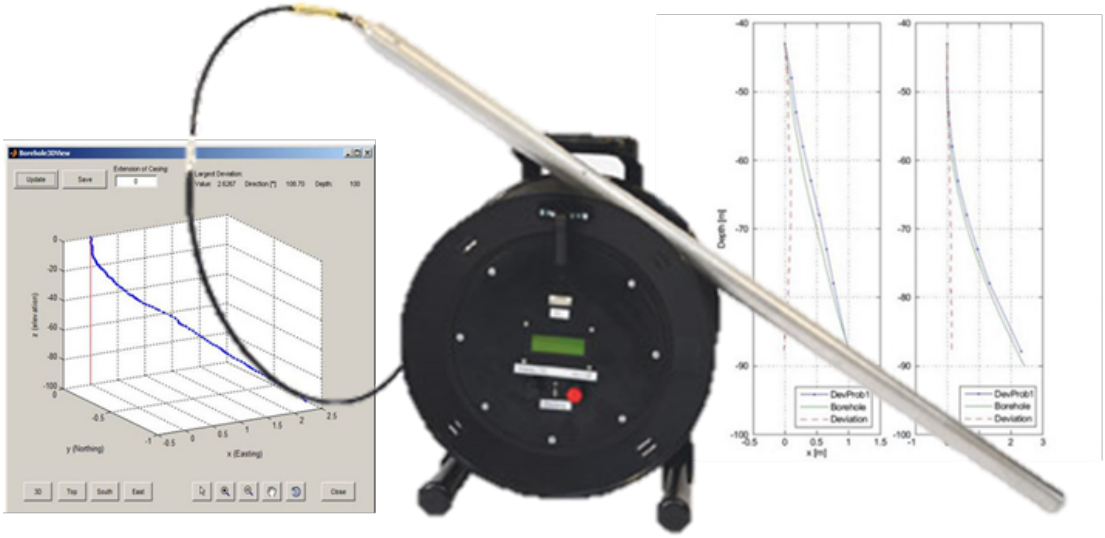
Deviation Probe -DevProbe1



Content

1. Introduction

In principle, boreholes should be drilled in a straight and perpendicular direction to carry out a cross-hole test. However, the drilling direction can be influenced by the drilling technique as well as the material properties of the subsurface (e.g. density and hardness of the formation), resulting in a drilling direction that varies with depth. As this deviation (or inclination) of a borehole from the vertical can strongly influence other measurement results that are based on the verticality of the borehole, the Measurement of the borehole deviation is essential for down-hole and cross-hole measurements.

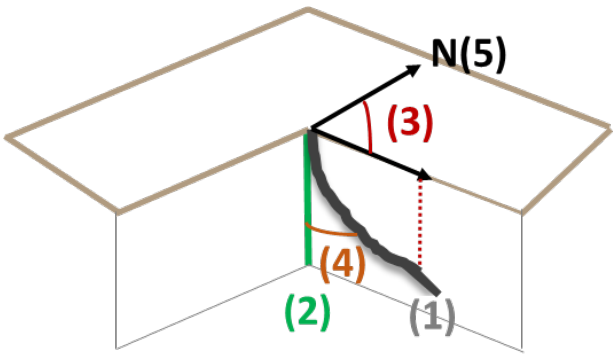
Drilling direction is needed where precise XYZ location of a downhole tool is required. The DevProbe1 borehole logging tool is designed to provide drilling deviation and inclination for numerous applications like seismic tomography and cross-hole testing. It is used to correct feature orientation and depth information recorded by other borehole geophysical logging tools.

The Deviation Probe DevProbe1 is used to measure the borehole deviation. A three-axis magnetometer measures the azimuthal direction of the borehole, and a dual tilt sensor provides information about the inclination. The DevProbe1 is sealed and temperature compensated. Borehole deviation is required to determine the precise XYZ location of a seismic source or geophone inside a borehole. Software is provided to visualize and store the deviation data (see Manual Deviation Logger Software Tool for DevProbe1).

1.1 Theory of borehole deviation

Borehole deviation logging continuously measures and records borehole inclination and direction (i.e., azimuth) with depth. Because inclination and direction vary mainly over the borehole length, borehole deviation is rarely consistent.

Inclination refers to the angle at which the borehole deviates from vertical. The inclination is usually measured in degrees and can range from 0° (vertical) to 90° (horizontal). The azimuth of a borehole is the angle between the vertical plane containing the borehole and the magnetic north direction, measured in degrees clockwise from north.

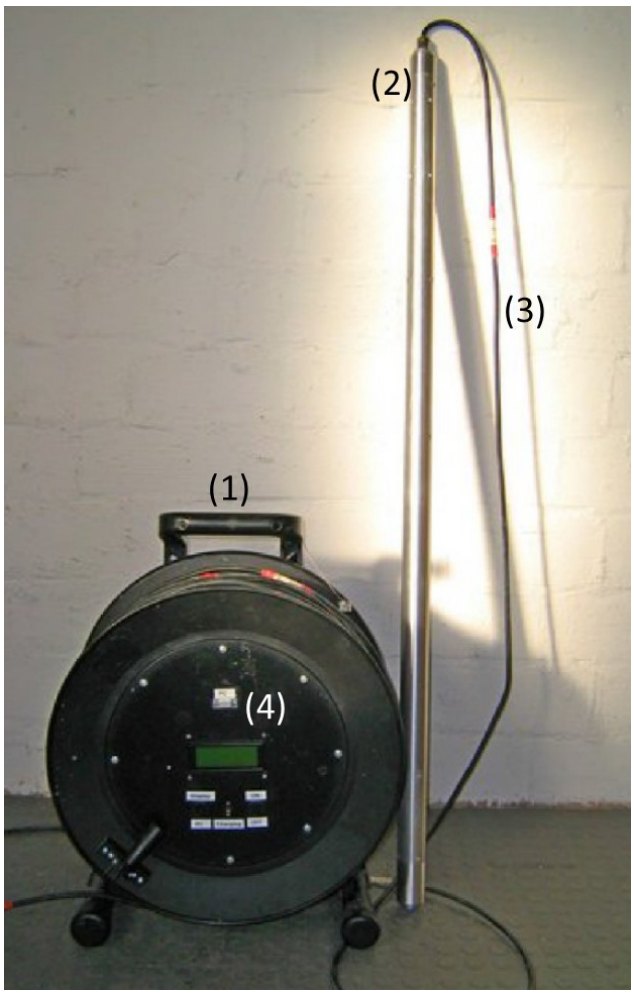


(1) Actual borehole path
(2) Vertical line (ideal borehole path)
(3) Azimuth
(4) Inclination
(5) Magnetic North Direction

Figure 1: Azimuth and Inclination of a true borehole path

2. Components of the DevProbe1

The borehole deviation probe DevProbe1 comes in a ruggedized hardcover case. The DevProbe1 consists of a downhole probe part and a cable drum with a connector (see Figure 2).



(1) Cable Drum with front panel and connector to probe with a maximum depth of 200m

(2) Probe with a length of 1235 mm, a diameter of 50 mm, and a weight of 3.45 kg

(3) Connecting Cable

(4) Front panel

Figure 2: Components of the DevProbe1

2.1 Probe

The Probe has a length of 1235 mm, a diameter of 40 mm, and a weight of 3.45 kg. A 3-axis magnetometer with a dual tilt sensor is housed inside the plastic body of the downhole probe.

The three-axis magnetometer is a type of sensor that is used to measure the strength and direction of a magnetic field in three dimensions. It is used to measure the azimuthal direction of the borehole. Dual tilt sensors typically use accelerometers or gyroscopes to measure changes in the orientation of an object in two dimensions which include both the pitch and roll of an object relative to the horizontal plane.

The inclination is measured in degrees ranging from 0° (vertical) to 90° (horizontal). The azimuth measures the angle between the vertical plane containing the borehole and the magnetic north direction in degrees clockwise from the North.

The deviation probe itself is made up of two aluminium rods. These have to be screwed together before the survey starts. The lower part acts as a stabiliser for the probe to give it weight and keep it vertical. Another function of the lower part of the probe is the extension of the probe to a length of approximately 1.2 m to assist in the accuracy of the inclination. The upper part of the probe contains the deviation sensor, the connection cable and plug, and the shock indicator.

The shock indicator is placed in the lower section of the upper probe part right above the thread and indicates if the probe undergoes an external mechanical shock during operation or transportation. The shock indicator is white in general. Once it turns completely **red** it indicates an external shock. In this case warranty expires as the sensor might get damaged due to hard handling or wrong transportation. Anyhow, it is most likely that the probe will still work and readings will be taken properly but we recommend a return to our manufacturing office in this case upon your convenience.

2.2 Cable Drum

A 20 cm spiral cable links the magnetometer probe to the cable connector. The cable weighs 62 g per m.

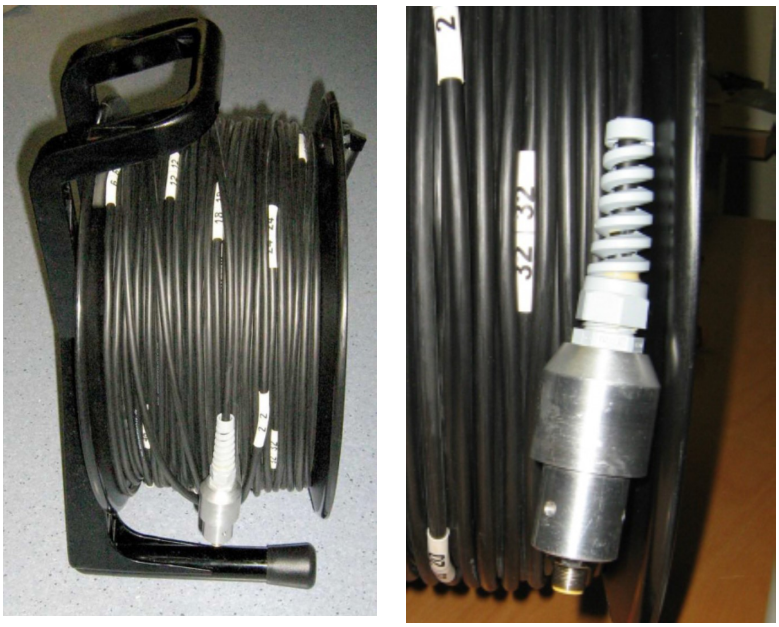


Figure 3: Cable drum with probe head and socket

2.3 Front panel

The front panel is on the cable drum. This front panel helps to keep the cable organized and prevents it from becoming tangled or twisted, serve as an extra layer of protection for the cable and ensure safety. The front panel can be labelled to identify the type of cable or its intended use.

The front panel at the DevProbe1 includes labels for a RS232 connection to the PC **(1),** one label for a button to switch between display on the fron panel or the PC **(2),** the label of the red ‘ON/OFF’ button **(3)** and the label for the connection for the battery charger **(4).**

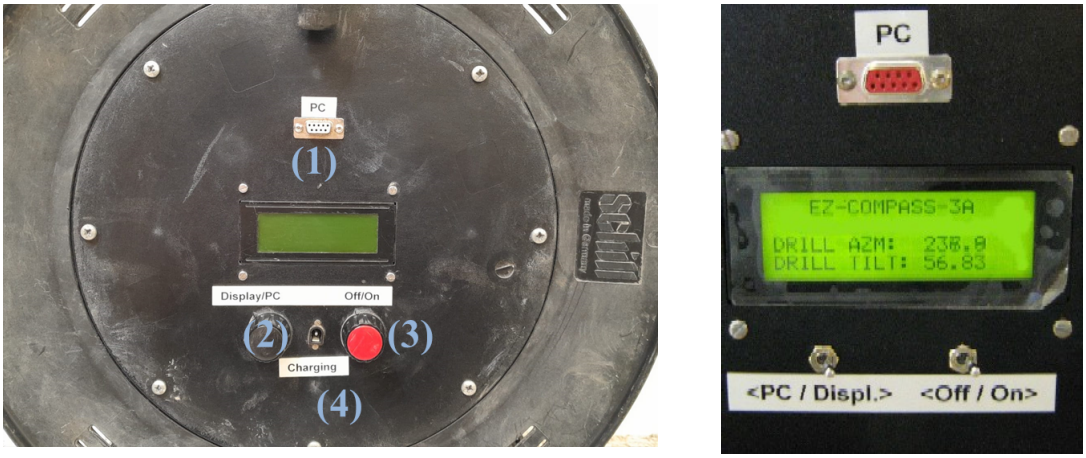


Figure 4: Front Panel

2.4 Battery charger

The battery charger supplied is designed for the 230V system. Please connect the charger to 'CHARGING'connection at the front panel.

The charge status of the internal battery can not be viewed. You have to check the charging status of the batteries using other devices.

It will take about one hour to charge the internal battery fully.

Please pay attention that during charging, no measurements are possible.

Figure 5: Battery charger

3. Operation

3.1 Special consideration

Handle the probe with extreme care. Do not hit or shock the probe.

This will damage the internal sensor !

The shock indicator is placed in the lower section of the upper probe part right above the thread and indicates when the probe has been subjected to an external mechanical shock during operation or transport. The shock indicator is normally white. If it turns completely **red**, it indicates an external shock. This will invalidate the warranty as the sensor may be damaged by rough handling or incorrect transport. In any case, it is likely that the probe will still work and give correct readings, but we recommend that you return it to our factory at your convenience.

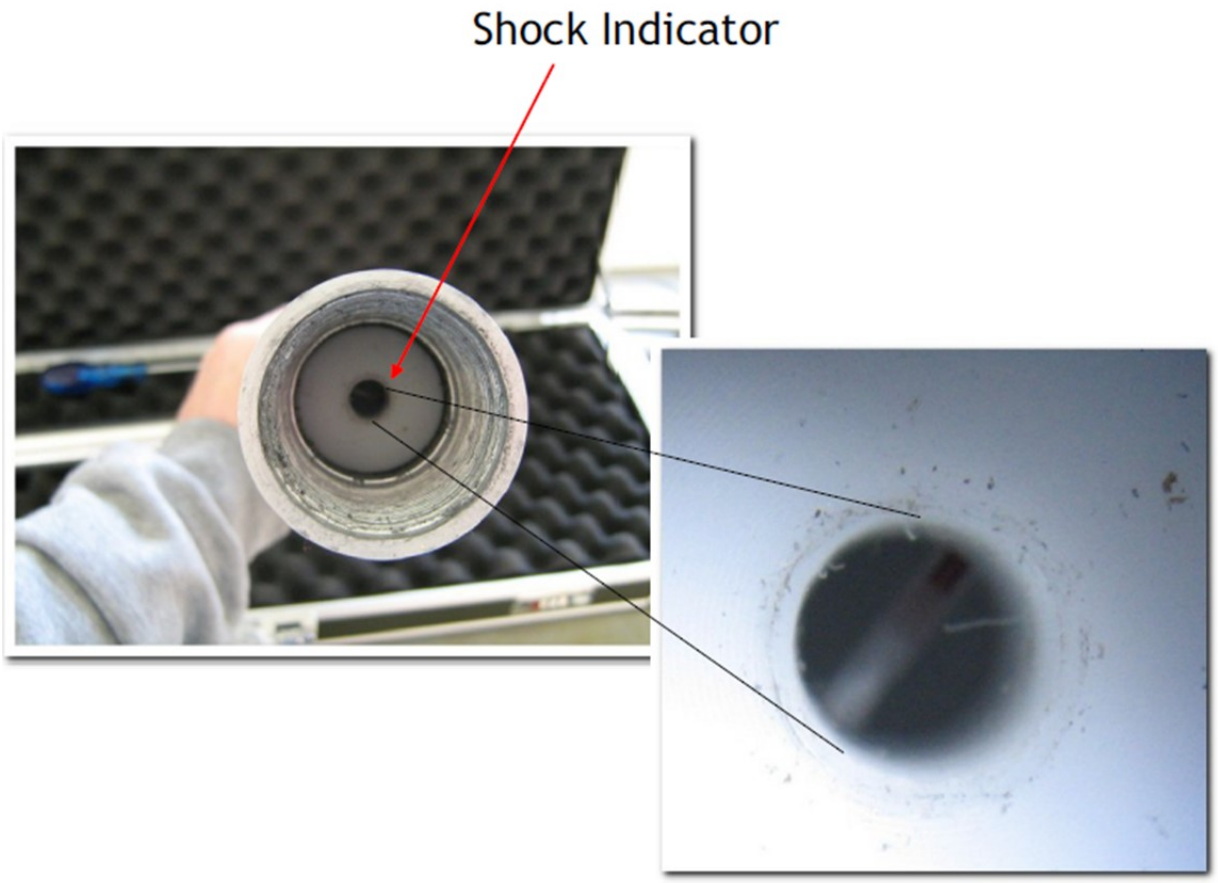


*Figure 6 . Shock indicator is normally white, **red** indicates an external shock*

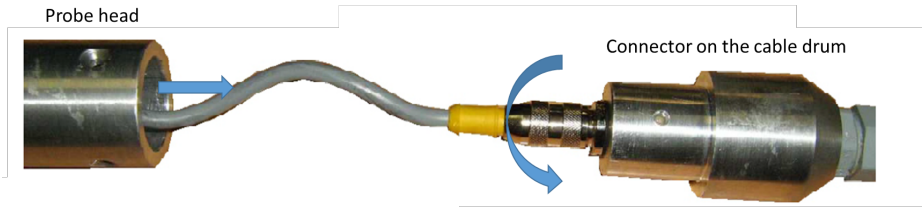
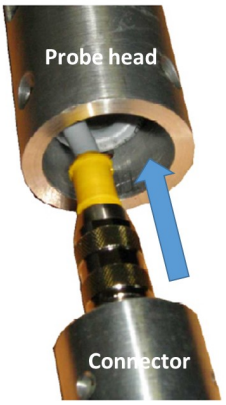
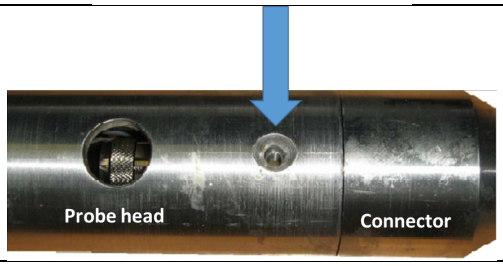
3.2 Battery Charging

- Disconnect the probe first!
- Use battery charger. It takes one hour for full charge.

- Connect the battery charger ‘CHARGING’connection at the front panel.
- No surveying while charging.
- The fully charged probe operates for approximately 6 hours.

3.3 Steps of operation

3.3.1 Setup

1	**Connect cable and connector** -Open the probe head -Connect the cable to the connector on the cable drum	 
2	**Push back cable**	
3	**Screw in connector tightly**	

4	**Switch the device ON at the Front panel on the drum**		
5	**Switch to Display and read values or use software to store data**		

3.3.2 Tilt Calibration

It is recommended to put tilt to zero before each borehole deviation measurement. This is done in an absolutely perfect vertical position.

- To calibrate the tilt, the drum (connection at the front panel) must be connected to the field PC, and the **Deviation logger Software** needs to be started (*see Chapter 5)*
- Please lower the entire borehole deviation probe in the borehole so that it hangs freely. Depth does not really matter, but a minimum of 1m is recommended.

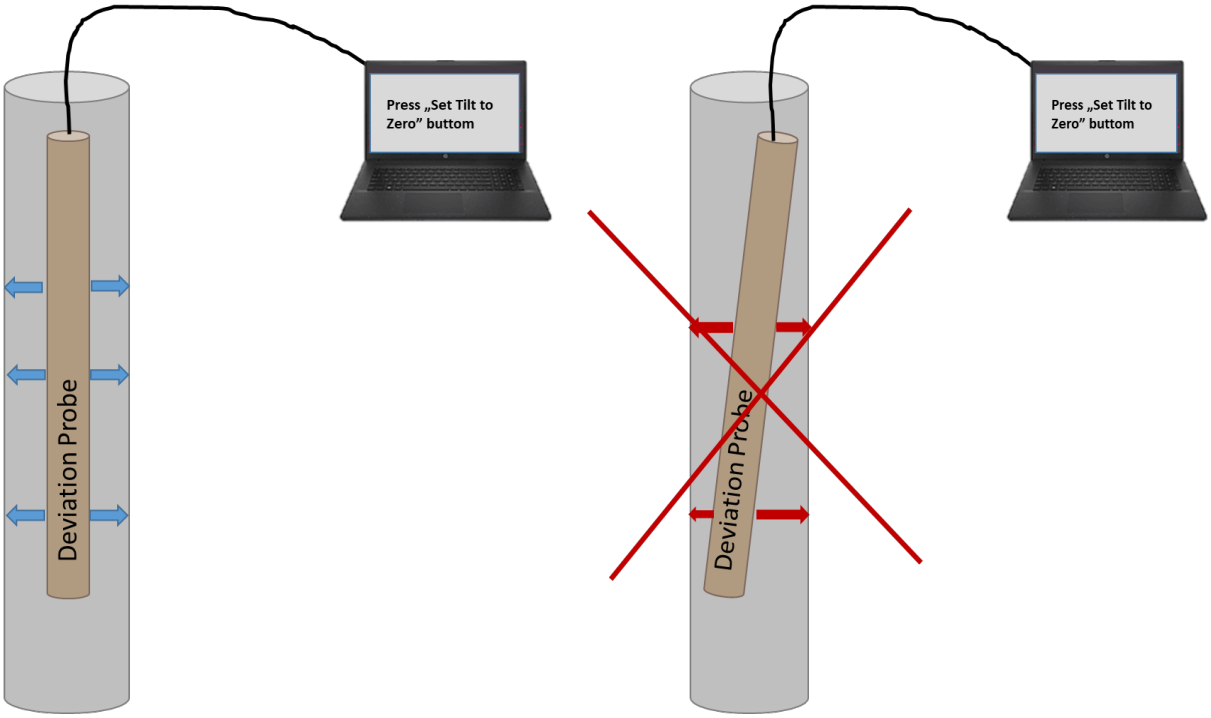


Figure 7: left) correct probe position and right) incorrect probe position for tilt calibration

- If the value of the current tilt reading is almost steady and higher than approximately 0.1°, the tilt sensor should be set to ZERO (0) using the "set Tilt to Zero" button in the software. If this is done, the tilt reading should be randomly around 0.01°.

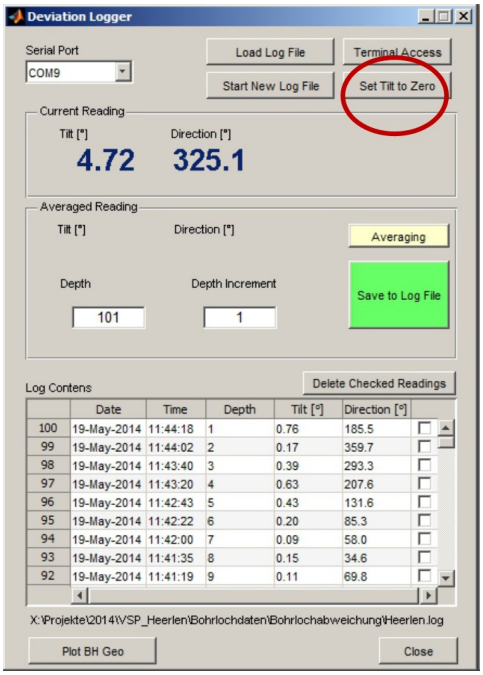


Figure 8: Deviation logger Software and the "Set Tilt to Zero" button

3.3.3 Handling instruction

- Only pull carefully probe using the cable.
- We recommend to measure the borehole deviation every 1-2 m.
- Handle the probe with extreme care. Do not hit or shock the probe which leads to a broken tilt sensor. **The warrenty does not apply for such improper handling.** However, we recommend that you return it to our factory at your convenience to ensure quality data.

3.3.4 Estimation of Depth

To measure the **depth**, attach a measuring tape to the cable ! Reference point is the mid of probe.

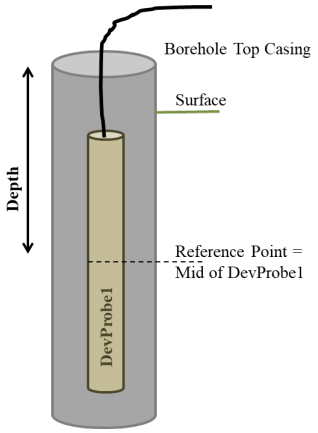


Figure 9: Reference point for depth estimation

3.3.5 Measurement of borehole deviation using the software

- Connect the drum (connection at the front panel) to the field PC, and start the **Deviation logger Software** (*see Chapter 5*).
- Select the correct serial port (COM) **(1)**.
- Create a new log file using the 'Start New Log File' button **(2)** or open an existing file using the 'Load Log File' button **(3)**. In the case of an existing file, the new measured values will be added to the old data, which will remain unchanged.
- Calibrate the tilt following the steps in Chapter 3.3.2 **(4)** if necessary.
- Enter the starting probe depth in the 'Depth' field **(6)**. The value entered in the 'Depth Increment' field **(7)** will be added to the value in the 'Depth' field when the reading of a certain depth is completed. Note that the depth value will automatically jump to the next measurement depth after storing a dataset according to the value in the Depth Increment field.
- Start data acquisition by pressing the "Averaging" button **(5)**. The current data values are averaged and displayed as long as the button is pressed.
- As soon as the averaged values are almost stable, they can be saved to the log file by pressing the green "Save to Log File" button **(8)**.
- Erroneous data lines can be deleted by checking the line in the last column of the table and pushing “Delete Checked Readings” button **(9)**.
- The content of the log file is shown in the table at the bottom of the program window **(10)**.

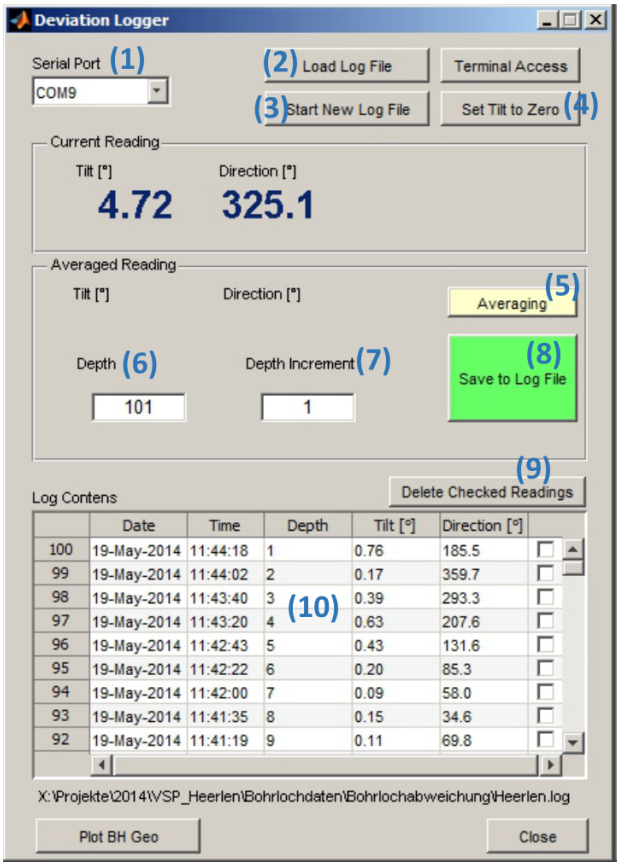


Figure 10: Deviation logger Software buttons

4. Probe Maintainance

4.1 Exchange of batteries

Use AA rechargeable batteries with 1,2V.

4.2 Greasing of the O-Ring

Grease the o-rings before survey.

4.3 Checking the shock indicator

The shock indicator indicates if the probe undergoes an external mechanical shock during operation or transportation. The shock indicator is white in general. Once it turns completely **red** it indicates an external shock.

In this case warranty expires as the sensor might get damaged to hard handling or wrong transportation. Anyhow, it is most likely that the probe will still work and readings will be taken properly but we recommend a return to our manufacturing office in this case upon your convenience. Please see chapter 3.1 for more details.

5. Deviation Logger Software Tool for DevProbe1

The Deviation Logger software, when used with the DevProbe1 borehole probe, allows the user to perform semi-automated borehole deviation measurements. The readings of tilt and direction angles can be recorded on a notebook computer running Microsoft Windows (tested on XP and Windows 7). A serial connection is made between the computer and the borehole probe. The depth of the deviation probe is still a manual measurement.
In addition to the software supported method of logging, the user can perform a manual measurement by manually copying tilt and direction values from the display of the deviation probe. Manual measurement does not require a computer at the test site.

5.1 Installation and start of software

The installation of the software requires the following steps:

(1) Install the driver software for the USB-to-serial adapter used to connect the DevProbe1 to the computer. Please follow the adapter manufacturer's instructions. If the driver is not included in the standard Windows installation, it will be provided on a separate disc. Driver software for some types of adapter can also be found in the "WinDriver_SerialToUSB_Adapter" folder on the USB flash drive containing this manual.
(2) The Deviation Logger software requires Microsoft .NET Framework 3.5 (or higher) to be installed. Windows 7 always includes this runtime environment. In the case of Windows XP and Vista, the user may need to download the .NET Framework 3.5 from the Microsoft website and install it manually. (You can check which version of the .NET framework is already installed by going to Control Panel >Add or Remove Programs).
(3) Install a Matlab runtime environment for the Deviation Logger software. This environment can be installed by running the supplied "MCRInstaller.exe". (supplied on CD or USB stick)
(4) Copy "DevLogger.exe", "LaunchDevLogger.exe" and "putty.exe" to a directory of your choice.
(5) Run LaunchDevLogger.exe to start the software. It is recommended that you create a shortcut to the file on the desktop or in the Program Files folder for ease of use.
(6) If the splash screen of the Deviation Logger software appears but the actual program does not, please install the Microsoft Visual C++ 2005 Redistributable Package. The installer for this package "vcredist_x86.exe" can be found on the USB stick or is available on request from Geotomographie GmbH.

5.2 Recording of borehole deviation data

The first step is to connect the DevProbe1 to the computer using the supplied USB to serial adapter. Please note that the USB driver must be installed before connecting to the computer. If this is the first time you are connecting, wait until Windows is ready. Sometimes Windows may also need to be restarted/re-booted. The USB-side of the adapter fits into a USB port of the computer. The serial (D-Sub) connector must be plugged into the socket in the cable drum of the DevProbe1. The switches on the drum should be set to 'ON' and 'PC'.

Before starting the software, it is recommended that you determine the number of the virtual serial port (COM port) that the USB-to-serial adapter driver has created. This can be done using the Device

Manager in Windows 10 (*In the search box on the taskbar, type **Device Manager**, then select from the menu*) while the adapter is connected to the computer. An example is shown in Figure 11.

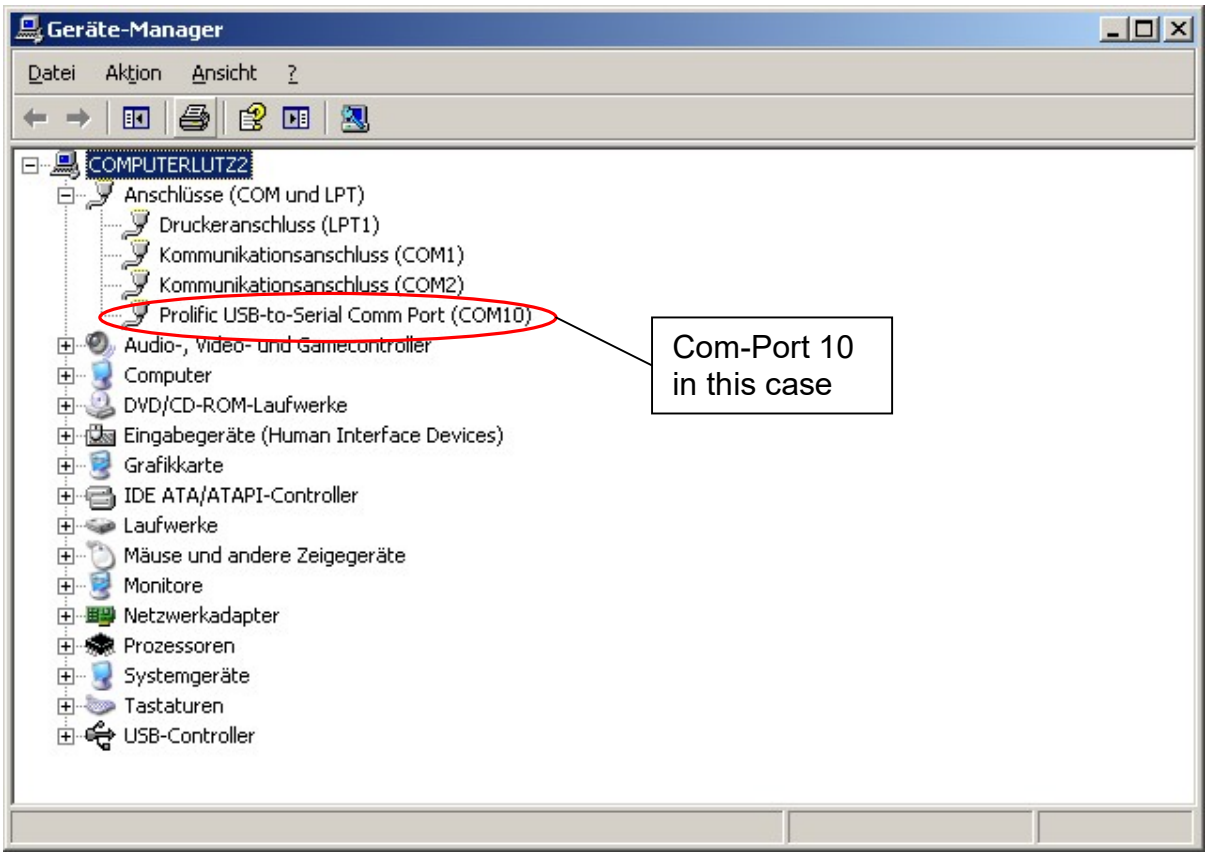


Figure 11: Generated virtual serial interface in Windows Device Manager

The logger software can be started by running "**LaunchDevLogger.exe**". Figure 12 shows the Deviation Logger interface.

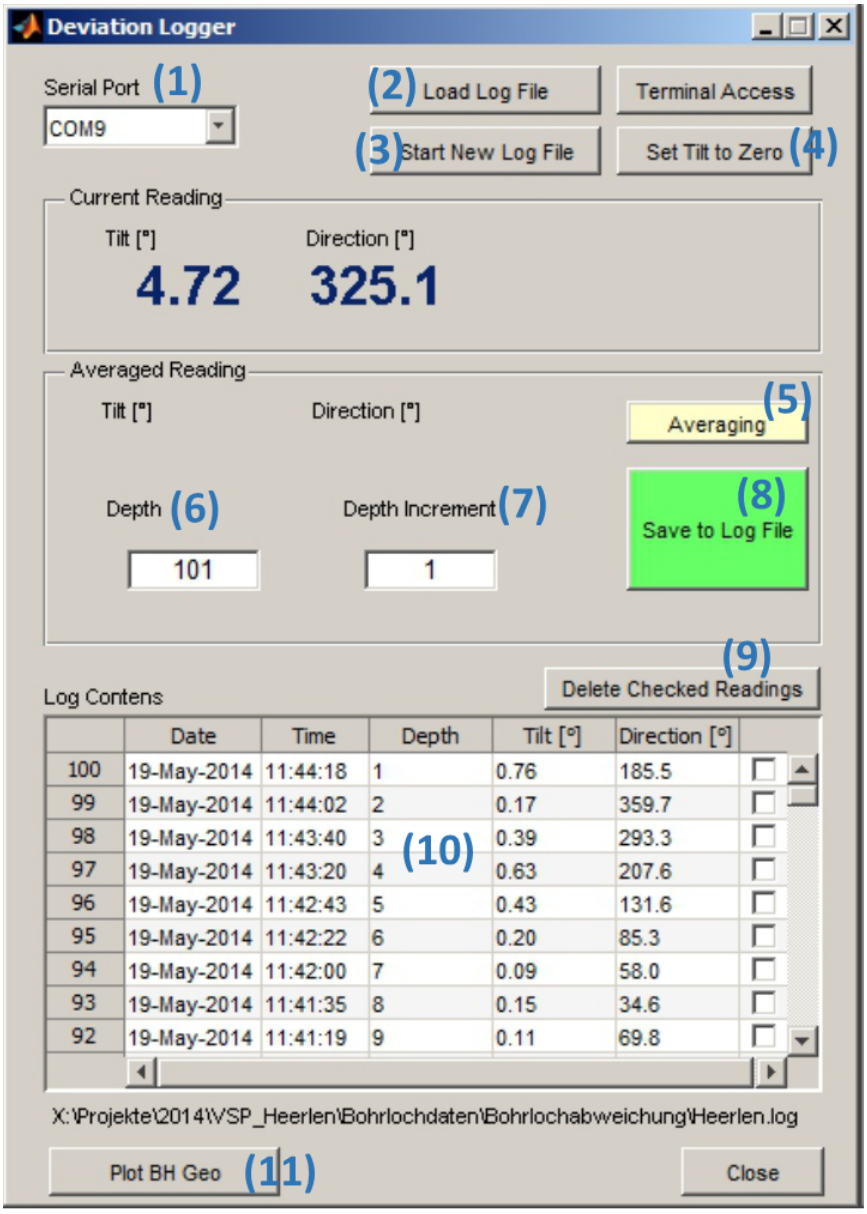


Figure 12: User interface of Deviation Logger software

- After selecting the correct **COM port** (1), the software will **connect to DevProbe1**. If the connection can be established the current values of tilt and direction angle are displayed and continuously updated. If the wrong port is selected or the connection is lost, an error message will be displayed.

- Tilt and direction readings can be recorded into an ASCII file with “log” extension. Create a new **log file** using the 'Start New Log File' button (3) or open an existing file using the 'Load Log File' button (2). If an existing file has been opened, its contents will be displayed in the table at the bottom of the program window. New readings are added to the old data. Old data remains unchanged.

- Enter the **starting probe depth** in the 'Depth' field (6) for depth recording. The value entered in the 'Depth Increment' field (7) is added to the value in the 'Depth' field (6) when the reading of a certain depth is completed. Only the value displayed in the Depth field will be recorded.

This means that if the reading points are not evenly spaced, the depths can be assigned individually for each point by manually entering the depth of each point.

- Readings will typically vary slightly. Averaging is used to estimate stable direction and pitch values. To start collecting data, press the 'Averaging' button **(5)**. The current data values will be averaged and displayed for as long as the button is pressed.

- As soon as the averaged values are almost stable, they can be stored in the log file by pressing the green "Save to Log File" button **(8)**. You can also stop averaging by releasing the 'Averaging' button **(5)** and then pressing the green "Save to Log File" button **(8)**. This may give a better control of the stored values. Note that the depth value automatically jumps to the next measurement depth **(6)** after a data set has been saved, according to the value in the Depth Increment field **(7).**

- The contents of the log file are shown in the table at the bottom of the program window **(10)**.

- Erroneous lines of data can be deleted by marking the line in the last column of the table and pressing the "Delete Checked Readings" button **(9)**.

- If an error message about a lost connection appears, check the physical connection and select the COM port again in the "Serial Port" menu **(1)**. Reselecting the COM port will close the open connection and re-establish it. This procedure will also help with occasional communication errors between the Deviation Logger and DevProbe1.

5.3 Calculation of borehole deviation

The borehole deviation in terms of x (Easting), y (Northing) and z (Elevation) can be calculated based on the logged values of tilt and deviation.

After pressing the "Plot BH Geo" button **(11)** the borehole geometry is displayed. Several options are available at the bottom of the window to rotate and zoom the 3D display.

- The origin of the coordinate system can be moved along the borehole if the value for the "Extension of Casing" is different from 0. This is particularly useful if the tilt and direction values are recorded with reference to the top of the casing but the deviation needs to be calculated with reference to the surface level.
- The "Update"-Button redraws the figure with the current number of readings and the actual value given in the "Extension of Casing" field.
- The numerical values of the deviation can be exported to an ASCII-file by using the Save button.

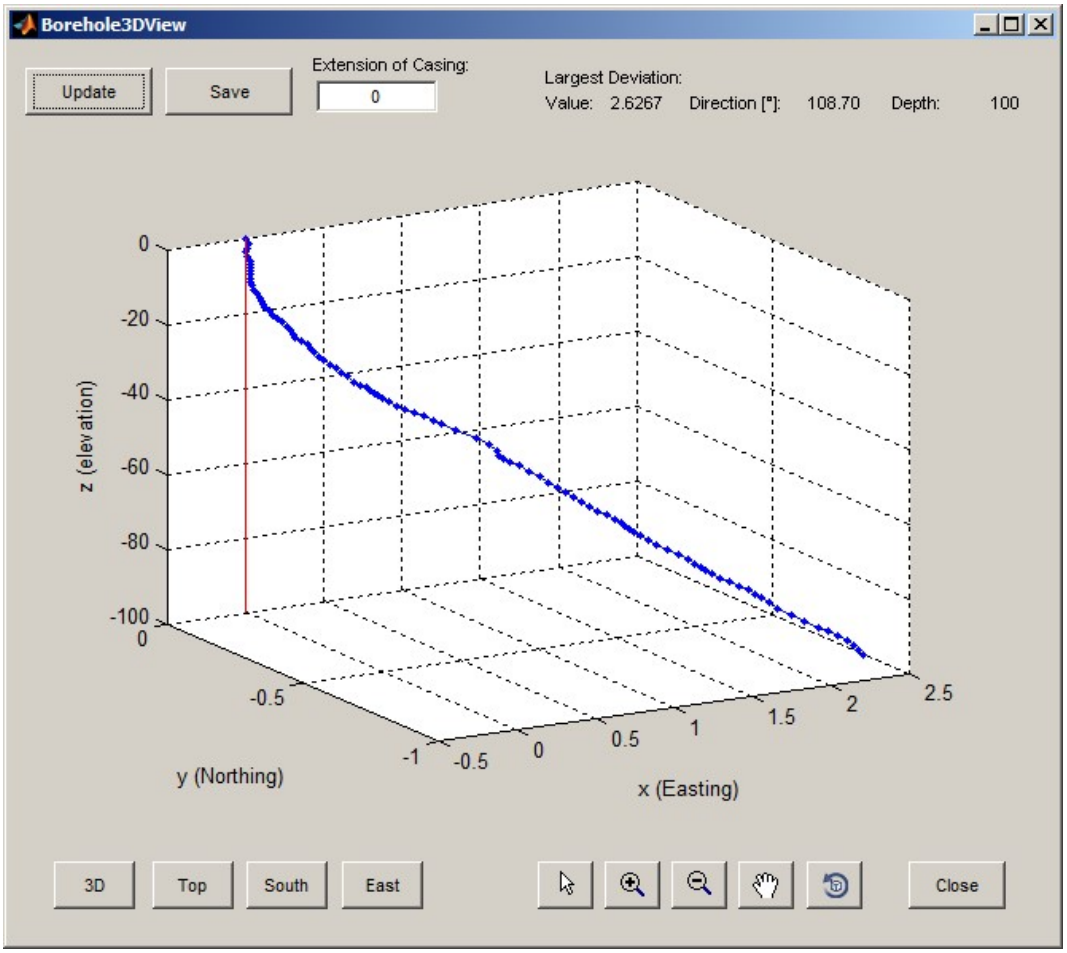


Figure 13: 3D view of the borehole deviation

5.4 Reset of tilt value

It is recommended to calibrate tilt to zero before each borehole deviation measurement. This is done in an absolutely perfect vertical position. **Please see chapter 3.3.2.**

Please use the 'Set Tilt to Zero' button to calibrate the tilt following the instructions.

5.5 Advanced control of the DevProbe1 using a terminal connection

Certain settings of the DevProbe1 can only be accessed using a terminal programme only. Such a terminal connection is established using the “Terminal Access” button. This interface is used to send commands to the DevProbe1 for debugging and calibration purposes only.

Please don't send any commands to the DevProbe1 other than the “**Hardiron Calibration**” commands described below until you are sure of their meaning or until you are instructed to do so by Geotomographie GmbH.

5.6 Hard Iron Calibration

The DevProbe1 borehole probe contains a 3-axis earth magnetic field sensor. The readings from this sensor are used to calculate the direction of the probe relative to North. Metallic components of the probe housing tend to affect the magnetic field readings. This is compensated for by what is known as 'hard iron calibration'. The calibration is performed before the probe is delivered. However, if the user

notices unreasonable directional readings, the calibration should be repeated using a terminal program such as the one included in the Deviation Logger software. The user must carry out the following steps:

1. Place the probe in an almost vertical position.
2. Establish a terminal connection to the DevProbe1 using either by the Deviation Logger software (“Terminal Access” button) or another terminal program (e.g. HyperTerminal in Windows XP).
3. Stop the continuous output of the data stream by sending “h” or “Esc”.
4. Type “HARDIRON CAL” and hit [Enter]. The magnetic field sensor values are displayed.
5. Slowly rotate the DevProbe1 at least one full turn for approximately 1 to 2 minutes while it collects the surrounding magnetic field. Keep the DevProbe1 as vertical as possible as it rotates. The computer will display four data lists. Continue to rotate until no new points are printed. When finished, press any key to stop the calibration. The computer will display four correction coefficients.
6. To activate the hard iron calibration, enter "HARDIRON ON" and press [Enter].

7. Visualisation borehole deviation

A excel sheet will be also provided by Geotomographie GmbH.

Borehole Deviation Sheet

Depth	Probe Readings		Deviation		TVD	Coordinates		
	A	D	East	North		East	North	Elevation
[m]	[°]	[°]	[m]	[m]	[m]	[m]	[m]	[m]
0	-	-	0.000	0.000	0.000	*5071.713*	*8976.303*	*2.858*
1	8.00	102.6	0.136	-0.030	-0.990	5071.849	8976.273	1.868
5	0.50	324.7	0.116	-0.002	-4.990	5071.829	8976.301	-2.132
10	0.40	161.3	0.127	-0.035	-9.990	5071.840	8976.268	-7.132
15	0.20	225.7	0.114	-0.047	-14.990	5071.827	8976.256	-12.132
20	0.70	210.5	0.083	-0.100	-19.990	5071.796	8976.203	-17.132
25	0.70	80.3	0.144	-0.089	-24.989	5071.857	8976.214	-22.131
30	0.70	134.3	0.187	-0.132	-29.989	5071.900	8976.171	-27.131

Figure 14: Excel sheet to visualize the borehole deviation

TVD is true vertical depth (calculated). Depth and TVD are with reference to the top of casing. The coordinates of the top point should be given in UTM coordinates (**East** [m], **North** [m]). The elevation refers to the top casing. You can use a coordinates converter tool to convert your coordinates to the requested format (https://coordinates-converter.com/en).

Only change values within the yellow fields:

- **A:** Deviation from vertical = Tilt
- **D:** Borehole direction = direction/inclination

You can copy the measured tilt and inclination parameters from the software.

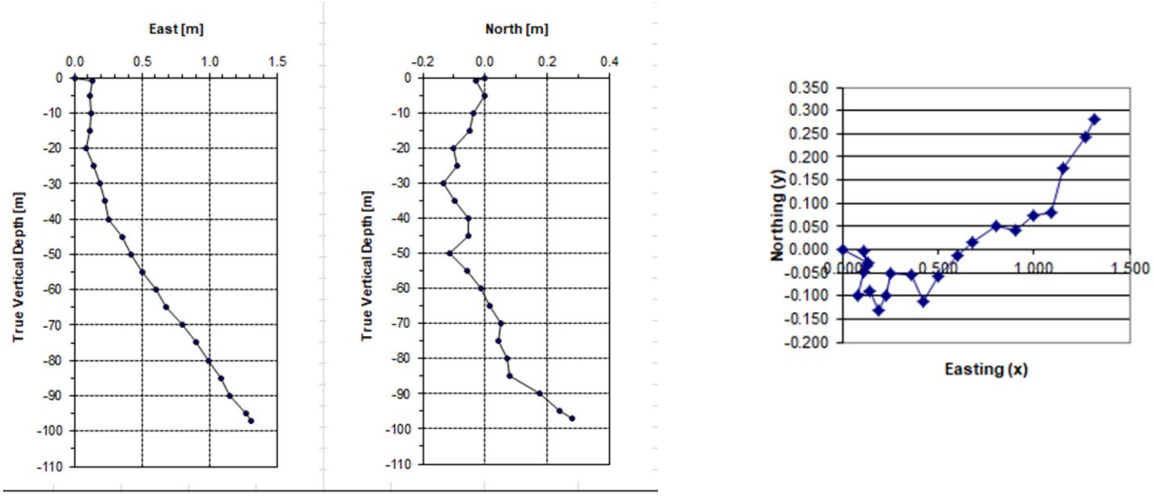


Figure 15: Visualization of borehole deviation