Introduction

Working in terms of rock classes (e.g. granite, sandstone) allows for a better understanding and completion of many important geological workflow steps, such as inferring depositional environments, understanding the evolution of geological systems, making coherent correlations between data from different wells and interpreting seismic profiles, amongst others. Unfortunately, physical samples are not always available. This is the case when there are so many wells being drilled that the cost of coring would be unaffordable, or when a well is perforated horizontally and therefore core extraction is impossible (Saggaf & Nebrija, 2003). Thus, geoscientists usually have to work only with information obtained through surface measurements and/or borehole logging.

The facies identification process from wire-line logs has usually been carried out by experts, either by visual inspection, or with the aid of crossplotting, although this is an arduous and slow task. In addition to the time-consuming disadvantage, the facies identification problem has another important issue to consider: data is intrinsically vague, imperfect and uncertain (Sagaff & Nebrija, 2003). One of the most intuitive mathematical constructions to handle uncertainty is fuzzy logic (Zadeh, 1965). Conventional techniques try to minimize or ignore the inherent error in the measure, but fuzzy logic asserts that there is useful information in this error and takes advantage of it.

Methodology

The main goal is to obtain a lithological column from an input well log. Each data point will be assigned a rock type. The inference behind this classification must be based in some a priori information, being usually a manually classified well log from a sufficiently nearby well (the *training* well) so that we can expect that the representativity hypothesis holds between the two wells.

The quantitative treatment of the information is done under the framework provided by fuzzy logic. The key concept of fuzzy logic is the *degree of membership* of an object to a set (Zadeh, 1965), a real number between 0 and 1 that indicates the subjective degree of truth of the statement "this object belongs to that set". The mathematical function that assigns a degree of membership of an object to a set is called a *membership function*, and the set characterized by it a *fuzzy set* (Zadeh, 1965).

The input consists on a vector of property values for a given depth. The first step is to obtain a confidence value of each property value for all the rock types considered. This is done by evaluating the corresponding membership functions at the given input values. We want to obtain a final confidence value for each rock type, so that we can decide which lithology is best represented by the data based on those numbers. We suggest the use of the *minimum* operator. Once we have the final lithology confidences, a decision must be made. Sometimes the final confidences can be very close and doubting between a number of lithologies is reasonable. We think that in this cases it is more useful to indicate that the program is in doubt between a number of lithologies.

Case Study

A complete description of the KTB project is given in Bram et al. (2009). Two boreholes were drilled, a Pilot Hole, 4000 meters deep, and a Main Hole, 9101 meters deep. In the Appendix (Figure A1) the classification results for the main well are shown.

Conclusions

In this work, a fuzzy inference procedure has been implemented as a MatLab program and tested for well log data classification using data from a public dataset coming from the KTB project (Germany).

A new final lithology confidence operator has been introduced and applied to adress the combination of individual confidences from different properties. Besides, a doubting class has been proposed for the final decision stage, as we think that it is more valuable an "in doubt" output that a wrong classification (and specially with this highly overlapping membership functions). The decision criteria is based on a relative confidence threshold, which value is entered by the end user.

Results show that this fuzzy logic based method is suited to rapidly and reasonably suggest a lithology column from well log data, provided that there is enough a priori information and that the hypothesis of representativity holds between lithologies from the train and test datasets. This methodology will be a very useful tool to aid in the interpretation of well log data from future CO_2 storage pilot sites.

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References

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Appendix

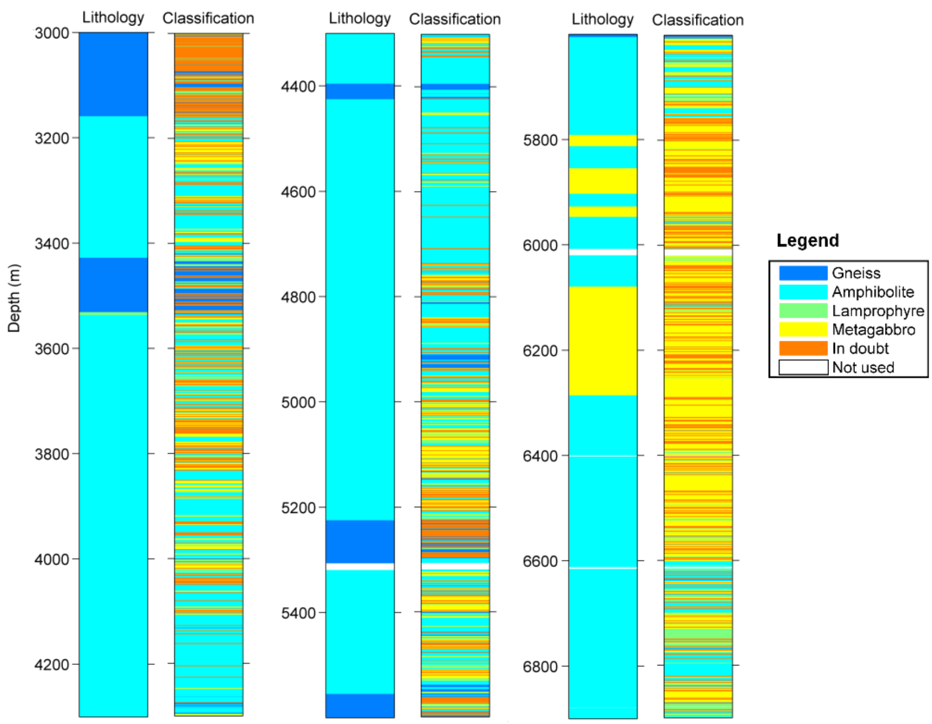

Figure A1: *Lithology column given by the program for the HB dataset.*