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THE DIRECTIONAL GAMMA-TOOL – MORE INFORMATION FROM SMALL DIAMETER BOREHOLES

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(10 figures)

ABSTRACT. Many boreholes are drilled into coal seams for purposes such as water injection and degasification. Until now, in a gaseous environment, these generally small diameter holes could not be logged geophysically and, hence, not be used as sources of information regarding seam structure and structural features. In an R & D-project, the "Directional Gamma-Tool" has been developed. In order to take care of the particular conditions in holes sub-parallel to the bedding, two detectors are recording simultaneously the natural gamma radiation independently from two directions, top and bottom. Another important part of the tool is the built-in orientation system. The tool works self-sufficient and is intrinsically safe.
In 2001, several test measurements of up to 100 m have been performed, particularly in multi-layered coal seams. The results showed the complexity of the interpretation of the parallel gamma curves due to geological variations in combination with the geometrical situation. Just recently, three boreholes have been logged in the Prosper Haniel Mine/Germany in order to determine the optimal position for a rise heading in a structurally and technically difficult situation. Driving the heading was accompanied by continuous logging of the faces. This allowed a very accurate comparison of logging curves, interpretation, and actual geology.

Keywords: Coal, borehole, geophysics, logging, gamma radiation, orientation.

1. Introduction

In the forefield of coal mining activities, many auger boreholes are drilled into coal seams for the purpose of injection of water or for degasification. So far, for underground use, no approved logging technique existed, neither for description of the borehole course nor for measuring physical parameters to describe the rocks surrounding the borehole (Lehmann *et al.*, 1998). Information about these rocks could only be obtained when an experienced drilling crew recorded the drilling progress and described the drill cuttings.

In the frame of a research programme, the development of the so-called Directional Gamma-Shuttle was supported by the State of North Rhine-Westphalia. This tool can be run in small diameter boreholes (generally 50 to 58 mm) with two detectors measuring simultaneously the gamma radiation from the strata above and below. The tool works self-sufficient and is certified for underground use in Germany. An important component of the tool is the built-in orientation measuring system aimed at determining the position of the tool within the borehole and at the calculation of the course of the borehole.

Slimhole tools, as they are used in the oil and gas industry, are not suitable for applications in coal mines and require boreholes of at least 10 cm (4") (Prensky, 1994).

2. General concept

2.1. Geophysical method

Figure 1 shows a section through one directional gamma detector. The directional gamma-tool has two gamma detectors (NaI scintillation counters), each of which is shielded by tungsten on one side. The reach of the gamma radiation lies in the range of some ten centimetres, depending on the density of the rock material. The club shaped sphere of influence of the gamma radiation

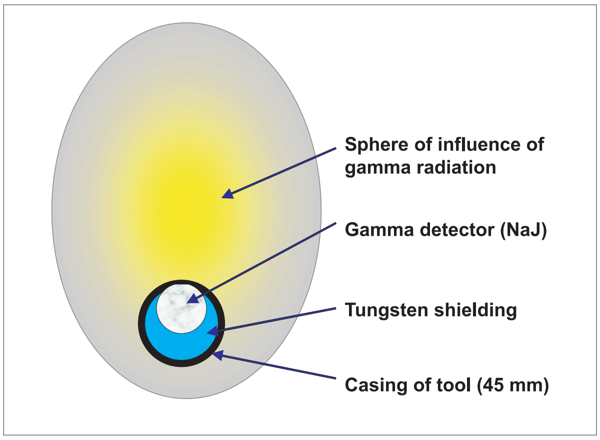

Figure 1. Section through directional gamma detector.

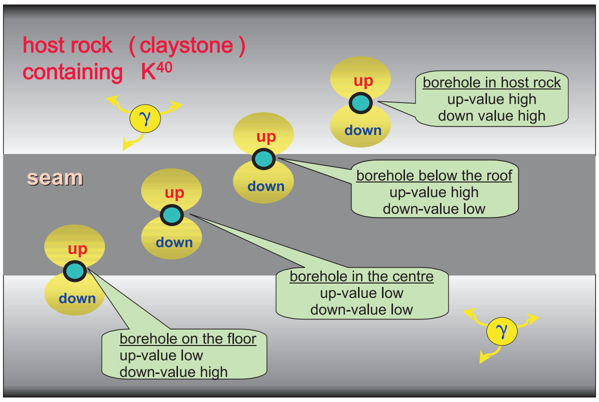

Figure 2. Section through Directional Gamma-Shuttle in different positions relative to the seam.

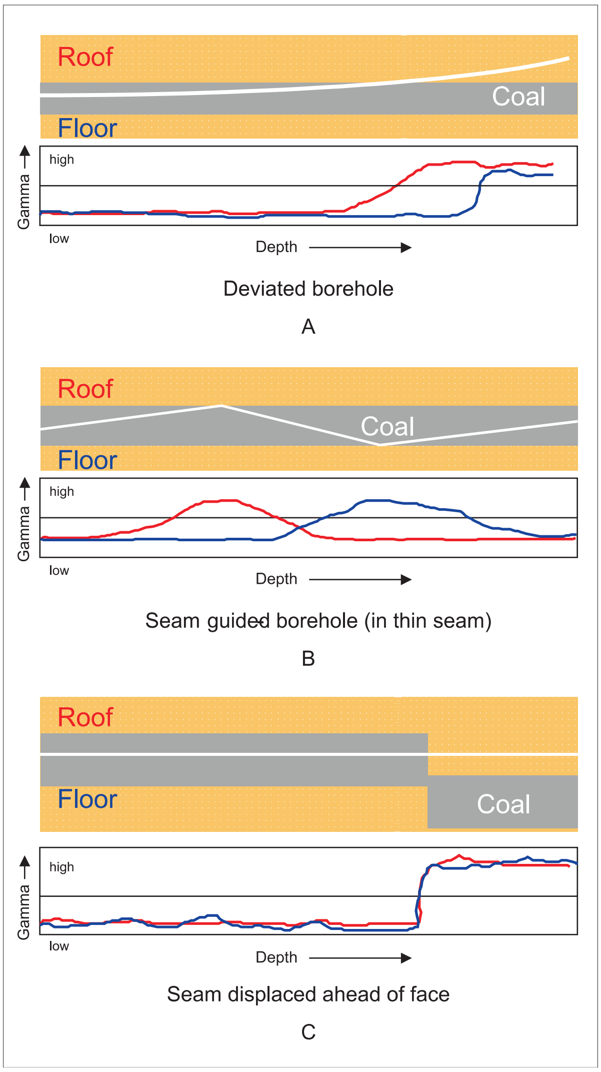

Figure 3. Exemplary situations and measuring curves: A. Deviated borehole B. Seam-guided borehole C. Seam displaced ahead of face.

is also sketched in Figure 1. Generally, gamma radiation is low in coal seams and high in the clayey immediate roof and floor strata of coal seams (Lehmann *et al.*, 1998; Schmitz, 1983).

In a horizontal or slightly inclined borehole, the tools adapts a preferential roll position, causing that one gamma detector is always directed upwards and the other one downwards. Relative to the seam, the tool can take four principal positions, as illustrated in Figure 2. At the seam bottom, the downward value is expected to be high, the upward value to be low. In the centre of the seam, both values will be low. Below the seam roof, the downward value will still be low, while the upward value is already high. Finally, while the borehole runs completely in the host rock, both gamma values will reflect the higher radiation of the rock.

The following theoretical examples display possible situations of the borehole and their influence on the two gamma curves (Fig. 3A-C).

If a borehole crosses the boundary between the seam and the roof rock, either due to deviation or inclination of the seam, the red line of the upward measurement increases prior to the blue line of the downward measurement. In a seam guided borehole, the tool may just touch the roof or the floor rock resulting in a one-sided increase of the gamma counts. Finally, both curves will jump up simultaneously when a seam-parallel borehole crosses a fault and runs into host rock beyond the fault (Hinz *et al.*, 2002).

2.2. Construction and operation of the tool

The tool has a total length of 186 cm and a diameter of 45 mm. For practicability reasons, it consists of two segments (Fig. 4), which are screwed together underground for the measurement. The pendulum segment is 66 cm long and contains semicircular swinging tungsten weights. These weights create a centre of gravity and provide for the positioning of the tool with it's face position (rolling angle) aligned with the z-component when being induced into a horizontal borehole. Thus, upward and downward positioning of the two gamma detectors is ensured.

The sonde segment , which is 120 cm long, contains the detectors and the electronical components of the tool. It is powered by a lithium battery, providing a measuring time of more than 12 h. Additionally, an acceleration detector identifies the status of motion or non-motion of the tool during the measurement. Through a pressure resistant glass window at the tool head, the sonde can exchange data and commands by infrared light with a PC or a handheld computer (PDA). The tool has been calibrated to convert the measured gamma counts into

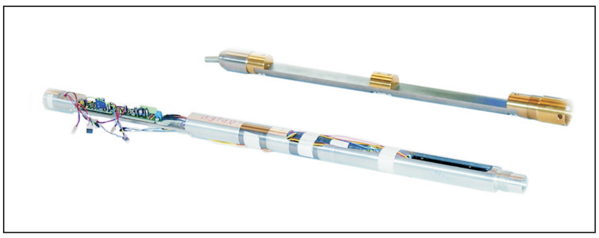

Figure 4. Internal parts of the Directional Gamma-Shuttle.

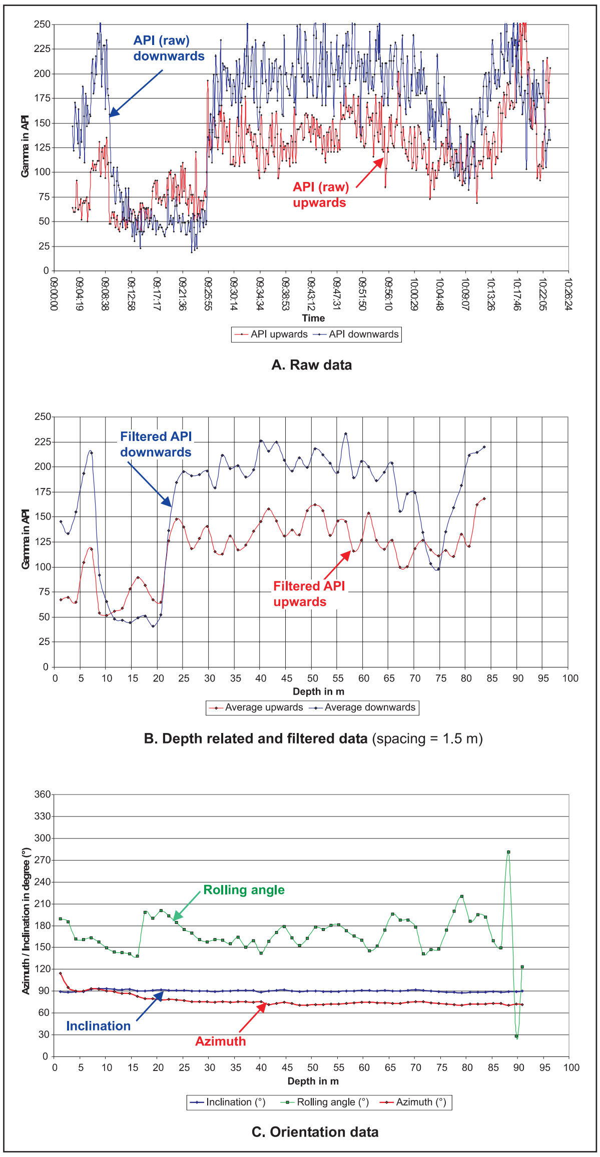

Figure 5. Typical measuring curves: A. Raw data B. Depth related and filtered data C. Orientation data.

the internationally widely used API (American Petroleum Institute) units for gamma radiation. More detailed technical information is provided by Hinz *et al.* (2002).

Immediately after the completion of the borehole, the auger bit is replaced by the tool. It is then induced into the borehole by the drill string, rod by rod. In a measuring cycle (normally 6 sec), it records the accurate time, gamma counts, directional and inclination data as well as information about the moving status. Figure 5 displays typical measuring curves acquired during previous test runs. Due to the phases of movement and standstill the time-based original curve (Fig. 5A) can not be converted directly into a depth related curve. The time-to-depth conversion of the filtered radiation data sets is based on the drilling time and drilling rod length (Fig. 5B). The same applies to the borehole azimuth, inclination and rolling angle (Fig. 5C).

3. Case study

3.1. Background

Earlier in 2002, the Prosper-Haniel mine commissioned DMT to carry out a measurement in order to collect as much information as possible for mine planning purposes. Due to the lack of space, at this particular location, no other drilling equipment and, hence, no larger logging tool could be applied.

A rise heading had to be planned crossing a thrust fault from the low wall to the high wall part of the seam (blue circle in Fig. 6). In order to design the ideal location of the rise heading the position of the thrust fault had to be determined. The original idea was to drill a hole parallel to the seam and subsequently log it with this gamma tool. Within the seam, gamma values would have to be low, but in the rock, as soon as the fault had been crossed, significantly higher (red circle in Fig. 6).

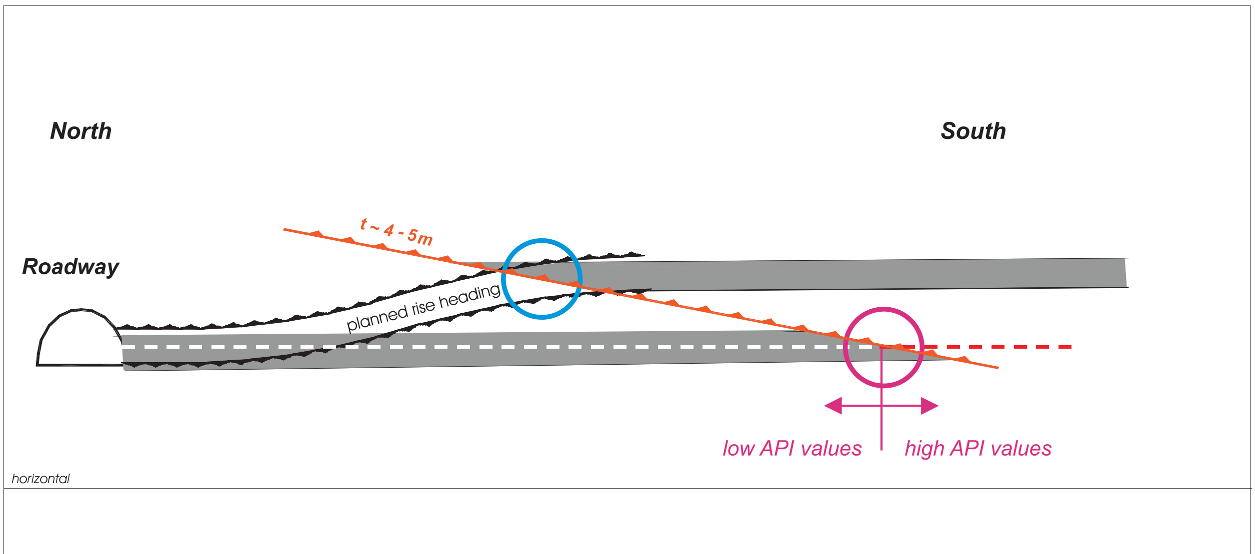

Figure 6. Cross-section posing the problem prior to drilling and logging.

3.2. First measurement

The hole was drilled to a depth of app. 60 m (borehole 1 in Fig. 8). For the measurement, the hole had to be cleared from the coal fragments. The driller's description of alternating coal and coaly claystone (green bars in Fig. 7B) could not clearly be interpreted. The gamma measurement showed distinct sequences of coal and rock, partly differing from the driller's description (Fig. 7B). The coaly claystone from the driller's description (in circles) was probably rather claystone mixed with coal from other parts of the borehole. Another significant result was an unexpected upward inclination of the hole of more than 20° (Fig. 7C). Displacements between the two curves in the detailed time-based curve (highlighted by circle and arrows in Fig. 7A) indicated that the redrilled logged borehole (1a) was possibly not identical with the original hole (1) and left the seam into the floor, crossed the fault and even hit the seam in the high wall.

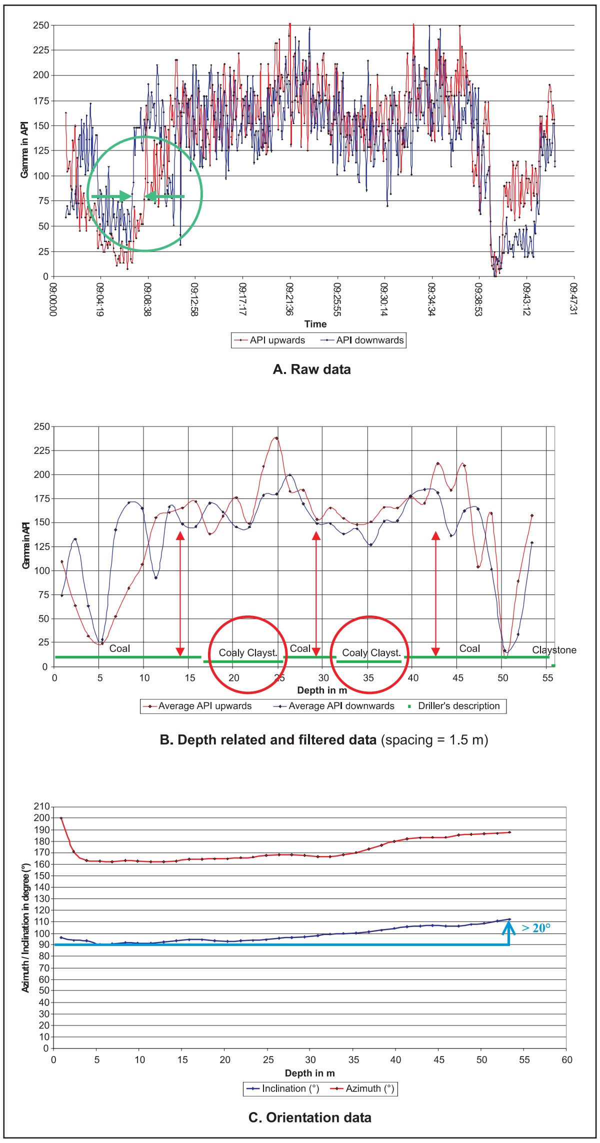

Figure 7. 1st measurement: A. Raw data B. Depth related and filtered data C. Orientation data.

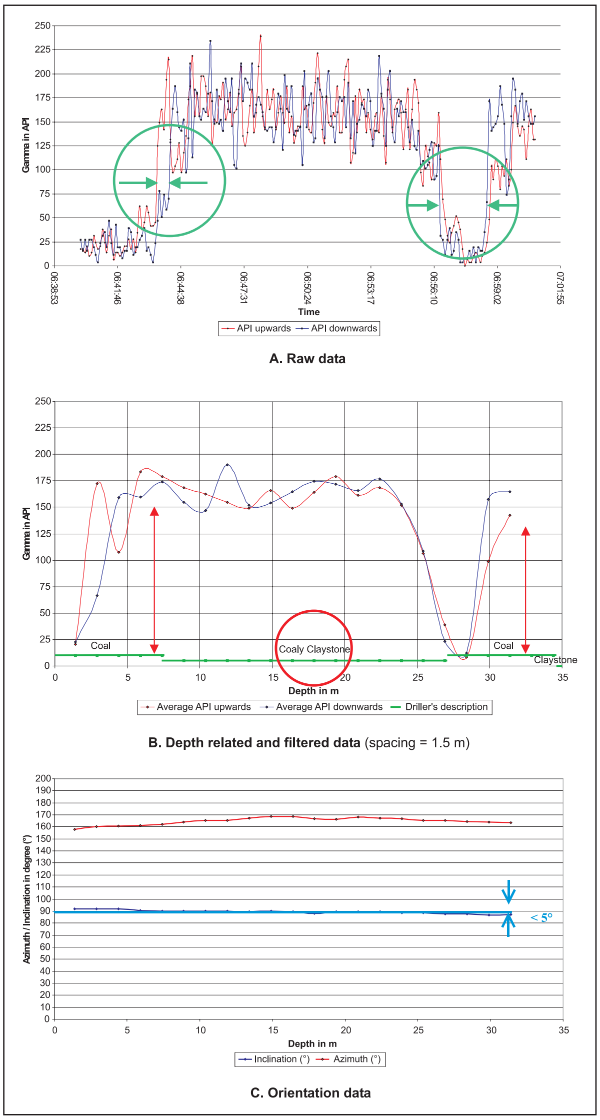

Figure 8. Projection at location of borehole 1/1a.

The section in Figure 8 shows the originally intended straight course of the borehole - with the wider black lines indicating coal, and the hole corrected according to the deviation measurement (borehole 1 in black). Finally, the reworked and logged hole is illustrated (borehole 1a in red).

3.3. Second measurement

Another hole was drilled some 10 m away. This time, the borehole was app. horizontal (Fig. 9C) with a minor downward inclination of less than 5°. Again the log differed from the driller's description with regard to the coal sections (marked by arrows) but, maybe even more important, the coaly claystone (marked by circle) again proved to be pure host rock (Fig. 9B). This proves the limited value of the description due to the mixing of the cuttings from different sections. The gamma curves showed coal in the beginning, a long section of claystone and towards the end of the hole another layer of coal and again claystone at total depth.

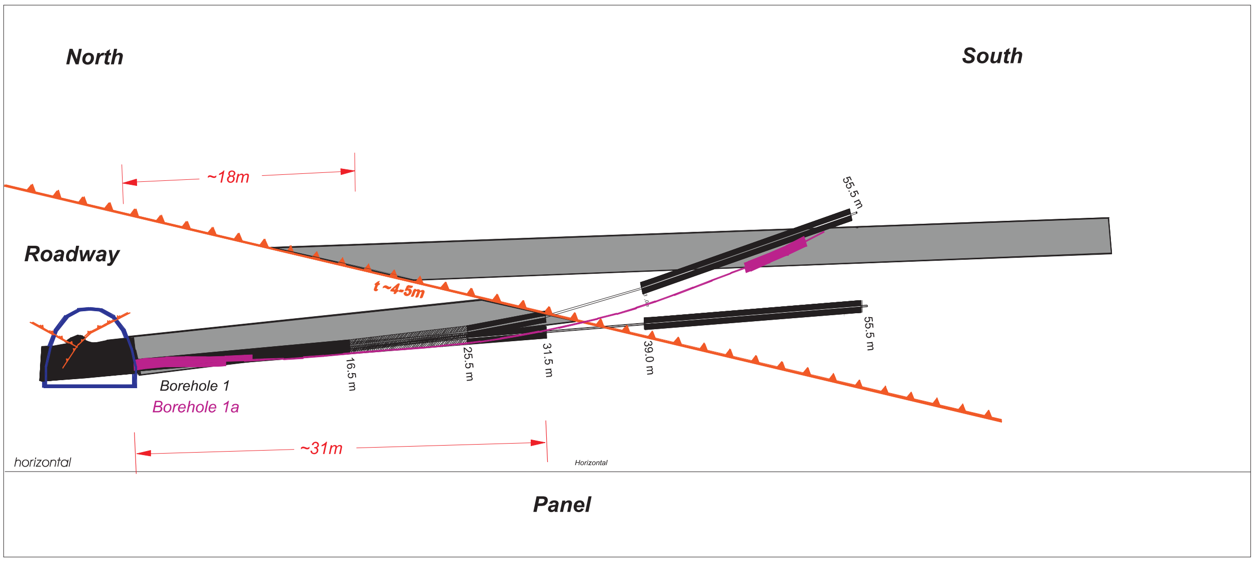

Figure 9. 2[nd] measurement: A. Raw data B. Depth related and filtered data C. Orientation data.

The time-based curves (Fig. 9A) indicated that the hole left the seam towards the roof - increase of gamma values of the red upward detector prior to the blue downward detector (highlighted by circle and arrows in the left-hand part of Figure 9A). The second coal layer was again entered from the roof – as the blue curve is decreasing prior to the red curve (circle and arrows in the right-hand part of Figure 9A).

3.4. Interpretation and results

The geological situation was interpreted as a small syncline, a fold associated with the thrust faulting. If this were true both coal layers would still be on the low wall side and the earliest point of the fault's dislocation could be just beyond the second coal.

Finally the location of the boreholes 1 and 1a was chosen as the starting point for the rise heading. After a couple of metres the seam plunged as predicted according to the log interpretation. Therefore, the driving was continued as planned. And, indeed, the seam (in grey, host rock in the heading in blue) was encountered again after app. 20 m (Fig. 10). Subsequently, the rise heading was driven slightly upwards to reach the seam on the hanging wall. It encountered a complicated set of thrust faults and finally ended up in the high wall as planned.

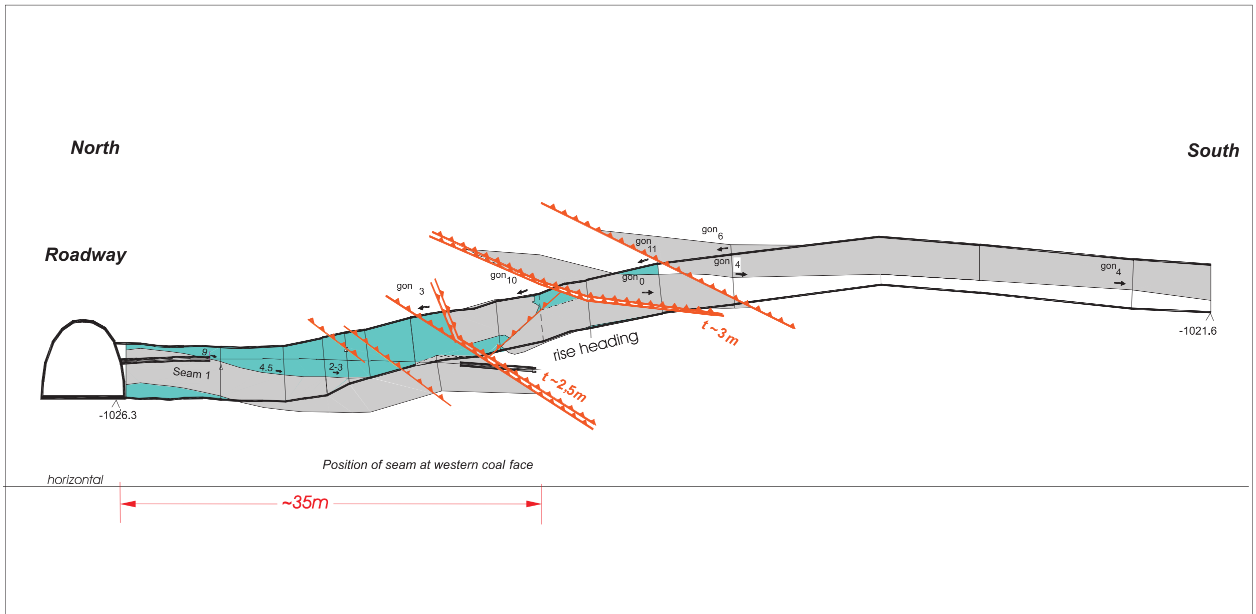

Figure 10. Actual situation in the rise heading.

4. Perspectives

This first successful application of the Directional Gamma-Shuttle can be considered as major impulse to commission the further development of this tool. This project will include laboratory measurements, refinement of the software, and a major number of logging runs in different geological situations. In future, with an improved Directional Gamma-Shuttle new and better information can be obtained from small diameter boreholes.

5. References

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