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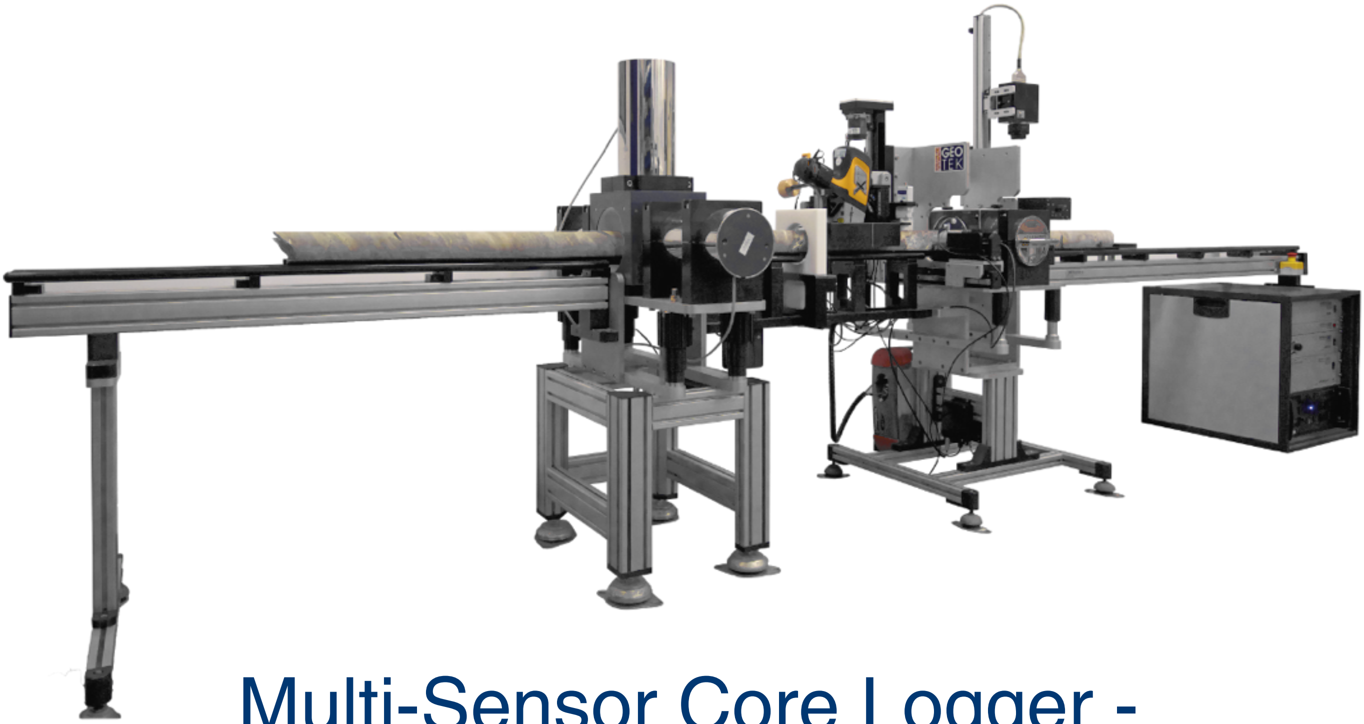


Multi-Sensor Core Logger - Standard Manual

1 INTRODUCTION

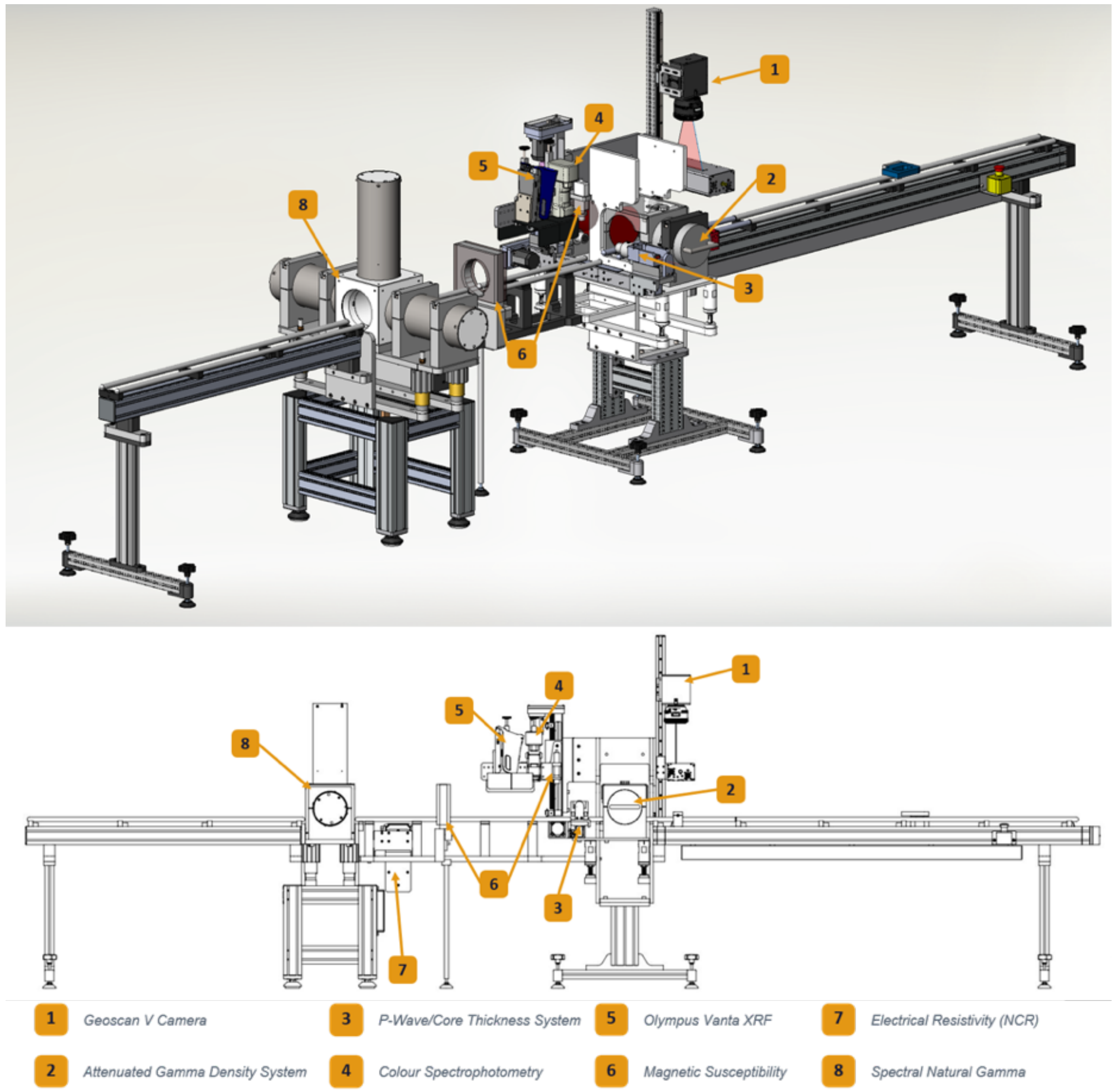


Figure 1.1: MSCL-S sensor configuration

1.1 GEOTEK STANDARD MULTI-SENSOR CORE LOGGER (MSCL-S)

The MSCL-S is a versatile core measurement system sold by Geotek Ltd. The MSCL-S can be floor- or bench-mounted and packed and taken to buildings or containers at field locations both onshore and offshore, if required. Measurements can be made on plastic- or metal-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 fixed positioned sensors, and data is collected from all sensors at once when the core pauses at each measurement point. 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 and 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 Geoscan 5 linescan camera, with both visible and ultraviolet fluorescence imaging capability, can also be mounted on the system.

1.2 CUSTOM AND LEGACY SYSTEMS

Geotek has been building multi-sensor core loggers for a range of users since 1989. During the 30+ years that Geotek has been active, there have been multiple iterations of the MSCL-S and bespoke systems created for specific clients, along with a vast number of smaller improvements and sensor updates. This document is intended for use with the most current MSCL-S systems, however the vast majority of this manual will be applicable across a range of custom and legacy systems.

1.3 WARNING SYMBOLS

The symbols displayed below show the warnings and safety notation used throughout this manual.

Safety warning regarding ionising radiation risk

Safety warning regarding ultraviolet radiation risk

Safety warning regarding risk of electrocution

Safety warning regarding laser radiation

Safety warning regarding risk of poisoning

Safety warning regarding personal injury from heavy weights

2 INSTALLATION

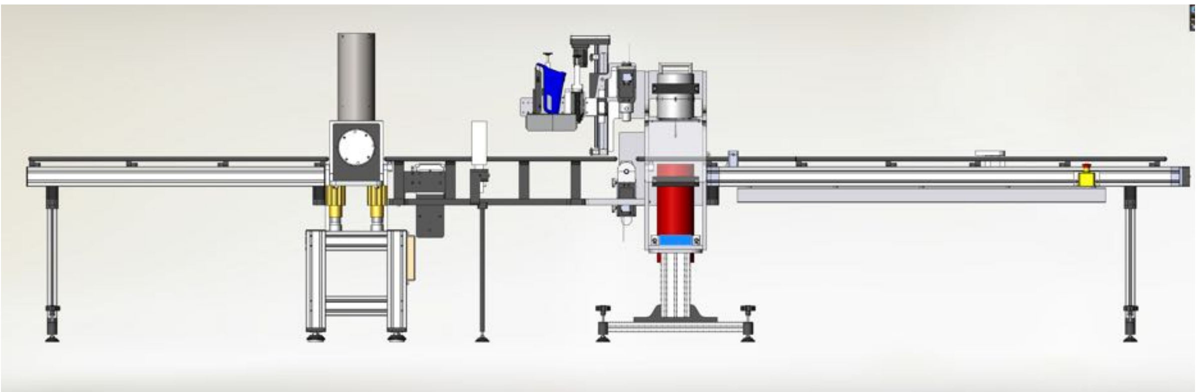


Figure 2.1: MSCL-S in vertical configuration

Unless the user is already familiar with the MSCL-S, then on first installation Geotek personnel will install, commission and provide instruction on the use of the equipment. Consequently, the following text 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.

If you are using the attenuated gamma 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 licensing and site safety plan.

2.1 UNPACKING THE MSCL-S

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 370 MBq. This is securely located in a shield that when closed restricts the exposure to less than 5 μSv/h. The shield has an asymmetric rotating shutter that allows the user to align a narrow collimator, which will allow a 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 Sensors – Attenuated Gamma Density 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.

CAUTION: DO NOT OPEN THE SOURCE SHUTTER UNLESS SHIELD IS SECURELY MOUNTED IN FRAME

CAUTION: DO NOT OPEN ANY ELECTRICAL COMPONENT UNLESS SUPERVISED BY A QUALIFIED ELECTRICIAN

Some components contain high voltages – such as the gamma detectors and P-wave TX box.

CAUTION: THE GAMMA SOURCE AND GAMMA DETECTOR (BOTH ATTENUATED AND NATURAL GAMMA) SHIELDS CONTAIN LEAD

The shields do not have any exposed lead on the surfaces and there is no hazard handling the shield surfaces.

THE LEAD SHIELDS ARE EXTREMELY HEAVY: MIND YOUR BACK WHEN LIFTING

Use two people to handle detectors and the gamma source, ensure they are placed onto soft, secure surfaces; do not drop.

WARNING: CLASS 3R AND 2 LASERS OPERATING ON MSCL-S SYSTEM

Avoid direct eye exposure to the laser beams.

WARNING: UV RADIATION RISK FROM UV LIGHTBOX

Avoid direct eye contact with UV light source, and wear appropriate eye protection.

The source and detector shipping boxes are reusable and should be retained. In principle, the remaining shipping cases are single use only, however, if carefully opened and stored, they may be reused. If you have a requirement to re-pack the MSCL-S system, ensure you use ample packaging materials so that the MSCL-S system, sensors and smaller accessories are not damaged in transit.

2.2 LABORATORY REQUIREMENTS

Depending on the MSCL-S system configuration, the MSCL-S can either be free standing, mounted on legs, or mounted to a bench top. In either case, the MSCL-S system should be positioned against a wall. The MSCL-S system electronics and personal computer (PC) should be installed on a bench top at the right-hand side of the system to ensure that water, soil and rock debris are kept away from these components.

2.3 GENERALISED ASSEMBLY INSTRUCTIONS

The MSCL-S system will arrive in wooden shipping crates. Please note that it is standard procedure for Geotek personnel to unpack, install and commission each MSCL-S system. The following text outlines a brief summary of the assembly of a MSCL-S system:

- Remove the MSCL-S main centre sensor stand from the wooden shipping crate and position against the laboratory wall. Note: Two persons minimum are required to lift and manoeuvre the centre section;

- Secure one of the loose MSCL-S system supporting legs to the right-hand end of the right-hand MSCL-S track section;
- Secure the right-hand track assembly to the main centre section. Note: Two people are required to complete this task;
- Secure the two remaining MSCL-S supporting legs to the left-hand track section so that it becomes self-supported. Position it in line with the main centre section;
- Attach the magnetic susceptibility and electrical resistivity Delrin section to the main centre section and left-hand track section using 2 x bolts at either end. At this point, the basic MSCL-S assembly is complete;
- If natural gamma assembly was purchased, remove from wooden shipping crate and position against laboratory wall and secure to the magnetic susceptibility and electrical resistivity Delrin section. Attach the left-hand track to the left-hand side of the natural gamma assembly. At this point the MSCL-S assembly is now complete;
- Secure all MSCL-S rail sections. Note: Ensure to position the rails to the appropriate spacing for your core sample size. For example narrow rails sets should be used for core diameters between 50 mm to 90 mm, and wide rail sets are recommended for use with core diameters between 80 mm to 150 mm;
- Install and secure all instruments in their correct positions. Note: Use an empty core liner of the largest size (with end caps) lying on the rails to ensure that it passes freely through the magnetic susceptibility loop sensor when run along the rails. The magnetic susceptibility loop sensor is adjusted vertically by loosening the 2 x nylon bolts securing the clamp;
- Check the alignment of the MSCL-S system and adjust as necessary by turning the handles installed at the top of each foot on the supporting legs;
- Install the scintillation detectors into their detector shields (if removed). Use the temporary handle on top of the detector shield to position onto the main centre section and/or natural gamma section.

THE SOURCE AND DETECTOR SHIELDS ARE EXTREMELY HEAVY AND SHOULD BE HANDLED WITH CARE AND CAUTION. ENSURE YOU WEAR THE APPROPRIATE PERSONAL PROTECTIVE EQUIPMENT WHEN PERFORMING A LIFT.

- Before commencing installation of the source, visually check the wooden source shipping box for any signs of damage. If it box appears undamaged, proceed to opening. The internal packaging should be intact and show no signs of having been tampered with. Prior to removal, should you have any concerns regarding the source shield condition, contact Geotek. Position the wooden source shipping box in front of the main centre section. Remove the foam packaging and ensure that the source shutter is closed and locked. If the MSCL-S main centre section assembly was built vertically then lift the source shield using the handle, up onto the source support bracket with the shutter lever oriented to the right. If the MSCL-S main centre section assembly was built horizontally, then lift the source shield using the handle, up into the source support clamps with the shutter lever oriented to the left. Note: A minimum of 2 persons are required to carry out this task.

- Adjust the source until the shutter lever is in the correct position and can be moved through 180°. Note: Loosen the clamps to rotate the source into the correct position. Do not attempt to open the gamma beam shutter on the source at this stage. Wait until all other instruments and components of the MSCL-S system are set up;
- Fit the Perspex guard around the source;

DO NOT LET GO OF THE SOURCE SHIELD HANDLE UNTIL THE SOURCE IS SECURED IN POSITION ON MSCL-S SYSTEM.

DO NOT OPEN THE SOURCE SHUTTER UNLESS THE SOURCE IS SECURELY MOUNTED ONTO THE MSCL-S SYSTEM.

DO NOT PLACE HANDS, ARMS OR ANY OTHER BODY PART BETWEEN THE SOURCE AND DETECTOR.

- If the MSCL-S main centre section assembly was built vertically then adjust the position of the lower P-wave transducer by placing a core sample on the rails and holding it down while sliding the lower P-wave transducer up towards and making contact with the core sample. Secure in position by turning the handles on the left-hand side of the lower P-wave transducer housing and check that the core sample moves over the spring-loaded assembly without difficulty. If the MSCL-S main centre section assembly was built horizontally, adjust the position of the 2 x P-wave transducers by sliding them along their mounts until in contact with the core sample. Secure in position. Tighten only sufficiently to prevent accidental movement. Do not over-tighten. Note: If the MSCL-S system is fitted with a reciprocating P-wave system, the position of the P-wave transducers is set via motor (Y) control for whole lined sediment core samples, and via software control when logging whole rock core samples;
- TAKE CARE NOT TO RUN THE CORE SAMPLE 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 SENSOR.

- Unpack and place the MSCL-S system electronics and PC rack, and mount either on the floor under the right-hand track assembly or on a bench at the right-hand end of the MSCL-S system. Remove the protective case parts from either side of electronics and PC rack.

MSCL-S SYSTEM MAINS POWER: 100 V TO 200 V at 50 Hz to 60 Hz.

- Connect the cable chain for all instruments to the correct ports at the rear of the electronics racks, following the labels on the cables and socket, ensure that you support the weight of the cable chain by cable-tying to the Schroff cabinet;
- Connect the MSCL-S system to the mains power. Note: All mains power for the MSCL-S system is supplied via a distribution board with the number of cables connected dependent on the number of instruments installed. As well as the cables for power supply to the instruments installed, there will also be cables for the camera interface electronics, electrical resistivity electronics, MSCL-S motor control electronics, MSCL-S main system electronics and the MSCL-S system operating PC;
- Once the MSCL-S system is connected to mains power, check that the motor control electronics is set to ‘manual’, and switch on each of the installed electronics racks and the PC;
- Under manual control, ensure that all MSCL-S system motors move freely and limit switches are correctly functioning by slowly moving each motor in turn and pressing the limit switch associated with the direction of movement:
- X: Horizontal right-hand track assembly motor and limit switches;
- Y: Horizontal main centre section reciprocating assembly motor and limit switches;
- Z: Vertical main centre section sensor arm motor and limit switches.

2.4 VESSEL LABORATORY OR CONTAINERISED LABORATORY INSTALLATION

The MSCL-S system can be installed into a vessel laboratory or purposely manufactured container laboratory. The support feet are anchored to the vessel laboratory floor or container floor with special anti-vibration plates depending on the type of floor material and fixings required.

If being installed on a vessel, the MSCL-S system should be pre-assembled and installed while the vessel is in port and should not be assembled or disassembled in any way at sea. Components such as the source and detector shields are very heavy and could cause serious injury if these became loose on board a moving vessel.

Ensure that the complete MSCL-S system is securely fastened to the vessel's structure or that the containerised laboratory is securely sea fastened (welded and/or chained) to the vessel deck with swivel pads etc. Ensure that the structure the MSCL-S system is secured to is fit and strong enough for the purpose. For example, if the vessel laboratory or containerised laboratory has aluminium box section installed throughout, then eyebolts can be pre-installed and the MSCL-S system further secured via these to ensure that it is sea fastened.

Please consult Geotek if you have any queries regarding installation of the MSCL-S system onboard a vessel or have specific questions regarding purposely manufactured containerised laboratories or run into difficulties when attempting this type of installation yourself.

3 MSCL-S MECHANICAL CONFIGURATION AND MOTOR CONTROL

Figure 3.1: MSCL-S Schroff cabinet containing PC and electronics racks

3.1 MSCL-S TRACK OVERVIEW

The track mechanism is constructed in two sections referred to as the 'right-hand section' and the 'left-hand section'. The sections are aligned and mounted on supporting feet end to end. Each section is composed of an extruded aluminium box section base on which parallel, cylindrical black plastic Delrin rails are mounted on Delrin sleepers (perpendicular tie pieces) and over which the core pusher travels.

Two sets of rail sleepers are provided to accommodate the range of core sizes that may be used. Narrow rails sets should be used for core diameters between 50 mm and 90 mm, and wide rail sets are recommended for use with core diameters between 80 mm and 150 mm.

3.1.1 BALL-SCREW DRIVE SYSTEM

The current generation of MSCL-S systems utilize a ball-screw drive system: for information on legacy systems, see Geotek legacy documents. The core pusher is driven from the stepper motor and gearbox assembly mounted at the end of the right-hand track motorised section. The pusher is attached to a yoke that in turn is attached to a ball-screw drive mechanism inside the aluminium box section of the right-hand track section. This enables the pusher to move along the right-hand track section in either direction.

3.1.2 SAFETY WHEN SETTING UP

The stepper motor and gearbox assembly provide the torque required to drive up to three 1.5 m core samples along the right-hand track at speeds of up to 3.5 m/minute. The stepper motor will stall if it is started at too high a speed BUT may not if the core sample is driven into an obstruction. In practice, this means that if the core sample inadvertently comes up against a solid obstruction, damage may occur. Care is required to ensure that this scenario does not occur as substantial damage may occur to both the core sample if it is inadvertently driven into any part of the MSCL-S system and to the instruments. The instruments most at risk after the initial assembly of the MSCL-S system are the P-wave transducers, magnetic susceptibility loop and electrical resistivity sensor as each of these instruments require positioning correctly for the core sample diameter. An emergency stop button is mounted on the right-hand track which when pressed will cut the power to the stepper motors instantly. Alternatively, the mains power switch on the MSCL-S motor control electronics mounted in the electronics rack or the mains power wall outlet will have the same effect.

KEEP FINGERS AND LOOSE ITEMS AWAY FROM MOVING PARTS!

The emergency stop should be placed within reach of the operator in the centre of the right-hand track. Entrapment of fingers, hair, key cards, clothing, etc. by the pusher is possible and the emergency stop will prevent damage to the operator. Loose neckwear should be kept away from the MSCL right-hand track.

3.1.3 CHANGING RAIL SETS

To change the MSCL-S system rail sets from narrow to wide or vice versa, the rail assemblies should be removed from all the MSCL-S track mounts. The rails detach from the mount via a single M5 stainless steel bolt (Figure 3.2). Rail sleepers are used to keep the individual rails paired. Remove the rails from the sleepers by loosening 2 x M5 stainless steel or nylon bolts (Figure 3.3); remove one rail at a time to ensure sleepers retain their location and orientation. Switch the rail position on the sleeper (narrow versus wide) and re-pair the rails. Reattach the rail sets to the mounts. Where rails are fixed to the magnetic susceptibility and electrical resistivity section, and the main centre section, the sleepers are specific to the rail spacing so additional sleepers are supplied for each rail spacing.

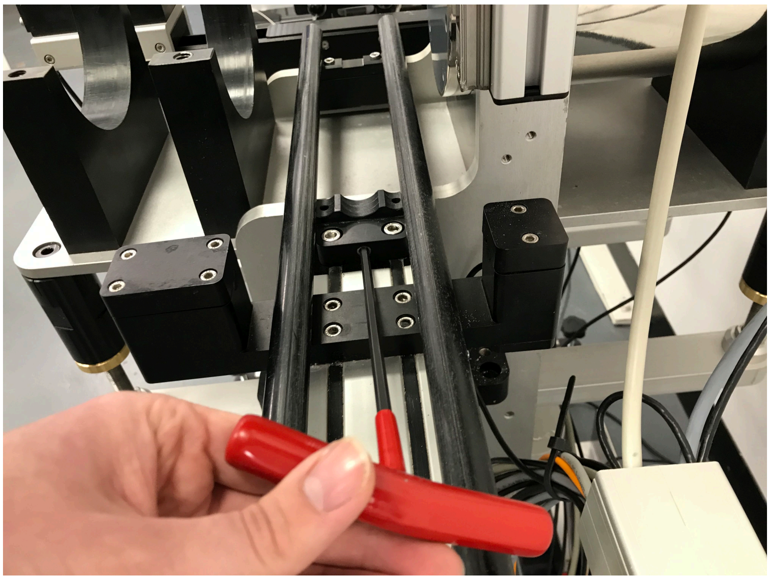


Figure 3.2: Rail sleeper removal bolt

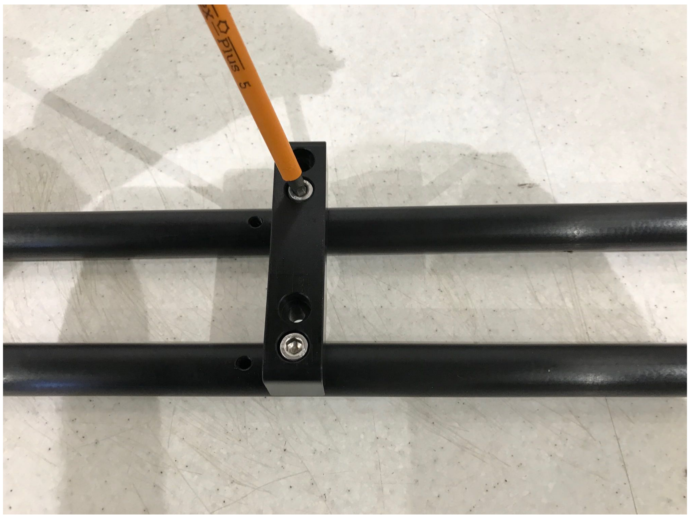


Figure 3.3: Switch over the rails to the narrow gauge sleeper threads. Remove only one rail at a time.

3.2 MOTOR POSITIONING AND DISTANCE CONTROL

When logging core samples on a three-way motor controlled MSCL-S system, the pusher (X-axis motor control) under automated control will push the core samples past the instruments installed. The reciprocating P-wave system (Y-axis motor control) will move under automated control toward the core sample to acquire a measurement and away from the core sample when not measuring to allow it to advance. The vertical sensor arm (Z-axis motor control) under automated control will move down so the instruments are in contact with the core sample to measure and upwards when not measuring to allow the core sample to advance.

The MSCL-S system main electronics do not independently measure the actual position of the motors. The X-axis motor control position is only determined when the pusher is reset to the 'laser reference position'. The Y-axis motor movement is predetermined via the Geotek software and the Z-axis motor control requires the user to set a 'vertical excursion distance' which is input by the user before logging commences.

These procedures take place at the start of logging and the user is prompted via the Geotek software to firstly allow the pusher to locate the laser reference position, the Y-axis motor will then perform a positioning set-up, and finally the user will be prompted to set the Z-axis motor vertical excursion height. Please note that these procedures are fully automated via the Geotek software. On completion of locating all motor positions, all other motor positions are determined by calculating subsequent motor movements.

The motion of the X, Y and Z motors is calculated as the number of motor steps needed to move a set distance (Table 3.1). The relationship is as follows:

$$NS = \frac{D \times SPR \times GBR}{\mathrm{P} \times \mathrm{NT}}$$

Where:

NS = Number of steps

D = The distance moved in mm

SPR = Number of steps per revolution of the stepper motor

GBR = Gearbox ratio

P = Pitch (0.5 cm ball screw system and 1.0 cm for toothed belt pulley)

NT = Number of teeth on the drive pulley

All current MSCL-S systems operate with a ball screw assembly for the X-axis motor and two lead screw assemblies for the Y-axis and Z-axis motors.

Older MSCL-S systems will have a vertical slide rack and pinion assembly for the Z-axis motor control. Note: If the slide is driven too high then the pinion gear disengages from the rack preventing any damage. The pinion gear will re-engage when the slide is driven down again. If the slide is driven down 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 driven down too low then the user can re-engage by simply applying slight upward pressure on the rack while the motor is operational.

3.3 MOTOR CONTROL

There is a simple two-way switch for ‘Manual’ and ‘Auto’, and a motor control knob located on the front of the motor control electronics rack that allow the user to operate the MSCL-S system.

In the ‘manual’ position the stepper motors for each of the X-, Y- and Z-axis are controlled by the motor control knob. The user can select either the X, Y or Z motor and turning the motor control knob left or right will determine the movement direction and speed of the selected motor. In the ‘auto’ position the stepper motors are under Geotek software control from the PC through the serial interface on the stepper motor controller. The speed and direction of movement are controlled via the Geotek software. In this way whenever the software ‘assumes’ that the switch is in the ‘auto’ position it checks and prevents the user proceeding until it is set appropriately and safe to do so. 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.

During normal MSCL-S operation, the motor control switch should be kept in the ‘X’ position to help prevent accidental manual movement of the Y and/or Z motors after having their positions set.

3.4 LASER CORE DETECTION AND CORE MEASUREMENT SYSTEM

Two laser-based systems are fitted as standard on the MSCL-S system: Right-hand track core sample detection and measurement laser, and Y-axis static or motor-controlled P-wave transducer assemblies or Z-axis vertical motor-controlled sensor arm, distance measurement lasers (Table 3.1).

WARNING: CLASS 3R AND 2 LASERS OPERATING ON MSCL-S SYSTEM

AVOID DIRECT EYE EXPOSURE

Table 3.1: Laser Systems Installed onto a MSCL-S System

Class	Operating Wavelength [nm]	Location
3R	400 – 695 (< 5 mW)	X-axis: Right-hand track
2	640 – 690 (< 1 mW)	Y-axis: Horizontal static P-wave transducer mounts, automated reciprocating P-wave transducer assembly Z-axis: Vertical automated P-wave transducer housing (Split core mode)

The right-hand track laser is housed in a black powder-coated aluminium assembly which is mounted perpendicular to the right-hand track section. The laser is a class 3R laser, is mounted on the user's side of the MSCL-S system, and is focused on a diode mounted on the opposite side of the right-hand track which reflects the laser. This creates a continuous 'unbroken' beam invisible to the human eye. Having a laser detector system achieves several objectives:

- The user does not have to align the first section with the reference position before logging begins. This is an automated process controlled via the Geotek software. When a core sample is pushed toward the laser reference position the laser is broken, the core motion control movement stops and the measurement length of the core sample is recorded;
- All subsequent core samples are measured, their depths cumulatively recorded, and each sample is automatically butted against the previous without the user having to position the core sample accurately by hand. This automatic operation enables the process to be achieved more accurately and is insensitive to user error;
- At the end of logging each core sample when the pusher reaches the laser reference position, the software checks the position and re-sets the pusher position. 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

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

The Y-axis or Z-axis (split core mode) Class 2 lasers are mounted on the P-wave transducer assemblies. The lasers are focused to a fixed point on the rear of each P-wave transducer housing. The lasers precisely measure the movement of the P-wave transducer housing. In practice the 'core thickness' (i.e. outer diameter of core sample) is measured with reference to a known thickness and the deviated measurement from this reference thickness is recorded (i.e. variation in core sample diameter).

3.5 LIMIT SWITCH SAFETY SYSTEMS

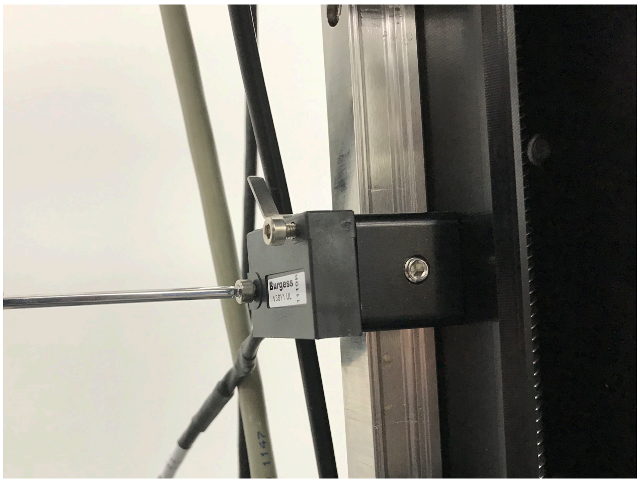


Figure 3.4: Limit switch safety system

Up to 3 pairs of 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. If they do contact then logging should be paused whilst appropriate measures are taken to 'reset' the system – with exception of the lower Z limit which may be set to core measuring height. The limit switch locations and functionality is as follows:

- The 1st pair of limit switches (X1 and X2) are located at either end of the right-hand track section. They prevent damage occurring to the system by cutting the power to the stepper motor (X 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 2nd pair of limit switches (Z1 and Z2) are mounted on the Z axis lead screw section (vertical slide or reciprocating transducers) to prevent both potential sensor and core damage. The lower limit switch (Z2) is set by the user to the lowest point they wish the Z-arm to travel to, so as to avoid any core damage or any sensor damage, should the Z motor be mistakenly activated. The upper limit switch (Z1) is also set by the user to the highest point they wish the Z-arm to

travel to, to avoid damage to any sensors attached to the arm from hitting the Z motor drive.

- The 3rd pair of limit switches (Y1) and (Y2), are both fitted to the back of the PWT drive, if this option is fitted. These are set by Geotek and define the compression limits of the PWT and also the maximum excursion possible by these sensors.

3.6 PHYSICAL SETUP PRIOR TO LOGGING CORE

The MSCL-S must be configured for the core to be measured. Each of these variables must be examined and the instrument adjusted prior to instrument calibration. More details on each of these can be found in the sensor chapters unless otherwise noted.

- Rail spacing: wide or narrow (Section 3.1.3)
- Centre section: horizontal or vertical orientation (Gamma Density & P-wave Velocity chapters)
- Gamma density source-detector spacing and choice of collimator
- P-wave transducer placement (rolling transducers only)
- Choice of magnetic susceptibility loop or point sensor; loop diameter & height
- Height of resistivity sensor
- Location of lower Z-limit switch if surface sensors are being used (Section 3.5)

4 USING MSCL-S SOFTWARE

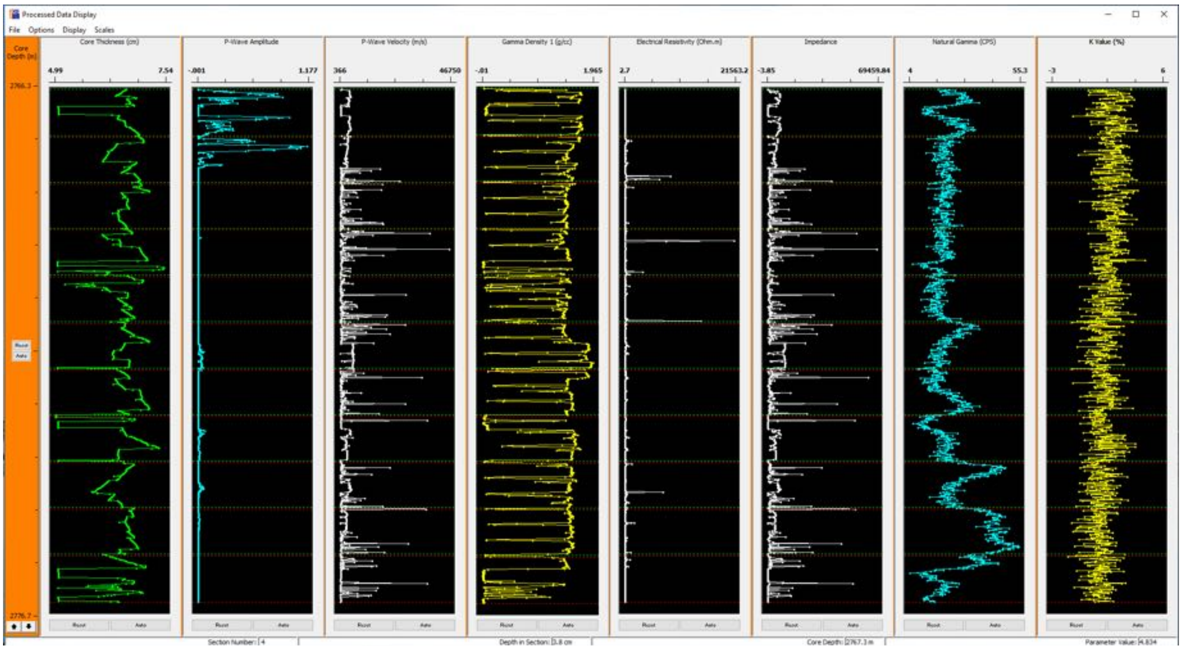


Figure 4.1: MSCL-S processed data window

4.1 INTRODUCTION

The MSCL-S software is included with every system and is a comprehensive piece of software that controls all the logger functions, data processing and data output. This chapter provides a short-form guide to automated core logging with an overview of the key features of the software. For any more ‘in depth’ questions, training notes should be referred to or queries submitted to support@geotek.co.uk. The MSCL-S software is only available on Windows™ systems and is a user friendly program that both acquires raw and processed data in real time, which is presented graphically – but can also be viewed in a tabular form. The same software allows the viewing and processing of previously acquired data and can be run on any computer free of charge. Along with the MSCL-S software, there is also an accompanying ‘Utilities’ program, which allows the user to run tests for individual sensors and set up configuration parameters, which is discussed further in Chapter 5.

4.2 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.

For lined sediment cores such as piston cores, 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 chapter 6.

Rock cores are normally stored in boxes, and pieces of core can be specified by box number and track or tray within the box. However, the MSCL-S software still uses sequential section number to curate the cores measured. In this case, a section corresponds to whatever core is placed on the track for logging; often this will be the material contained in a single track of the box.

4.3 LOGGING OVERVIEW

In the sections below the general logging principles are described for the standard current generation track type; any variations that exist for previous or alternate track types are discussed in Geotek legacy documents.

Before logging, ensure that the 'track type' is set to 'standard – ballscrew' in the settings and that the right and left hand limits are set correctly (Settings, Chapter 5). A core is automatically logged by sequentially loading core sections onto the RH (right hand) 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 check section or the top section of core) onto the RH end of the track with the top to the left and clear of the laser detection 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 approximately at the left side of the laser housing. 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 detection system, then continue logging. The MSCL automatically measures the core section, 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. 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 resistivity sensor or the natural gamma section). Normally a core section can be removed each time a new section is added (if the cores are a consistent length).

To end the logging process, one or more dummy core sections must be used which are 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.

4.4 LOGGING A NEW CORE

In these short form instructions it is assumed that all pre-checks have been carried out and all sensor systems are properly calibrated (see sensor-specific chapters). 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. More detailed information can be found in this and sensor specific chapters, which explain all options in detail. These instructions assume the logger is a standard ball-screw system.

Instructions on how to log a core:

- Open the software and the main menu will be displayed, Figure 4.2:

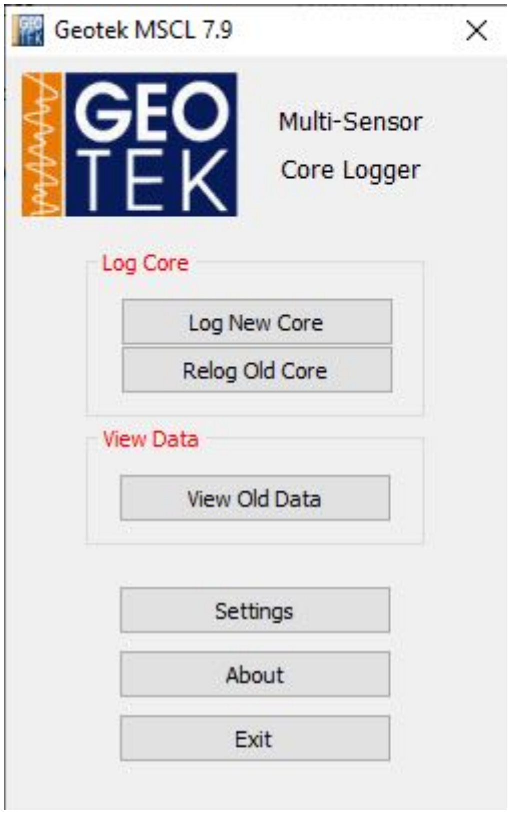


Figure 4.2: MSCL-S software main menu

- Click [Log New Core] from the main menu
- The new file window will open, Figure 4.3. Enter a new core name in the 'Enter New Filename' panel and choose the directory in which the data is to be stored (normally C:\GeotekData). 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.

Click [OK] when ready.

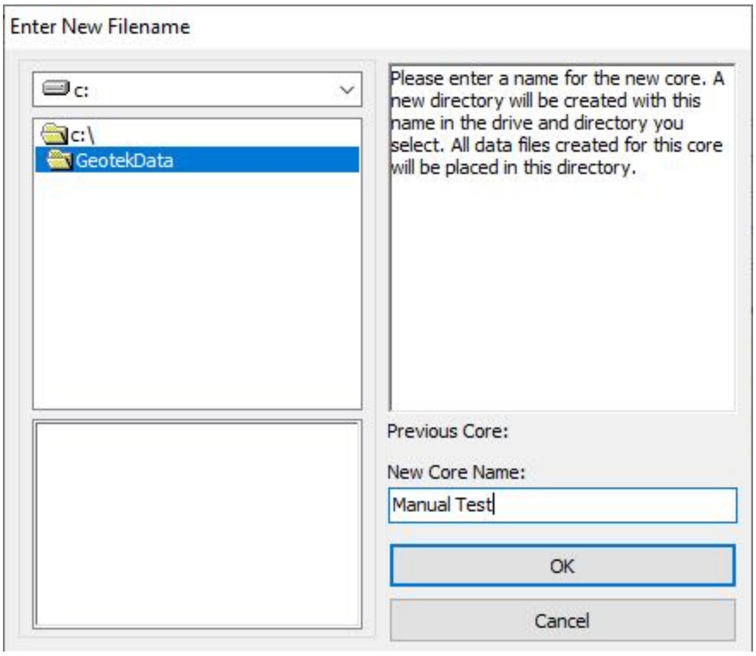


Figure 4.3: Enter New Filename panel in MSCL-S software

- Complete the setup panel as required (Figure 4.4)

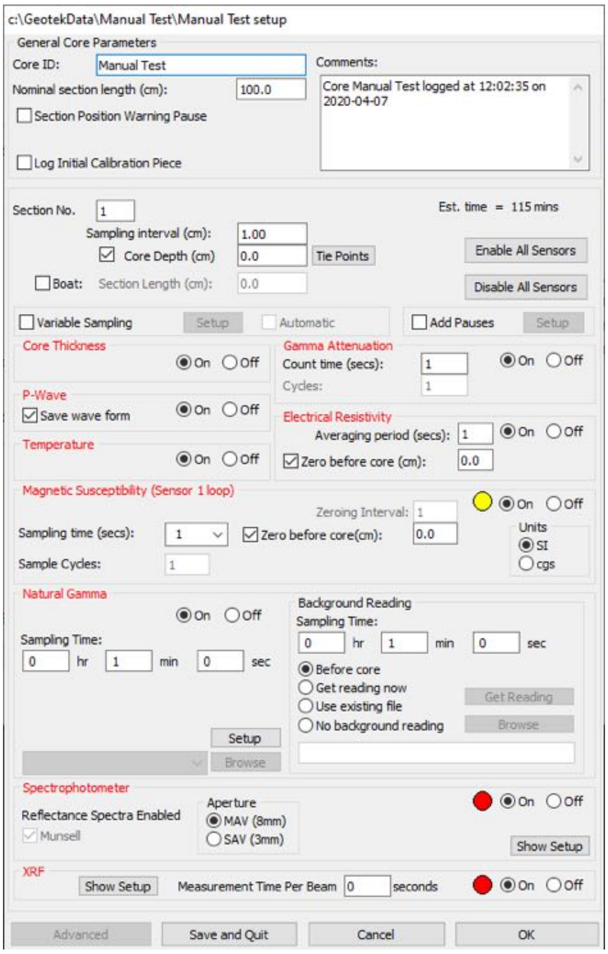


Figure 4.4: Setup window in the MSCL-S software

- 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.

- Whole Lined Sediment Core

  Place the reference core thickness piece for the core being logged between the P-wave transducers, Figure 4.5. If on static mounts, then they should be adjusted so they are reasonably tight to accommodate for any core thickness deviation. If they are on a motorised system, they should be brought into contact until the housing is halfway in its travel (Figure 4.6).

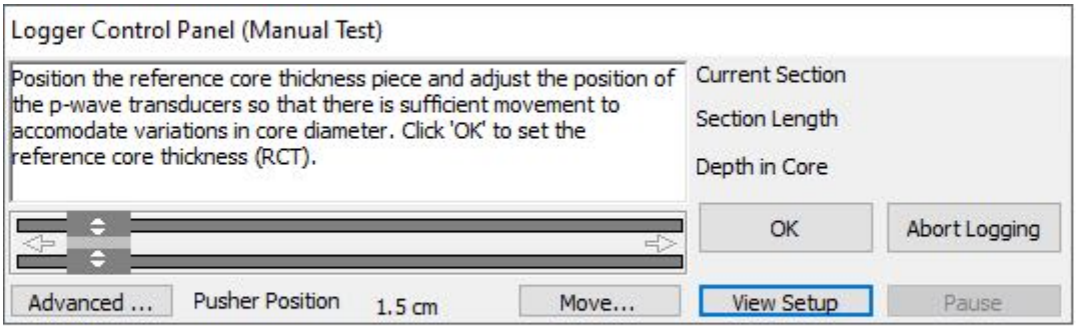


Figure 4.5: Logger control panel in MSCL-S software

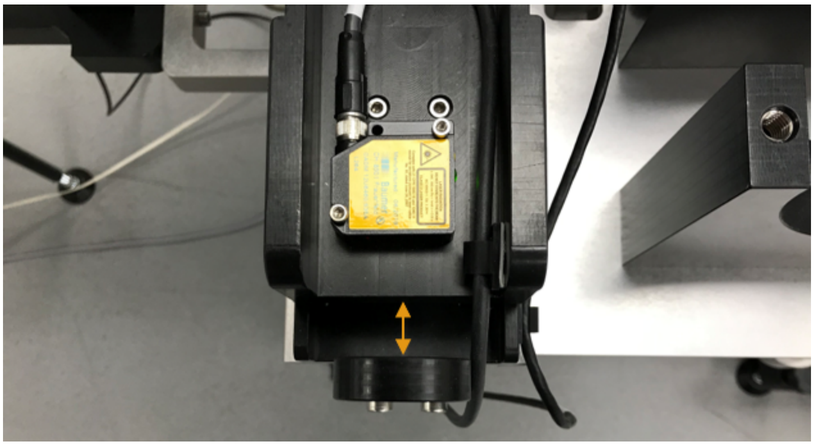


Figure 4.6: Transducer housing halfway in travel (orange arrow)

- Whole Rock Core

  If the user is working with whole rock core and sensors on the Z-arm are active, then the user will be asked to set the measurement height of the sensors (Figure 4.7). The z-arm should be lowered slowly in manual mode until the sensor is touching the core, then lowered further so the sensors are compressed half way in their travel. This is done to compensate for variations in core thickness. (The Z2 limit switch should be set just below this point.)

- Split Core

  If working with split core (rock or sediment) then the user is prompted to 'position the reference core thickness piece and adjust the position of the P-wave transducers so that there is sufficient movement to accommodate variations in core diameter' (Figure 4.8). The Z-arm should be lowered slowly in manual mode until the upper P-wave transducer is touching the core, then lowered further so the transducer is compressed half way in its travel, see Figure 4.6. The Z2 limit switch should be set just below this point.

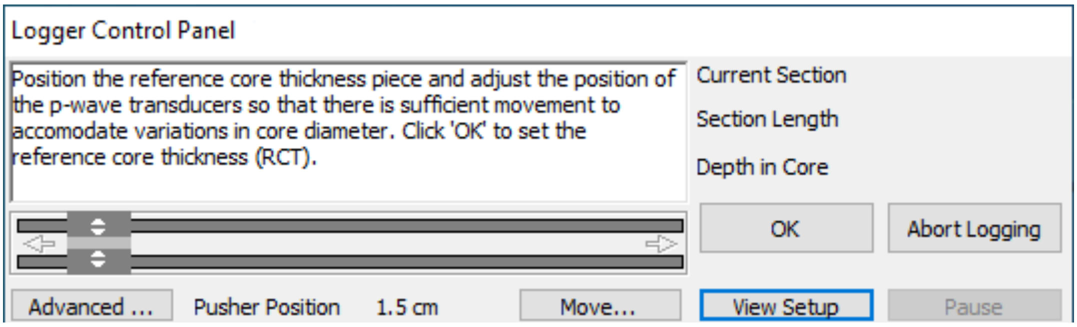


Figure 4.8: Logger Control Panel in MSCL-S software

- The Excursion Distance control panel will be displayed if the Z motor is in use (Figure 4.9). This is the distance the Z motor will move upwards after every measurement, allowing the sensors to move clear of the core before the core advances. The excursion distance is very important if using the magnetic susceptibility point sensor, as the sensors must move up high enough to be outside the magnetic influence of the core to allow the point sensor to "zero".

  Ensure that the distance set is enough to allow the core to travel freely without contacting any sensors. If the magnetic susceptibility point sensor is being used, a 50 mm excursion distance is a good starting value to test. (Experiments should be conducted using Utilities.) If there is a large amount of variability in core thickness, then the excursion distance should be increased.

  Enter the vertical excursion distance for the vertical (Z) motor (eg. 30 mm), ensure the electronics are set to 'Auto' and click [OK] when ready.

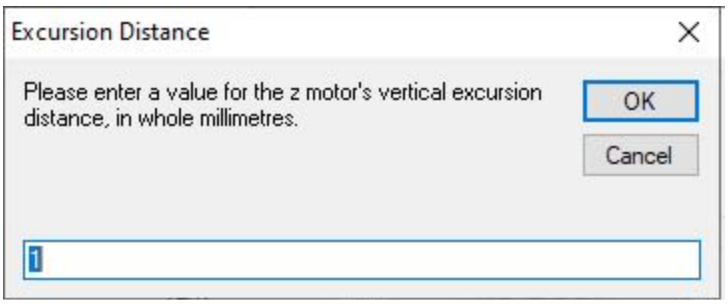


Figure 4.9: Vertical excursion distance in MSCL-S software

- The core pusher will now locate the laser reference point as seen in Figure 4.10. Ensure the RH track is clear and click [OK] when ready.

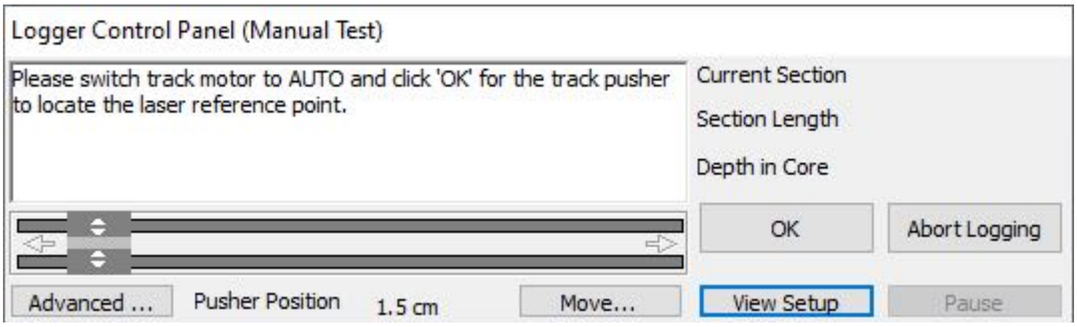


Figure 4.10: Logger Control Panel in MSCL-S software

- 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, (Figure 4.11).

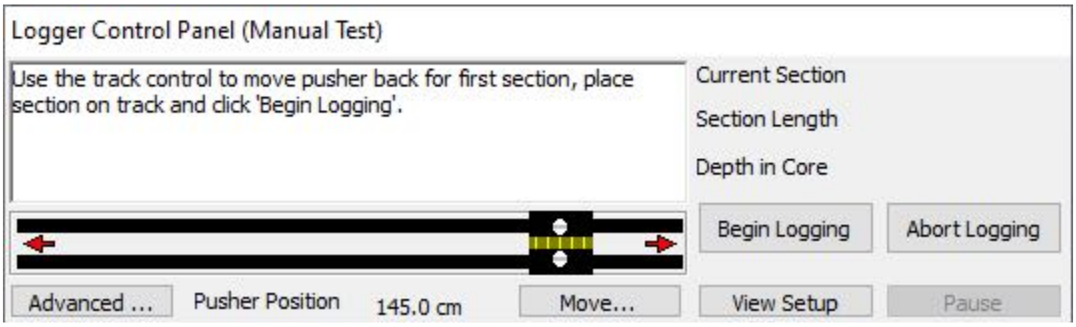


Figure 4.11: Logger Control Panel in MSCL-S software

- Place the first section on the track with the top of the section on the left and not obstructing the laser detection 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.
- Click [Begin Logging]
- The setup panel will be displayed again, Figure 4.4; check over the configuration and edit if necessary, then click [OK] when ready. The automated logging will now start.
- Ensure whilst the core section moves to its first measurement position that there are no obstructions to its movement. Note, if using gamma density, ensure the source is open! (see gamma density chapter).
- 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 4.12.

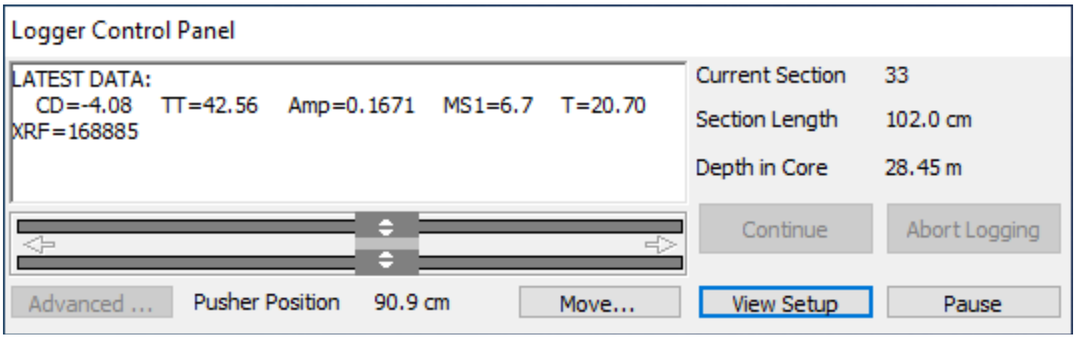


Figure 4.12: Logger Control Panel in MSCL-S software

- While it is doing this the user can observe the raw data being collected in the ‘Raw Data Display’ panel (Figure 4.13) which appears automatically and can be formatted as desired.
- The user can also observe and process the data by selecting the processed data display, (Figure 4.14). The processed data displayed is determined by the setting entered in the processing panel ([Options] + [Processing Panel]). For information about processing parameters, see specific sensor chapters.

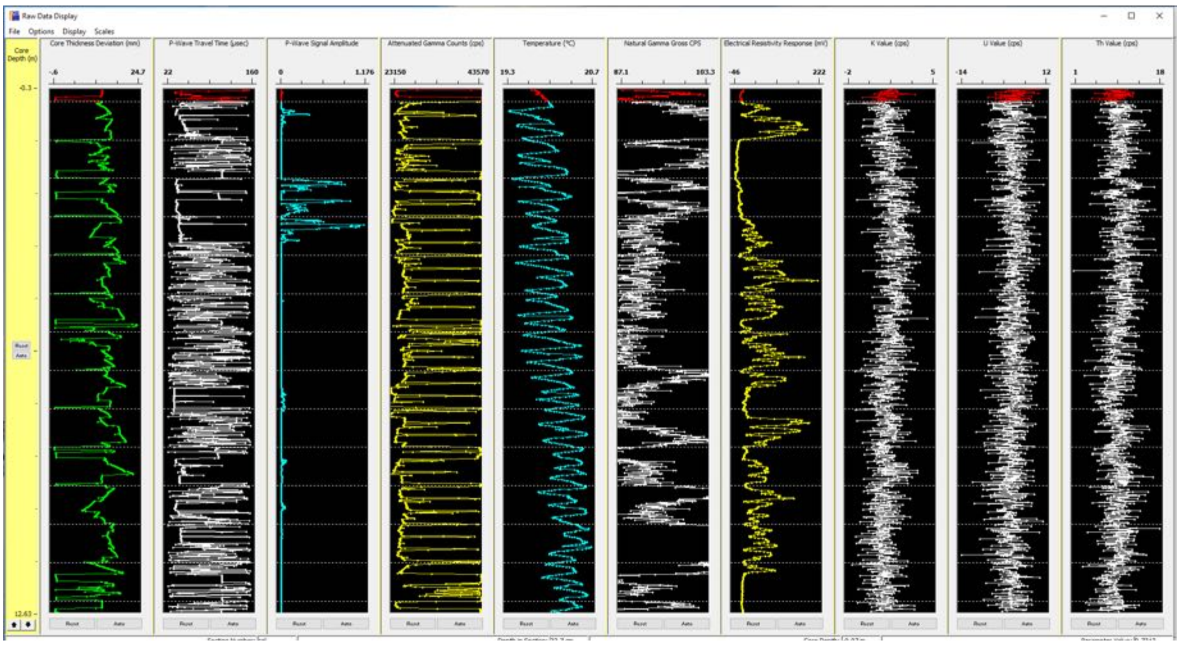


Figure 4.13: Raw Data Display panel in the MSCL-S software

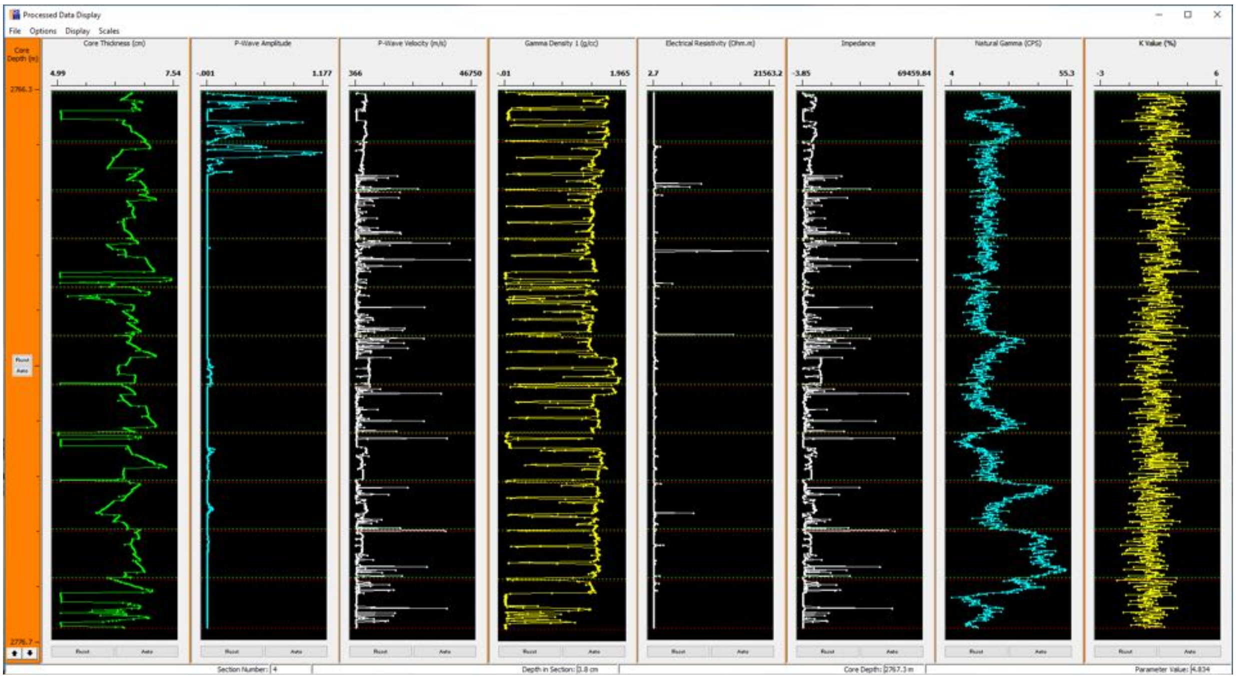


Figure 4.14: Processed Data Display panel in the MSCL-S software

- In the event that something is wrong, the user should click [Pause] in the Logger Control Panel and assess the situation before continuing.
- 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 detection system, notify the user of any error and move along the track by the nominal core length entered in the setup panel.
- 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.
- Edit the setup panel as required for the new section and click [OK].
- Both core sections will be pushed through the sensor systems and will be logged incrementally according to the configuration set-up for each section.
- The process is continued until the last core section has been placed on the track.
- 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, (a previously logged section will suffice if nothing else can be used) and click [Continue], but this time disable all sensors in the setup panel. This will enable the last core section to finish the logging process. Multiple 'dummy' sections can be used if necessary.
- 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.

4.5 RELOGGING OLD CORE

This legacy feature may not be compatible with all new systems, and should not be used unless Geotek has specifically recommended it.

4.6 PROCESSING ACQUIRED DATA

The MSCL-S software is also used to process any acquired data and can be used to reprocess previously acquired data. The following outlines the post-acquisition processing that the MSCL-S software is capable of.

4.6.1 HIDING DATA POINTS

Before exporting data it is important to remove any inaccurate or unrequired data points. This is achieved in the MSCL-S software by drawing a box around the data the user wishes to remove, then right clicking in the box (Figure 4.17). This gives the user multiple options:

- Hide Points – Hides the highlighted points for the specific sensor
- Hide All Points At Depth – Hides specific highlighted points across all sensors
- Replace All Hidden Points at Depth – Replaces previously hidden points across all sensors in the highlighted depth range
- Replace Hidden Points – Replaces previous highlighted points for the specific sensor

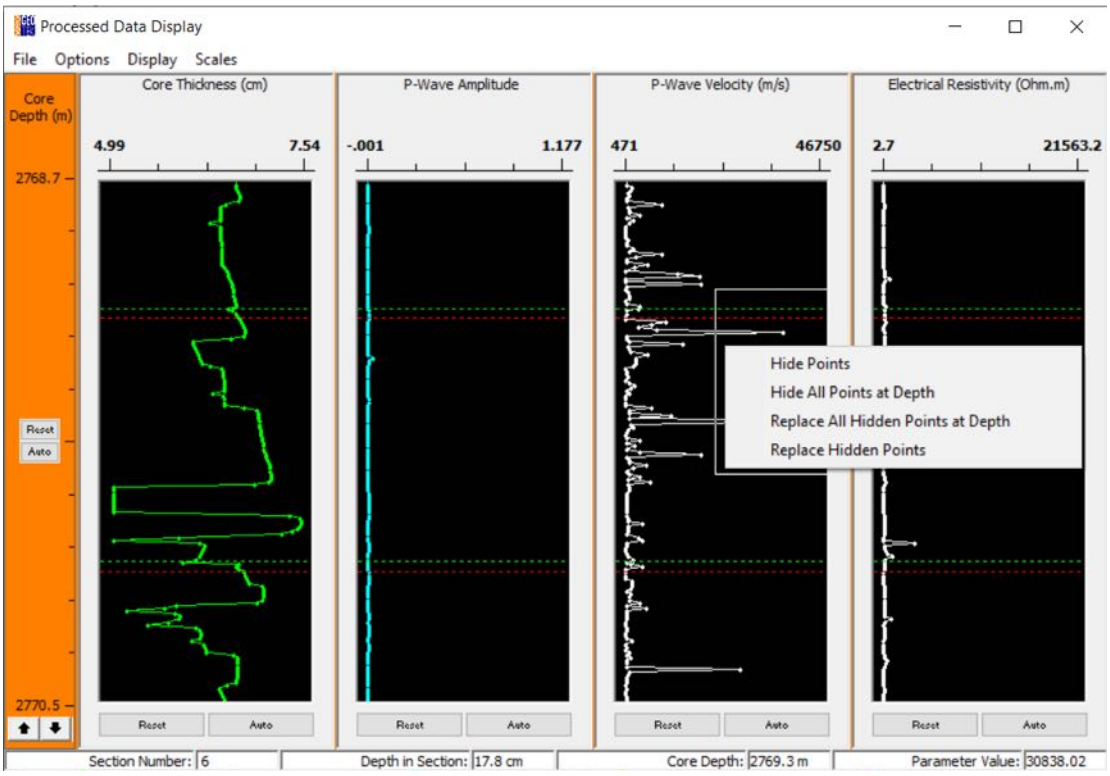


Figure 4.17: Removing data points in the MSCL-S software

4.6.2 PROCESSING PANEL

The parameters used to convert the raw acquired data into processed usable data are defined in the processing panel. The processing panel is accessed through the options menu. New parameters can be entered into the processing panel at any time and are applied by selecting the “Update Graphs” option, (Figure 4.18). Parameters can be saved and loaded by the user if required by using the “Save Parameters” and “Load Parameters” options. For specifics on what parameters to enter into the processing panel, see specific relevant sensor chapters.

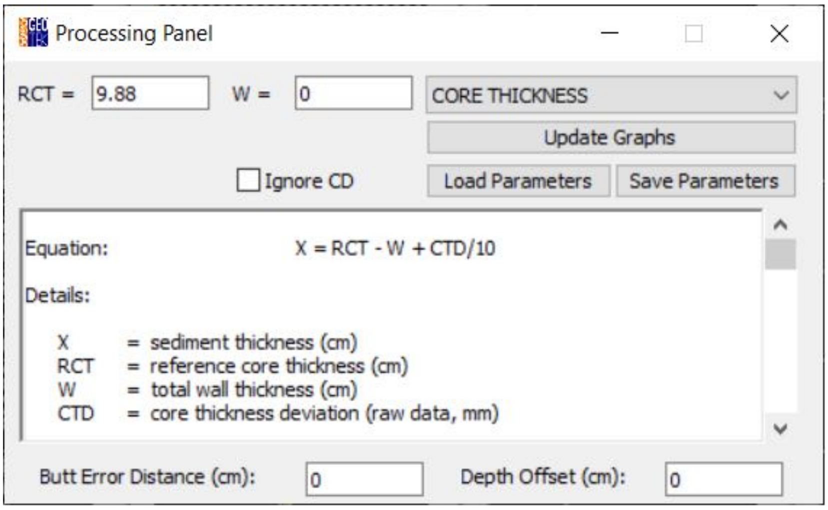
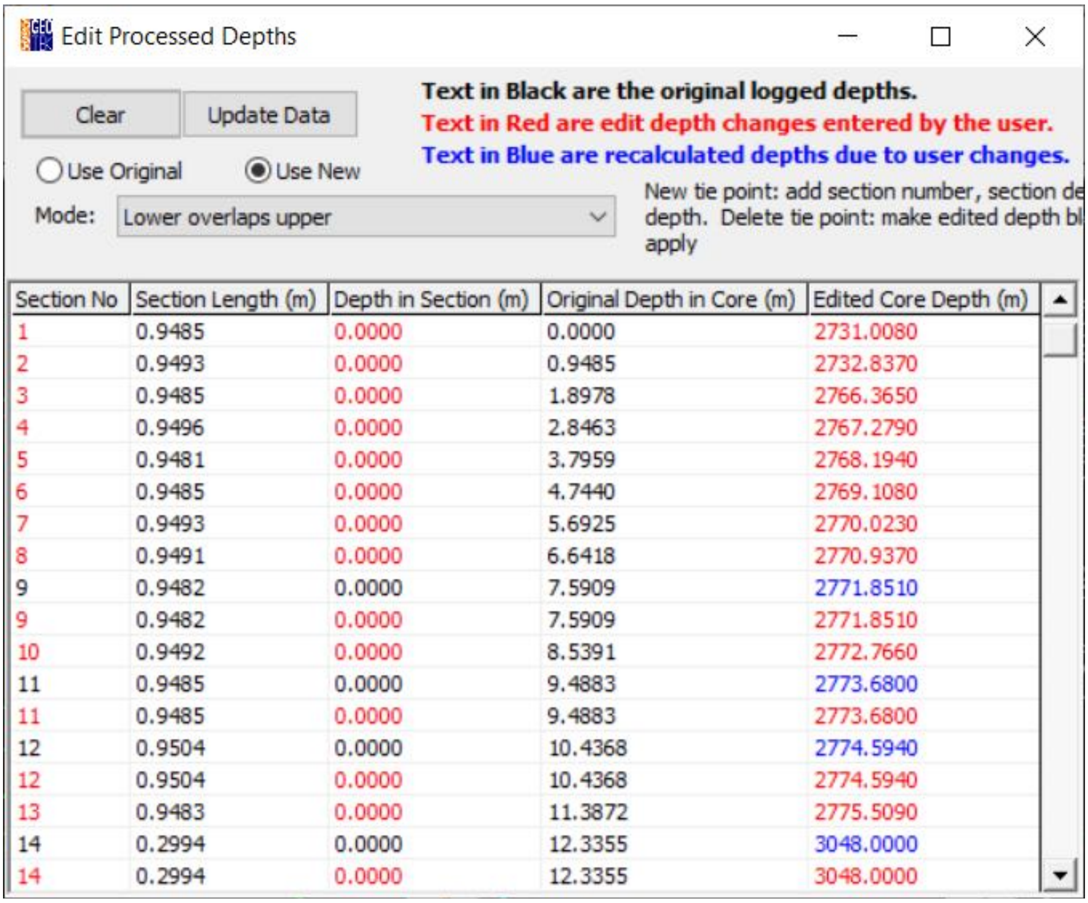


Figure 4.18: Processing panel in MSCL-S software

4.6.3 EDIT DEPTHS

If depths are not entered in the core setup panel prior to logging, or should they need to be modified, the user can edit the recorded depths at any point using the ‘Edit Depths’ function in the Options menu, (Figure 4.19). This feature is especially important when logging rock core that has "tie points" created by depth blocks or curated metre marks.



Section No	Section Length (m)	Depth in Section (m)	Original Depth in Core (m)	Edited Core Depth (m)
1	0.9485	0.0000	0.0000	2731.0080
2	0.9493	0.0000	0.9485	2732.8370
3	0.9485	0.0000	1.8978	2766.3650
4	0.9496	0.0000	2.8463	2767.2790
5	0.9481	0.0000	3.7959	2768.1940
6	0.9485	0.0000	4.7440	2769.1080
7	0.9493	0.0000	5.6925	2770.0230
8	0.9491	0.0000	6.6418	2770.9370
9	0.9482	0.0000	7.5909	2771.8510
9	0.9482	0.0000	7.5909	2771.8510
10	0.9492	0.0000	8.5391	2772.7660
11	0.9485	0.0000	9.4883	2773.6800
11	0.9485	0.0000	9.4883	2773.6800
12	0.9504	0.0000	10.4368	2774.5940
12	0.9504	0.0000	10.4368	2774.5940
13	0.9483	0.0000	11.3872	2775.5090
14	0.2994	0.0000	12.3355	3048.0000
14	0.2994	0.0000	12.3355	3048.0000

Figure 4.19: Edit processed depths panel in the MSCL-S software

To edit the depths recorded when logging, simply input the new depth under the ‘Edited Core Depth’ column and select ‘Use New’ then ‘Update Data’. The MSCL software will now modify the section depths in the processed data window, note that the raw data depths will not change. The units that the depths are measured in can be changed between metres, centimetres and feet in the MCSL/Utilities settings, under the ‘general’ tab.

4.7 EXPORTING DATA

Once data has been processed with the required parameters and any unwanted data points hidden, the data can be exported for analysis or plotting. To export the processed data, simply select the ‘Create Ascii File’ option in the ‘File’ menu. This will export the data into a processed ascii file format as a .out file. This file can be opened in any spreadsheet software, such as Microsoft Excel or Libre Office Calc. To export raw data, the same process is followed, though any processing performed will not be included.

5 USING UTILITIES AND PC HARDWARE CONFIGURATION

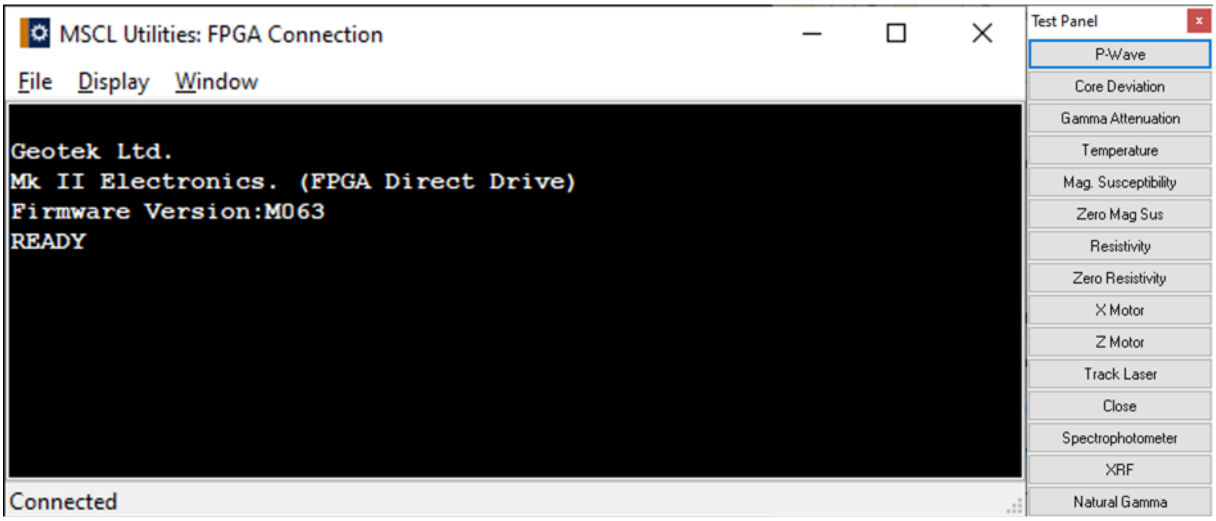


Figure 5.1: Utilities main screen and test panel

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.

5.1 COMPUTER

All MSCL systems are supplied with a PC running the Windows operating system 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 high 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, with an SSD as the primary C: drive.

5.2 UTILITIES SOFTWARE

The Utilities software gives the user direct access to the components and sensors of the MSCL and allows testing of the system. An interface to the instrument settings that describe a MSCL system is also provided. Features and functions that are greyed out in the menus will not be applicable to the system version as defined in the settings.

Current MSCL systems all run off the Geotek Mk II electronics system, but older systems utilise the original Mk I system. For details of the Mk I system, see Geotek legacy documents.

The Geotek Mk II 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 are controlled through the FPGA and data passed back to the PC.

The terminal window in the Utilities software (Figure 1) acts as a window to show the results of sensor tests. The [File_Log to File] can be used to record to file what is displayed in the terminal during any testing of sensors. The following headings describe the functions available in the ‘Display’ and ‘Window’ drop-down menus of the Utilities main terminal screen.

5.3 DISPLAY

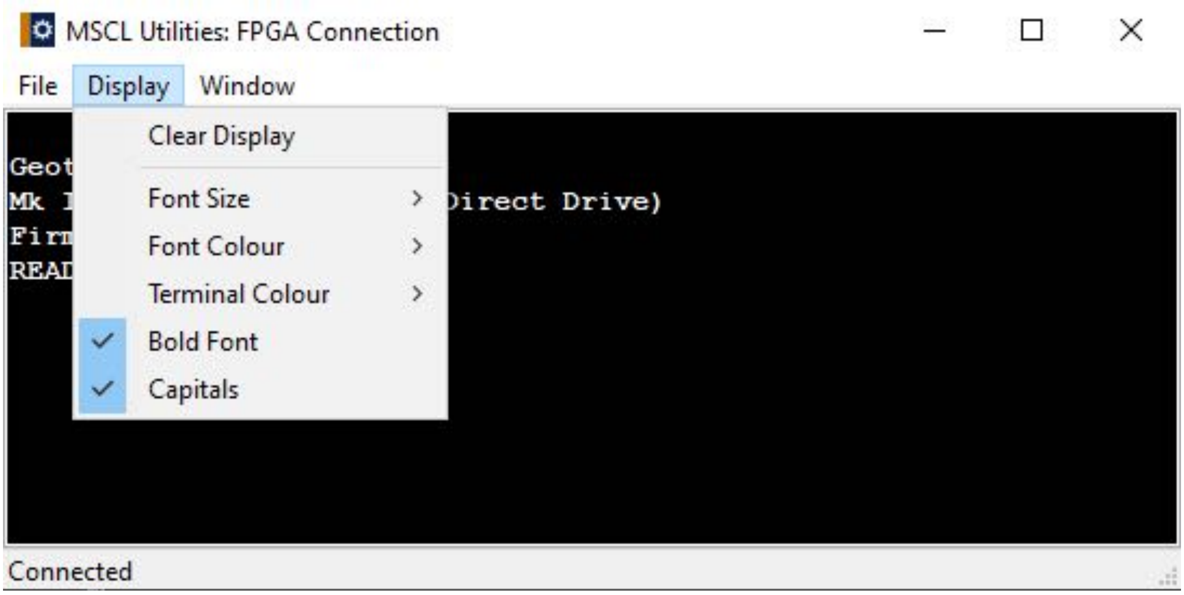


Figure 5.2: Utilities terminal window highlighting ‘Display’ menu

The most useful command in the ‘Display’ menu is the option for the user to clear the display, which is used before logging to file, or if the user wishes to clear the previous data off the display without restarting the software. The other settings in this menu are related to the font and display colour which can be configured to the user’s requirements.

5.4 WINDOW

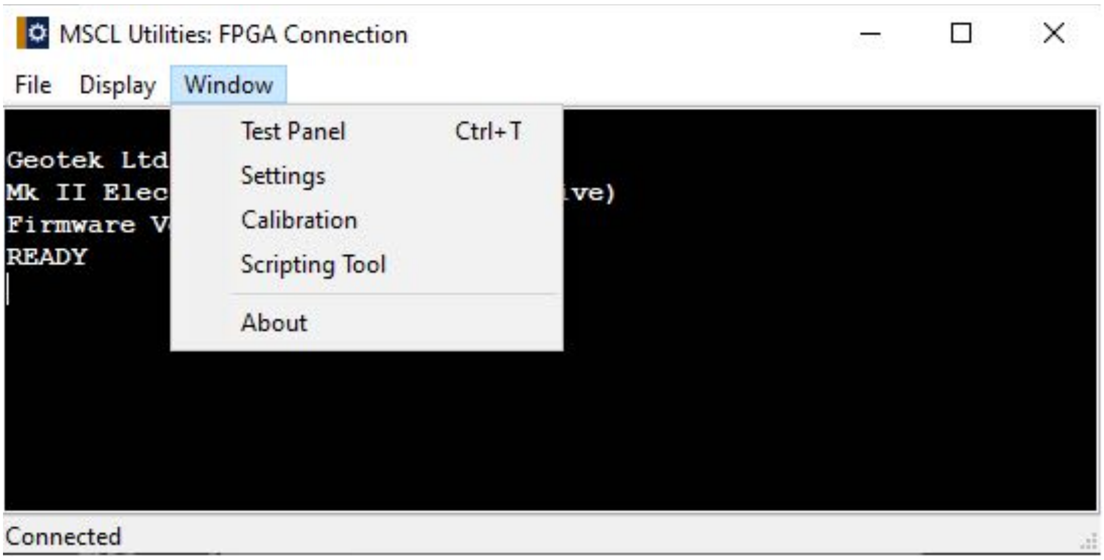


Figure 5.3: Utilities terminal window highlighting 'Window' menu

5.4.1 TEST PANEL

Figure 5.4: Mk II electronics test panel

The test panel appears when [Window_Test Panel] is selected as shown in Figure 5.4. The test panel enables the user to operate the X axis track motor, the Z axis motor, the Y axis motor 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 or calibration 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 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. The following describe the function of each box in the test panel:

P-Wave: Provides the TOT (total travel time) in μS between the two P-wave transducers and the P-wave amplitude in mV/V.

Core Deviation: Provides the ADC (analogue to digital converter) value calibrated displacement in mm.

Gamma Attenuation: Displays the raw windowed counts and the calibrated CPS (counts per second).

Temperature: Provides the ADC value and the calibrated temperature in °C.

Mag Sus: Displays the magnetic susceptibility reading (SI units) x 10^{-5}.

Zero Mag Sus: Used before measuring the magnetic susceptibility. Allows the user to zero the sensor to current conditions.

Resistivity: Displays the ADC value and the calibrated resistivity in mV.

Zero resistivity: Used before measuring the resistivity. Allows the user to zero the sensor to current conditions.

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.

Y Motor: When this box is selected the user is prompted to enter a distance that the reciprocators will move. If a positive number is entered the reciprocators will move inwards (together) and a negative number will cause them to move outwards (apart). The user can test the ramp routine by checking the box provided.

Z Motor: When this box is selected the user is prompted to enter a distance that the Z-sensor arm will move. If a positive number is entered then the sensor arm will move upwards (away from the core) and if a negative number is entered then it will move downwards (towards the core).

Track laser: Displays the current status of the track laser beam, either “Beam Unbroken” or “Beam Broken”. If the track laser is free of any obstruction the beam should display as unbroken. To test the functionality of the laser, the user should place an item in the way of the beam and the response should change to broken.

Spectrophotometer: Displays the spectrophotometer setup window; allows the selection of the installed aperture and calibration. Can also be used to make single discrete measurements.

XRF: Opens the XRF controller window.

Natural Gamma: Opens NG spectra windows for each detector. CPS will be displayed in the terminal window.

5.4.2 SETTINGS

The settings are a series of parameters that define the sensors and mechanical configuration of the logger as well as some invariable sensor 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 5.5.

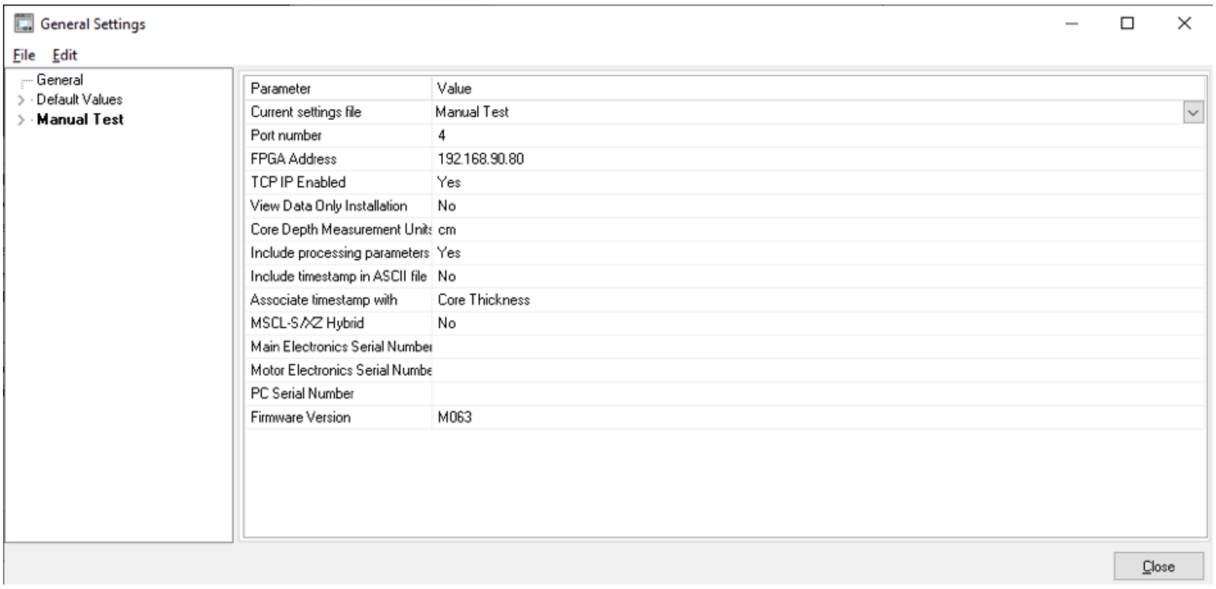


Figure 5.5: General Settings Panel

The settings panel has multiple options on the left side of the window; general, default values and any custom settings files that Geotek or the user has created. These options that can be created are known as the ‘settings files’ and the desired settings file is selected under “Current settings file” on the general tab. This is useful for when sensor configurations and calibrations change between different logging projects, or for when changing from whole core to split core mode. The rest of the [General] tab displays generic settings along with some options for user personalisation.

5.4.3 CREATING NEW SETTINGS FILES

New settings can be created in the ‘New settings’ window (Figure 5.6), which allows new settings to be made based on default settings or on existing settings files.

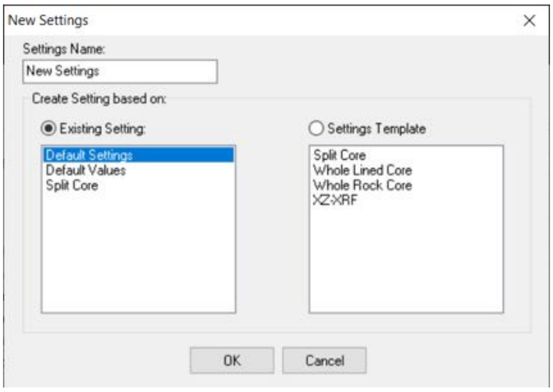


Figure 5.6: New settings window

5.4.4 SENSOR SUB-CATEGORIES

The sensor sub-menus 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, on the left hand side of the track laser). 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.

Below are listed the settings options for each of the sensor sub-menus:

Gamma Density

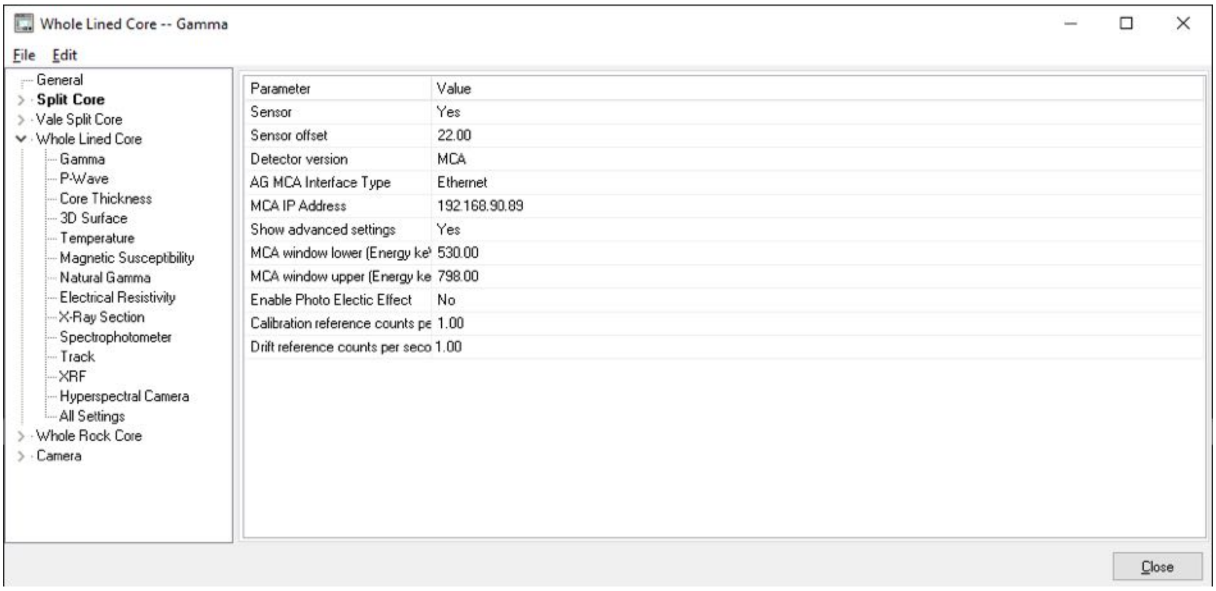


Figure 5.7: Gamma Density settings

Detector Version: the type of detector installed here should be input, modern systems with a 3" detector are MCA detectors, and older systems with 2" detectors are sensor versions 1 and 2.

AG MCA interface type: determines the connection from the detector to the PC, standard is ethernet.

MCA IP Address: the IP address of the detector, this should never change and remain at 192.168.90.89.

Further advanced settings exist below to allow Geotek to modify the windowing of the detector.

P-Wave

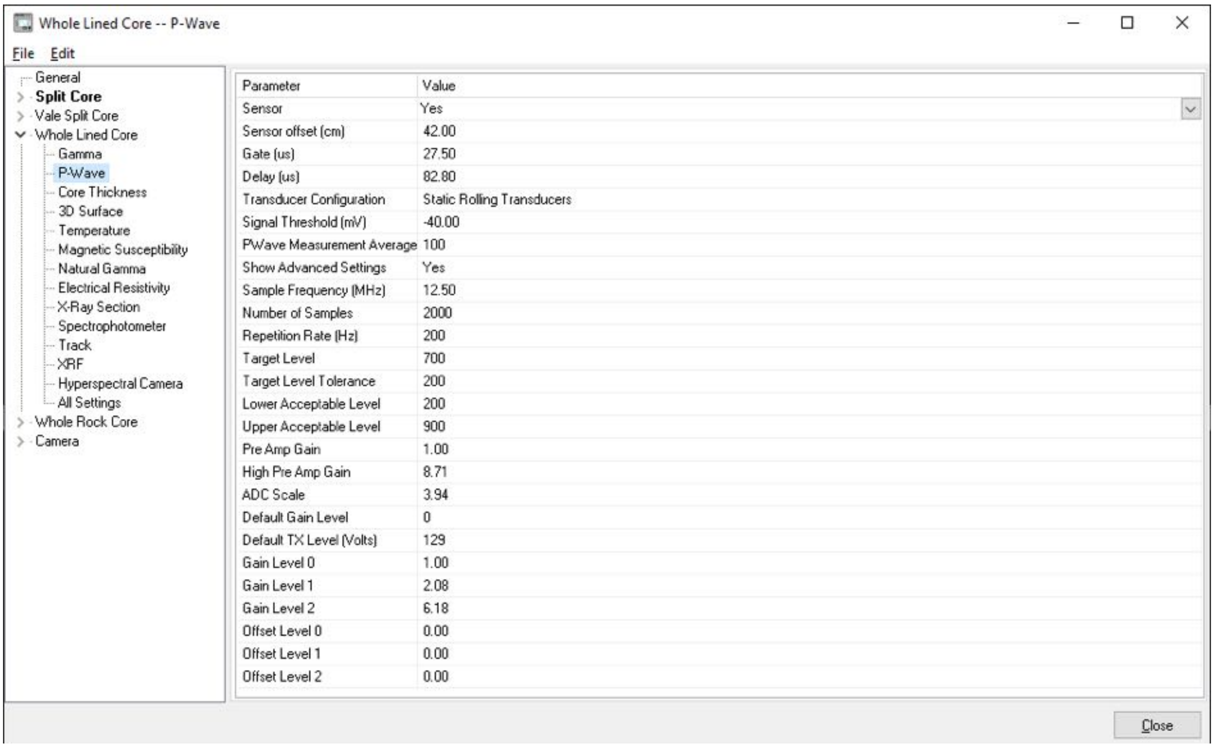


Figure 5.8: P-wave settings

There are a lot of settings relating to the P-wave system, but many of these are for factory use 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.

Delay (μs): defines the point in time (μs) at which the software should start its threshold detection.

Signal Threshold (mV): 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’.

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’.

Target Level and Target Level Tolerance: defines the optimal signal level (mV peak to peak) used in the automatic transmit and gain adjustments.

Lower and Upper Acceptance Levels: defines the signal level (mV peak to peak) that the system will accept for a signal timing measurement before automatically adjusting the transmit and gain.

Pre Amp Gain: defines the level of signal amplification close to the receiver.

ADC Scale: used to convert the ADC bits into mV (mV/bit).

Default Gain Level: defines the level of variable gain applied when initialising a measurement or starting to log core.

Default TX Level: the starting transmit voltage used when initialising a measurement or starting to log core.

Gain Levels 0, 1 and 2: defines the amplification stages of the variable gain.

Offset Levels 0, 1 and 2: defines any signal offset required when using the variable gain.

Core Thickness

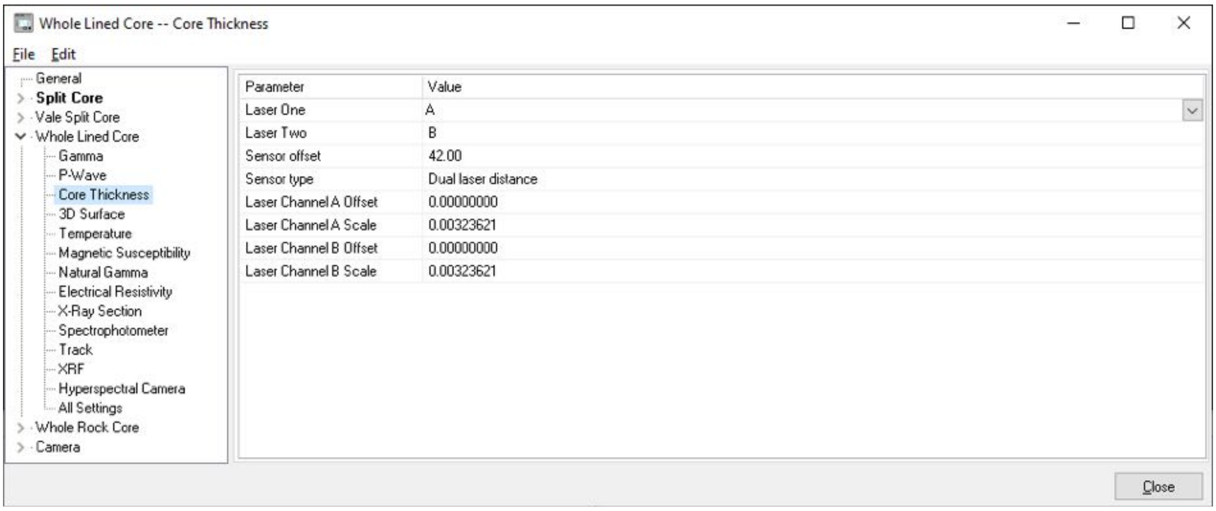


Figure 5.9: Core thickness settings

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 edited.

Temperature

A to D data channel: the channel used 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 (°C per bit) and offset (°C) is defined as per the protocol defined in the temperature chapter. These values should not change over the lifetime of the MSCL and so should not be edited.

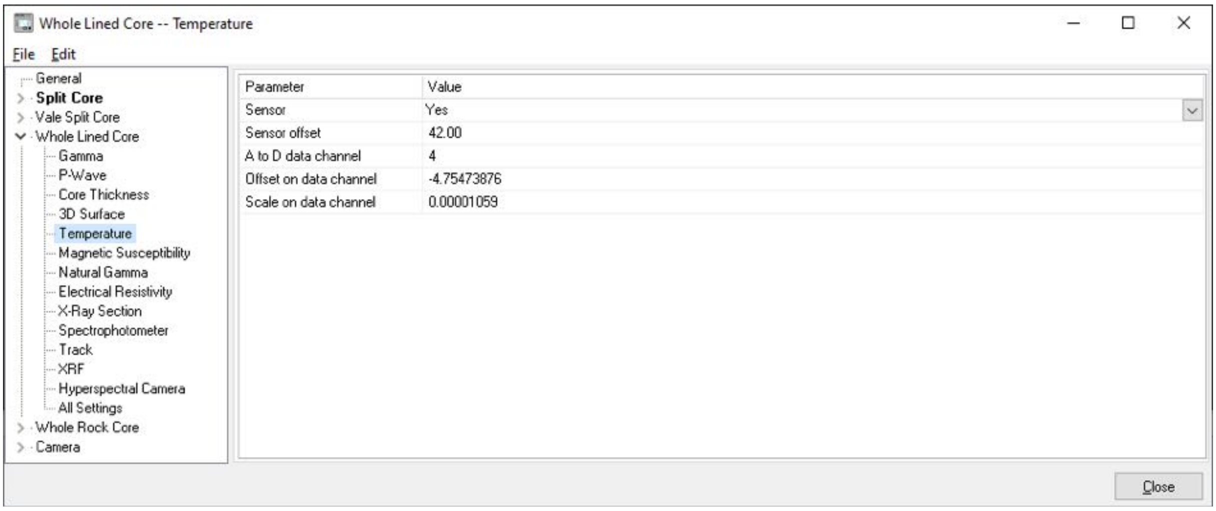


Figure 5.10: Temperature settings

Magnetic Susceptibility

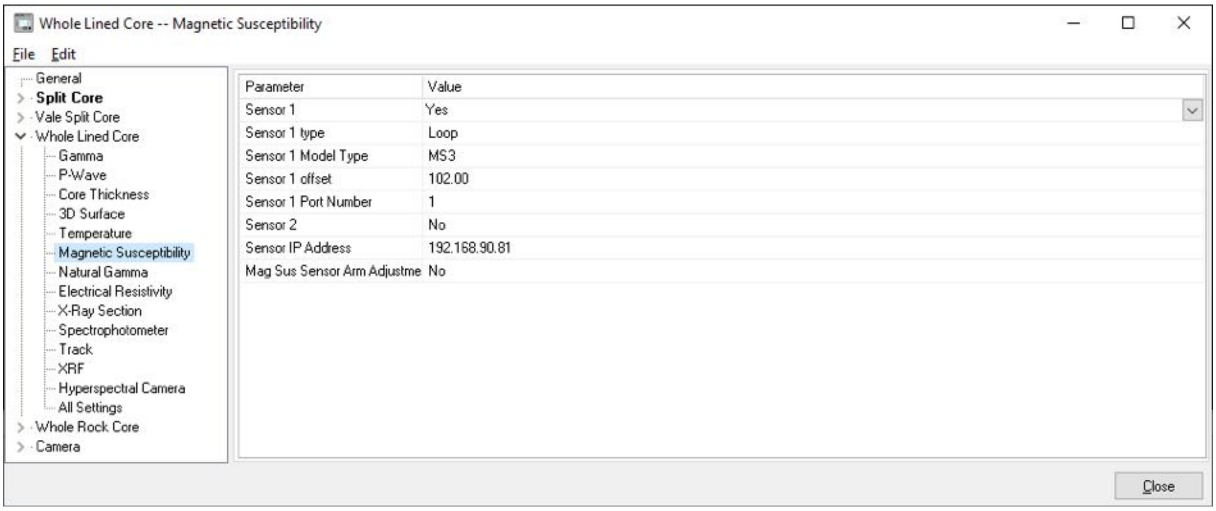


Figure 5.11: Magnetic susceptibility settings

The MSCL-S can be configured to have two magnetic susceptibility loop sensors installed and therefore options for Sensor 1 and Sensor 2 are available. Most systems only accept a single sensor.

Sensor type: can be either ‘Loop’ (MS2C) or ‘Point’ (MS2E).

Model type: defines whether the system is installed with a Bartington MS3 meter (newer systems) or an MS2 (older systems).

IP address and port number: On TCP/IP enabled systems 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

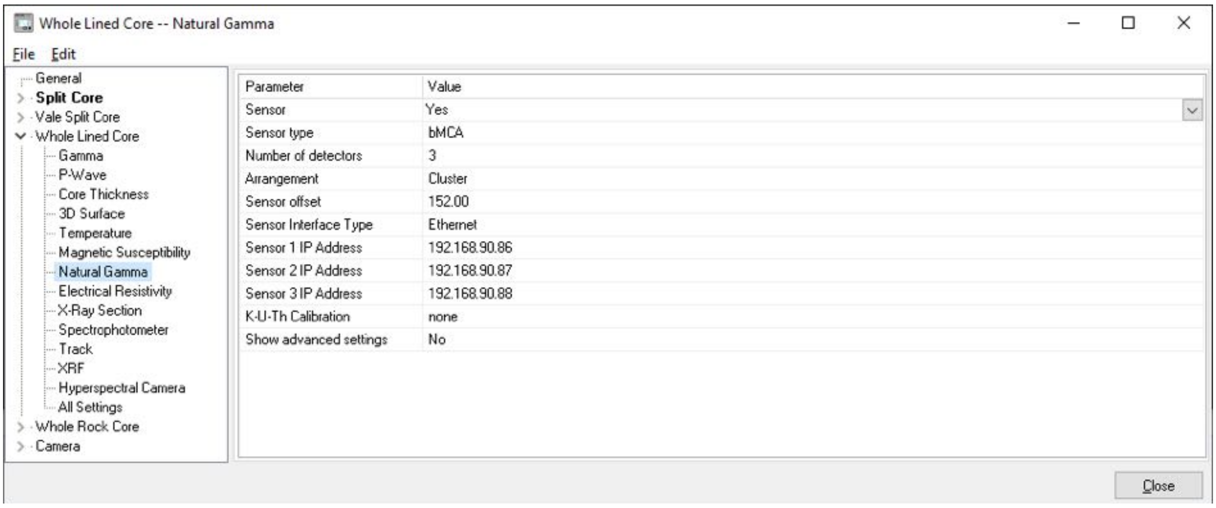


Figure 5.12: Natural gamma settings

Sensor type: the type of detectors installed; newer systems have bMCA sensors.

Number of detectors: the number of detectors installed on the NG system.

Arrangement: how the detectors are arranged. Almost all systems have detectors arranged in a cluster at a single location on the track.

Sensor interface type: defines the connection from the detectors to the PC. The standard connection for bMCA is ethernet.

IP Addresses: the IP addresses of each detector if using ethernet. An IP address label should be stuck to each detector for reference.

K-U-Th Calibration: allows the user to select which K-U-Th calibration file they wish to apply to the data. For more information on K-U-Th, contact Geotek.

Electrical Resistivity

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 must be defined.

Concurrent resistivity measurement: defines if the sensor should measure at the same time as the other sensors; enabled by default.

A hardware calibration is required to convert the voltage output from the sensor (through the AD converter) into a sensor response in mV. 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 edited.

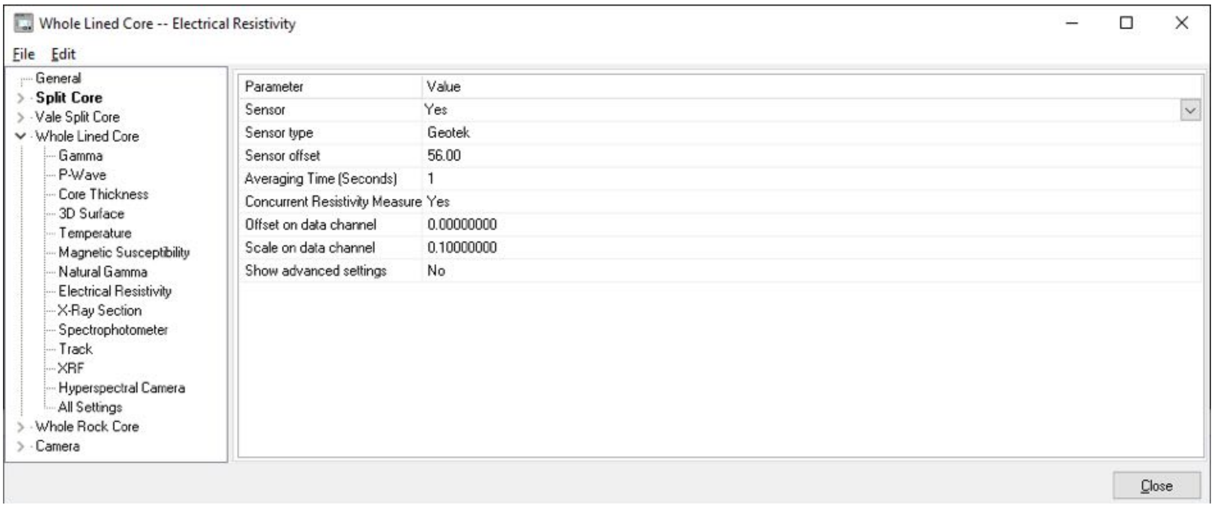


Figure 5.13: Electrical Resistivity settings

Spectrophotometer

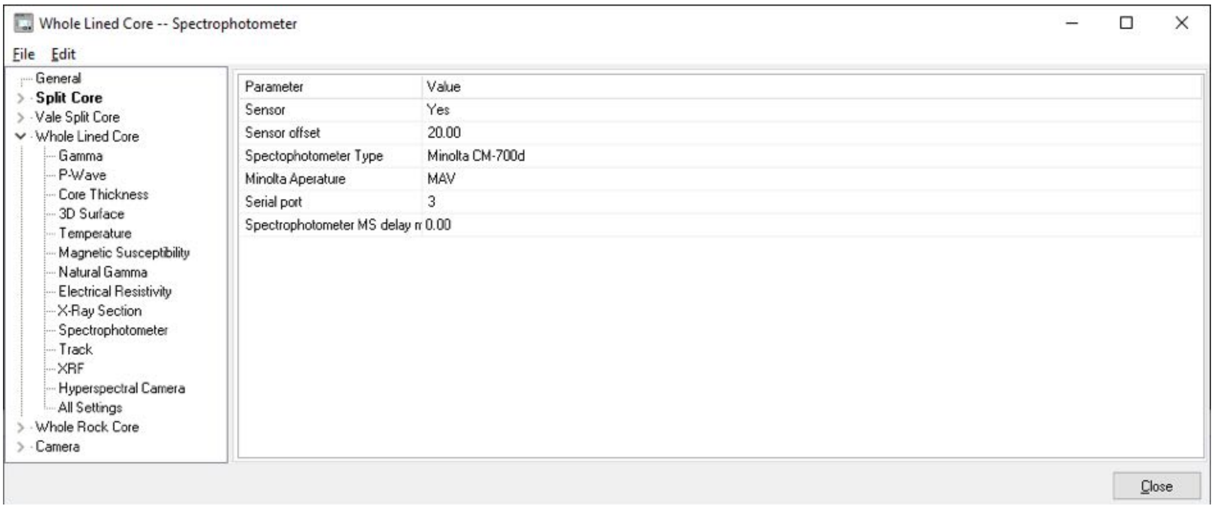


Figure 5.14: Spectrophotometer settings

This example is for Konica Minolta spectrophotometers. The settings for the VNIR LabSpec are similar.

Spectrophotometer type: the model of sensor being used.

Minolta aperture: select depending on whether the MAV or the SAV aperture is installed on the Minolta

Serial port: PC 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

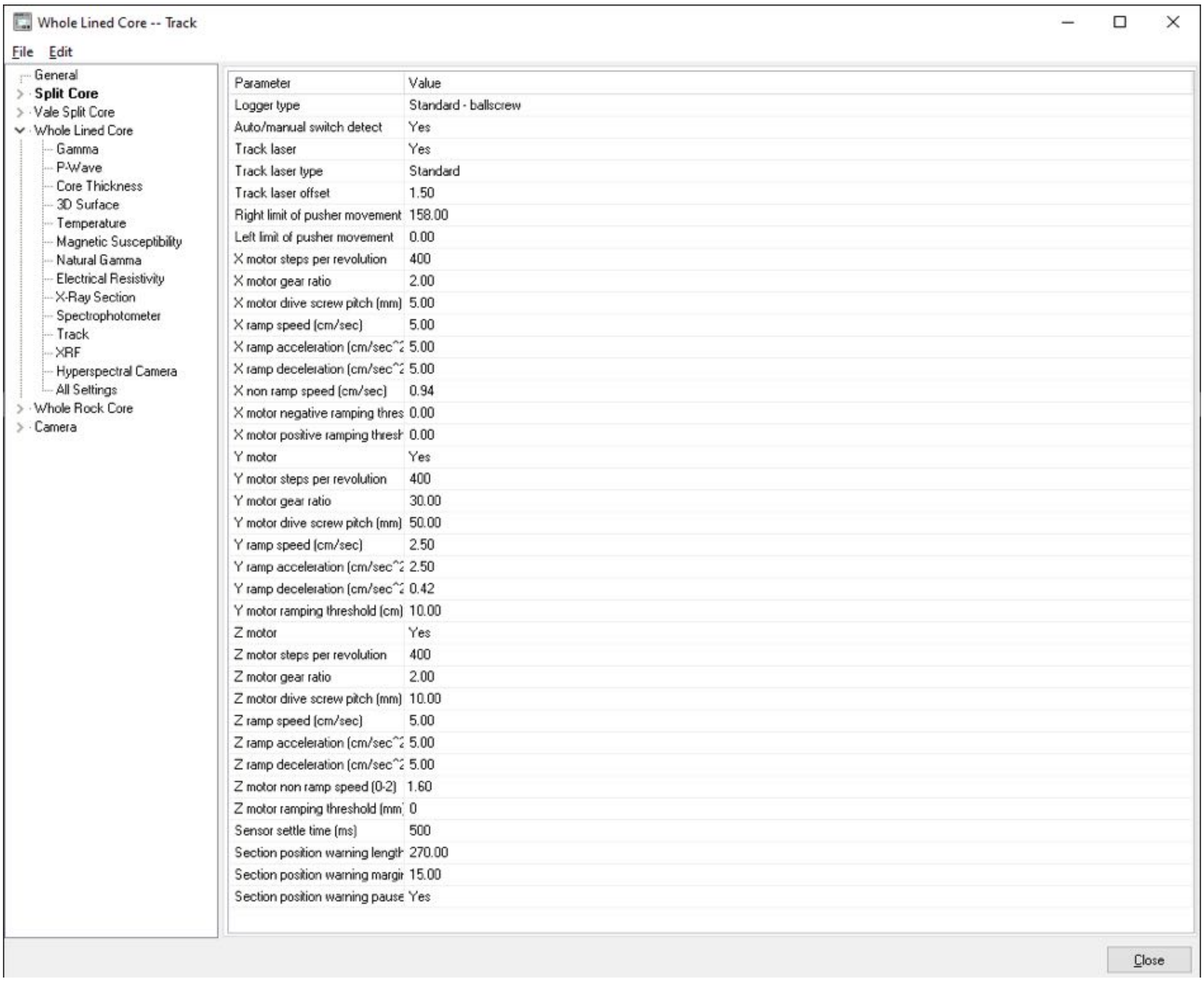


Figure 5.15: Track settings

The settings under the track heading define the type of track system and the mechanical configuration of the stepper motors and how they are attached to the MSCL. These should not be changed by the user except under the direction of Geotek, with the exception of the "Section position warning" settings.

Logger type: defines the type of drive system and in so doing customises the MSCL software interface appropriately. The current MSCL-S systems in use are ‘Standard - ballscrew’, where core is pushed past stationary sensors via a ballscrew within the RH box section. MSCL-XZ systems are ‘Moving sensors’, where sensors move past stationary horizontal core; MSCL-V systems are ‘Vertical’, where sensors move past stationary vertical core; MSCL-XYZ systems are ‘XYZ Table’, where sensors move over multiple sections of stationary core. Very old MSCL-S systems may be of type 'Standard' (belt drive), 'Unrestricted Pusher' or 'Boat'.

Auto/Manual switch detect: defines if 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.

Track laser offset: defines the location of the laser with respect to the reference point of the track in cm. The laser is always to the right of the reference point.

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: the number of steps needed to rotate the motor shaft by one turn. This is always 400.

Track motor gear ratio: 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.

Drive screw pitch (mm): 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.

Ramp speed, ramp acceleration and deceleration: control the rate at which the motor will speed up or slow down.

Non-ramp speed: defines the speed of the pusher when no ramp is applied. This a relative measure and should be set at no more than 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.

Negative ramping threshold and Positive ramping threshold: parameters to set the distance above which the track motor will ramp

The Z and Y motor systems are also driven by stepper motors and so require similar parameters to be defined. The ‘Z motor’ and 'Y motor' main settings indicate the presence or absence of these motors in the particular settings. For instance, an MSCL-S with a Z motor may use the Z-motor when making surface measurements with the XRF, but may not use the Z motor when making only gamma density and P-wave measurements. Two sets of settings would be defined, and the 'Z motor' setting for the second set would have the value 'NO'.

Y or Z motor steps per revolution: the number of steps needed to rotate the motor shaft by one turn. This is always 400.

Y or Z motor gear ratio: the gear ratio between the motor shaft and the drive shaft or the track (normally 30 on Y motor and 2 on Z motor).

Y or Z ramping threshold (mm): the distance the motors will move before being ramped.

Sensor settle time (ms): defines the time the sensors will be in place before they start taking measurements.

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.

Section position warning length: defines the distance (in cm) from the track reference point beyond which the core sections being logged must not pass.

Section position warning margin: defines 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.

Section position warning pause: defines whether the section positions pause feature is enabled by default in the MSCL software.

XRF

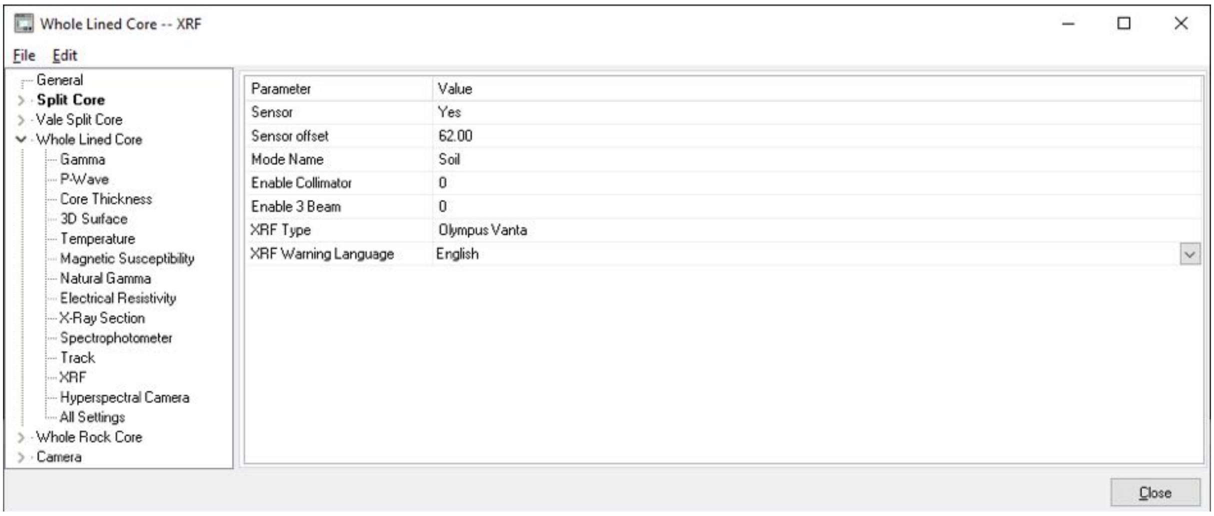


Figure 5.16: XRF settings

XRF type: the XRF model being used.

Mode Name: defines the active operational mode for different beam conditions and different spectral analysis algorithms.

Enable 3 Beam: enables the Vanta 3 beam mode (2 beam standard).

All Settings

This sub-menu lists all settings parameters in a complete list.

6 GETTING THE BEST DATA FROM CORES

6.1 LINED CORE MUST FILL LINER

When logging whole cores, only high quality cores where the liner is full of sediment will provide consistently good data. Figure 6.1 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.

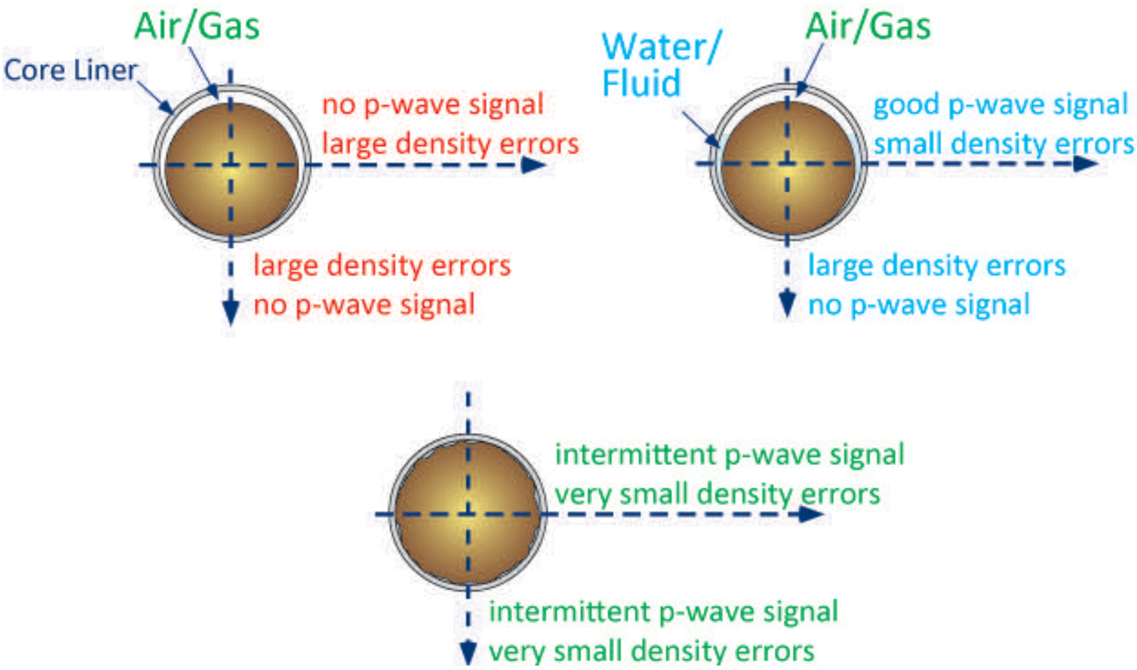


Figure 6.1: Horizontal vs Vertical acoustic coupling

6.2 SEDIMENT CORE HANDLING FOR BEST DATA

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:

6.2.1 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).

6.2.2 CORE SECTIONING

Problems:

A. Errors in measuring section lengths and butt error distance (see figure 6.2).

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.

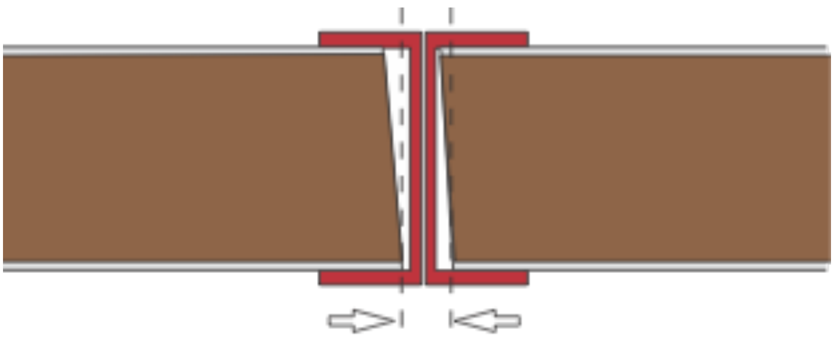


Figure 6.2: Representation of butt error distance

6.2.3 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.

6.2.4 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.

6.2.5 CORER ENDCAPS (FIGURE 6.3)

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 6.3. 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!

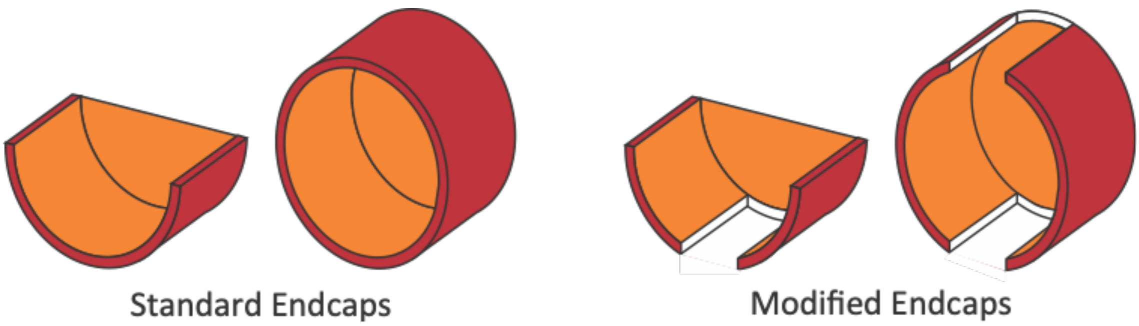


Figure 6.3: Cut away endcaps to improve quality of P-wave velocity and gamma density data. Modified endcaps shown are oriented for vertical logging; for horizontal logging, the cutouts should be in the centre of the core, where the P-wave transducers contact the core.

6.3 ROCK CORE DATA ISSUES

Rock core brings different challenges. The most difficult problems involve core quality and core curation.

All sensors are impacted by core geometry. If whole rock core deviates from a cylinder, or slabbed rock core from a flat surface, the data will suffer.

Core curation for rock core can be very confusing before it is removed from the box and placed on the MSCL. Clarity regarding borehole depths is key; create a table of tie points: known borehole depths that correspond to a specific depth within a section.

ATTENUATED GAMMA DENSITY

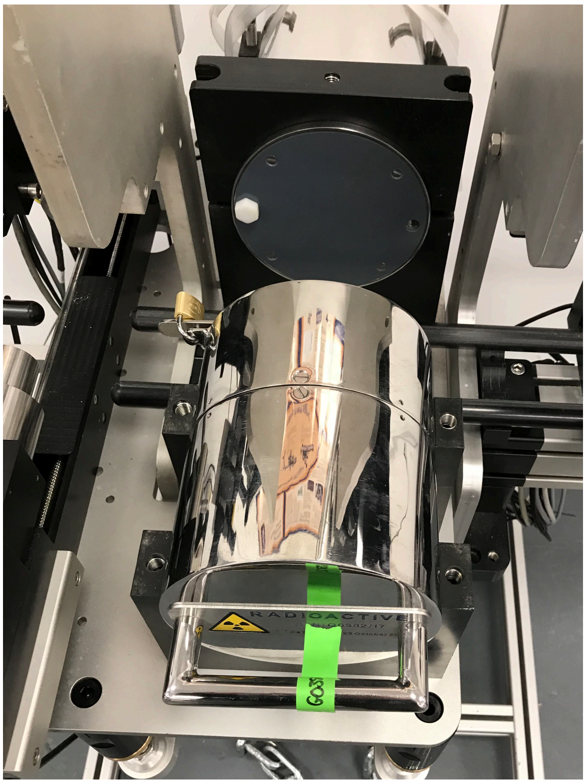


Figure 1: Attenuated gamma density system

1. 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 commonly given in the cgs units of grams per cubic centimetre (g/cm^3 or g/cc).

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 is also referred to as GRAPE (gamma ray attenuation porosity evaluator) after Evans (1965)[1] who used the technique in a device to compute porosity.

2. 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 (Table 1). These photons pass through the core sample and are detected on the opposite side by the detector.

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 sample 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 gamma ray source. A counting window is set which spans the region of interest around 0.662 MeV.

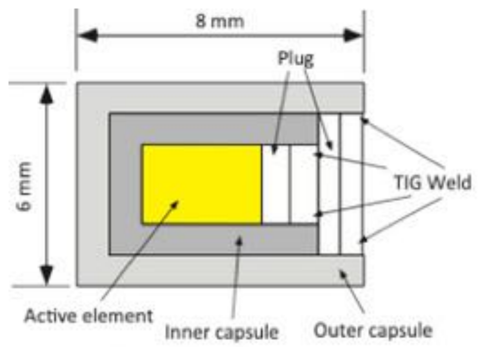
CAUTION: DO NOT OPEN THE SOURCE SHUTTER UNLESS SHIELD IS SECURELY MOUNTED IN FRAME

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

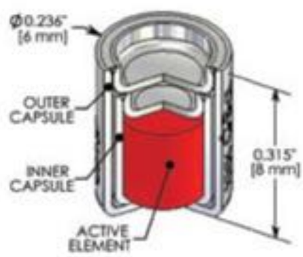
ENSURE SOURCE SHUTTER IS CLOSED AND PADLOCKED WHEN NOT IN USE

3. GAMMA RAY SOURCE

A 370 MBq Caesium-137 (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 (Figure 2). The design restricts the radiation at the surface of the container to less than 5 μSv/h.



X.8 CAPSULE
ISO classification: C66546
IAEA special form: GB/24/S85



P03 CAPSULE
ISO classification: C65445
IAEA special form: CZ/1013/S-96

Figure 2: Caesium Source Capsule. To identify the type of your source look at the certificate supplied at the time of delivery - the X.8 capsule is supplied by AEA Technology and the Cs7 PO3 by Eckert and Ziegler

The gamma beam is collimated through a choice of two collimators (5 mm and 2.5 mm diameter) in the rotating shutter at the front of the housing. The shutter is a small rotating cylinder with an axis of rotation offset from the centre of the main shield. The shutter has three operating positions: Two for the use of different diameter collimators and one which closes the beam (see Figure 3).

Position 1. Source closed.

Position 2. 2.5 mm collimator open

Position 3. 5.0 mm collimator open

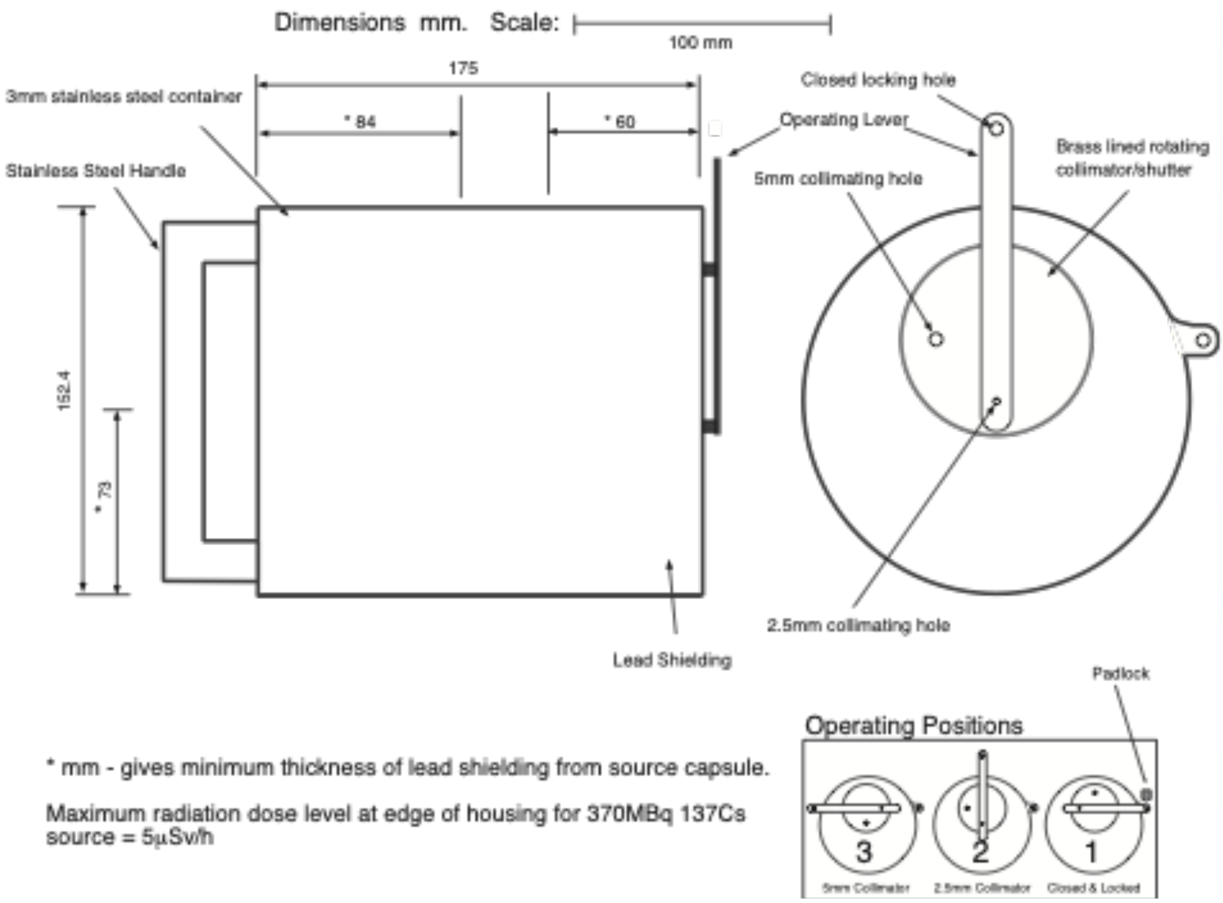


Figure 3: Technical drawing of gamma density source

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 1 cm is required, the 5 mm collimating hole should be used to minimise the counting time needed to obtain accurate data.

4. GAMMA DETECTOR

The Geotek gamma 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. The current Geotek gamma detector is comprised of a 3” scintillator detector with a 3” NaI(Ti) crystal and an integral photo multiplier tube.

Spectra are collected and actively windowed by the MSCL software around the primary ^{137}Cs peak (0.662 MeV). This active windowing compensates for any drift in the detector over time or due to temperature fluctuation (Figure 4). Note that older systems may be equipped with a 2” scintillator detector which has a slightly different set up (see Geotek legacy documents).

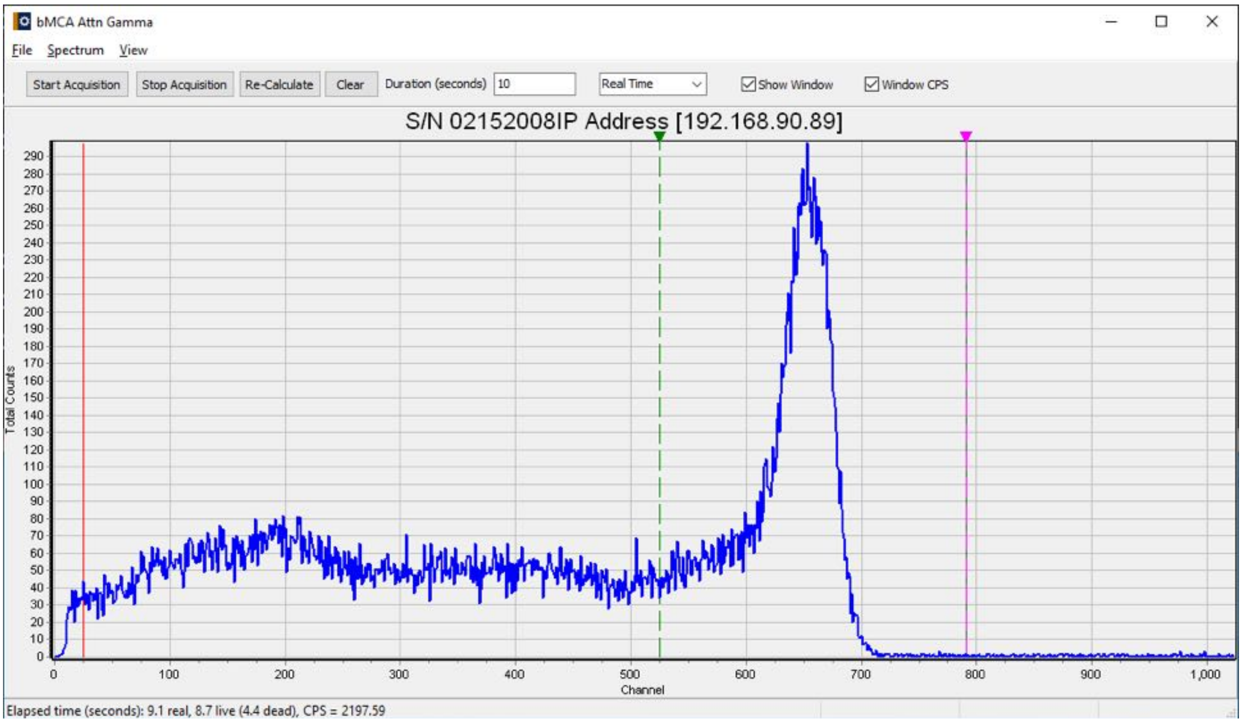


Figure 4: Active windowing around Cs-137 peak

5. REMOVING THE DETECTOR FROM THE HOUSING

It is recommended that the detector is always kept in the housing, even during most shipping applications. However it is sometimes necessary to remove the detector if it is being shipped by air for security reasons or customs clearance. In this circumstance, or for any other reason, follow these instructions.

THE LEAD SHIELDING IS VERY HEAVY! ENSURE TWO PEOPLE LIFT THE DETECTOR

THE DETECTOR INTERIOR CONTAINS EXPOSED LEAD – WEAR APPROPRIATE PPE

- Remove the detector housing from the MSCL-S
  - Horizontal orientation – Unplug the detector from the modem/extension cable and loosen the clamps holding the detector. Attach the handle to the front of the detector and carefully lift off the logger.
  - Vertical orientation – Unplug the detector from the modem/extension cable, remove the short rail section above the detector and attach the handle to the detector. Remove the upper clamp and lift out of the logger.
- Lay the detector on a padded, but secure surface
- Remove the locator screw on the side of the detector, found towards the rear of the housing, and loosen the opposite screw
- Carefully withdraw the rear lead backing plate and nylon tube that contains the scintillation detector
- Disconnect and remove the detector, ensure if shipping it is well packaged as it is fragile.

To install the detector in the housing, reverse the above procedures.

6. GAMMA SYSTEM TESTING

The gamma counting electronics can only be tested when the Utilities software is running (see Chapter 5). 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 with a new source and the 3” detector (2” detector in parentheses).

Position 1.	**Source closed.**	**Approx. 1000 CPS (200 CPS)**
Position 2.	**2.5 mm collimator**	**Approx. 12000 CPS (9000 CPS)**
Position 3.	**5.0 mm collimator**	**Approx. 45000 CPS (27000 CPS)**

The detector should not be exposed to very high count rates: for example, when the 5 mm collimator is open, attenuating material (a sediment core or calibration piece) should be in the path of the gamma beam. This is especially important for the 2" detectors, as 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.

7. CALIBRATION AND PROCESSING

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

$$\rho = \frac{1}{\mu d} In \frac{Io}{I}$$

Where:

ρ = Sediment bulk density

μ = Compton attenuation coefficient

d = Sediment thickness

I_0 = Gamma ray source intensity

I = Measured intensity through the core 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 core sample (and liner if present) and the effect of water in the sediments which has a significantly different attenuation coefficient to the sediment or rock minerals.

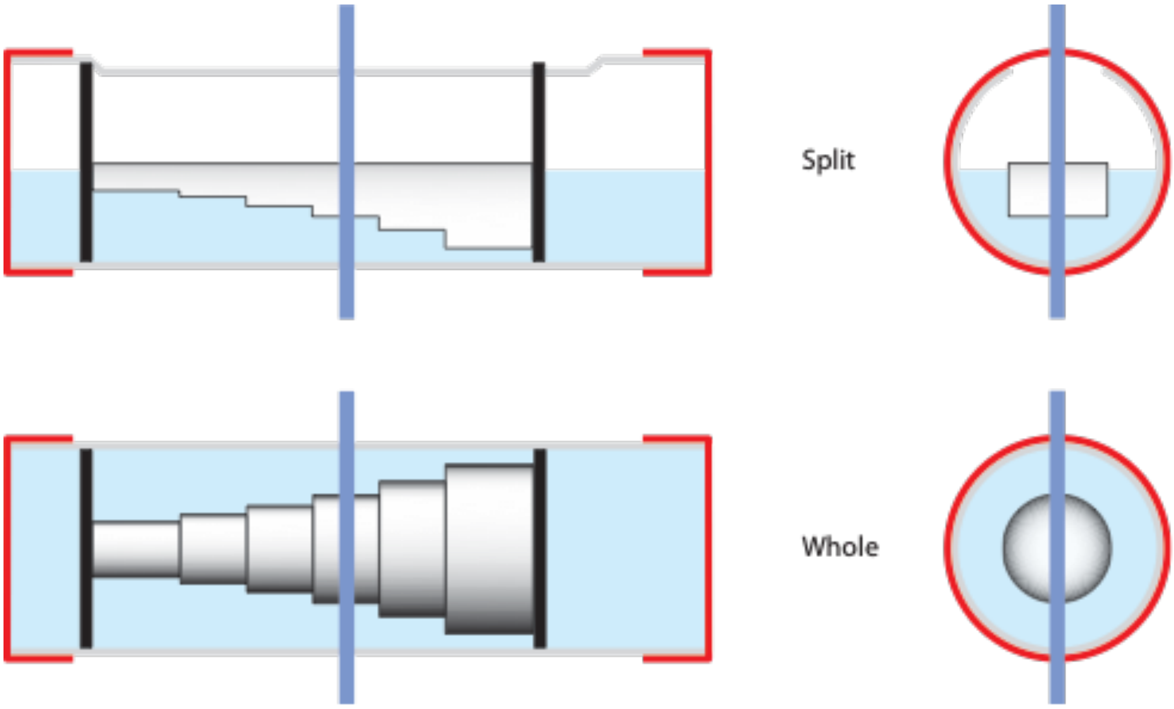


Figure 5: Gamma density calibration pieces for whole and split lined core

Consequently, the simplest and most reliable method for the calibration and calculation of bulk 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 core sample liner in which the core sample is contained and the fluid which the sediment contains. For example: When calibrating for a whole core sample containing water (i.e. saturated sediments) a calibration piece should be made which consists of a cylindrical piece of aluminium of varying thickness surrounded completely by deionised water in the sealed core sample liner (Figure 5), saturated split core samples are also manufactured in a similar way, but with the top half of the liner open. (Figure 6).

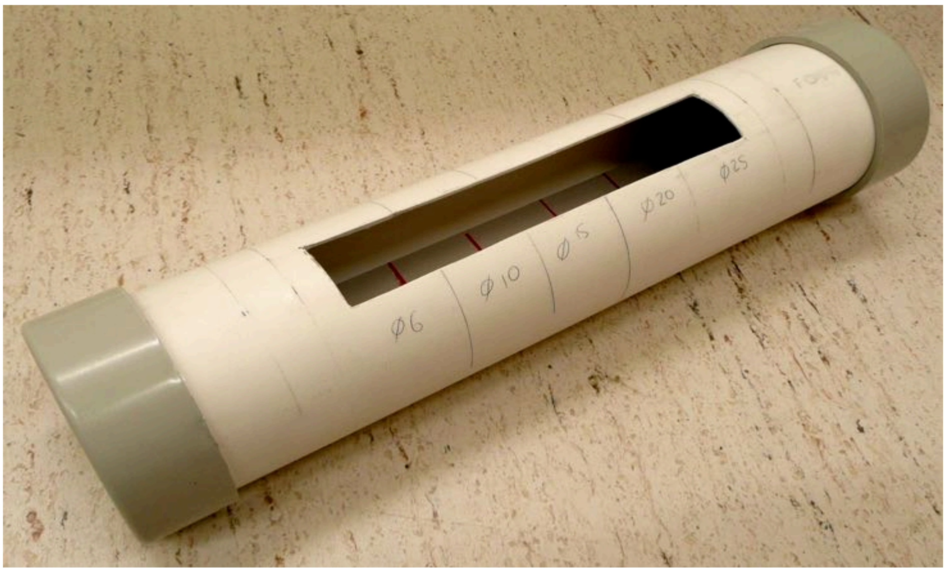


Figure 6: Split lined core calibration piece

For a dry split core sample contained within a liner, the calibration piece should be made with a piece of aluminium of varying thickness in a dry split liner. For a whole rock core sample, the cylindrical piece of aluminium of varying thickness should be positioned onto a Geotek core boat.

The calibration piece should be logged in the MSCL-S software, with a spatial resolution of 2 mm and a gamma density count time of 30 seconds per measurement point. If calibrating on a core liner filled with water, also make measurements beyond the calibration piece in a portion of the liner that contains only water.

This data can now be used with the provided MSCL_Calibration spreadsheet, under the “Gam Cal” or “Bare Rock Gam Cal” sheet (if this sheet cannot be located, contact support@geotek.co.uk to request a new copy). To accommodate any variations from a straight line, a second order polynomial equation is fitted to the graph (Figure 7). The points should fit the second-order curve very well; any points falling off the curve are due to measurement error (of thickness or gamma attenuation) and should be repeated.

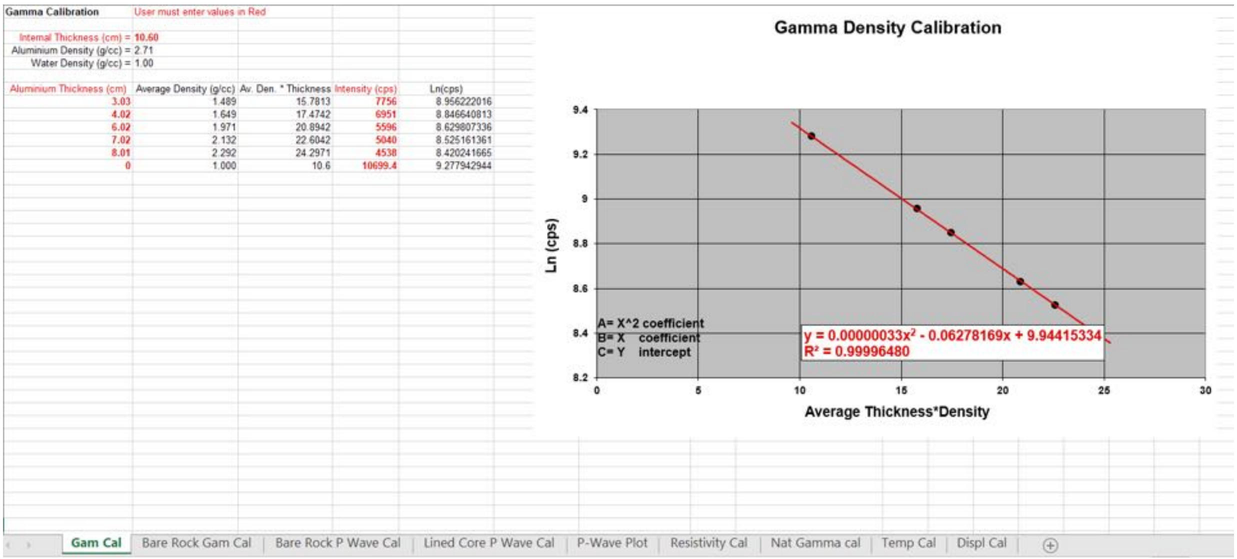


Figure 7: Provided MSCL calibration spreadsheet

The coefficients A, B & C should be entered into the gamma density processing panel in the MSCL-S software, under “Gamma Density 1” and the software will make the necessary empirical adjustments to the dataset (Figure 8).

Note that the calculation of gamma density is dependent on both gamma attenuation and core thickness. Errors in gamma density may often be traced to poor core thickness measurements, which in turn can often be traced to a poor Reference Core Thickness measurement.

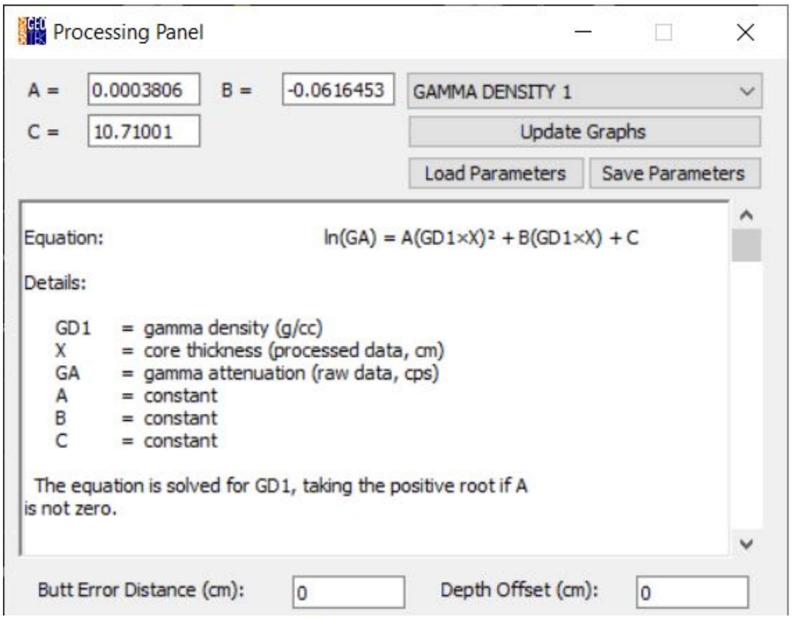


Figure 8: Gamma density processing panel

8. FRACTIONAL POROSITY

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

- The sediment is fully saturated (i.e. water)
- Mineral grain density
- Fluid density

The user can select 'Fractional Porosity' from the processing panel in the Geotek MSCL software (Figure 9). 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 the fractional porosity values by 100. Fractional porosity is calculated from the following equation:

$$FP = \frac{MGD - GD1}{MGD - WD}$$

Where:

FP = Fractional porosity

MGD = Mineral grain density (gm/cc) (typically 2.65)

GD1 = Gamma density as determined by the 'Gamma Density 1' in the processing panel of the Geotek MSCL software

WD = Fluid phase density (gm/cc) (typically 1.026)

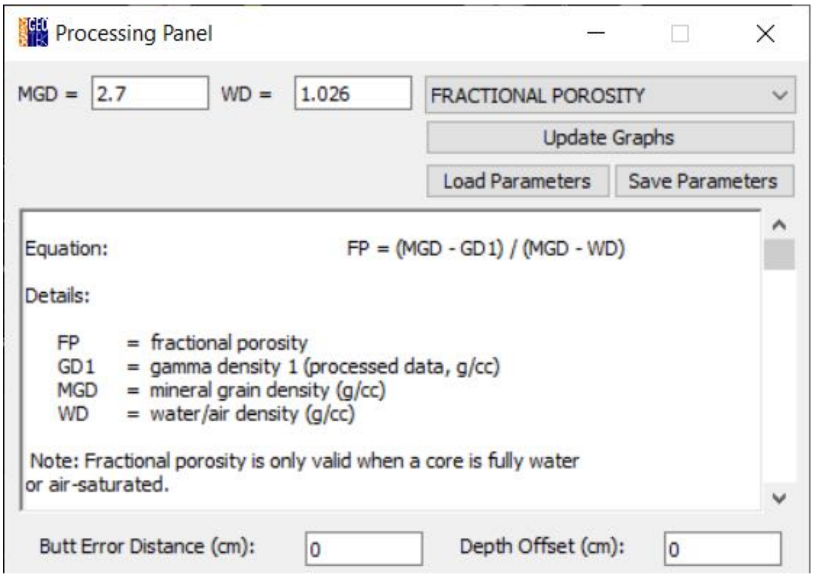


Figure 9: Fractional porosity processing panel

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

Table 1: Mineral grain densities of common minerals

Mineral	Density (g/CC)
Biogenic Silica [$SiO_2 nH_2O$] (Opal)	2.15
Quartz [SiO_2]	2.65
Calcium Carbonate [$CaCO_3$] (Calcite)	2.71
Calcium Carbonate [$CaCO_3$] (Aragonite)	2.93
Pyrite [FeS_2]	4.95 – 5.10
Galena [PbS]	7.40 – 7.60
Haematite [Fe_2O_3]	4.90 – 5.30

References

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.

ULTRASONIC P-WAVE VELOCITY

Figure 1: ARC rolling transducer (left), piston transducer (right)

1. 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, P-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 approximately 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:

$$Vp = \sqrt{\frac{k + \frac{4}{3}\mu}{\rho}}$$

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:

$$Vp = \frac{d}{t}$$

Where:

d = Distance travelled

t = Time taken to travel distance d

2. OPERATING PRINCIPLE

A short P-wave pulse is produced at the transmitter and this pulse propagates through the core sample 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 sample diameter with an accuracy of 0.1 mm. After suitable calibration procedures are followed (see below) the P-wave velocity is calculated with a resolution of approximately 1.5 m/s. The accuracy of the measurements will largely depend on any variations in the core sample liner thickness. However, experience has shown that an absolute accuracy of ± 3 m/s is normally achievable with some care.

3. P-WAVE TRANSDUCERS

The P-wave transducers (PWTs) are mounted on the MSCL-S centre section with the attenuated gamma ray source and detector. If the MSCL-S system is set-up in vertical mode, the upper PWT is mounted on the vertical sensor arm which is raised and lowered by the 'Z' stepper motor. When logging whole core samples, the position of the P-wave mounting slide is fixed during the logging process. When logging split core samples, the upper PWT is lowered onto the core surface to take a measurement and raised prior to the core sample moving to the next increment along the MSCL-S system. If the MSCL-S system is set-up in horizontal mode, the P-wave transducers will either be static-mounted on either side of the core samples, or the reciprocating P-wave assembly will be installed (Z or Y stepper motor driven depending on the instrument configuration of the MSCL-S). When logging whole core samples, both PWTs are spring-loaded against the core sample liner or core sample surface.

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

• Stainless steel piston transducers;

• Oil-filled acoustic rolling contact (ARC) Transducers

3.1 PISTON TRANSDUCERS

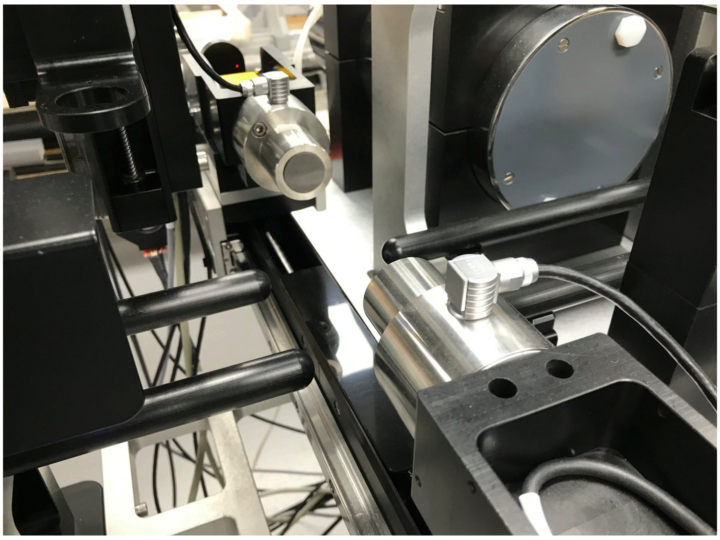


Figure 2: Reciprocating piston transducers

These transducers are typically used in a horizontal reciprocating assembly on rock core samples or in a vertical orientation on split sediment core samples. If used in the vertical orientation, the receiving PWT (ARC transducer) is normally mounted on the lower Delrin housing, and the transmitting PWT (piston transducer) is mounted on the upper vertical Delrin slide. Connection between the rear of each PWT is made to the TX and RX electronics boxes located at the base of the MSCL-S main centre section assembly.

The active element of each piston PWT is a thickness-mode 250 kHz (500 kHz for older MSCL-S system PWT assemblies) piezoelectric crystal, and each transducer is faced with a stiff rubber surface suitable for dry acoustic coupling with bare rock samples. When using the piston PWTs in horizontal mode, both piston PWTs should be sprung so that they press against the core sample surface. To avoid any disturbance to the core sample surface during split core logging (vertical mode) the springs must be disengaged within the upper piston PWT housing.

3.2 ACOUSTIC ROLLING CONTACT TRANSDUCERS

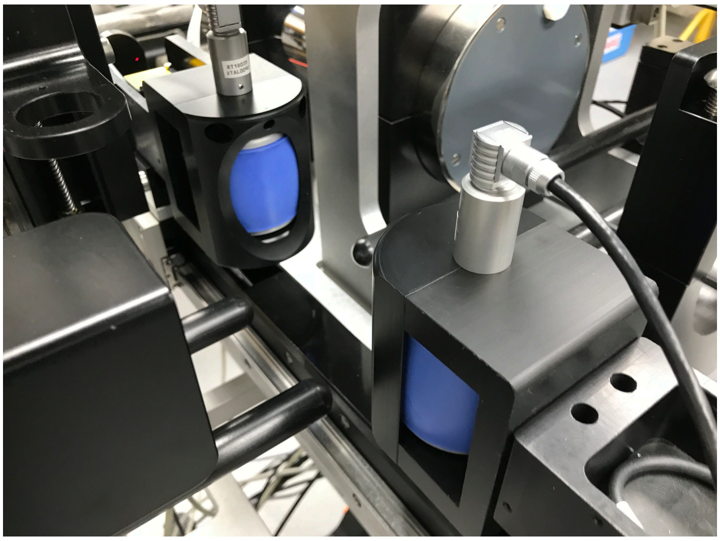


Figure 3: Acoustic Rolling Contact (ARC) transducers

The active element in ARC transducers is also a thickness-mode 250 kHz piezoelectric crystal, mounted on the fixed central spindle, surrounded by nontoxic coupling fluid and encapsulated in a soft synthetic rubber sheath. The ARC PWTs are mounted on spring-loaded linear slides in a Delrin housing. The main advantage of ARC PWTs is vastly improved acoustic coupling characteristics compared to piston transducers. A new active element is incorporated to enhance the frequency content of the transmitted pulse. Connection to the transmit (TX) and receive (RX) electronic boxes, located at the base of the MSCL-S main centre section assembly, is made at the top of the ARC PWTs nonrotating central spindle.

4. ACOUSTIC COUPLING

When using the ARC PWTs, it is not necessary to wet the core sample liner to achieve good acoustic coupling. It should be noted that good acoustic coupling is also required between the sediment and the core sample liner. Consequently, when logging whole core samples within a liner, only high-quality core sample where the liner is full of sediment will provide consistently good data. When using the piston PWTs, it is essential to maintain good acoustic coupling between the piston PWTs faces and the core sample: wiping the core surfaces clean prior to logging may be required.

For horizontally-split sediment core samples it is necessary for the upper piston PWT to be lowered onto the split core surface at each measurement increment. To avoid contamination along the core in soft sediments it is recommended that the split core surface be covered with a layer of thin plastic film ('cling film', 'glad wrap' etc.). A few drops of water spread along the surface of this plastic film can improve the acoustic contact if necessary. With split rock core samples, acoustic gel is generally required in the bottom of the Geotek core boat or core liner to maintain good acoustic contact.

5. PULSE TIMING

The accuracy of the Geotek P-wave 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 measurement 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 or rock type.

The TX pulse is sent to the transmitting PWT that generates an ultrasonic compressional pulse at 250 kHz (500 kHz for older MSCL-S system PWT assemblies). The TX pulse level is adjustable in the Geotek MSCL-S software from 0 to 255 V; this control allows the amount of energy imparted to the core sample to be varied according to the acoustic characteristics of the core sample and is the primary mechanism for ensuring that a good signal reaches the timing software. The TX pulse propagates through the core sample and is detected by the receiving PWT and is amplified by a pre-amplifier providing the signal returned to the MSCL-S main electronics for digitisation using a high-speed analogue to digital converter (ADC). The pre-amplifier applies a fixed 150 x gain. Before the signal is digitised, it is possible to apply further variable gain which is controlled automatically by the Geotek MSCL software 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 P-wave measurement 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 MSCL-S settings (Chapter 5) and can be set in the P-wave Scope Display. When measuring through very highly-attenuating core samples it is possible that the transmit voltage will be set to maximum but the signal level will not be at a target level; at this point the variable gain amplifier will be used to bring the signal level into the target range. When the signal is within the upper and lower acceptable levels a measurement is made and an adjustment will be made to the TX voltage (or gain level) to bring the level closer to the target level (Figure 4).

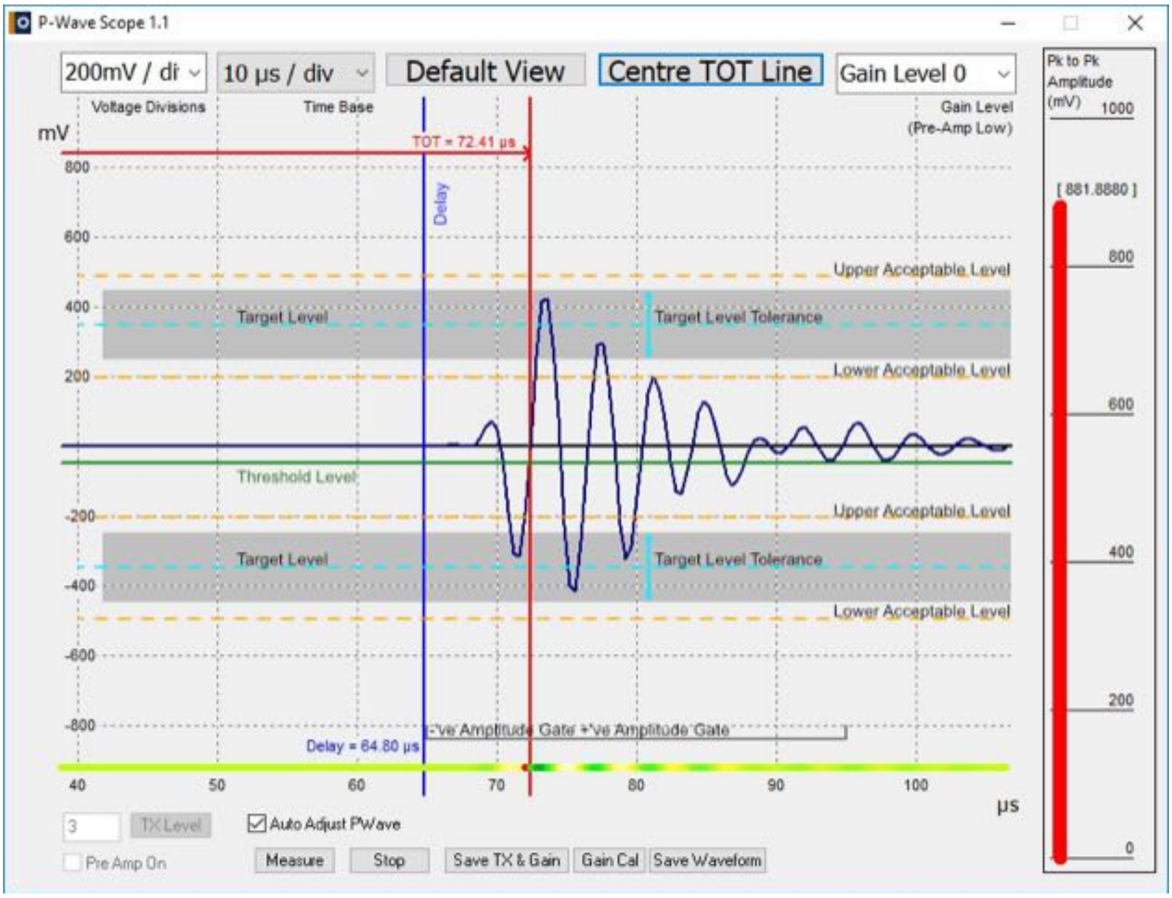


Figure 4: P-Wave scope - pulse timing, automatic level settings and amplitude gate

The received P-wave signal is processed through an ADC before being displayed in the P-wave scope window of the MSCL software. The P-wave signal is (by default) digitised at a default sampling frequency of 12.5 MHz. In the Geotek MSCL software a threshold detector determines the first positive or negative going excursion (as defined in the MSCL-S Settings) on the received pulse after the user-defined Delay (Figure 4). The pulse timing is achieved by measuring the time to the first zero crossing after the threshold is exceeded. In this way the travel time measured (TOT) is approximately one half or one wavelength after the start of the pulse, but it is measured without any errors caused by signal amplitude. The Delay is used to define the point at which the Geotek MSCL software should start its threshold detection. The Delay should be set before the start of the P-wave signal to ensure good signal timing measurements.

The P-wave Scope window (Figure 4) shows the pulse as it enters the ADC (so after any gain is 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 PWTs are touching or there is a core sample between them a P-wave will appear in the window. The view is changed using the time base and voltage division drop down boxes (the X and Y scales respectively). The user can drag the time base by moving the mouse over the zero-crossing line of the y-axis (bold black line) 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 or lines presented in the P-wave Scope window:

- The waveform (dark blue);
- The y-axis zero-crossing line (bold black);
- The Delay (light blue vertical line);
- The Threshold Level (green)
- The measurement (TOT) (red). The red vertical line is the timing measurement and should be monitored throughout logging to ensure it is in the correct place on the P-wave signal.

The Delay and Threshold lines can be moved by positioning the mouse pointer over the line and clicking and dragging if they have not been locked ([right click] and select from a drop-down contextual menu to unlock). These two lines define how the measurement is made and their positions should be saved using the contextual menu. Alternatively, [right clicking] on the P-wave Scope window will display a drop-down 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’ which will set the current view (X and Y scales) and, ‘Show Data Points’ which will show the sampled data points along the P-wave.

At the top of the P-wave Scope window there are two buttons and three drop-down boxes. Clicking the [Default View] button will return the P-wave Scope window view to the user defined default view. Clicking the [Centre TOT Line] button will centre the TOT line (red vertical line) in the centre of the P-wave Scope window. The right-hand drop-down box is used to apply one of three gain levels to amplify a weak P-wave signal. The two drop-down boxes at the top left of the P-wave Scope window allow the user to change the display scale by changing the voltage level or time increment per division. To the right of the P-wave Scope display there is a bar plot showing the signal level.

At the base of the P-wave Scope window there is a text box and a button that is used to set the TX voltage (enter a number between 0 and 255 and click [TX Level]). The automatic procedure that is used during core logging is switched on using the ‘Auto Adjust P-wave’ tick box. The automatic procedure changes the TX voltage and the gain level to bring the signal into the target zone so that:

- The dynamic range of the ADC is maximised;
- There is a larger signal for timing measurements.

6. 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) (Figure 4). The final amplitude values are reported as RMS mV amplitude per transmit volt level.

7. CALIBRATION AND PROCESSING

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

$$VP = \frac{X}{TT}$$

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 TOT which is all the additional time delays.

The PTO includes:

- The pulse travel time through the core sample liner;
- The pulse travel time through the PWTs;
- The delay caused by measuring the P-wave, which is approximately one cycle after the onset, as well as a small electronic delay in the system circuitry.

The PTO value must be determined to calibrate the P-wave measurement system. It will vary depending on both the core sample liner being used and whether whole core or split core sample measurements are being made.

7.1 DETERMINING PTO & CALCULATING VELOCITY

For whole core sediment samples cut a short length of core sample liner (approximately 30 cm) of the same core sample liner type (and preferably the same manufacturer's batch) being logged. Seal the core sample liner with end caps and fill with distilled water. Place between the PWTs as if logging a normal core sample (Figure 5).

For unlined rock core samples move the PWTs together until they are touching each other with a similar pressure to which they touch the core sample, until the PWT housings are half-way compressed in their travel.

For split sediment core samples move the PWTs together as above but insert a small square of core liner between them. Alternately, cut a slit in the top of a capped section of core sample liner (Figure 6), but with a section cut out large enough to accommodate the upper piston PWT, fill halfway with distilled water and lower the upper transducer just beneath the water surface.

The following values should be recorded:

- Water temperature (T);
- The distance between the transducers (D);
- The TOT recorded from the P-wave Scope window.

The velocity (Vt) of the distilled water at the given temperature (T) should be looked up from a standard reference source (Leroy, 1969)[1]. The PTO can then be simply calculated from the following equation:

$$PTO = TOT - \frac{D - W}{Vt}$$

Where:

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

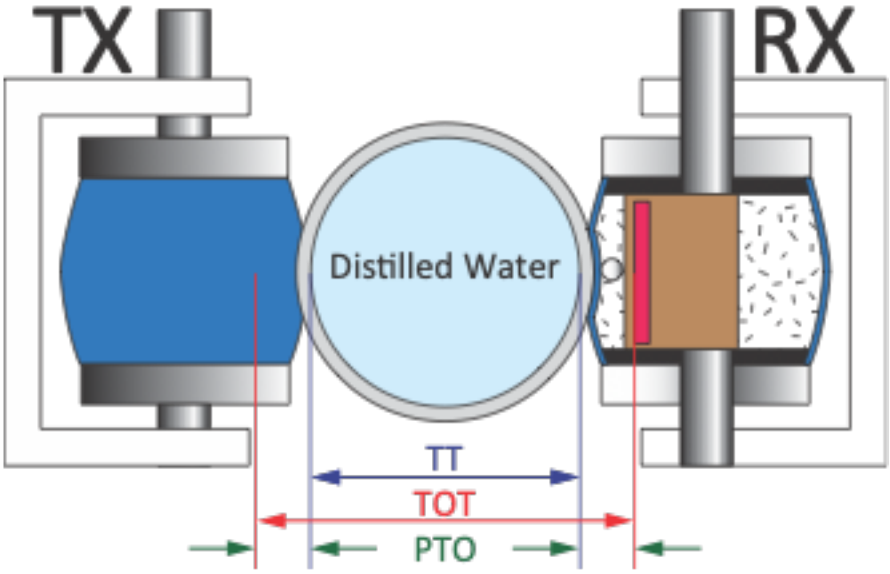


Figure 5: Schematic view of P-wave calibration for whole lined sediment core samples using ARC transducers

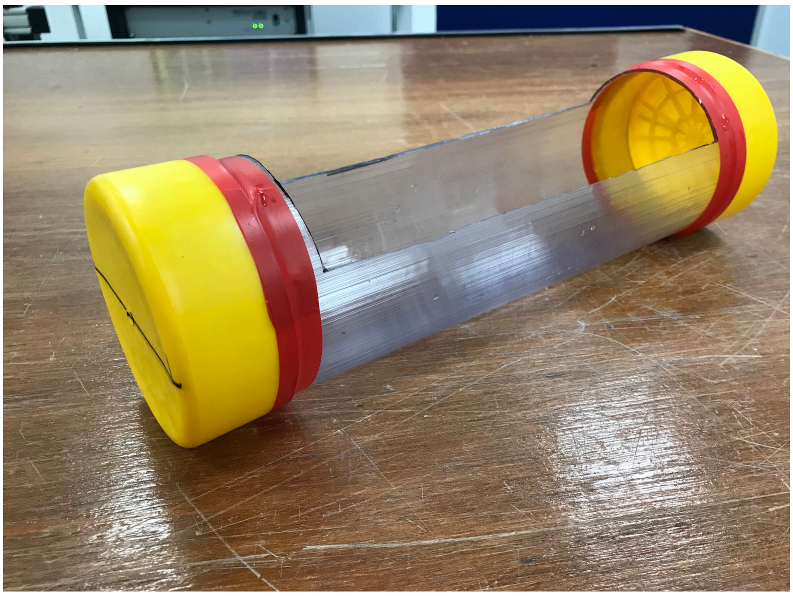


Figure 6: Split sediment core P-wave calibration section

Having determined the value of PTO this can be entered the box provided in P-wave velocity processing panel (Figure 7). The velocity will then be automatically calculated using the equations shown for V_P.

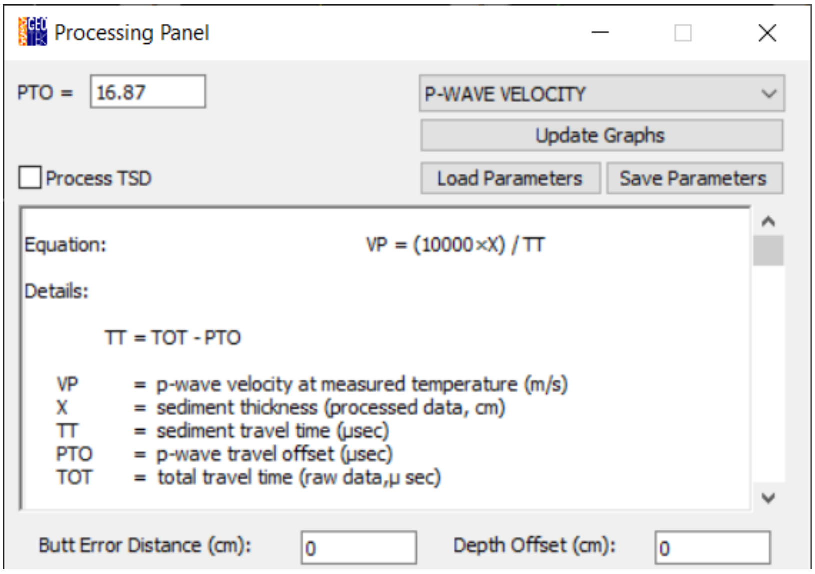


Figure 7: Processing panel for P-wave velocity

Note that the calculation of P-wave velocity is dependent on both travel time measurement and core thickness. Errors in P-wave velocity may often be traced to poor core thickness measurements, which in turn can often be traced to a poor Reference Core Thickness measurement.

7.2 TEMPERATURE, SALINITY AND DEPTH CORRECTIONS (WATER-SATURATED SEDIMENTS ONLY)

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

The temperature of each core sample is measured during logging by the MSCL-S temperature probe. If the cores are not at room temperature, then a correction can be made 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 be known. This means that all these parameters can be corrected for in the MSCL processed data. Geotek use an empirically derived formulation developed by Leroy (1969) in the Processing Panel of the Geotek MSCL software to apply a correction factor to the measured P-wave velocity.

This correction is simply defined as:

$$VPCorr = VP * VPFac$$

Where:

V_P Corr = Corrected P-wave velocity;

V_P = Measured P-wave velocity;

V_P Fac = Ratio of V_w at required conditions / V_w at measured conditions;

V_w = P-wave velocity in water.

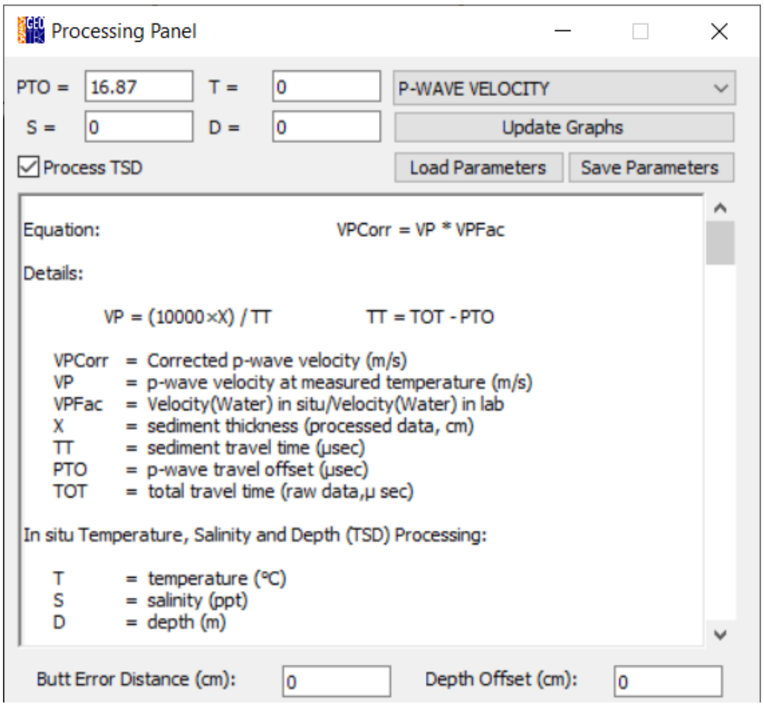


Figure 8: Processing panel for P-wave velocity, with "Process TSD" selected

To process for temperature, salinity and depth, select the "Process TSD" option in the P-wave velocity processing panel, this will give three additional options for entering overrides for temperature (°C), salinity (ppt) and depth (m). Selecting "update graphs" will apply the corrections to the data.

7.3 AMPLITUDE CORRECTION

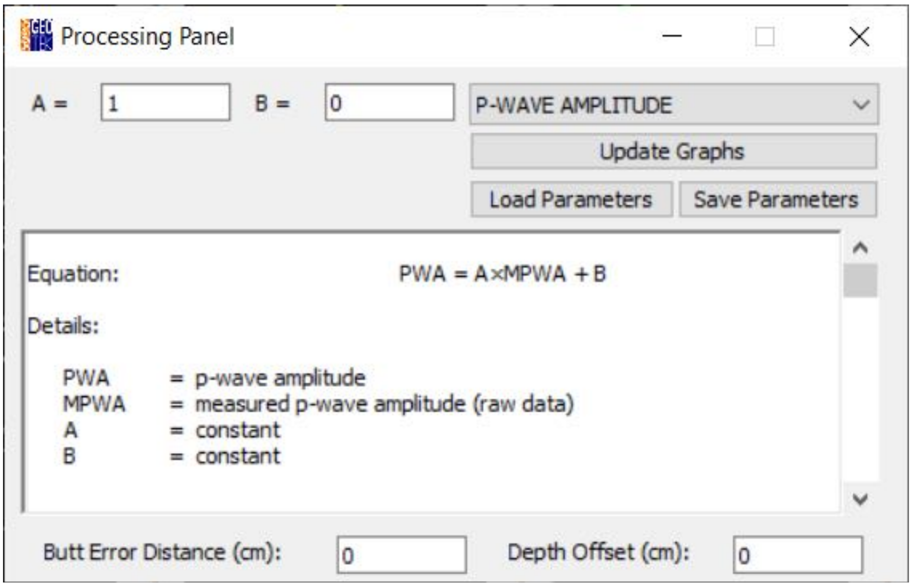


Figure 9: Processing panel for P-wave amplitude

The P-wave amplitude processing panel simply allows the user to make a linear correction to the signal amplitude if desired (Figure 9).

7.4 ACOUSTIC IMPEDANCE

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

$$Z = V * \rho$$

Where:

Z = Acoustic impedance;

V = P-wave velocity;

ρ = Bulk density.

The MSCL processed data Processing Panel is self-explanatory and requires no inputs from the user, (Figure 10). Acoustic impedance is reported with units of x 10^3 kg m^{-2} s^{-1}.

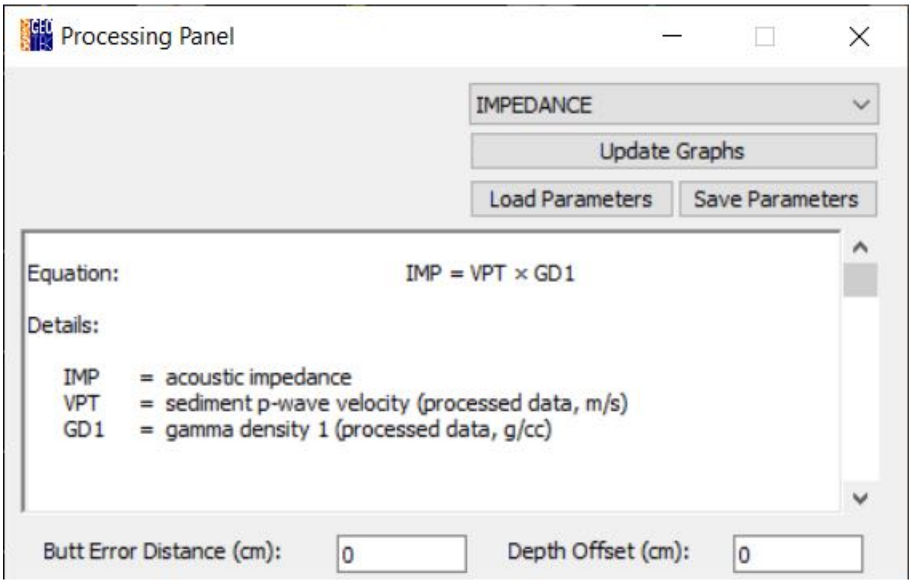


Figure 10: Impedance processing panel

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

The reflection coefficients are calculated using the following equation:

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

Where:

R_i = Reflection coefficient;

Z = Acoustic impedance.

The depth to TWT time conversion is made using the following equation:

$$t_i = \sum_{j=1}^{i-1} 2 * \frac{\Delta zj}{Vj}$$

Where:

Δzj = 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 11, a zero phase Ricker wavelet (Figure 12), with a dominant frequency of 3.5 kHz was convolved with the data.

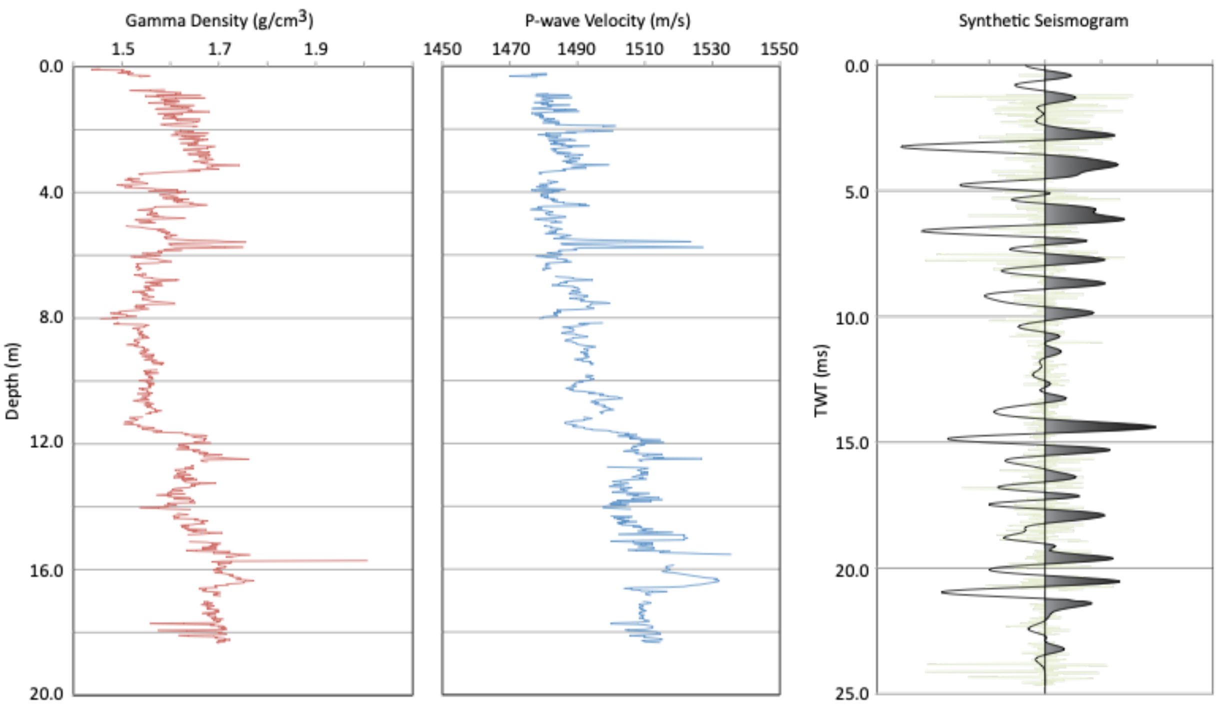


Figure 11: P-wave velocity and gamma density data used to produce a synthetic seismogram.

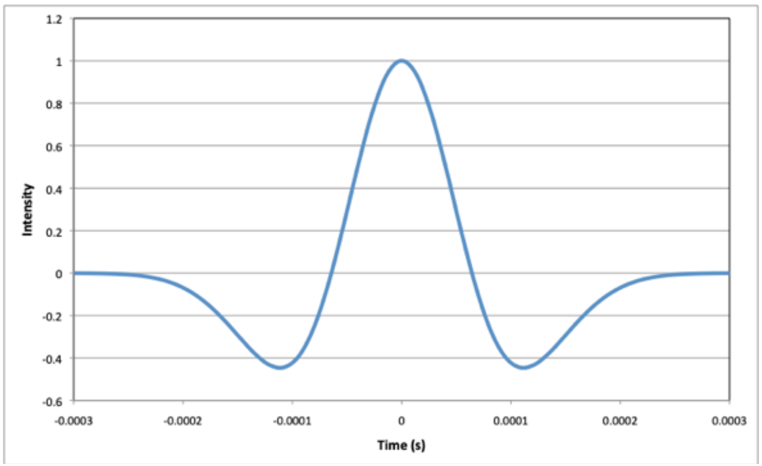


Figure 12: A zero phase Ricker wavelet with a dominant frequency of 3.5 kHz used in the creation of the synthetic seismogram in Figure 8

References

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.

MAGNETIC SUSCEPTIBILITY

Figure 1: Bartington point (left) and Bartington loop (right) magnetic susceptibility sensors

1. 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 (Table 1).

Magnetic susceptibility is a dimensionless number that can be reported in the SI system of units or the cps system of units. Magnetic susceptibility in SI units is typically reported as a number "x 10^{-5}" while magnetic susceptibility in cps units is typically reported as a number " x 10^{-6}".

In sedimentary materials, magnetic susceptibility is a commonly-used proxy for composition and provenance of sedimentary packages. It is often used for correlation between nearby cores. In hard rocks, increased magnetic susceptibility generally indicates the presence of iron-containing minerals.

Table 1: Magnetic susceptibility of common minerals (from Hunt et al., 1995)

Mineral	Magnetic Susceptibility (x 10^{-5}) SI
Water	0.9
Calcite	-0.75 to -3.9
Quartz, Feldspar	-1.3 to -1.7
Kaolinite	-5
Halite, Gypsum	-1 to -6
Illite, Montmorillonite	33 to 41
Biotite	150 to 290
Pyrite	0.5 to 350
Haematite	50 to 4,000
Magnetite	100,000 to 570,000

Geotek has two sensors available for MSCL-S systems, a Bartington magnetic susceptibility point sensor – for use with split core only, and a Bartington magnetic susceptibility loop sensor – for use with whole cores only. The Geotek MSCL-XZ or MSCL-XYZ can also use the Bartington magnetic susceptibility point sensor.

1.1 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 on a Delrin rail section in such a way that no magnetic or metallic components come close to the sensor. Note that the loop sensor has a field of influence of approximately 70 mm either side of the sensor, so sharp changes in magnetic susceptibility will likely be displayed as a smoother curve over a greater area. For this reason, to ensure 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.

The loop sensor comes with a cylindrical check standard which can be used to check the function of the sensor and the meter. Using the Utilities software (see Utilities chapter), the background magnetic susceptibility should be measured with the loop empty (press "Zero Magnetic Susceptibility" button on the Test Panel). Once the zero or background measurement has been made, the check standard should be placed in the centre of the magnetic susceptibility loop, with the dashed line on the standard in the plane of the loop. The magnetic susceptibility should be measured (press "Magnetic Susceptibility" on the Test Panel in Utilities). Values vary with temperature but should be within 5% of the certified value.

1.2 POINT SENSOR

The Bartington point sensor (MS2E) is mounted on the Z sensor arm, along with any other split core sensors installed. The active element in the sensor is linear, and is oriented parallel to the broadest dimension of the sensor. The sensor is lowered for each measurement, then raised for the core to move beneath it (or to move along the core), which allows the sensor to come into direct contact with the core to give the most reliable data. Note that the point sensor measures at a much higher spatial resolution than the loop sensor as it has a much smaller field of influence of approximately 3 mm around the linear sensor. When using the point sensor it is important to ensure that ambient temperature should be stabilised as much is reasonably practicable as the point sensor is more sensitive to temperature fluctuations than the loop.

As with the loop sensor, the point sensor has a check standard. This can be checked using the Utilities program in a similar fashion. To measure the check standard, after zeroing the sensor in free air, align the line on the check standard with the line on the sensor and place the sensor on the check standard (label facing away from the sensor). As with the loop sensor, values should be within 5% of certified value.

1.3 MS3 MAGNETIC SUSCEPTIBILITY METER

The Bartington magnetic susceptibility sensors must be connected to a measurement device, the Bartington MS3 meter, found in the back of the MSCL electronics rack. Note: older MSCLs may utilise an MS2 system, which is no longer manufactured (see legacy documentation). The MS3 meter has a series of coloured LEDs that can be used for troubleshooting. A correctly-operating meter with a sensor connected shows a green light. An orange light indicates that there is no sensor attached, and a red light indicates a computer communications issue. NEVER CONNECT OR DISCONNECT A SENSOR WHILE THE MS3 IS POWERED. The power can be removed from the MS3 meter by turning off the MSCL electronics unit (located over the computer).

2. 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. RADIO FREQUENCY EMISSIONS CAN INTERFERE WITH THE MEASUREMENTS. For further details refer to the manufacturer's documentation.

2.1 SETTING UP

Before operating, ensure that the electronics are switched on for at least 30 minutes prior to allow the sensor to 'warm' to minimise drift.

- Ensure that the correct sensor is connected, point sensor for split core and loop sensor for whole core – **IF CONNECTING OR DISCONNECTING A SENSOR ENSURE THE MS3 METER IS OFF** (generally powered through main MSCL electronics rack).
- Ensure that the positioning of the sensor does not obstruct the movement of the core

- To ensure the meter is working as expected, the supplied calibration piece can be used. First zero the sensor in utilities, then measure the check piece. Note that the displayed value on the check piece is measured at 22°C, so at slightly variable room temperatures a value within 5% is generally acceptable.
- Ensure that no magnetically-susceptible materials are close to the sensor, such as wrist watches

2.2 ZERO MEASUREMENTS AND DRIFT

All magnetic susceptibility systems are susceptible to drift with temperature or time. A background reading ("zero") is collected for the loop sensor at the beginning of logging; the loop sensor is usually stable enough in a controlled-temperature environment that a single background measurement will suffice for a day's logging. The point sensor is less stable and zero measurements are collected periodically when the point sensor is in use; the frequency of zero measurements can be set by the user on the Setup pane ("zeroing interval" or "zero every N measurements").

3. CALIBRATION AND PROCESSING FOR LOOP SENSOR

The magnetic susceptibility sensor is set electronically 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 due to 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.

3.1 VOLUME SPECIFIC MAGNETIC SUSCEPTIBILITY

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

κ_{uncor} is dimensionless ($\times 10^{-5}$ SI units)

To obtain the corrected volume specific magnetic susceptibility (κ), this value must be corrected for the relative effect of core size and size of the loop's internal diameter:

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

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

The relationship between core loop diameter (D_l), core diameter (d) and K_{rel} has been determined experimentally (Figure 2) and the following relationship can be used:

$\kappa_{rel} = 4.8566 \times (d / D_l)^2 - 3.0163 \times (d / D_l) - 0.6448$

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

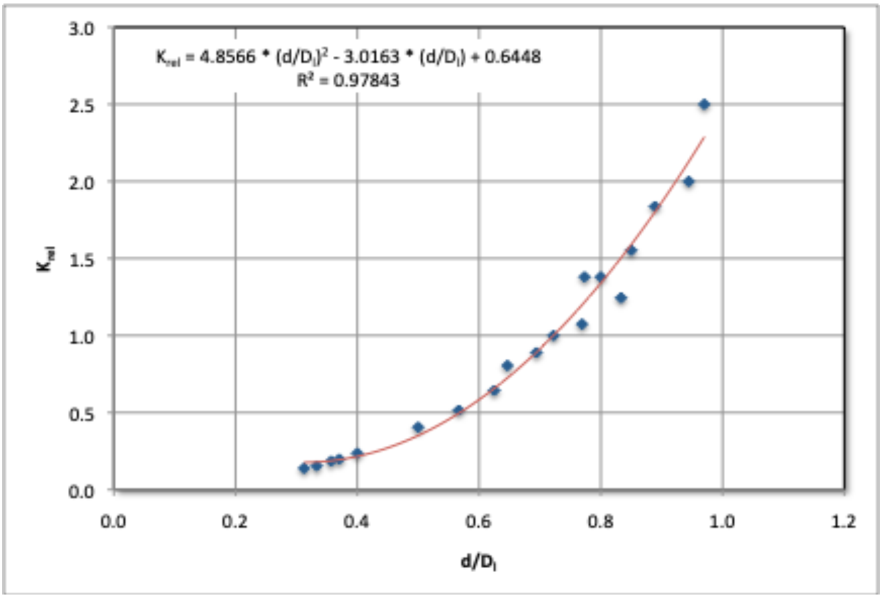


Figure 2: Response of magnetic susceptibility measurements to varying core and loop diameters.

3.2 MASS SPECIFIC MAGNETIC SUSCEPTIBILITY

Volume specific magnetic susceptibility does not take into account the density of the sample being measured. Consequently it is possible to have variations in κ down the length of the core that reflect changes in material density only, rather than a change in the relative proportion of magnetically susceptible minerals in relation to other minerals. If the system is equipped with an attenuated gamma density system, then mass specific susceptibility correction can be applied by taking into account the density of the sample being measured, using the measured density at each point. Mass specific magnetic susceptibility (χ) is calculated as follows:

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

Where:

ρ = material density ($kg\ m^{-3}$)

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

χ (SI units) = $4\pi \times 10^{-3}$ χ (cgs units)

For more detailed information on the measurement of magnetic susceptibility, refer to manuals supplied by Bartington Instruments Ltd. The nomenclature used in this manual is the same as used by Bartington.

3.3 PROCESSING PANEL

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

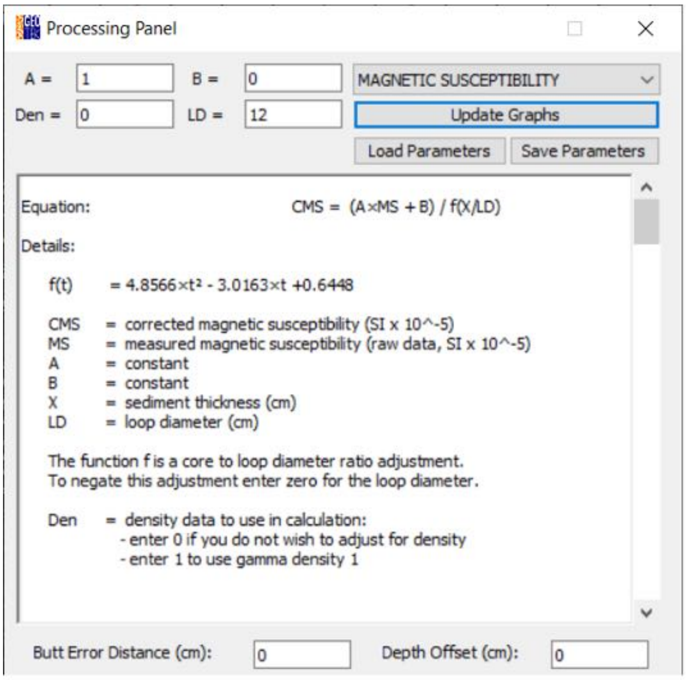


Figure 3: Processing panel for magnetic susceptibility using a loop sensor

The general processing panel is shown in Figure 3; 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 CMS = 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 should be used.
- 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 enter the loop diameter (in cm) into LD. 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 (χ) then set A = 1, B = 0, Den = 1 and enter the loop diameter (in cm) into LD. The values then (if using SI) are given in CMS × 10^{-8} m^3kg^{-1}.

4. CALIBRATING AND PROCESSING FOR POINT SENSOR

The protocol for inter-calibrating the point sensor with the loop sensor is not well established and can only be performed on extremely homogeneous material. 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:

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

These values of A & B can be used directly in the processing panel (Figure 4).

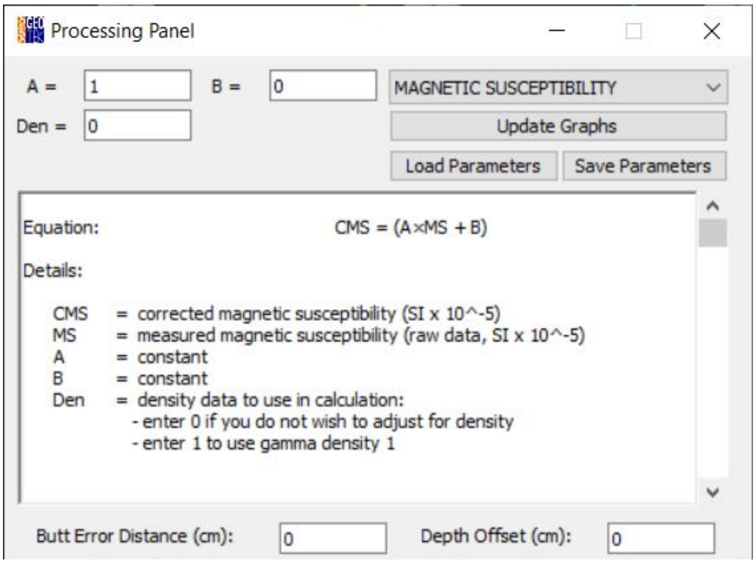


Figure 4: Processing panel for magnetic susceptibility using a point sensor in the MSCL-S

5. DUAL SENSOR LOGGING

The MSCL-S software supports the ability to use both the MS2C and MS2E sensors concurrently, assuming the logger has been set up for this by Geotek with two MS3 meters. In order for the system to use this capability, the MS3 connected to the MS2E (point sensor) must be connected to serial port 1, and the MS3 connected to the MS2C (loop sensor), should be connected to serial port 2 if this is available, or port 3 otherwise. This will be dependent on whether the system is equipped for non-contact resistivity. To use both the sensors concurrently, 'Dual Sensor' should be selected in the setup panel prior to logging, (Figure 5).

This panel still displays the same options as in single sensor mode, with the 'zeroing interval' referring to how often the MS2E (point sensor) takes a zero measurement, and 'zero before core' referring to at what point before logging core the MS2C (loop sensor) will take its zero measurement.

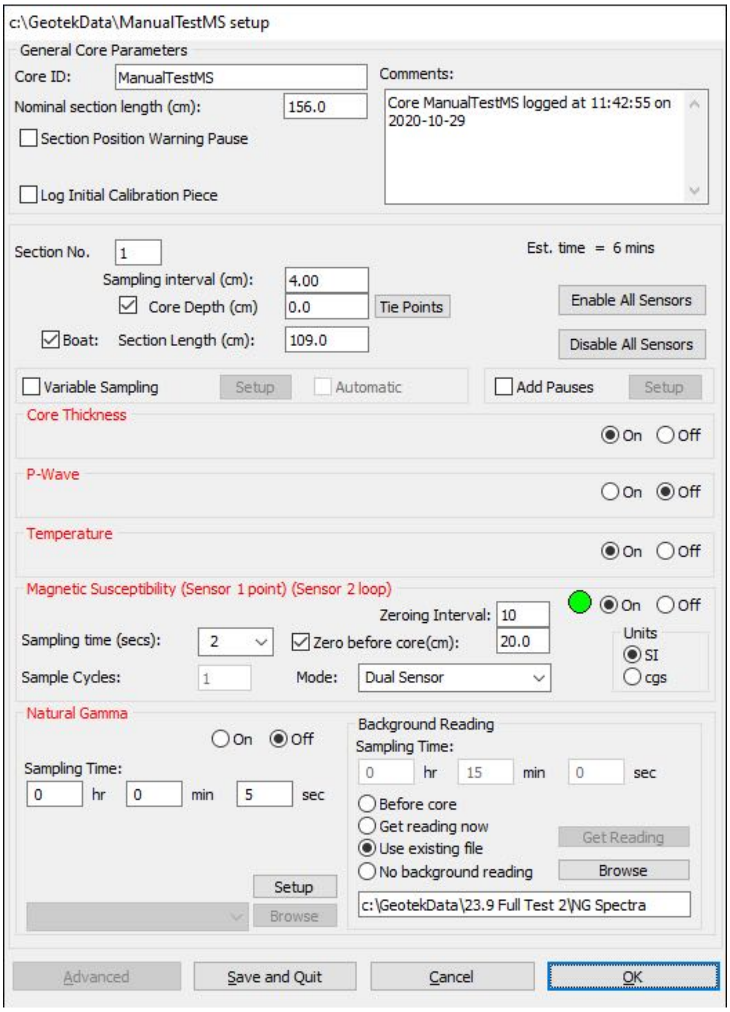


Figure 5: Setup panel with 'dual sensor' mode selected

The user will then be prompted to 'manually lower the z-axis until sensors are at measurement height' as would be done as standard with the MS2E (point sensor). Logging can be commenced as normal, though with two graphs presented for magnetic susceptibility, with 'Magnetic susceptibility' referring to MS2E (point sensor) data and 'Magnetic susceptibility 2' referring to MS2C (loop sensor) data, this numbering is the same in the processing panel, where a tab for each will be present.

NON-CONTACT ELECTRICAL RESISTIVITY

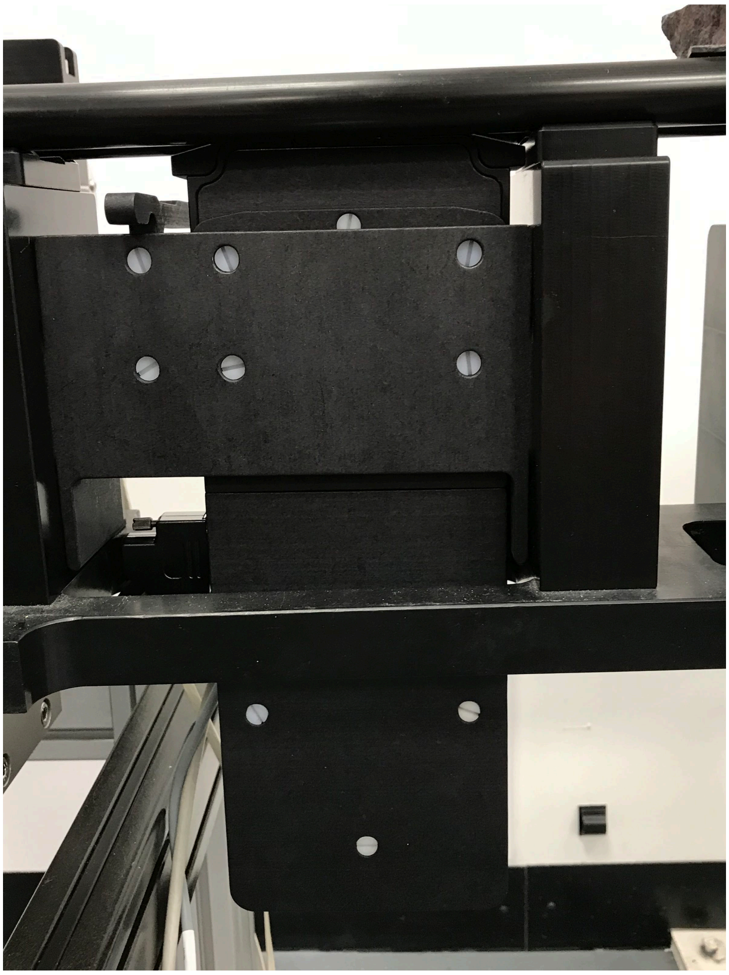


Figure 1: Geotek NCR sensor mounted on MSCL-S

1. 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-meter and the SI unit of electrical conductivity is Siemens per meter. Non-contact resistivity (NCR) measurements on the Geotek MSCL are made using a non-contact system that is positioned on the Delrin plastic part of the track between the magnetic susceptibility and natural gamma 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)

2. 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 different 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 4 cm.

3. SETTING UP

- Ensure that the NCR sensor does not obstruct the core.
- Switch the NCR meter on to warm up before testing - overnight is ideal. The system needs to come to an equilibrium temperature 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: If the logger will be in constant use, it is best to leave the NCR unit switched on constantly, to avoid long 'warm up' times and possible recalibrating. For this reason the NCR electronics are controlled separately to the main MSCL electronics (Figure 2).

Figure 2: NCR electronics

4. 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 for as long as possible (overnight) prior to logging cores in order for the system to stabilise. The resistivity sensor is sensitive to changes in temperature so the instrument should be used in a room with good temperature control.

A factory calibration has been provided for each resistivity sensor. This calibration is specific to cylindrical sample geometry and can be applied to rock or sediment cores. Three parameters are required for the calibration: the distance between the centre of the core and the top of the sensor, the diameter of the core (including any plastic core liner), and, if there is a plastic core liner present, the thickness of the core liner. The relationship is shown in Figure 3.

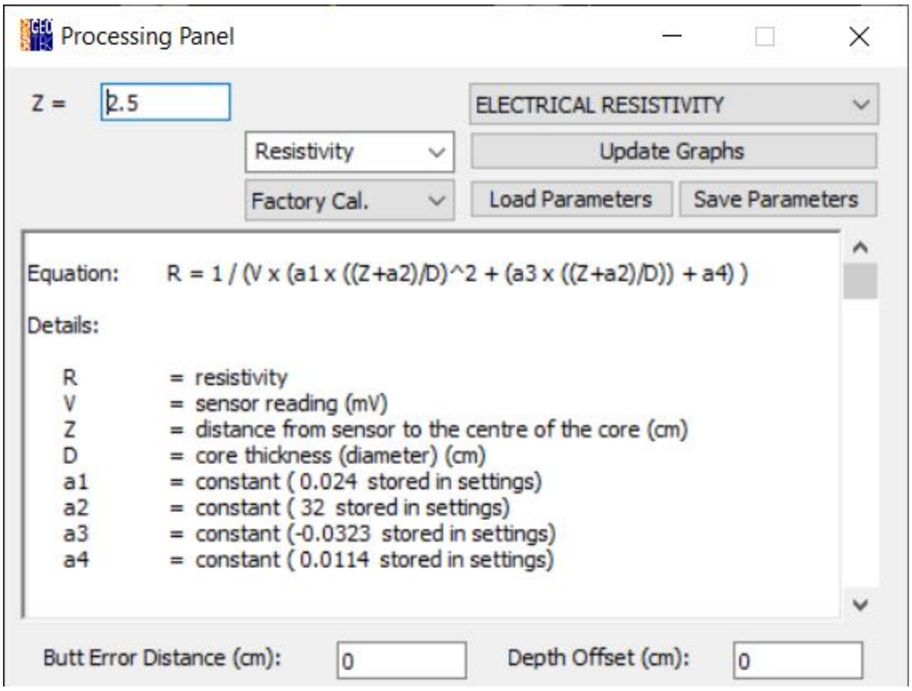


Figure 3: Resistivity processing panel showing factory calibration

Note that the liner wall thickness is entered in the processing panel under “Core Thickness”. The core thickness (diameter) is measured by the P-wave transducers at each point on the core, as described in “Sensors – Core Thickness”

4.1 CALIBRATING FOR LINED SEDIMENT CORE

The factory calibration can be improved for a lined sediment core by performing an empirical calibration. To empirically calibrate the non-contact resistivity for a plastic-lined core, 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 (35ppt; 0.21 ohm.m at 20°C) will be encountered in marine sediments so 35ppt can be considered the upper boundary for most applications.

In Table 1 are a series of suggested concentrations of saline solution that can be used for calibrating the system. These range from resistivities of 0.21-15.48 ohm.m (at 20°C). The solutions should be prepared in 30 cm long sections of core liner that are identical to the liner containing the cores to be logged. This is very important as the resistivity sensor is very sensitive to different measurement geometries.

Table 1: Suggested concentrations of saline solutions for calibrating NCR systems

Concentration (g/L)	Resistivity (OHM.M)	Conductivity (SM^{-1})
35.0	0.205	4.878
17.50	0.392	2.551
8.75	0.749	1.335
3.50	1.763	0.567
1.75	3.371	0.297
0.35	15.176	0.066

This suggestion 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:

$ER = 5.6878 \times C^{-0.9348}$

Where:

ER = Electrical Resistivity (ohm.m)

C = Salt concentration (g/L^{-1})

The calibration sections should be made so that they can be refilled and resealed; an example of an ideal calibration section is shown in Figure 4.

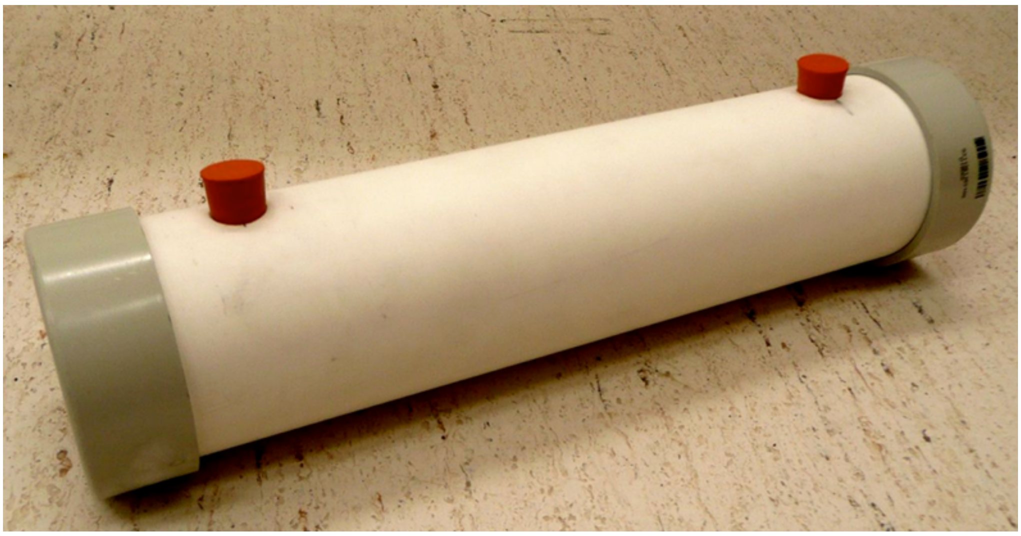
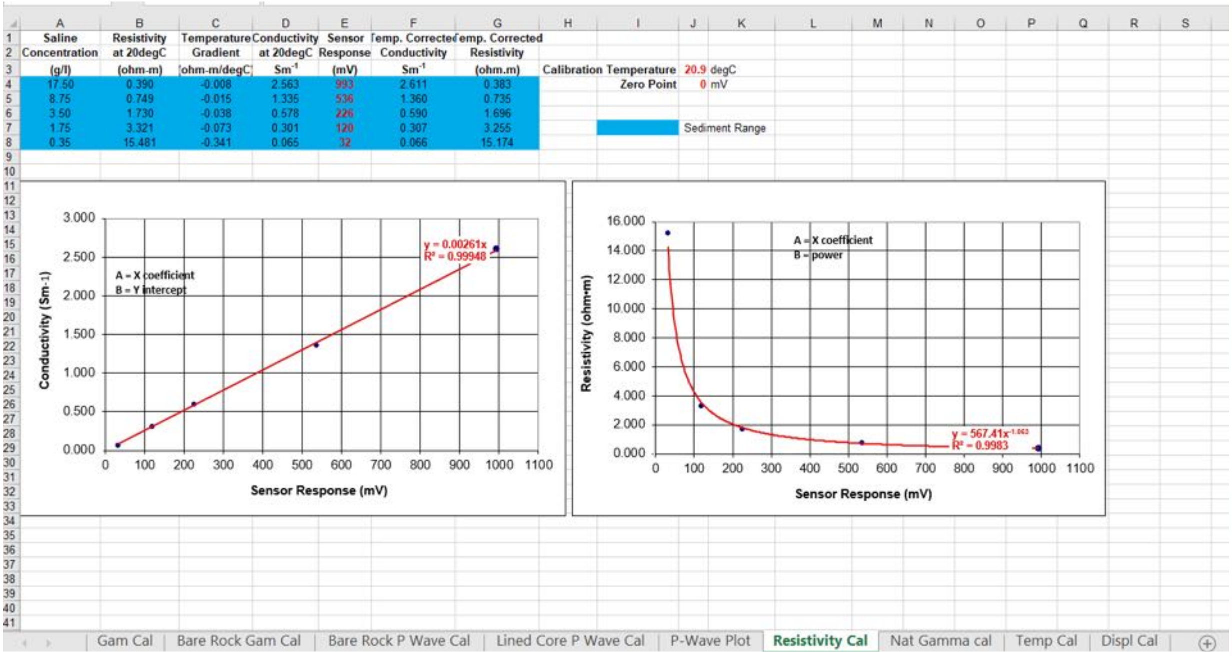


Figure 4: Example of a resistivity calibration piece, with removable bungs, so salinity can be changed as required

Once calibration pieces have been made, the sensor can be calibrated to convert its response (mV) into resistivity (ohm.m). This is done in the utilities software in the resistivity test panel. First the user must zero the resistivity sensor, ensuring that there is nothing on the rails or above the sensor, and that there are no loose cables or anything underneath the sensor. Once the sensor has been zeroed in air, each of the calibration pieces of known salinity can be placed on the rails over the sensor and their raw response noted.

This data can now be used with the provided MSCL_Calibration spreadsheet, under the "Resistivity Cal" sheet (if this sheet cannot be located, contact support@geotek.co.uk to request a new copy). For each of the known salinity values, enter the corresponding raw sensor response. Also enter the temperature the calibration was collected at (to find the temperature, simply run the temperature option on the test panel in utilities) and the value of a core liner filled with the same water that was used to make the resisitivity standards (the "zero point" on the spreadsheet). This sheet, with red text showing the values the user should input, is shown in Figure 5.



Saline Concentration (g/l)	Resistivity at 20degC (ohm-m)	Temperature Gradient (ohm-m/degC)	Conductivity at 20degC Sm^{-1}	Sensor Response (mV)	Temp. Corrected Conductivity Sm^{-1}	Temp. Corrected Resistivity (ohm.m)
17.50	0.390	-0.008	2.563	993	2.611	0.383
8.75	0.749	-0.015	1.335	536	1.360	0.735
3.50	1.730	-0.038	0.578	226	0.590	1.696
1.75	3.321	-0.073	0.301	120	0.307	3.255
0.35	15.481	-0.341	0.065	32	0.066	15.174

Figure 5: Provided MSCL Calibration spreadsheet

Once this information is entered by the user, two graphs will be created displaying a linear trend line for conductivity vs sensor response and a power trend line for resistivity vs sensor response. In the processing panel the "linear cal." option should be selected along with "resistivity" and the X coefficient for conductivity vs server response entered into "A =", (Figure 6).

Alternatively the "power cal." option can be selected, and X coefficient and the power value from the resistivity vs sensor response graph should be entered into "A =" and "B =" (Figure 7).

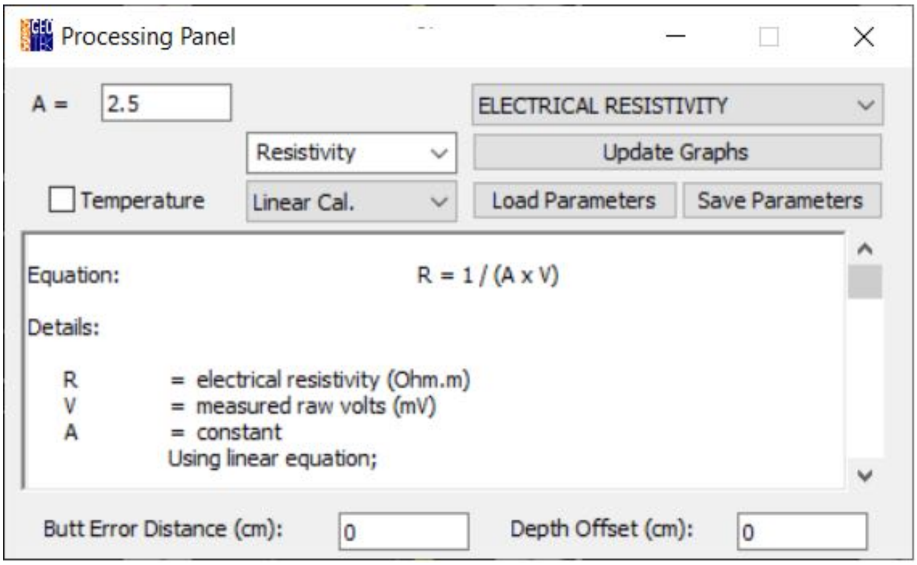


Figure 6: Processing panel for electrical resistivity, with "linear cal." option selected

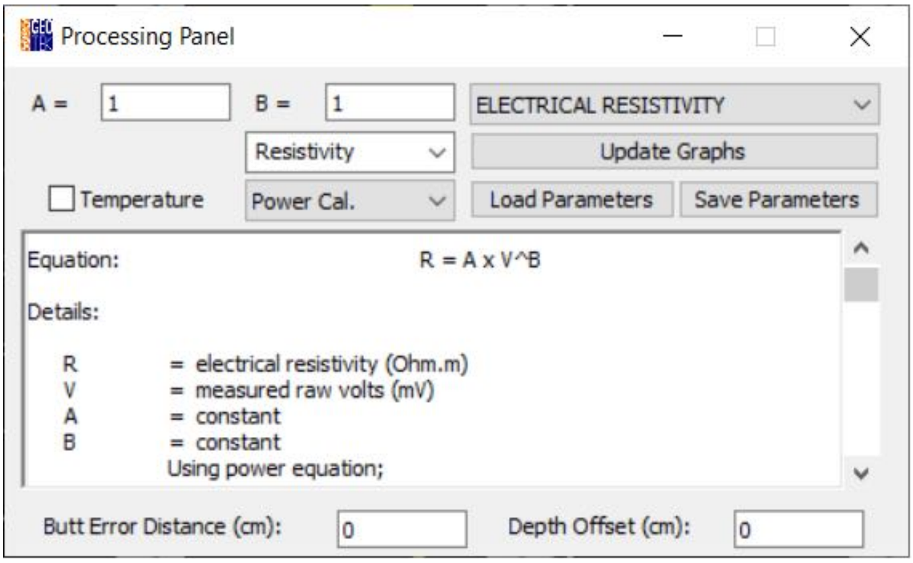


Figure 7: Processing panel for electrical resistivity, with "power cal." option selected

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

4.2 CALIBRATING FOR ROCK CORE

Due to the nature of rock core, calibration pieces cannot be manufactured, so for this reason a factory calibration is supplied. When using rock core ensure that "factory cal." is selected in the processing panel (Figure 3). The user must enter the distance from the top of the NCR sensor to the centre of the material being measured in cm (note, this must take into account boat thickness).

NATURAL GAMMA SPECTROMETRY

Figure 1: Geotek Natural Gamma system mounted on MSCL-S

1. BACKGROUND

The Geotek natural gamma system measures the natural radioactivity, specifically gamma rays, emitted from rock cores and sediments on MSCL-S systems, concurrently with any other active sensors.

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 (v) as given below. The energy is expressed in electron volts (eV).

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

where:

c = Velocity of light

h = The Planck constant

Gamma rays have energies from a few keV to 1 or 2 MeV.

2. OPERATING PRINCIPLE

Up to 3 scintillation detectors, housed in lead shields, are mounted on a large lead cube that sits level with the core track on a sensor stand, which allows core to pass through in order to record natural radioactivity. The spectra from the sensors are merged and exported into the MSCL-S software as raw counts, which can be background corrected to give counts per second (CPS) and, with additional calibration, API values and K-U-Th abundances can be calculated. Up to 3 detectors are used as natural radioactivity from rocks and sediments is very low, so spectra are combined to improve the data quality. The number of detectors used to acquire a spectra is inversely proportional to the count time required to get the same value, e.g. if a user acquires a spectra with one detector for 1 minute and 30 seconds, they will get the same result by acquiring spectra from 3 detectors simultaneously with a 30 second count time.

3. SEDIMENT AND ROCK RADIOACTIVITY

The elements that constitute the Earth, both stable and unstable (radioactive), were formed in 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.

Table 1: Decay series and daughter isotopes for K, U and Th.

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
	^{214}Bi	1.765	16
	^{214}Bi	2.204	5

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 x 10^9 years; uranium (^{238}U) with a half-life of 4.5 x 10^9 years; and thorium (^{232}Th) with a half-life of 1.4 x 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 Table 1.

It is important to note that it is assumed secular equilibrium has been reached in all Geotek K-U-Th calculations. 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.

4. USE OF NATURAL GAMMA DATA

Natural gamma measurements have three standard uses:

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.

5. NATURAL GAMMA MEASUREMENTS

The well logging industry uses a relative unit standard known as the GAPI (Gamma ray, American Petroleum Institute), often 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. An API unit 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 API while shales vary from 75-150 API although in highly radioactive shales, readings of 300 API 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. CPS can be converted to API for particular core sizes using standards.

5.1 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, ^{40}K, ^{238}U, ^{232}Th, 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 (5-30 seconds per sample). This allows cores to be logged in limited time schedules.

5.2 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

In addition, low intensity discrete emissions from the ^{238}U and ^{232}Th series are indiscernible from the scatter. The peaks from the sample are also masked by emissions from the local background, which can be higher in the vicinity of bricks or concrete.

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 (minutes to hours per sample).

6. NATURAL GAMMA SYSTEM

The current natural gamma system has up to 3 x 3 inch NaI(Tl) detectors, housed in 6 inch diameter lead shields. Each detector is optically coupled to a photomultiplier tube and connected to an integrated bias base and MCA. Emitted gamma rays from the core hit the NaI(Tl) crystals, which produces a pulse of light which 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.

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 Geotek system makes use of multiple detectors relatively easy. The sensors are controlled through the software interface that allows collection of calibrated spectra, meaning that each detector and MCA pairing is calibrated using known isotopes at specific energy levels.

7. CALIBRATION

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 legacy versions of the Geotek software acquire data by communicating with the WinTMCA programs. When running the Geotek MSCL program, do not close any WinTMCA windows that are automatically opened; however, they may be minimized.

7.1 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 and IAEA-RGTh-1, Thorium Ore). More details of these materials can be found on the IAEA website. These samples provide emission peaks at various energies as detailed in the table at the end 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 ±5% and remain acceptable, but if the natural gamma spectra are being analysed for K-U-Th, the deviation should remain less than ±2%.

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 labelled, the calibration is good and should not be changed.

If recalibration is necessary, acquire a new spectrum using a calibration standard. Move the cursor (red vertical line) to the centre 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 centre the cursor on the peak. Select **[Add Calibration Point]** from the contextual menu to bring up the Add Calibration Point pane.

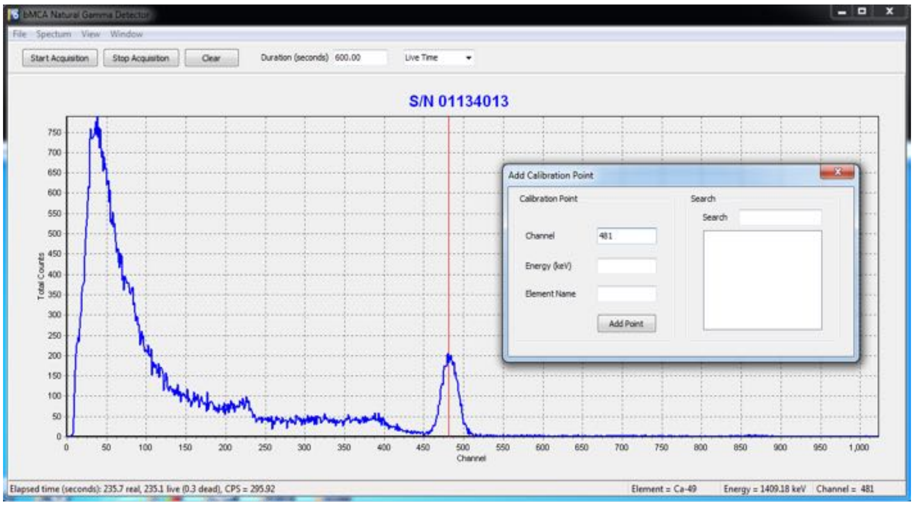


Figure 2: bMCA Natural Gamma pane with cursor on ^{40}K peak and Add Calibration Point pane open

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]**.

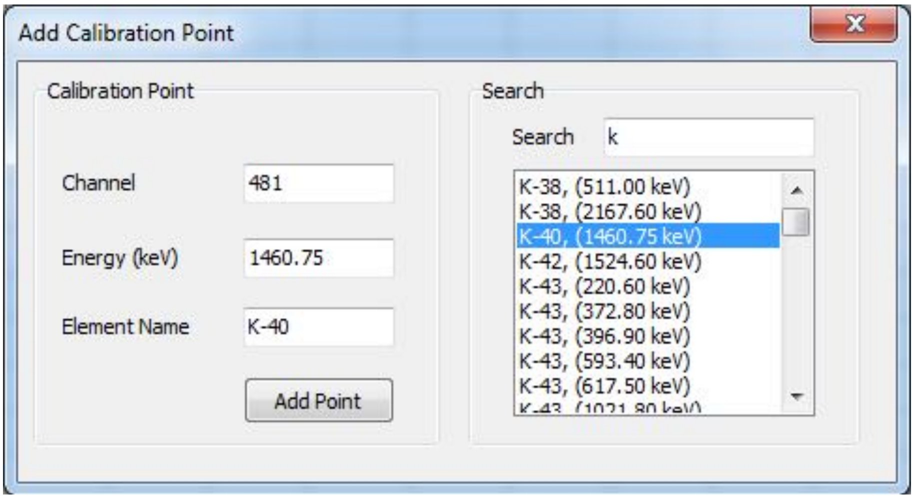


Figure 3: Add Calibration Point pane

The NG Calibration pane will appear. This pane can also be displayed by selecting **[Show Calibration Chart]** in the contextual menu. Figures 4 and 5 show addition of ^{208}Tl and ^{214}Bi 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.

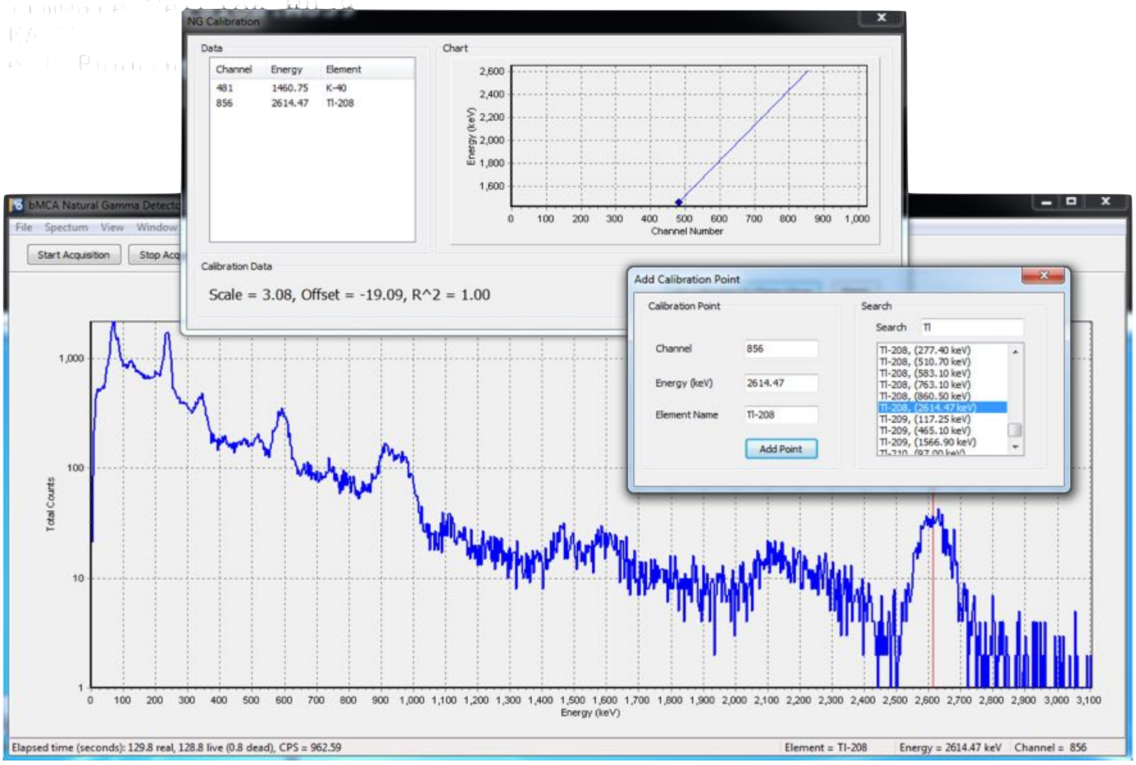


Figure 4: bMCA pane showing ^{232}Th spectra with cursor on ^{208}Tl peak, Add Calibration Point pane, and NG calibration pane

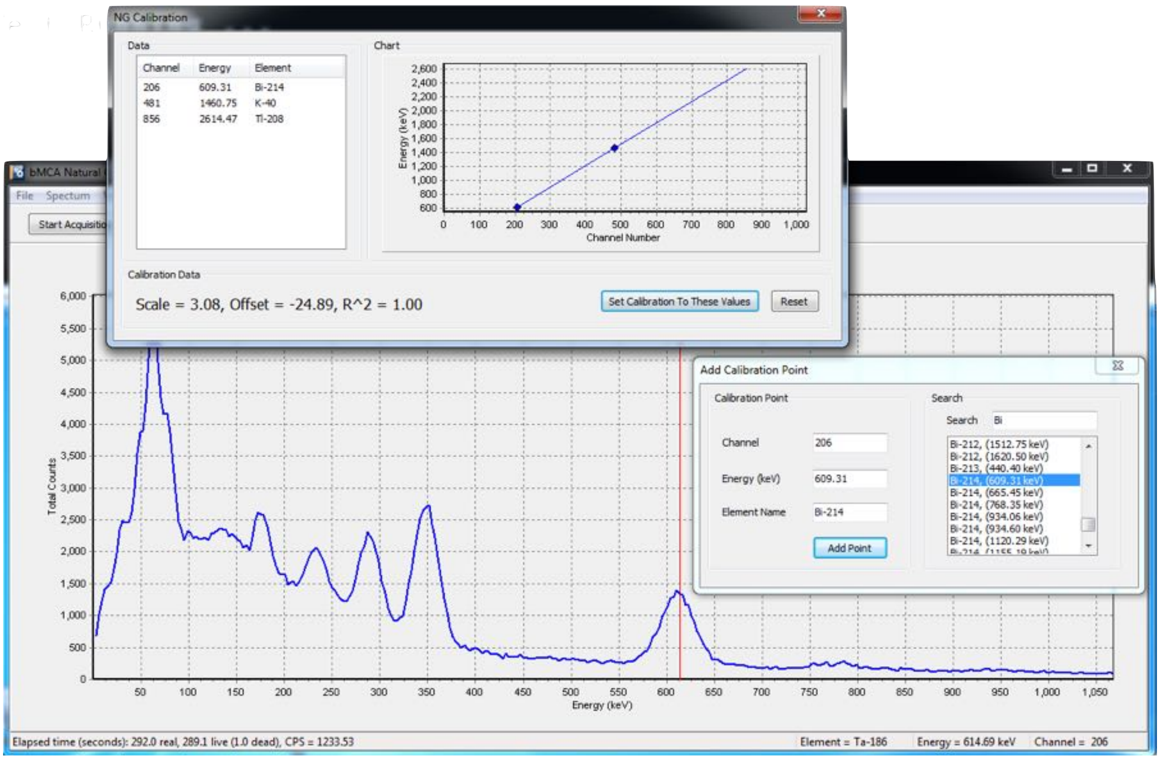


Figure 5: bMCA pane showing ^{238}U spectra with cursor on ^{214}Bi peak, Add Calibration Point pane, and NG calibration pane

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.

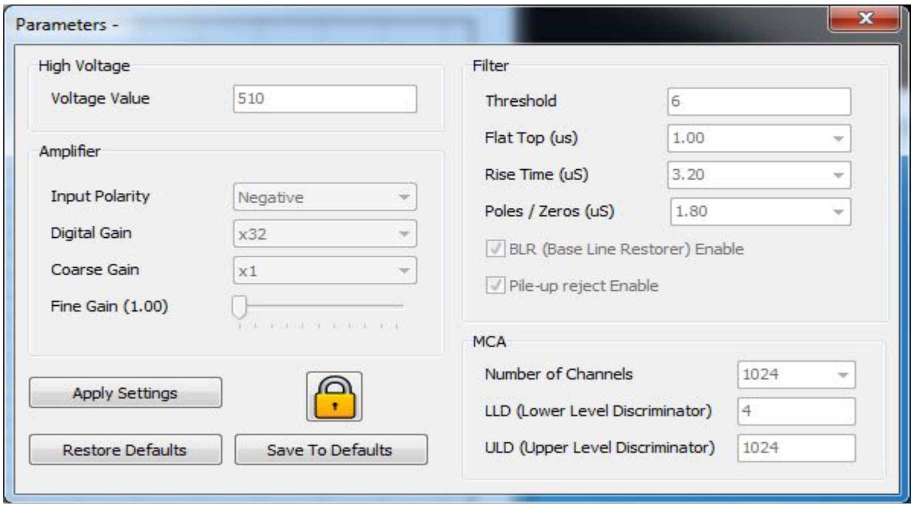


Figure 6: bMCA Parameters pane.

7.2 API CALIBRATION

Users can calibrate the natural gamma system using API standards with the same core diameter. The background-subtracted counts per second should be measured using either the MSCL-S software or the Utilities software. A linear relationship between cps and API can be constructed, and the slope and offset for the line should be entered into the natural gamma processing panel. There is a tab for this calibration in the msclcal.xls spreadsheet downloadable fromt the Geotek website.

7.3 POTASSIUM, URANIUM, THORIUM CONCENTRATION CALIBRATION

Users that have purchased Geotek K-U-Th calibration standards can measure potassium, uranium, and thorium concentrations as calculated from the natural gamma spectra. To calculate the concentrations of these elements, the background-subtracted spectra are windowed around the ^{40}K peak at 1461 keV, the ^{214}Bi peak at 1765 keV, and the ^{208}Tl peak at 2610 keV. Lower energies are avoided to reduce interference effects from the gamma density source. Secular equilibrium is assumed. The three energy windows are used with three rock standards to generate a simple 3 x 3 matrix, with each element concentration a linear combination of the window counts. The matrix coefficients form a calibration file which is used by the MSCL-S software during acquisition to generate elemental concentrations.

Users who need to update their K-U-Th calibration should follow these instructions to send Geotek their data, and Geotek will send back an updated KUTh.xml file to place in C:\geotek\Settings\NaturalGamma.

1. Collect a 12-24 hour natural gamma background spectra using Utilities (see section 9).

2. Collect a 12-24 hour set of spectra for each rock standard, with the background subtracted, using Utilities (see section 9).

3. Using SpectralElements.exe, create a calibration (see below). This calibration will be added to the KUTh.xml file and can be selected in the Geotek Settings under Natural Gamma.

Using Spectral Elements to create a K-U-Th calibration

Open SpectralElements.exe and choose File --> Create KUTh calibration.

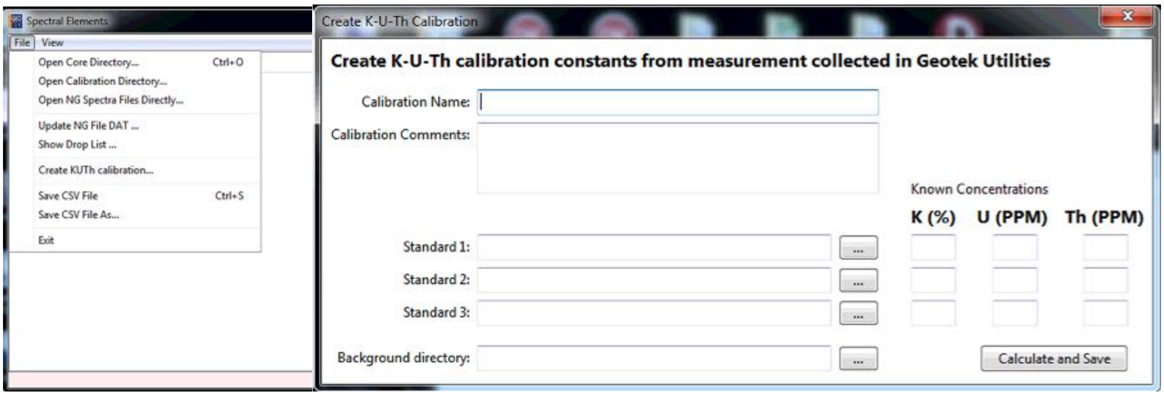


Figure 7: Spectral Elements menu (left) and K-U-Th calibration window (right).

Enter a name for the calibration. Comments can be added. Navigate to each of the spectra for the three standards using the (...) button, and navigate to the folder containing the background files. Type in the known concentrations for K (%), U (ppm), and Th (ppm) for the standards. If using Geotek rock standards, these can be found on the rock, or on the certificate, or from support@geotek.co.uk. Press **[Calculate and Save]**. Close the software.

8. NATURAL GAMMA SPECTRUM ACQUISITION USING UTILITIES

Collecting a background spectrum using Utilities:

1. Open Utilities --> Test Panel --> Natural Gamma.

2. Place the appropriate background piece within the natural gamma cube. Ensure that all external sources of radioactivity (e.g., cement floor, brick walls, active rocks or standards) will be static for the duration of logging.

3. Choose a folder for the background acquisition and give the background a name (yyyymmdd-diameter is a good starting point). Click **[Acquire Background]** (Fig. 8).

Collecting a sample spectrum using Utilities:

1. Open Utilities --> Test Panel --> Natural Gamma.

2. If using a background, select **[Subtract Background]** and navigate to the background file to be used.

3. Choose a folder for the sample acquisition and give the sample a name (yyyymmdd-diameter-rock is a good starting point). Click **[Acquire Spectrum]** (Fig. 8).

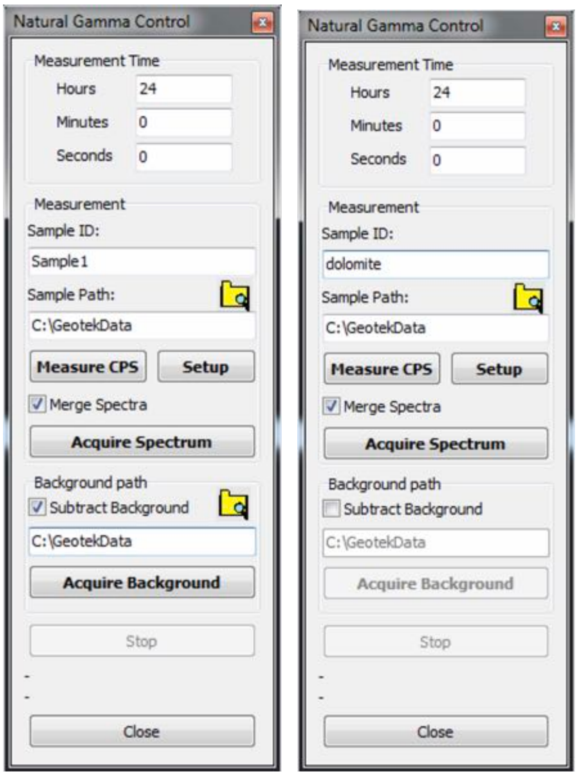


Figure 8: Utiliies Natural Gamma control pane showing background acquisition (left) and sample acquisition without background (right).

9. NATURAL GAMMA LOGGING SETUP

Select 'On' in the Natural Gamma box of the logging configuration panel (see Figure 9). 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.

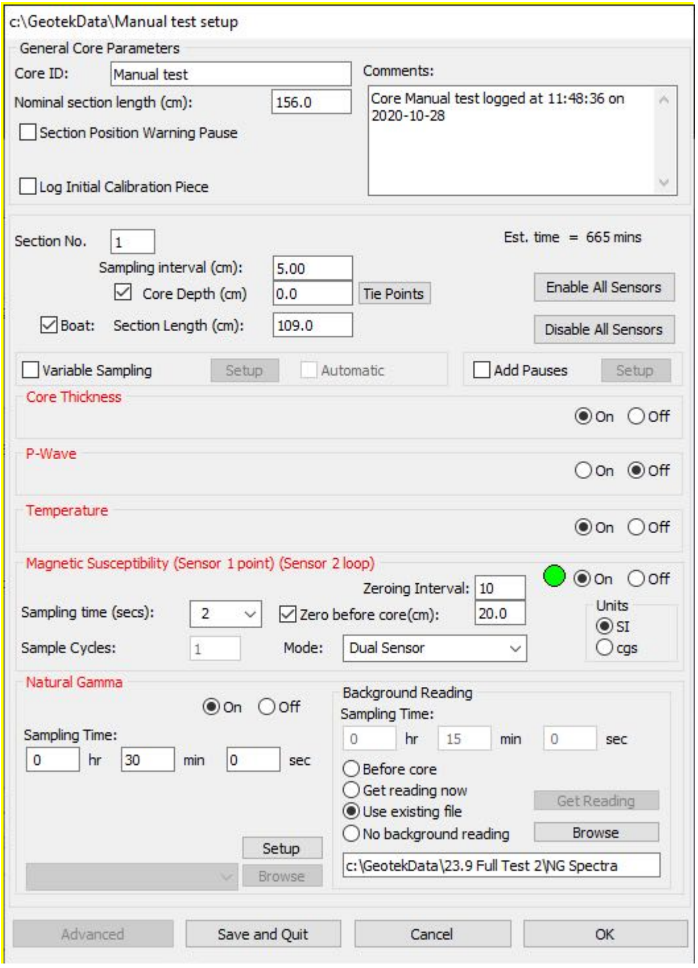


Figure 9: Natural gamma logging setup panel

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. Suggested sampling times for total radioactivity (cps or API) range from 5-30 seconds, depending on the size and radioactivity of the core; sampling times for K-U-Th measurement can be anywhere from 30 seconds to 15 minutes or more for very small diameter core.

Background Reading

A background reading must be taken in order to correct the data for the ambient levels of radiation. Geotek suggests that in most circumstances the background be collected in Utilities (see section 8) and then specified with the **[Use Existing File]** option. The previous background file will be used as a default. To use a background that was collected earlier, navigate to and select any of the files containing the background spectra – all background spectra will be used if one is selected.

When collecting a background, the background reading should be taken whilst there is a non-radioactive sample within the central cube of similar density to the sediment being logged. This means that the scattering of background radiation through the central lead cube will be at the same levels as during core logging. Background readings should be taken for 30 minutes and above for measuring gross CPS or API and for 12-24 hours and for measuring K-U-Th concentration, or for as long as is reasonably possible. The user can also choose to acquire data without background subtraction.

K-U-Th Calibration File

A set of calibration constants must be created by Geotek for each core size to be used. These are stored the KUTh.xml calibration file. Choose the correct K-U-Th calibration in the Geotek Settings before logging. The KUTh.xml file itself resides in C:\geotek\Settings\NaturalGamma.

10. DATA PROCESSING AND OUTPUT

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.

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).

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.

K-U-Th Concentrations

The processed data will also show the concentrations of K (%), U (ppm), and Th (ppm) if a calibration file has been used. These concentrations are exported with the processed data.

Spectral Data

The spectral data are saved to a text file with the extension .SPC.XML, and can be reprocessed if required with the help of Geotek.

Spectral data is saved as an XML text file (*.spc), containing header and setup information and is stored in text format that is self-explanatory. A spectral file is created for each detector and each sample point, and for systems with multiple detectors, a combined file is also saved. The files are saved in the core directory with the following name formats:

xxxxxxxx.spc.xml (merged spectra)

dddddddddxxxx.spc.xml (single-detector spectra)

Here d refers to detector number and xxxx gives the depth in core of the sample point in millimetres. If the spectral data is for a background reading then the data is saved in a file of the format bkgnd_xx.spc.xml where xx indicates the detector serial number. For example, bkgnd_06L319.spc.xml would contain the background spectrum for detector serial number 06L319.

TEMPERATURE

Figure 1: Platinum Resistance Thermometer used on the MSCL-S System

1. BACKGROUND

A standard Platinum Resistance Thermometer (PRT) probe is used to measure ambient temperature. The PRT probe is connected directly to the temperature port on the electronics and sits in a small holding clip connected to the centre section. The temperature measurement can be used to correct P-wave velocity value and to calculate corrected electrical resistivity. It can also be used as an indicator to assess data accuracy by looking at temperature drift over a period of logging.

2. CALIBRATION

The PRT system is calibrated by Geotek prior to shipping, however the details on its calibration are given below.

The analogue voltage from the PRT probe is digitised through the MSCL system electronics. When [Temperature] is selected from the test panel in the Geotek Utilities software, a continuously updated display is provided in the main window. For example, ADC = 10136 Temperature ˚C = 16.35. The voltage output by the PRT probe is directly proportional to temperature.

To calibrate the PRT probe, the operator must obtain ADC readings at known temperatures, and use a linear regression to obtain the slope and offset. This is most easily done by inserting the probe in a beaker of water with a calibrated thermometer. The scale and offsets for the PRT probe must be entered in the MSCL settings and then the temperature output will be correct. This can be checked by observing the temperature reading when the temperature test is running. This calibration should not change over time as it is a function of the hardware in the MSCL system electronics.

CORE THICKNESS

1. BACKGROUND

The thickness or diameter of the core sample is usually measured as the distance between the active faces of the two P-wave transducers (PWT). This is achieved by mounting two distance lasers on top of both of the PWT housings. The distance lasers are factory calibrated, so require no prior calibration by Geotek or the end user, however the distance lasers can only measure distance deviation from a known value, so manual input of the reference core thickness (RCT) is required.

Figure 1: Core thickness laser measurement system

WARNING: CLASS 2 LASERS OPERATING ON CORE THICKNESS SYSTEM

2. SETTING UP AND CALIBRATION

The set up for measuring core thickness differs depending on whether the user is in whole core or split core orientation and whether whole rock core or lined sediment core is being measured. For physical setup of P-wave transducer systems, see ‘Sensors – Ultrasonic P-Wave Velocity’.

2.1 WHOLE CORE

Lined Sediment Core

For use on whole lined sediment core, the distance lasers are mounted on the top of the P-wave transducer housing. For lined sediment core ARC rolling transducers are used, either mounted on static housings, which are manually brought into contact with the core by the user, or mounted onto the reciprocating housing (if the system is equipped with this).

Rock Core

For use on whole rock core, the distance lasers are mounted to the top of the reciprocating P-wave transducer housing. This setup allows the piston transducers to come in and measure the core thickness at each measurement point on the core.

Non-Contact Measurements

If P-wave mounting hardware is not installed, or there is reason not to contact the core, lasers can be mounted facing the core instead.

Calibration and Testing

A reference piece should be manufactured out of a rigid material that is approximately equal in diameter to the core liner diameter or the diameter of the rock core (within 1 mm). The diameter of this reference piece at its centre point should be measured and recorded.

To check the distance lasers are working correctly, position the reference piece between the transducers and bring the transducers in so they are just touching. Open the test panel in utilities and check that the deviation is showing 0, then slowly bring the transducers in and ensure the deviation changes accordingly.

When beginning a log, position this reference piece between the transducers when prompted. When using the rolling P-wave transducers, manually adjust the transducers so the reference piece is compressed with the transducer housings approximately mid-way in their travel (Figure 2). When using the reciprocating piston transducers, follow the instructions in the software.

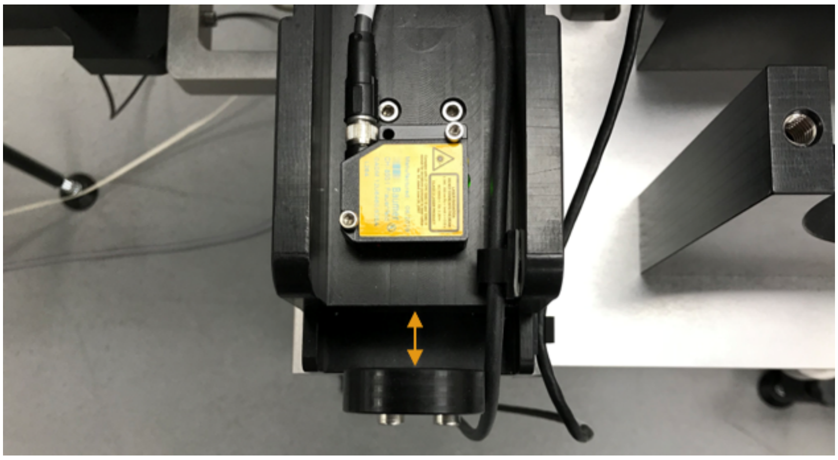


Figure 2: Transducer housings mid-way in their travel (orange arrow)

2.2 SPLIT CORE

Lined Sediment Core and Rock Core

The setup for split rock core and split lined core is the same; the distance lasers are mounted on a lower ARC rolling transducer, mounted beneath the rails, and to an upper P-wave piston transducer housing on the Z sensor arm. Split rock core in a core boat may need acoustic coupling gel between the boat and the rock to provide good signal transmission.

Calibration and Testing

A semi-cylindrical reference piece should be manufactured out of a rigid material – for example aluminium, to simulate the sediment or rock with the nominal or anticipated average core half-width. This reference piece should have a precisely-known thickness. Fit this piece into a short length of split core liner or onto a Geotek Core Boat.

To check the distance lasers are working correctly, position the reference piece between the transducers and bring the Z-arm down so the piston transducer is just touching. Open the test panel in utilities and check that the deviation is showing 0, then slowly bring the Z-arm down and check that the deviation changes accordingly.

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:

- 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;

- When prompted to by the software, slowly lower the Z-arm so the reference piece is in contact, and the transducer housing is approximately mid-way in its travel. (Figure 3);
- Switch the motor setting back to "Auto" and the user will be asked to enter a vertical excursion distance – this is the distance the Z-arm will move vertically after every movement. It is extremely important to ensure that the excursion set is enough to ensure all sensors on the Z-arm are raised sufficiently from the core surface so as not to cause any damage.

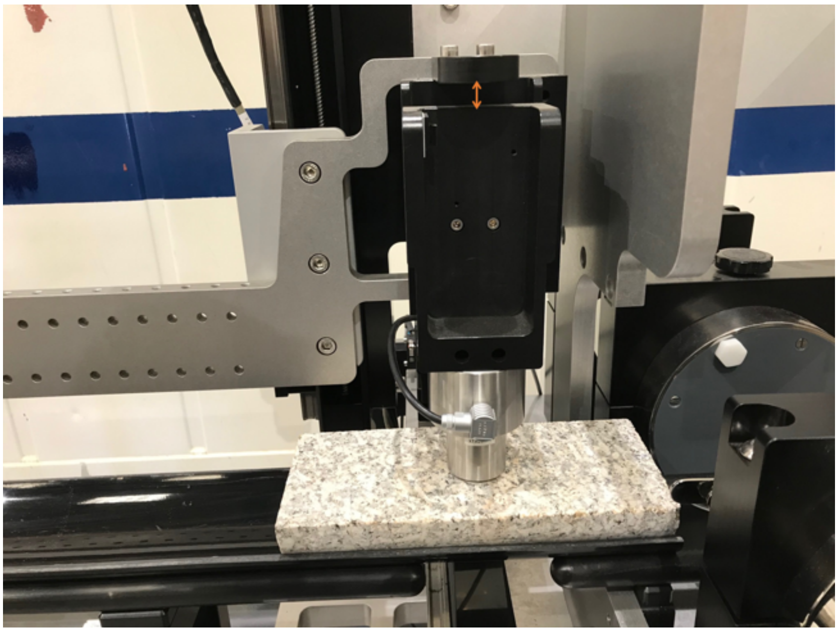


Figure 3: Transducer in contact with split core and housing mid-way in its travel (orange arrow)

3. PROCESSING

To calculate the core thickness for the raw data (core deviation), the following equation is used in the processing panel:

$$X = RCT - W + \frac{CTD}{10}$$

Where:

X = Sediment thickness (cm);

RCT = Reference Core Thickness (cm);

W = Total liner wall thickness (cm);

CTD = Core Thickness Deviation (mm);

This equation is shown in the Sediment Thickness processing panel as shown in Figure 4.

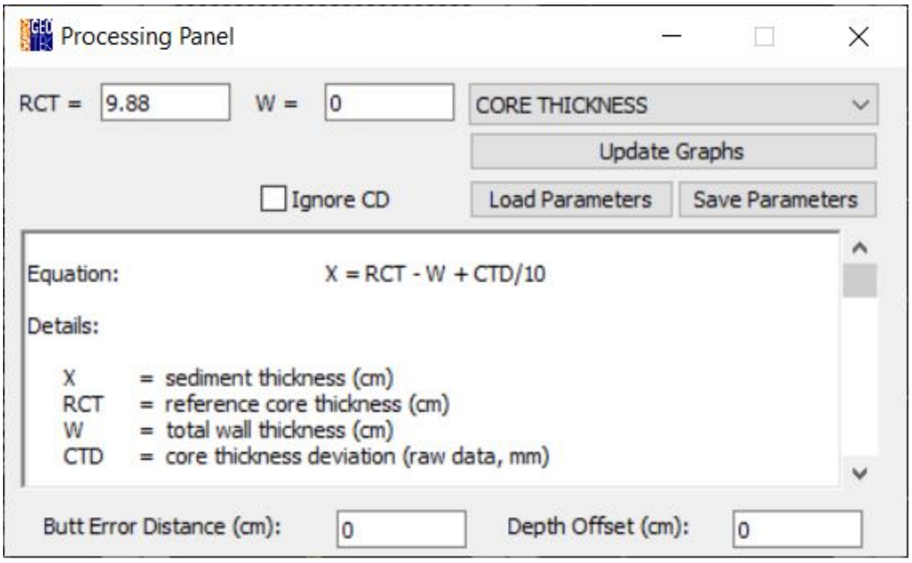


Figure 4: Core thickness processing panel

The operator enters the values of RCT and W in the boxes provided. Note that for whole sediment cores W = 2 × liner wall thickness, whereas for split sediment cores W = 1 × liner wall thickness. For rock cores, the wall value is left as 0. Having followed the above procedures, the correct values of core thickness will be recorded, displayed and used to calculate other important parameters (e.g., gamma density, P-wave velocity, volume-corrected magnetic susceptibility).

4. PROCESSING DATA WITHOUT CORE THICKNESS

Gamma density, P-wave velocity, and volume-corrected magnetic susceptibility all require the core thickness as an input. If, for some reason, core thickness cannot be measured, use the "Ignore CD" checkbox and set W = 0. The value entered as the RCT will be used as a constant sediment or rock thickness.

COLOUR (VISIBLE) SPECTROPHOTOMETRY

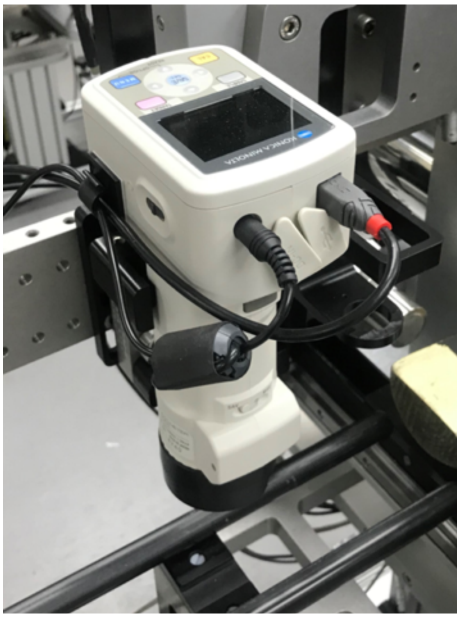


Figure 1: Konica Minolta visible light spectrophotometer

1. 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 colour to its physical specification.

The familiar colours of the rainbow in the spectrum include all those colours that can be produced by visible light of a single wavelength only, the pure spectral or monochromatic colours. 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.

Table 1: Typical wave length and frequency range for visible light

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

2. 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.

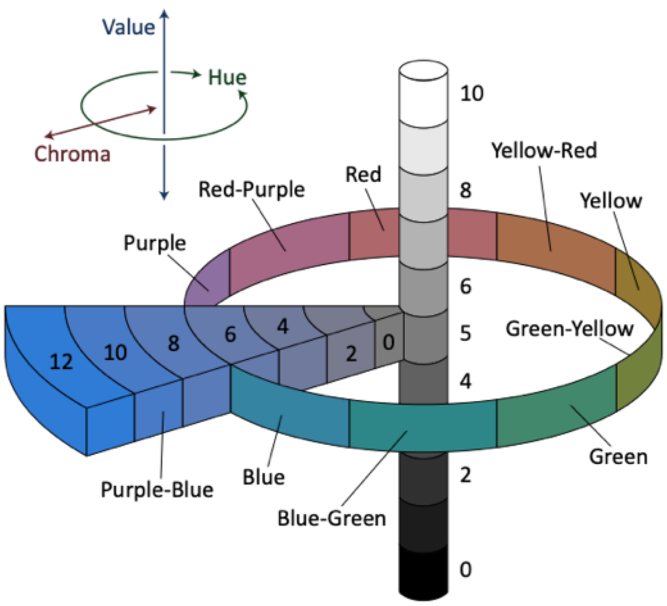


Figure 2: The Munsell Colour System

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 colour and expressing it numerically. These methods attempt to provide a way of expressing colours 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 colours which utilised a great number of paper colour chips classified according to their hue (Munsell Hue), lightness (Munsell Value), and saturation (Munsell Chroma) for visual comparison with a specimen colour. 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 2). In this system, any given colour 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.

Other methods for expressing colour numerically were developed by the Commission Internationale de l'Eclairage (CIE, an international organization concerned with light and colour). The two most widely known of these methods are the Yxy colour 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 colour differences in relation to visual differences. Colour spaces such as these are now used widely.

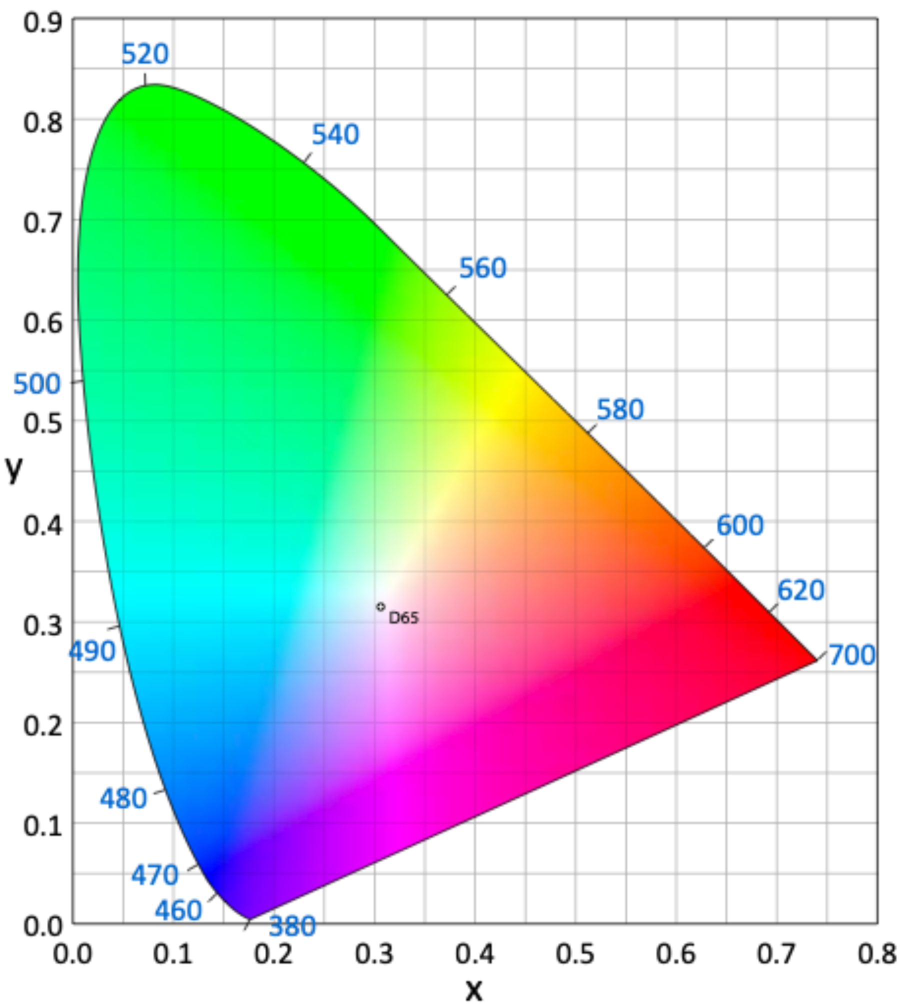


Figure 3: The CIE 1931 colour space chromaticity diagram. The outer curved boundary is the spectral (or monochromatic) locus, with wavelengths shown in nanometres.

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 colour (Figure 3) 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:

$$x = \frac{X}{X} + Y + Z$$

$$y = \frac{Y}{X} + Y + Z$$

$$z = \frac{Z}{X} + Y + Z = 1 - x - y$$

3. 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 4).

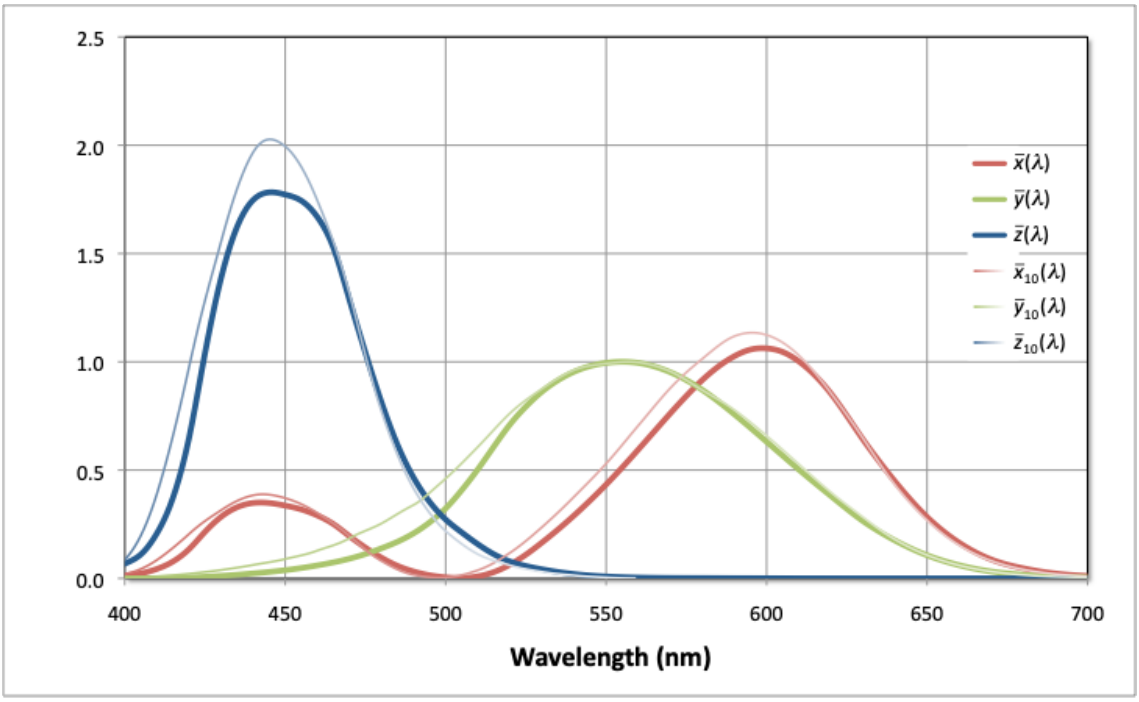


Figure 4: CIE 2° and 10° Standard Observer colour matching functions

4. 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.

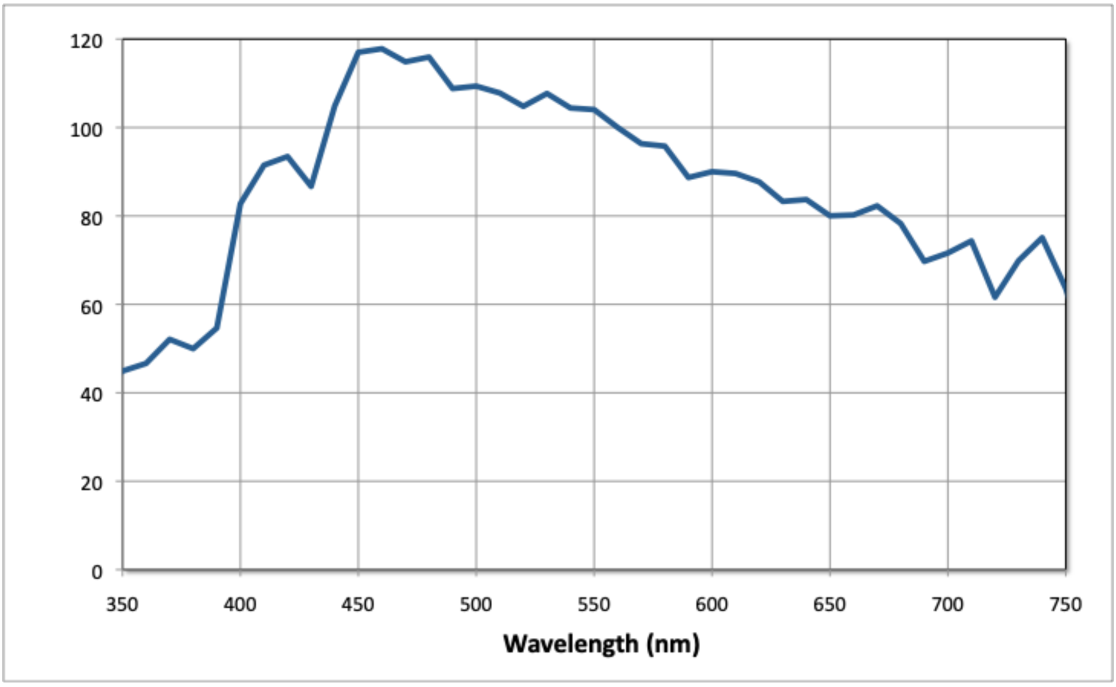


Figure 5: The CIE D65 illuminant spectral power distribution

The CIE chromaticity coordinates of D65 are x = 0.31271, y = 0.32902 using the 2° standard observer and can be plotted on figure 9.3. 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.

5. 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:

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

$S(\lambda)$ = 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 diffuser[1]

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

[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.

$(X / X_n)^{1/3}$ 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 $7.787 * (Z / Z_n) + (16/116)$

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.

6. 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.

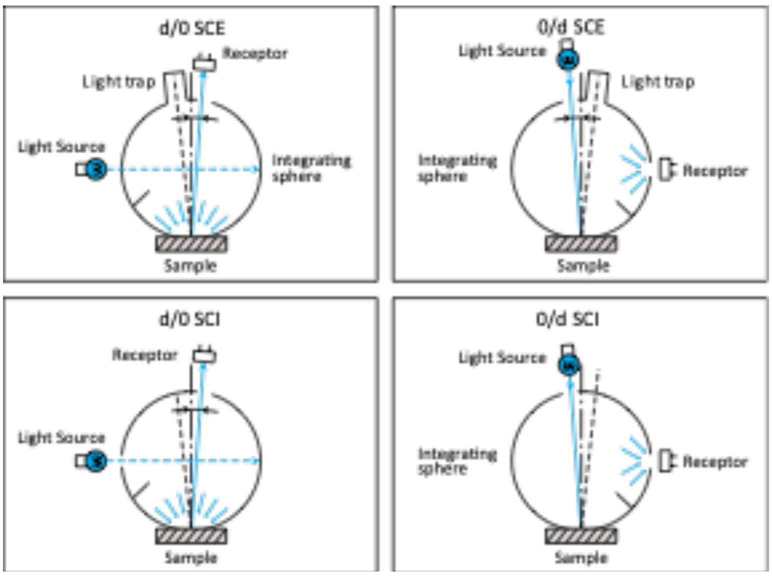


Figure 6: Different measurement geometries of an integrating sphere for measuring SCI and SCE spectra. The d/0 optical geometry illuminates the sample diffusely and detects the light at the normal direction (0 degrees). The 0/d optical geometry illuminates the sample at the normal angle (0 degrees) and collects the light reflected in all directions

7. 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 sulphate 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.

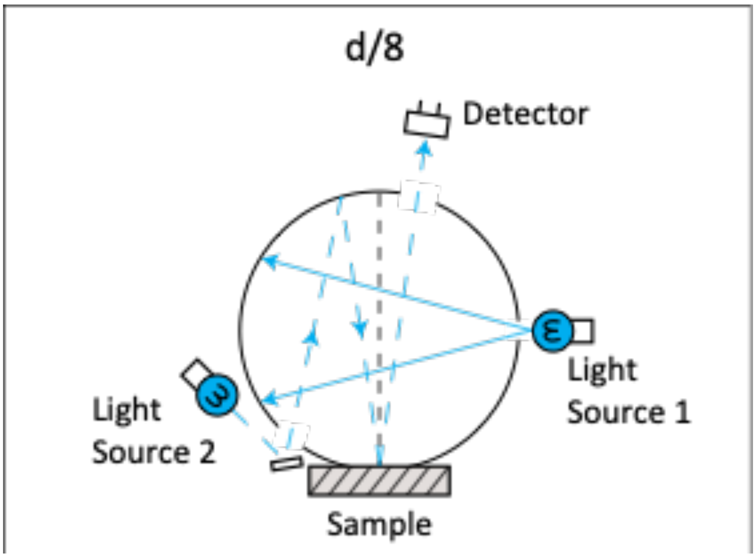


Figure 7. The two light source geometries used during measurement. Light source 1 is the diffused illumination used to measure SCI. Light source 2 is used to measure the amount of specular reflection to be subtracted from the SCI measurement to give SCE. UV measurements are made by using part of light 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.

8. 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 piece provided. The reflectance levels of the white calibration piece 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.

9. CALIBRATION AND OPERATION

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

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.

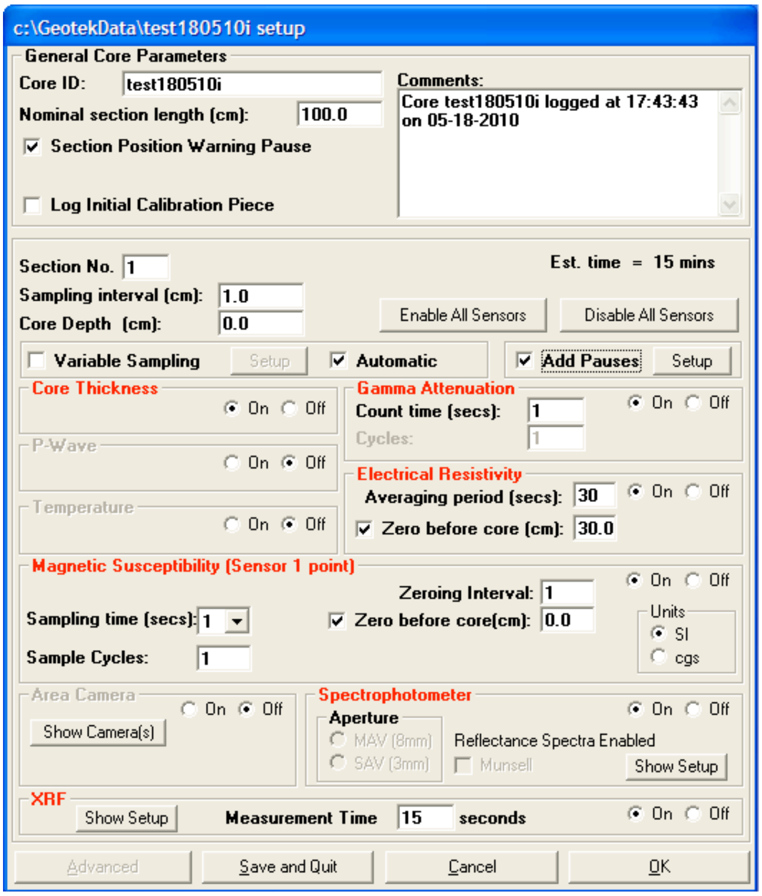


Figure 8. The Setup pane, showing the Spectrophotometer sub-pane. User must choose MAV or SAV (aperture size) and whether Munsell data should be collected.

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 displayed slightly differently depending on the MSCL system. On the MSCL-S, data from the colour spectrophotometer 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.

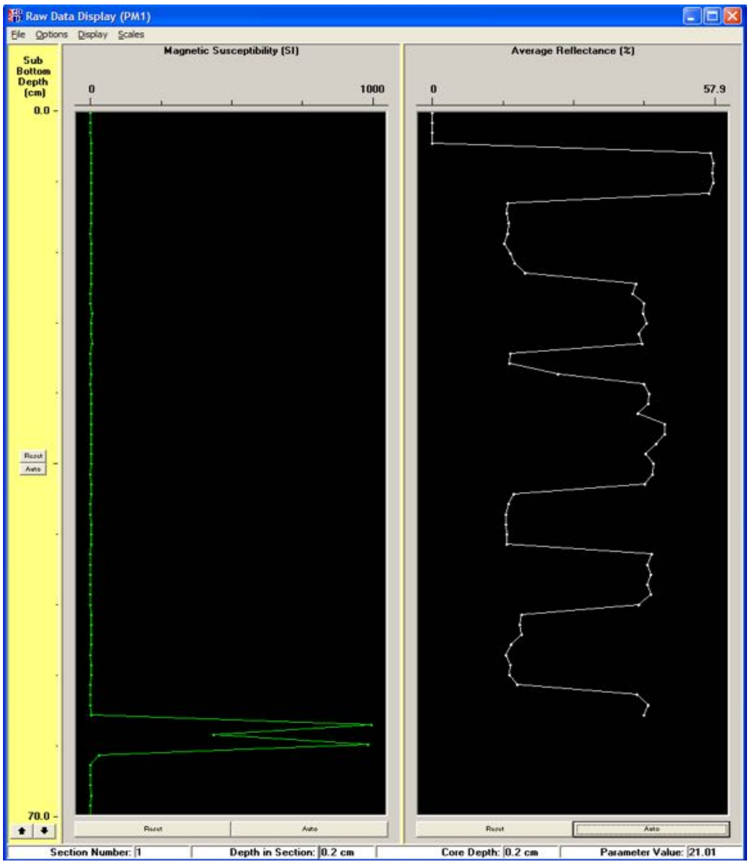


Figure 9: The Raw Data Display, with Average Reflectance from the colour spectrophotometer shown on the right.

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.

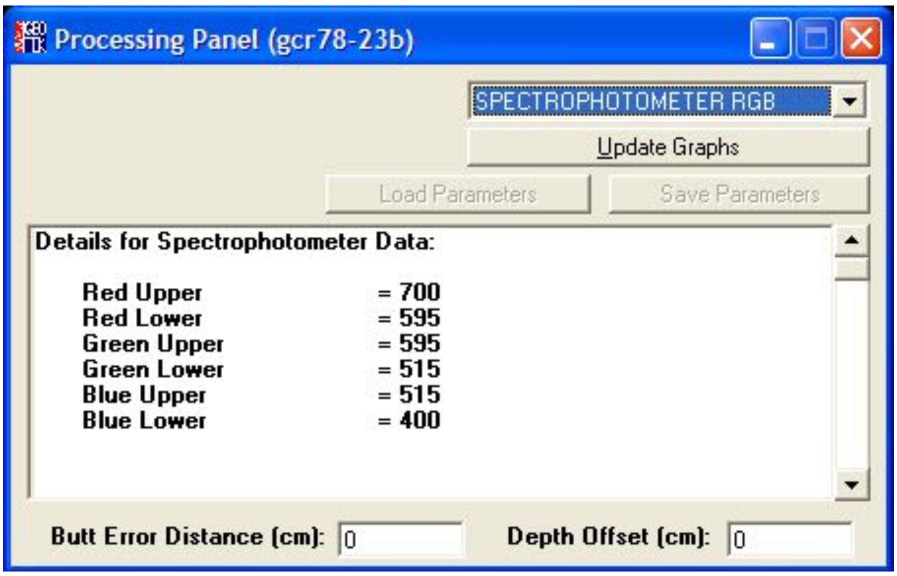


Figure 10: Spectrophotometer processing panel window.

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.

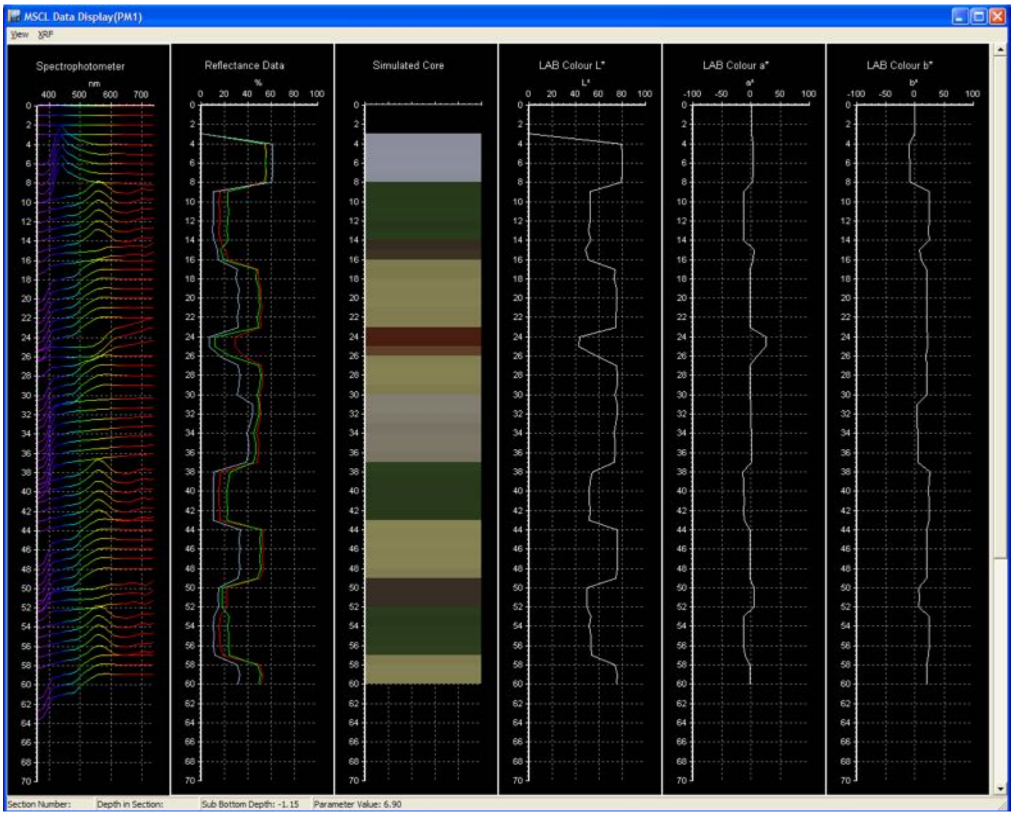


Figure 11: MSCL-S Spectrophotometer data display; MSCL-XZ main display.

On the MSCL-XZ, all the colour spectrophotometer data is displayed together as in the Spectral Display shown in Figure 11.

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.

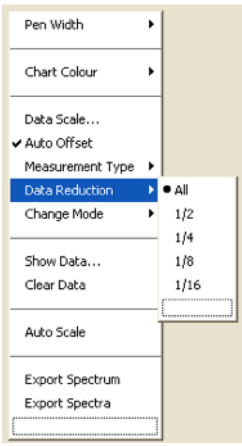


Figure 12: Spectral data contextual menu.

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.

10. 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 12), which is useful when single spectra are needed quickly.

X-RAY FLUORESCENCE (XRF)

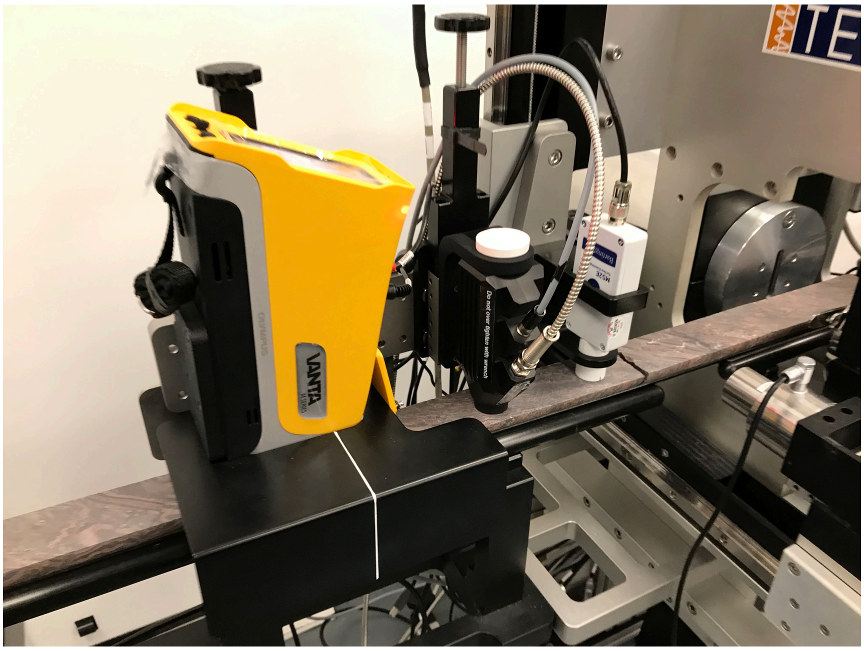


Figure 1: Olympus Vanta XRF mounted on MSCL-S

1. BACKGROUND

X-ray fluorescence (XRF) spectrometry is a non-destructive 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 non-destructive techniques that can provide chemical information directly from core surfaces. XRF measurements on the Geotek MSCL systems can be made using an Olympus handheld XRF spectrometer or the Geotek XRF spectrometer. This chapter describes the use of the Olympus XRF spectrometers on Geotek equipment.

2. 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 photon 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. Characteristic radiation is displayed as peaks at particular positions in spectra.

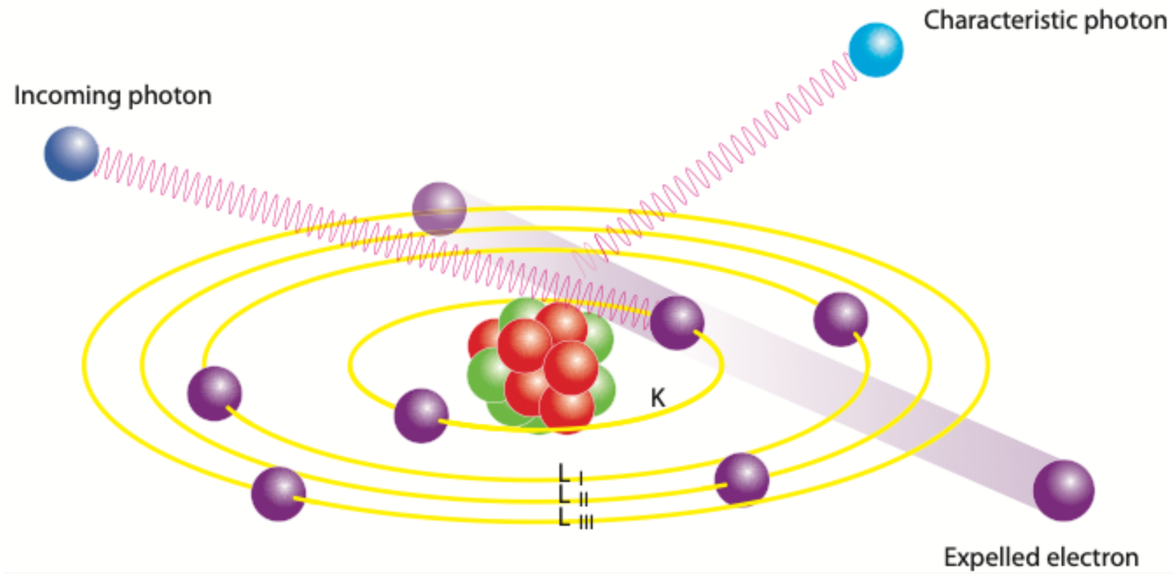


Figure 2: Production of characteristic X-ray photons (fluorescence) as an electron fills the space in the K orbital left by the electron expelled by the excitation X-ray photon. (Figure credit: Panalytical)

3. OPERATIONAL MODES

The Olympus Innov-X (models Alpha and Delta) and the Olympus Vanta portable X-ray fluorescence (pXRF) spectrometers 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 one or more of the following modes: Mining, Mining Plus, Soil, and Geochem, with Geochem being the most common on the Olympus Vanta (Note: not all modes will be present on all instruments when purchased. Those looking for additional modes should contact Olympus after-sales support).

3.1 MINING MODE (DELTA ONLY)

Mining mode uses a single beam of 40 kV to perform a measurement. The spectrum is analysed 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 modelling works well when analysing a sample with high concentrations of elements of interest. Users can apply their own calibration to adjust for matrix effects.

3.2 MINING PLUS MODE (DELTA ONLY)

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 modelling using the method of fundamental parameters. This mode is the most appropriate for measuring the overall composition of a rock or sediment.

3.3 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

3.4 GEOCHEM MODE

Geochem mode combines measurement of the bulk composition with improved detection of elements in lower concentrations (10-1000 ppm). Like Mining Plus mode, there are multiple beam conditions used together (40kV filtered and 10 kV in the two-beam mode; an additional 50kV filtered beam in the 3-beam mode) and a fundamental parameters model applied. Elements are also calibrated individually by Olympus at the factory. The user can add linear factors to adjust the calibration for different matrices ("site-specific" calibration).

4. BEFORE LOGGING WITH THE OLYMPUS VANTA OR DELTA

It is important to ensure the following safety and setup procedures are followed;

- Ensure that the XRF spectrometer moves freely up and down on its mount, and is not obstructed by cabling.
- Cover the core with plastic wrap to avoid contaminating the sensor. If light elements (Mg, Si) are being measured, the thinnest, non-chlorine plastic wrap possible (e.g., Prolene®) will provide the best data.
- **Caution:** X-rays are emitted by the spectrometer when it flashes red.

WARNING: X-RAY RADIATION. DO NOT HOLD SAMPLES UP TO THE XRF SPECTROMETER. DO NOT ATTEMPT TO LOOK AT THE APERTURE OF THE XRF DEVICE WHEN ACTIVE.

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 3).

Figure 3: "X-rays on" warning in MSCL-S software

The Geotek software interfaces with the internal Olympus software to collect measurements. Important settings on the XRF such as mode and XRF test duration can be controlled through the Geotek software. More detailed settings can be modified on the instrument itself.

5. SETTING UP XRF FOR LOGGING ON MSCL

When logging a new core, the setup panel opens (Figure 4) where there is an option to enter the measurement time per beam. This time is per beam, so a Delta logging in Mining Plus mode would make two measurements, one per beam, and a Vanta logging in Geochem mode (3-beam) would make three measurements, one for each beam.

The XRF has a traffic light indicator, displaying the current status of the sensor. Red means that there is no connection to the device, yellow means the device is connected but not ready to measure (e.g., it may currently be making a measurement), and green indicates connected and ready to measure.

The user has the option to "show setup" of the XRF and the XRF controller window will open, (Figure 5). Note that the status light will remain red or yellow until the "show setup" button is selected.

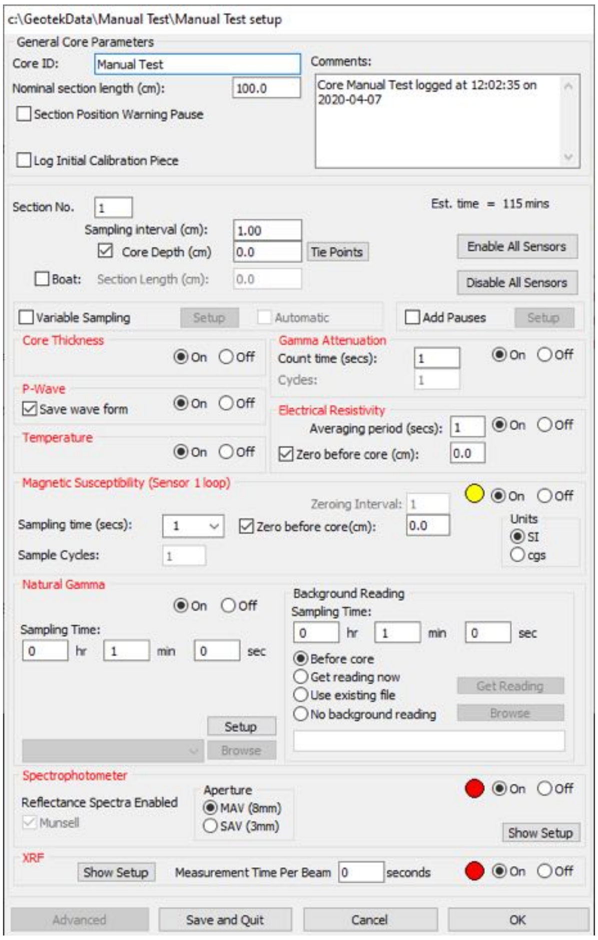


Figure 4: Set up panel for logging new core on MSCL

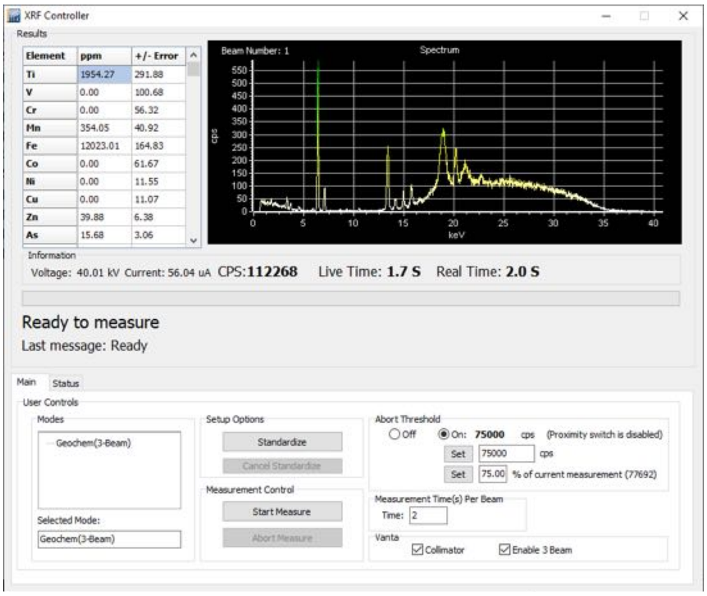


Figure 5: XRF controller window

6. DATA ACQUISITION DISPLAY

Data is displayed as elemental abundances in ppm (parts per million). The elemental abundances come directly from the Olympus software, which processes the spectra and returns elemental data. The data can be changed to percentages if required, by right clicking on the data column and navigating to ‘Select units > Percent’. It may also be displayed on a log scale.

Data for each point is continuously displayed in the XRF Controller Pane as it is acquired, including the raw XRF spectrum.

Data is plotted in the MSCL Spectral Data Display (Figure 6) along with data from the colour spectrophotometer, if installed.

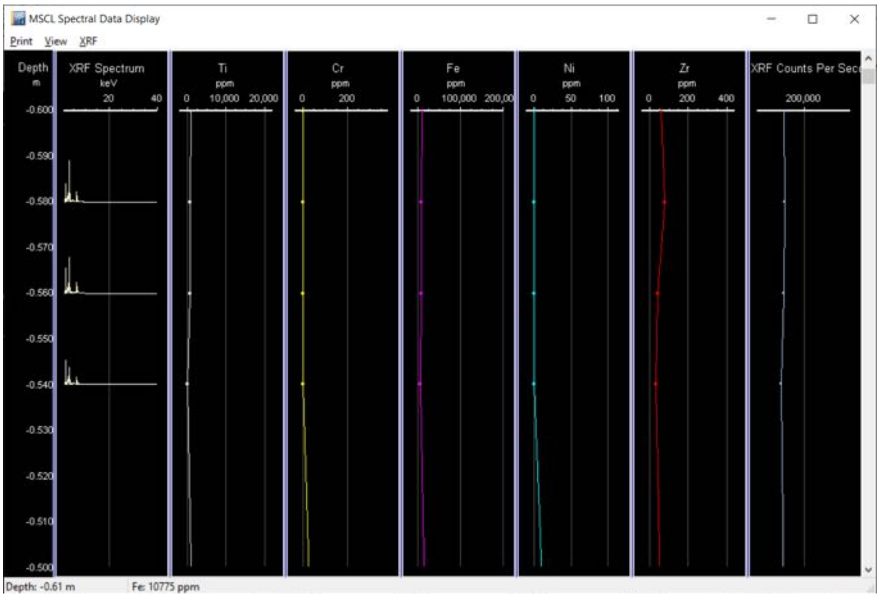


Figure 6: MSCL-S Spectral Data Display

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 (Figure 7), accessed through the [XRF] menu on the MSCL-S or the [View] menu on the MSCL-XZ or MSCL-XYZ. In addition, several elements can be plotted on a single chart in order to save space in the data display window. To hide or show all single element plots, select Hide Element Chart in the [XRF] or [View] menu. Data can also be displayed as a percent or logarithmically by right clicking on the column in the ‘select units’ option.

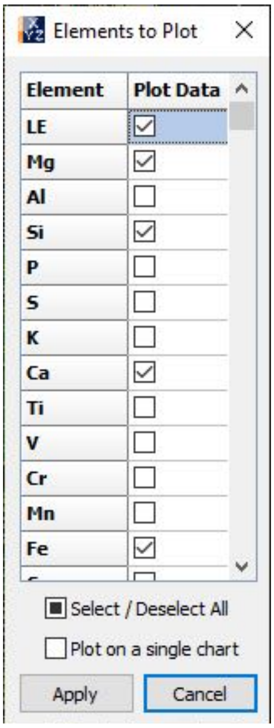


Figure 7: Elements to Plot window

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

7. CALIBRATION, PROCESSING AND EXPORTING

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

The Delta handheld XRF allows the user to adjust the calibration performed by Innov-X. This can be 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.

XRF data is exported along with the rest of the MSCL data by selecting [File > create Ascii file] in the processed data window of the MSCL-S or the main window of the MSCL-XZ or MSCL-XYZ. XRF data is exported as concentration of each element (in ppm) and, if desired, statistical error in ppm.

GEOSCAN V

Geotek has manufactured five generations of its custom specification line-scan camera, the Geoscan camera. The current version is the Geoscan V; for information regarding the operational use of previous versions of Geoscan cameras, please contact Geotek.

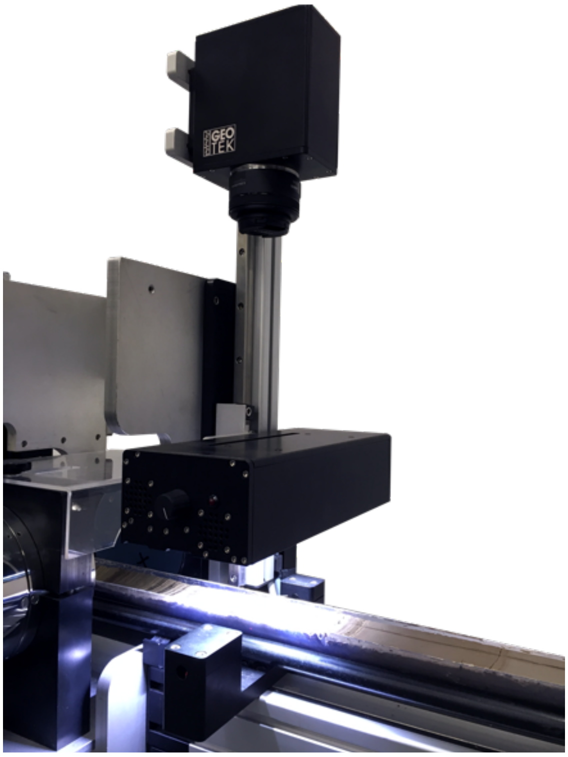


Figure 1: Geotek Ltd Geoscan V line-scan camera mounted on MSCL-S

1. GEOSCAN V CAMERA TECHNICAL SPECIFICATION

The Geoscan V camera system consists of the line-scan camera and visible and/or ultraviolet (UV) lightbox. The Geoscan V is a line-scan camera with automated focus, aperture and illumination control that is designed to image split sediment or slabbed rock core surfaces as well as whole rock core surfaces. A polarising camera lens and filters for the light box are provided to reduce direct reflection from wet core surfaces. A UV camera lens filter is also provided if the UV lightbox is purchased.

The Geoscan V camera contains a single charge-coupled device (CCD) generating 5340 useable Red, Green and Blue (RGB) pixels. Each pixel is 4.0 μm square with a total active array length of 21.3 mm. Dark reference pixels are used to compensate for electrical drift within the sensor due to temperature variations. These reference pixels are electrically identical to the active pixels, but are fabricated with an opaque layer over them. The digitised data from the CCD is 14 bits per channel and is multiplexed and transmitted in 16 bit streams to the MSCL-S PC via a GigE interface.

Synchronisation between the Geoscan V camera and the MSCL-S right-hand 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 movement, the Geoscan V camera images a line across the core sample at precise spatial intervals down the core sample. This means that there is no optical distortion from the camera lens in the down-core direction, an important factor for high-resolution studies. The motor speed defines the time between motor 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. The Geoscan camera data is transmitted to the MSCL-S PC interface card where it is corrected for gains and offsets.

Offset correction ensures that the RGB channels are referenced to a true black level. This is achieved by measuring the signal level of the pixels when unilluminated as well as correcting for thermal variations with the dark reference pixels. Gain correction compensates for pixel-to-pixel response variation, uneven lighting, and lens effects. Lenses typically darken the edges of the field of view, an effect which becomes more pronounced with increasing aperture. To correct for all of these artefacts, a software gain correction is calculated for each pixel using a reference grey card. This correction is then applied to subsequently acquired image data. The corrected data are stored in a TIFF format with depth and calibration information stored in an associated metadata XML file that is read by the image viewing software.

2. GEOSCAN V VISIBLE AND ULTRAVIOLET LIGHTBOX

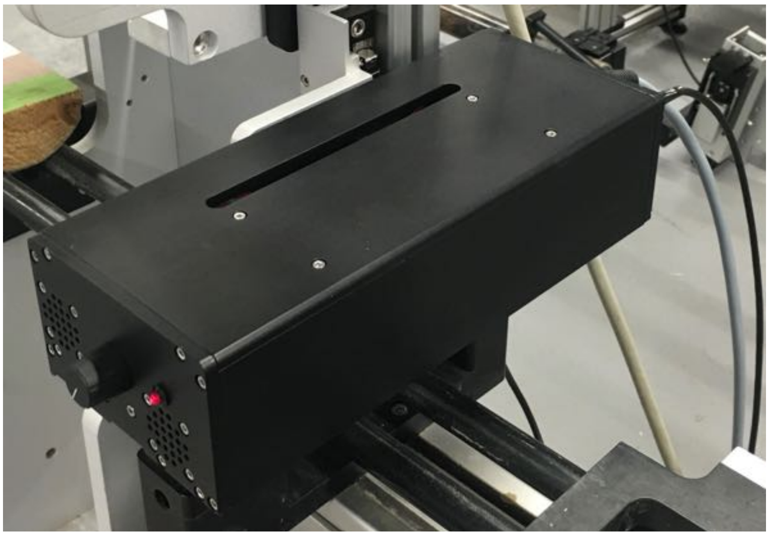


Figure 2: Geoscan V automated LED lightbox

The Geoscan V camera comes with a lightbox specifically designed to illuminate core surfaces. For normal RGB imaging, the Geoscan V system uses white light-emitting diodes (LEDs). Two banks of LEDs are used to illuminate the core surface evenly from both sides of the image line. This provides a flooded illumination area that minimises any shadow effects that could be caused from micro-topographic effects.

The Geoscan V camera is positioned directly above the lightbox and views through a slit in the top surface of the lightbox. Spurious reflections are reduced by black anodising on both the Geoscan V camera and lightbox. There are slots below each LED bank for insertion of polarizing filters (Figure 3). The polarizing filters inserted into the lightbox, in conjunction with a polarizing filter fitted to the camera lens, can eliminate reflections from shiny or wet core surfaces.

Geotek produces a combination visible and UV lightbox. Ten high-power ultraviolet LEDs provide narrow- band ultraviolet radiation centred around 365 nm (full width half max approximately 12.0 nm) and are shielded by a UG1 bandpass filter. The visible light LEDs are the same as used in the standard Geotek visible lightbox.

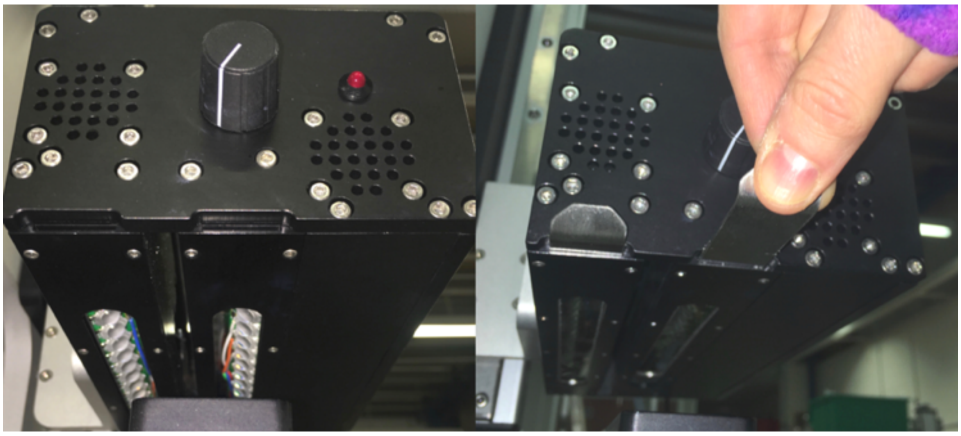


Figure 3: Slots for inserting polarising filters in front of the LED banks

3. GEOSCAN V CAMERA SET-UP AND CALIBRATION

On opening of the Geotek Imaging software the user will be presented will the ‘main menu’ window (Figure 4). The options available to the user are Acquire Image, Set-up, About, Settings and Exit. The following text will provide a summary of a basic set-up to help the user get started.

Figure 4: Geotek Imaging main menu

Open the Geotek Imaging software and from the main menu window select ‘setup’. This will open the basic setup window (Figure 5). The user will be presented with the following options: ‘Focus’, ‘colour balance’, ‘aperture’, ‘advanced setup’ and ‘back to main menu’.

Figure 5: Geotek Imaging basic setup window

When selecting any of the above 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.

The camera scope window provides direct access to the data from the CCD sensor monitoring the output of all 5000 useable pixels. The window shows the output of the RGB channels within a dashed yellow lined box. The camera scope window can be resized if required (bottom right hand corner). Clicking on and dragging a box in the camera scope window from top left to bottom right can enlarge portions of the camera scope window display and corresponding line-scan view. Dragging and drawing a box in reverse, from bottom right to top left, will reset the zoom.

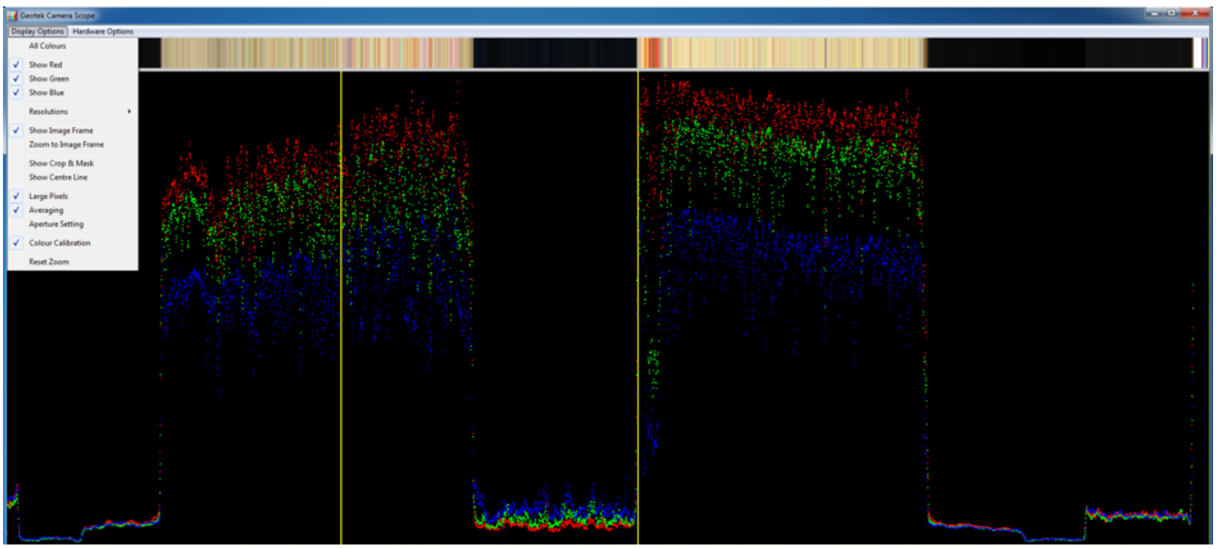


Figure 6: Geotek live image "scope display"

The [Display Options] menu from the camera scope window allows the user customisation of the camera scope window display. The options available are presented below in Table 1.

Table 1: Geotek Imaging Software Camera Scope Window Display Options

Menu sub-option	Explanation
All Colours	Displays the individual RGB colour channels together.
Show Red Show Green Show Blue	Shows the individual colour channel response ON and OFF.
Resolutions	Allows the user to set the number of pixels viewed across the camera scope window.
Show Image Frame	Displays the image frame in the horizontal (edge to edge of the image) and in the vertical to between 0 and 255.
Show Crop & Mask	Displays the cropped/masked region in the line scan image above the scope display.
Show Centre Line	Switches ON and OFF a yellow vertical line in the centre of the image frame area.
Large Pixels	Doubles the size of the camera scope window RGB channel pixels on the screen for easy viewing.
Averaging	Averages individual scans to reduce noise in the display.
Dark Correction	Switches ON and OFF the dark correction from the reference pixels
Colour Calibration	Switches ON and OFF the calibration corrections applied to each pixel from the High and Low calibration files.
Reset Zoom	Returns the camera scope window to full view. Areas can be enlarged by clicking and drawing a box. Note: The maximum zoom is 20 x in either dimension; if this value is exceeded the zoom will not proceed.

The [Hardware Options] menu from the camera scope window allows the user custom control of the Geoscan camera lens and lightbox. The options available are presented below in Table 2.

Table 2: Geotek Imaging Hardware Window Display Options

Menu sub-option		Explanation
Lighting Setup		Opens the 'Lighting Control' window. The user has the option to select the lighting level either independently for each lighting bank or by checking the box next to 'Link Banks' to adjust the lighting level in sync.
Lens	Auto Focus	Geotek imaging software will automatically attempt to complete the focusing procedure.
	Auto Aperture	Geotek imaging software will automatically attempt to find the appropriate aperture setting.
	Advanced…	Opens the 'Lens Control' window. The user can fine adjust the focus and aperture settings.
Notes: 1. These options should not be used on a routine basis, rather, the user should allow the Geotek software to adjust the lighting levels, camera focus and camera aperture.		

4. VISIBLE IMAGING PHYSICAL SET-UP AND OPERATION

The Geotek V camera standard operational mode is 25 microns or 400 pixels per cm. The primary pixel dimensions of images taken by the Geoscan V camera are controlled by the physical height of the camera (horizontal or cross-core resolution). Lower resolution images are acquired through the binning of pixels from this 400 pixel per cm image acquisition and a reduced frequency of line-scan image collection relative to the core sample (vertical or down-core resolution). The imaging speed is adjusted to always ensure that these two resolutions are equal, providing square pixels in the final images.

The Geoscan V camera should always be set at a fixed height above the surface to be imaged. Place a core sample on the MSCL-S track and measure from the top of the core surface to the base of the black camera housing (not to the camera lens). The correct height is 38 cm for the standard 25 micron pixel size (= 400 pixels per cm resolution).

Images can also be collected at resolutions that are lower than the standard resolution that is set. This is done via the Geotek imaging software by adding or 'binning' adjacent pixels. The user can choose between resolutions of 400 pixels per cm, 200 pixels per cm, and 100 pixels per cm using the drop-down box in the 'Resolution' window, without readjusting the height of the Geoscan V camera.

Setting the Focus

To automatically set the Geoscan V camera focus, select 'Focus' from the main menu window. A subset of the pixels (those between the vertical yellow lines on the camera scope window display) are examined and the contrast between these pixels is maximized during the autofocus procedure. Place a core with good local contrast under the camera, then select "auto focus". After the auto focussing has taken place, the scope display should show pixels with a maximum level of noise, and the image should be sharply defined above the scope window.

Once set, the focus will not change again until this window is revisited. Note: The aperture will affect the depth of field, so if the core varies widely in height, the aperture should be as small (large f-number) as practically possible, therefore the focus should be set on a portion of core sample with average height.

Setting the Aperture

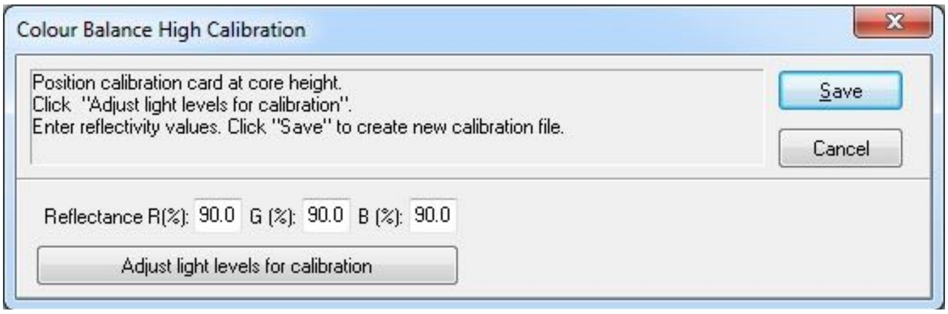
To set the Geoscan V camera aperture select ‘Aperture’ from the main menu window. In the ‘Aperture’ window the user can adjust the lens to the chosen aperture value and automatically adjusts the light levels. The lightest part of the core sample should be used for this setup to avoid saturation during imaging. If there are no other constraints, Geotek suggests turning the light to maximum and choosing a mid-range aperture (8 or 11) as this is where camera lenses perform their best. If the core sample is extremely variable in height, a small aperture (larger f-value) will be required to increase the depth of field. Adjust the vertical yellow lines so that they are either side of the core sample and click ‘Auto Visible Light & Aperture’. Once complete click ‘Save’.

Colour Balance

Select ‘Colour Balance’ from the main menu window. The colour balance procedure writes calibration files containing the low and high calibrations for each pixel 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 the white side of the provided grey calibration card, and low calibrations are performed by attaching the lens cap when prompted.

When preparing for the high calibration, the red, green and blue traces on the camera scope window should be at a minimum 40.0 % of maximum value, and for best results, they should be close to their maximum levels but not saturated. It is recommended that the user leave the high calibration aperture the same as the scanning aperture but, if absolutely necessary, the user can **temporarily** change the aperture using the software by choosing "auto adjust aperture". 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 calibration card to remove the effects of any dust or imperfections.



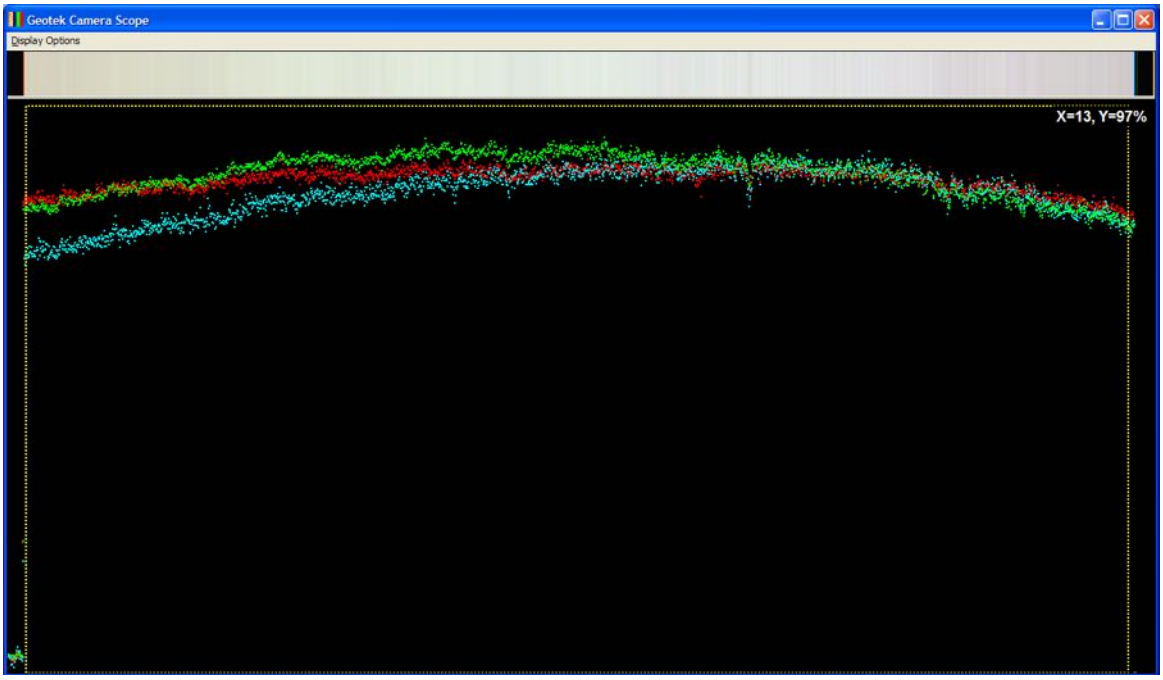


Figure 19: High calibration panel and scope display

Low calibrations are performed with the lens cap on. Data is collected for few seconds and averaged.

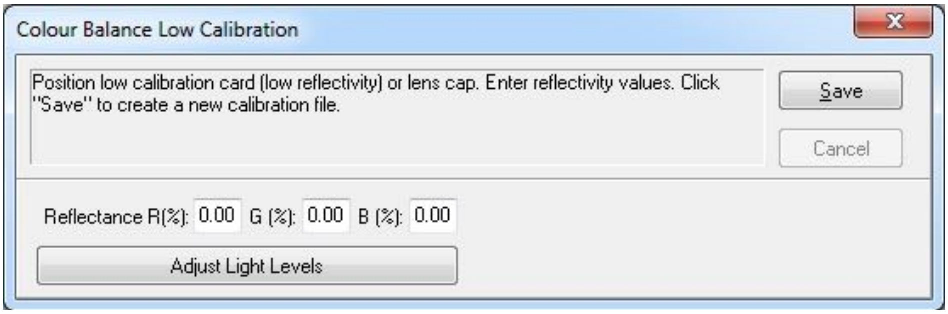


Figure 20. Low calibration panel.

The data from the two calibrations are stored in files (high.cal and low.cal.) in the c:\geotek directory.

If the light intensity or height was changed for the calibration, it should be changed back to the correct height or intensity for imaging.

Advanced Setup

This menu contains options that are likely to be used relatively infrequently and normally by experienced operators:

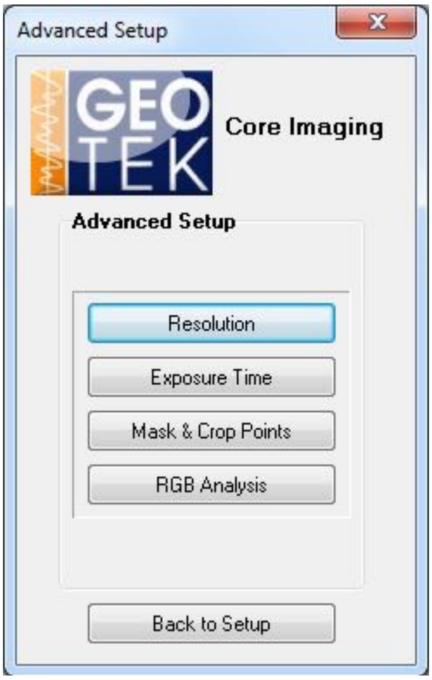


Figure 21. Advanced setup menu for MSCL-S imaging.

Resolution

The primary pixel dimensions of images taken by the Geoscan V are controlled by the height of the camera (horizontal or cross-core resolution) and the frequency of linescan image collection relative to the movement of the core (vertical or down-core resolution). The Geotek software adjusts the motion of the core (or camera) to always ensure that these two resolutions are the same, providing square pixels in the images.

The primary resolution is chosen by the user, and for a given lens, the distance between the base of the camera and the surface to be imaged will always be the same. For instance, using the Canon EF 50mm f/1.8 STM lens, the camera/lens interface should be 38.2 cm from the core surface for a primary resolution of 400 pixels per cm. The camera must be physically moved up and down for larger or smaller cores.

Images can also be collected at resolutions that are lower than the primary resolution of the camera. This is done in software by averaging adjacent pixels. If the camera is set to a primary resolution of 400 pixels per cm, the user can easily choose between resolutions of 400, 200, and 100 pixels per cm using the drop-down box in the Resolution pane, without adjusting any hardware.

Geotek suggests that unless there are pressing reasons, the primary resolution should always be set to 400 pixels per cm and the camera height adjusted for each core as necessary. The user can select the desired imaging resolution in the Resolution pane. (In older versions of software that have separate Crosscore Resolution and Downcore Resolution buttons, the crosscore resolution should be set first, and the downcore resolution then set to match the crosscore resolution.)

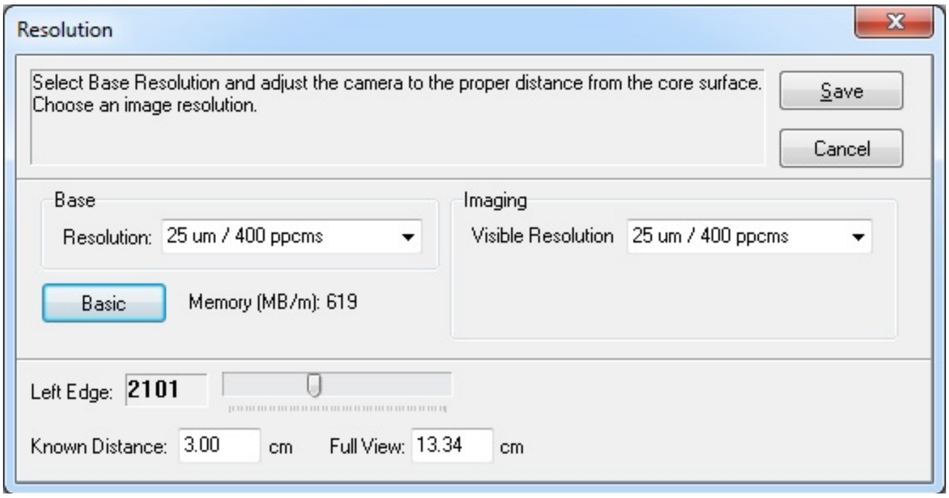


Figure 22. Cross-core resolution dialogue.

If the user wishes to check the resolution of the camera, this can be performed in the Resolution panel. An object of known dimension should be placed under the camera at the height of the core surface, and this known dimension should be typed into the “Known Distance” field. The yellow vertical lines will move to this distance. The camera height can be adjusted so the object exactly matches the yellow vertical lines. Please note that occasional refocusing may have to be performed during such a check.

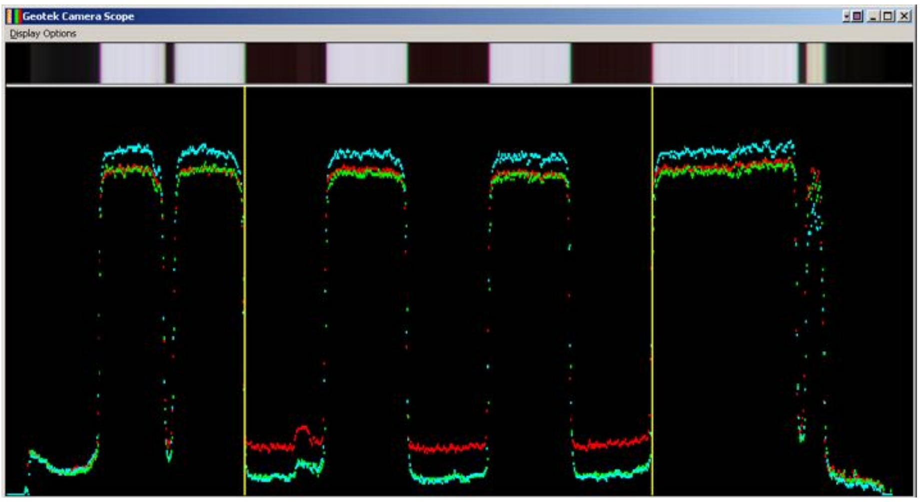


Figure 23. Checking the cross-core resolution using a known distance.

Exposure Time

The exposure time can be adjusted as required. The exposure time can be varied from 5 to 80 ms for both visible imaging and UV imaging. Geotek recommends that in the absence of other criteria, exposure time be set at 10 ms for visible imaging and 40 or 80 ms for UV imaging. If polarizing filters are used for visible light, exposure times may have to be increased to 20 ms or more.

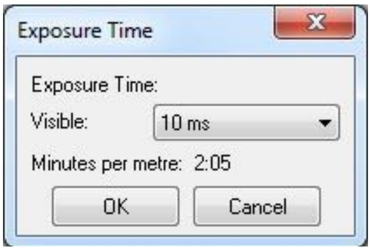


Figure 24. Exposure time pane.

There are interactions between exposure time and image resolution, so a few combinations of exposure time and image resolution are disallowed by the software. The table below shows an example of how the exposure time and down-core resolution affect image acquisition time.

Resolution (pixels per cm)	Time to collect 1 m core image (minutes)		
	5 ms exposure	10 ms exposure	20 ms exposure
400	03:20	06:40	13:20
200	01:40	03:20	06:40
100	n/a	01:40	03:20

Mask and Crop Points

This option allows the user to discard or mask data at the edge of the CCD array where the field of view extends past the surface of the core. 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 or can be disabled completely using the tick box.

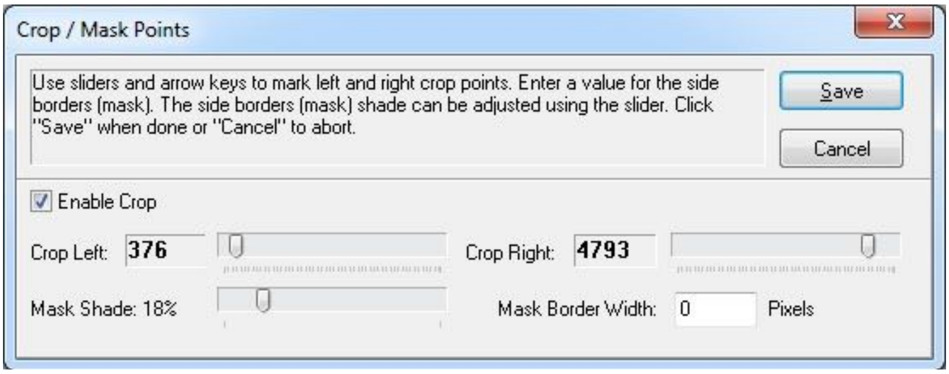


Figure 25. Crop and mask control.

5. OUTPUT FORMATS

Image Data

The files created by the Geotek Digital Imaging software are 16-bit tagged image file format (TIFF) files. Additional information is included in a associated XML file that is used by various ancillary Geotek image replay software. This metadata file includes calibration information (image aperture and white calibration aperture), resolution parameters, 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 any associated Geotek software. Files are generally named with the Core ID and Section Number (e.g., CoreID_001.TIF); files can also be named with top and bottom depth imaged.

RGB Analysis

The data from the individual red, greed, and blue channels can be automatically extracted from the image files immediately after acquisition and written to a ASCII text file. This process can be enabled or disabled and defined through the RGB Analysis option in the Advanced Setup Panel.

The left and right edges of the data to be used for RGB analysis can be defined in the RGB Analysis Setup panel. The Sampling Interval defines how often a line of data will be written to the ASCII data file. Geotek suggests that data taken for RGB analysis is averaged (checkbox "Average RGB Values"), otherwise individual lines will be reported. RGB data will be extracted from the full length of the acquired image.

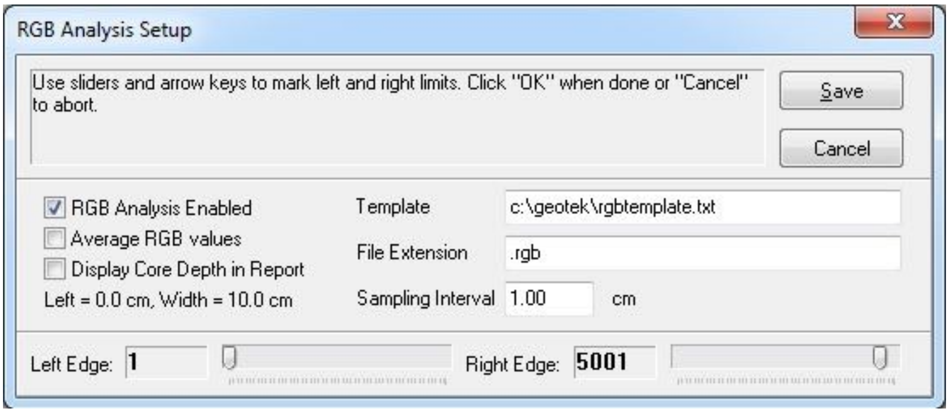


Figure 26. RGB Analysis Setup Dialog.

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. To modify this file, please contact Geotek for a current list of useable RGB tags.

6. ULTRAVIOLET FLUORESCENCE IMAGING SETUP AND OPERATION

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.

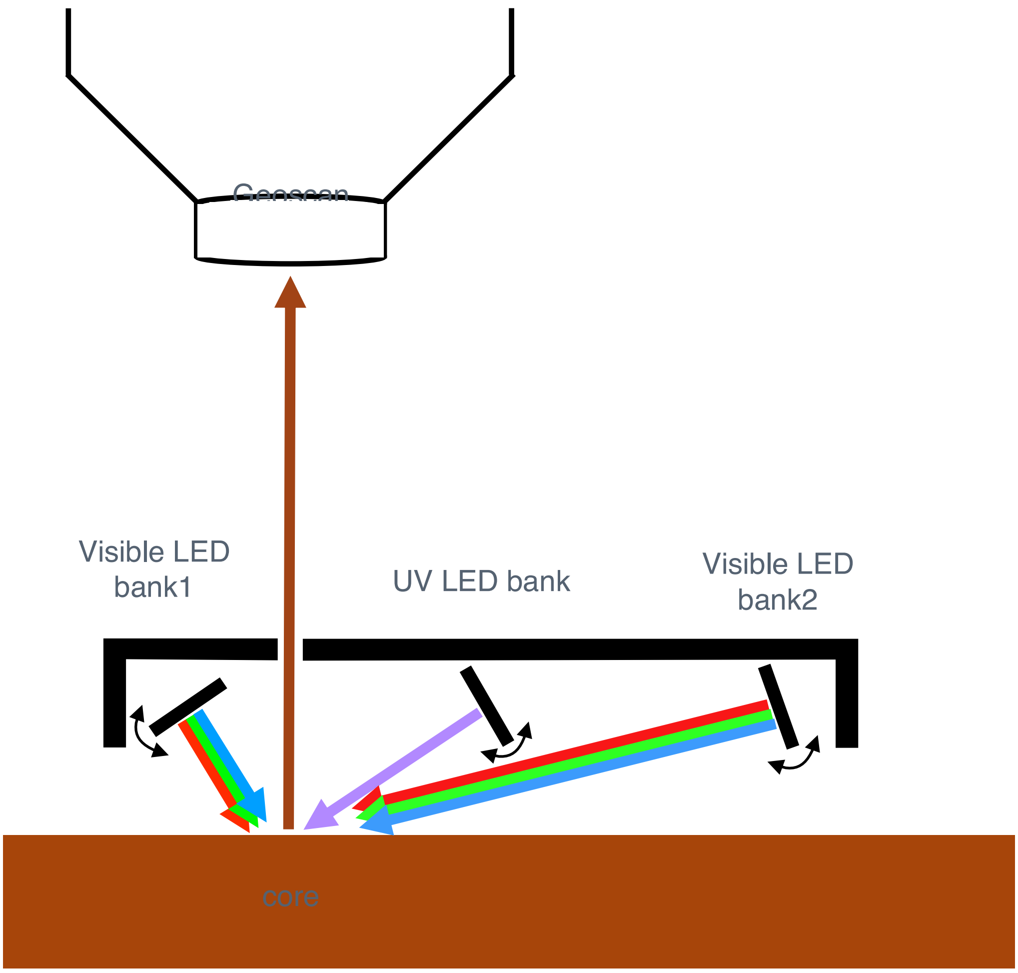


Figure 27: Diagram of Geotek combination UV/visible light source.

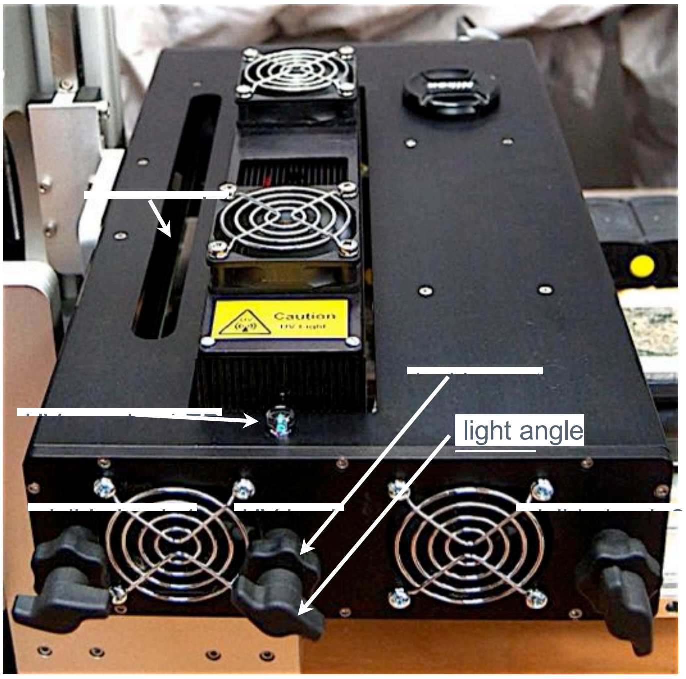


Figure 28: Picture of Geotek combination UV/visible light source as seen from the top.

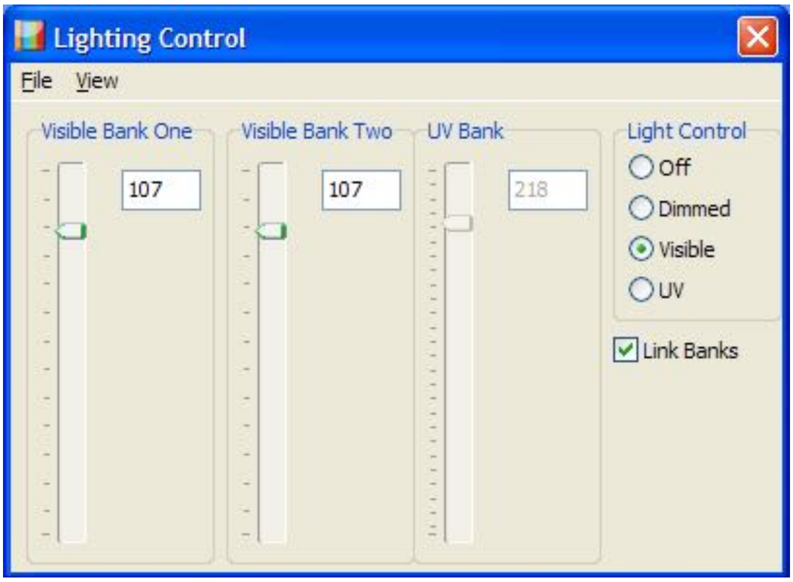


Figure 29: Simplified version of UV/visible light control.

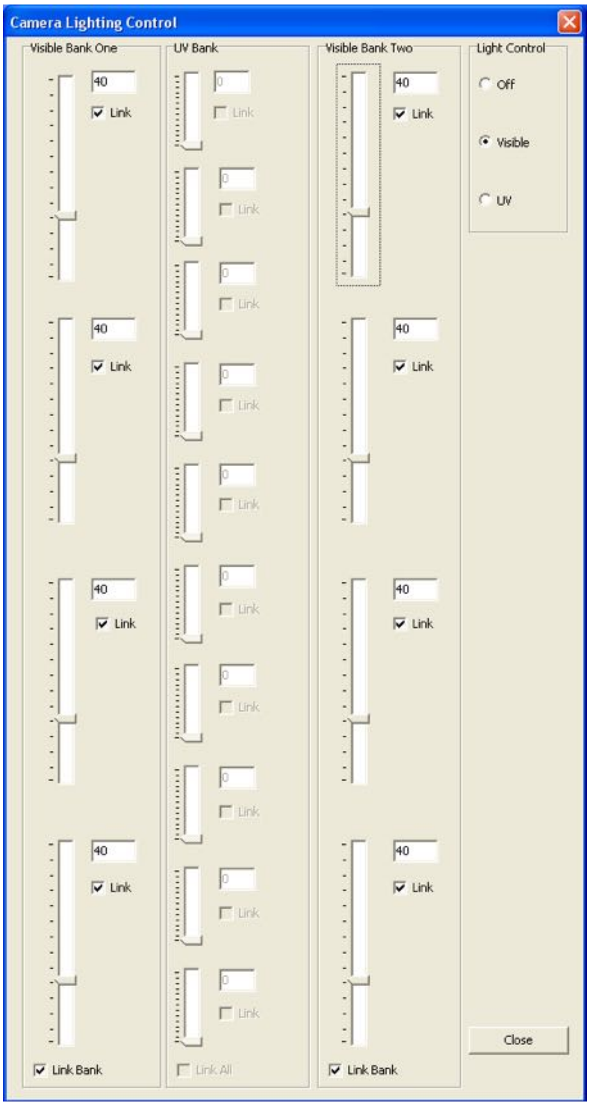


Figure 30. Geotek combination UV/visible light source control pane, showing intensity controls for groups of lights within banks. Light groups can be linked to one another so their intensities can be controlled together.

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.

	**DO NOT LOOK AT THE ULTRAVIOLET LIGHT SOURCE WITHOUT EYE PROTECTION!**

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 31. 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.

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.

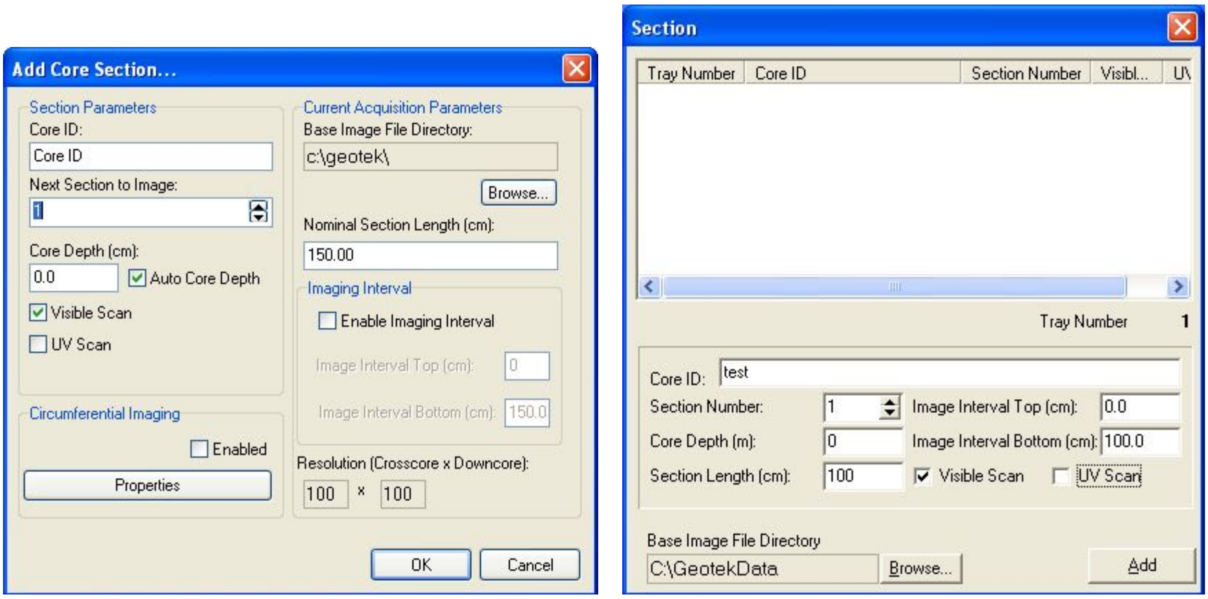


Figure 32. Add core section dialogue showing visible and UV checkboxes for the MSCL-S (left) and MSCL-XZ (right).

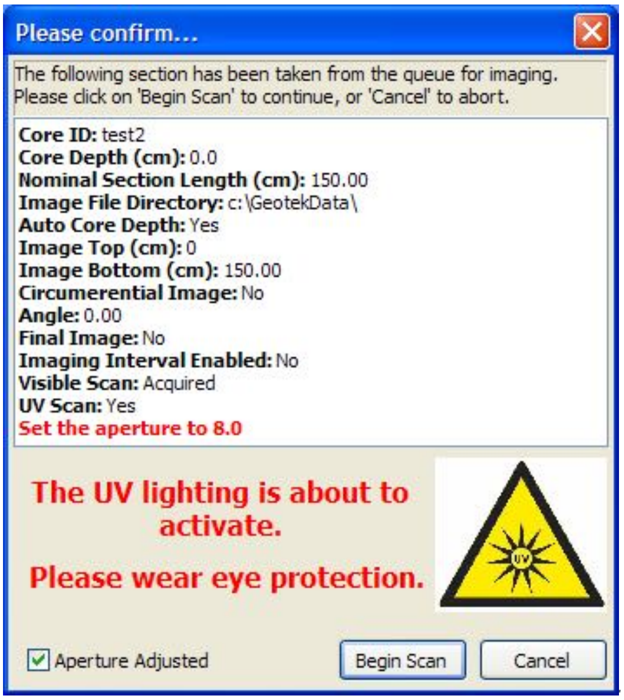


Figure 33. Prompt for user to change aperture and prepare for ultraviolet imaging.