FEASIBILITY STUDY OF ARTIFACTS APPEARING ON NEUTRON LOGGING CURVE NEAR THE BOUNDAY OF LAYERS

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Introduction

The borehole neutron probe is equipped with a fast neutrons source (e.g. Am-Be) and a system of neutron detectors located at fixed distances from the source (near and far detectors). The measurement of neutrons counts reaching detectors, after applying an appropriate calibration and interpretation procedures, gives information on petrophysical parameters of rocks, mainly porosity.

From the point of view of a neutron transport physics in medium we are dealing with a phenomenon of scattering neutrons coming from the source. It causes the reduction of neutron energy and with their final absorption. These phenomena cause that a small number of neutrons from the source reaches the detectors, and their number depends on neutron properties of the medium. A typical course of the curve (the so-called anomaly), recorded by the detector for bordering layers of different neutron properties, changes monotonically (Fig. 1), e.g. from the characteristic counts rate for M4 layer to the appropriate counts rate for the layer M6.

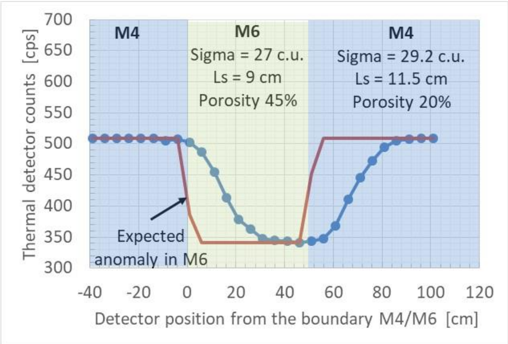

***Figure 1**. The typical course of the anomaly for the M6 layer bordering on the M4 layer.*

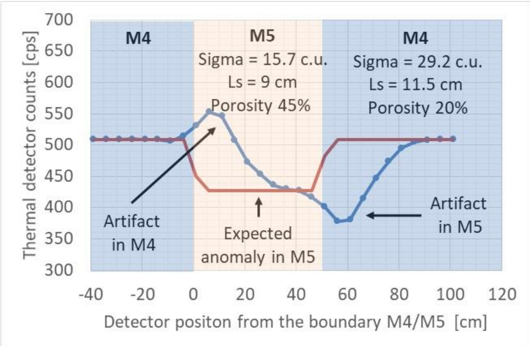

***Figure 2**. Presence of artifacts along the anomaly at the boundary of layers M4 / M5 and M5 / M4.*

However, sometimes the strange course of the curve is observed, as shown in Fig. 2. Although in the medium M5 we expect a lower counts rate than in M4, we observe a significant increase in counts near the M4/M5 border. It exceeds the counts rate both in the M4 medium, and the more in M5. There may also be a reverse situation when the probe moves from the M5 medium to M4. In this case we observe a sharp drop in the neutron counts rate near the M5/M4 border, instead the expected increase. These disturbances observed of the curves along the borders are called artifacts.

Calculations and results

It is not possible to conduct an in-depth analysis of the reasons for artifacts appearance only on the basis of the data from the borehole logs. In order to explain this phenomenon, a lot of numerical simulations were carried out using the Monte Carlo method [MCNP, 2008]. The detectors responses of the neutron probe with the Am-Be source were simulated within two bordered media with different neutron parameters. The source – thermal detector distance was assumed to 31 cm. Rock models of high and low porosity and the high and low thermal neutron absorption cross-sections (Sigma) were taken into account. The detailed description of numerical calculations can be found in the works [Wiącek, 2018; Wiącek and Dworak, 2018].

It was observed that artifacts appear only on the thermal neutron detector responses for media differing significantly in Sigma and in the slowing down length (Ls) of fast neutrons. To explain the phenomenon, let's focus on the example in Fig. 2. The horizontal axis corresponds to the position of the detector in relation to the layer boundary. When the detector is in the position x = 0, the Am-Be source is still in the previous layer at the point x = -31 cm. Because the medium M4 has a large Ls, a significant part of fast neutrons gets into the medium M5 where are slowed down and can reach the detector. Because M5 medium weakly absorbs neutrons, a significant number of neutrons accumulate close to the border, forming the artifact.

Detailed analysis of the observed phenomenon can be performed by analyzing the detection conditions of the thermal neutron detector. The detector's signal is generated as a result of neutron absorption in its volume. The total detector signal is formed by neutrons from a particular range of their energy spectrum. With numerical calculations, two parts of this spectrum can be distinguished: low-energy component with the maximum for energy E1 < 0.4 eV and higher energy component with the maximum for energy E2 > 0.4 eV. Fig. 3 shows the distributions of the spectral components forming the detector response representative for the anomaly without artifacts, as in Fig. 1. Fig. 4 shows an analogous example, but for the anomaly disturbed by the artifacts (corresponding to Fig. 2). We observe the reciprocal behavior of spectral components. The excess neutrons of the E1 component within the layer is the cause of the formation of the artifact.

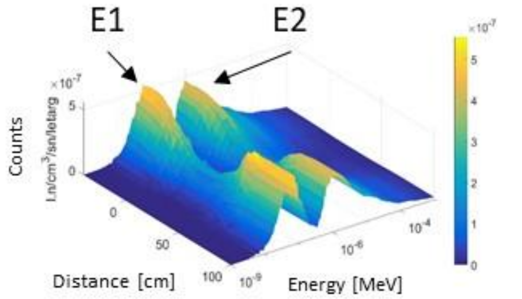

***Figure 3**. Neutron energy-spatial distribution forming the response of the thermal detector that registers the typical anomaly (see Fig. 1).*

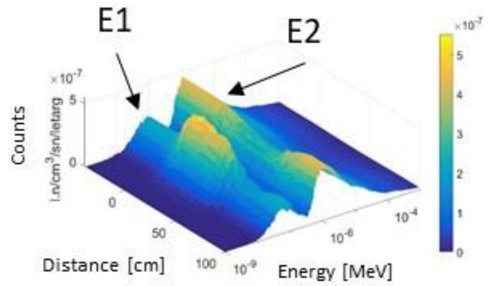

***Figure 4**. Neutron energy-spatial distribution forming the response of the thermal detector that registers the anomaly with artifacts (see Fig. 2).*

Conclusions

The aim of the work was to show that the appearance of artifacts near the boundary of layers results from physical phenomena that occur during the transport of neutrons in that region. The appearance of artefacts is caused by the specific difference in parameters of bordering media for both fast neutrons (Ls) and thermal neutrons (Sigma). For this reason, it can be expected that in the case of a probe equipped with a neutron source of a different energy spectrum than the Am-Be source (for which the maximum intensity of emitted neutrons is about 3.3 MeV) artifacts will appear for materials of other neutron parameters. For example, such a source is 14 MeV neutron generator. The same remark concerns the relationship between the occurrence of artifacts and the distance of the thermal neutron detector from the source. The greater distance, the less likely artefacts will appear. The presence of artifacts on the neutron profiling curve may be a cause of interpretation errors. Particularly with thin layers, the artifact can be misinterpreted as the layer's response, whereas in fact the actual anomaly has an opposite course.

References

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