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Testing the results of estimating lithological stratigraphy through cluster analysis on geophysical borehole logging data through Multi Sensor Core Logging data

Pascal Methe, Andreas Goepel, and Nina Kukowski
Friedrich-Schiller-Universität Jena, Institut für Geowissenschaften, Jena, Germany (nina.kukowski@uni-jena.de)

To identify lithological stratigraphy of the deep subsurface usually requires probing through coring, as only core samples allow to determination a lithological profile with high precision and spatial resolution. However, since coring is expensive, geophysical borehole logs often are the only data available to obtain information on subsurface rocks.
Different sedimentary rocks usually exert distinct specific physical properties, e.g. differ significantly with respect to properties as measured e.g. with gamma ray, density, sonic, or porosity logs. This offers to employ cluster analysis to derive information on lithology. To do so, we tested several cluster analysis algorithms (Ward hierarchical clustering, k-Means, Mean-Shift and DBSCAN) on geophysical borehole data.
Our data set consists of borehole wireline logging data from the 1,179 m deep drill hole EF-FB 1/12, which was drilled in the framework of the INFLUINS (INtegrated FLUid dynamics IN Sedimentary basins) project in the center of the Thuringian Basin (Central Germany) and from which Triassic sedimentary rocks were recovered. To evaluate the outcome of our cluster analysis, we used independent data consisting of laboratory MSCL (Multi Sensor Core Logger) and rock physical measurements on altogether more than 500 m drill cores and individual core samples.
The analysis of the borehole geophysical logging data along the entire borehole length allowed identification of lithology on the meter-scale, e.g. we could identify the Middle Dolomite (6 m thick) of the Middle Muschelkalk as well as embedded interlayers of anhydrite and mudstone (a few meters thick) in between the rock salt of the Salinarröt-formation in the Upper Buntsandstein. Further, we show that the density log and the sonic log are the most suitable ones for cluster analysis, as density and p-wave velocity show significant contrasts between different lithologies. The certainty of cluster analysis algorithms decreases in cases of gradual lithological changes or the occurrence of high-frequency alternating sequences, i.e. alternating layers that are thinner than sample intervals and/or below the maximum vertical resolution of the logging tool. With regard to the various cluster analysis approaches tested, we obtained the most valid lithological profile from DBSCAN.