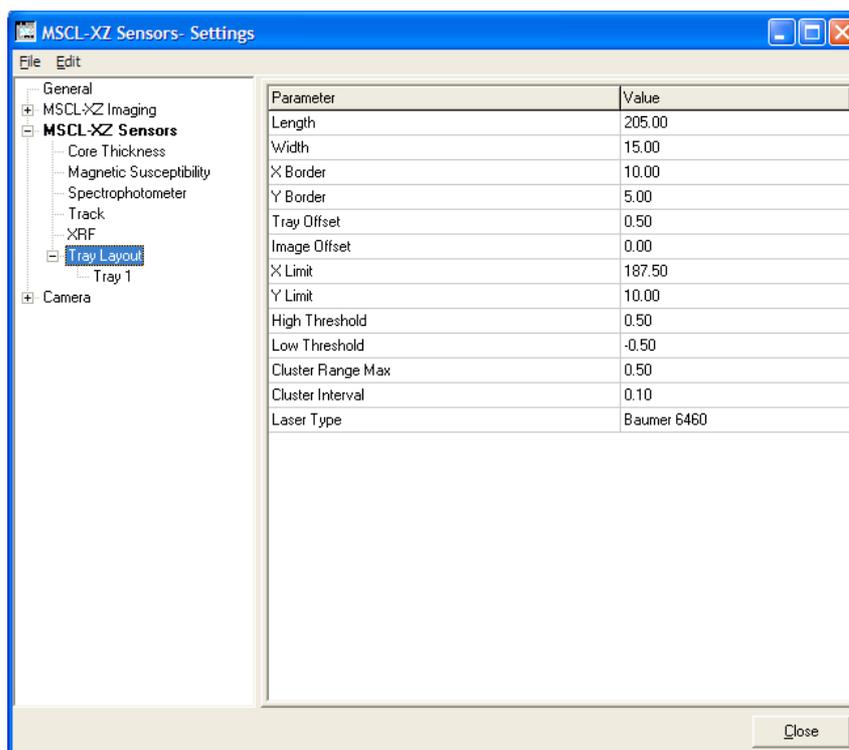
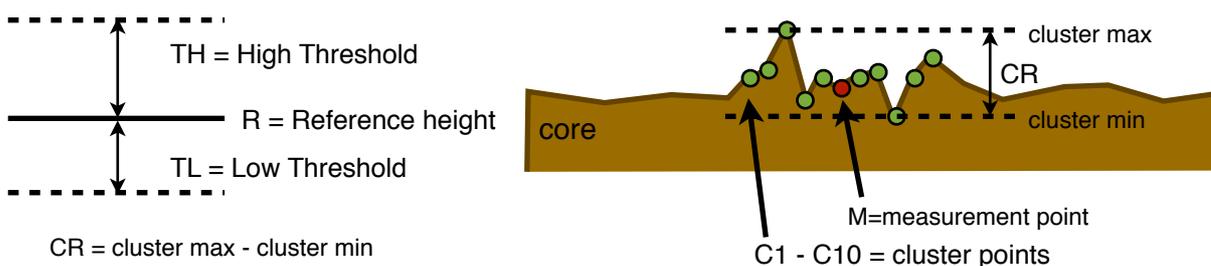


Figure APP-20. MSCL-XZ Tray Layout Settings.

The first four settings (Length, Width, X Border, Y Border) are related to the accurate display of the track in the software. The next four settings (Tray Offset, Image Offset, X Limit, Y Limit) define the dimensions of the track and the start of data collection relative to the reference point. None of these settings should be changed once the track is set up.

The High Threshold, Low Threshold, and Cluster Range Max are part of the rejection criteria for XRF data. If the core has gaps or very uneven locations, measurements should not be taken. Thresholds relative to the reference height (the core stop) can be set, as well as a maximum variation within a sample point. The Cluster Interval sets the distance between cluster measurement points.



If any laser measurement > R+TH

OR

If any laser measurement < R-TL

OR

If CR > Cluster Range Max

then REJECT sample

Figure APP-21. MSCL-XZ laser measurement rejection criteria.

Load Previous Data

This option enables the user to view data sets collected previously. It enables data files to be created for export to other applications for either further processing or for presentation. Choose the data set from the Filename panel, and the data will be displayed just as while logging.