IMAGE petrophysical catalogue – an international database of rock properties for reservoir characterization

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ABSTRACT

Petrophysical rock properties are key to populate local and/or regional numerical models and for the interpretation of many geophysical investigation methods. Searching for rock property values that have been measured for a specific rock unit at a specific site might become a very time-consuming challenge given that such data are spread across diverse compilations and that the number of publications on new measurements is continuously increasing. Furthermore, the applicability of laboratory data to specific locations or reservoir units might be questionable if information on the sample location, petrography, stratigraphy, measuring method and conditions are too sparse or even lacking.

Within the scope of the EC funded project IMAGE (Integrated Methods for Advanced Geothermal Exploration, grant agreement No. 608553) an open-access database is currently under development. This database aims at providing easily accessible information on physical rock properties relevant for geothermal exploration and reservoir characterization in one single compilation. Hence, collected data include hydraulic, thermophysical and mechanical properties and, in addition, electrical resistivity and magnetic susceptibility. Each measured value is complemented by relevant meta-information such as the corresponding sample location, petrographic description and, most importantly, original citation. Within this publication, we describe the structure and contents of the database and discuss its limitations and advantages in terms of applicability.

1. INTRODUCTION

The characterisation and utilisation of subsurface reservoirs generally relies on applying geophysical investigation methods and/or numerical models – both requiring, in turn, the knowledge of physical rock properties at depth. The strategy of populating numerical models with petrophysical properties can differ. For local scale models laboratory measurements may exist that have been applied to samples directly taken from the volume of the unit of interest. In this case, it is reasonable to use this direct information together with sophisticated (physical and empirical) laws to populate the entire geological unit. For regional and continental scale models, by contrast, parameters have to be generalised, for example by associating locally measured properties with the spatial distribution of corresponding lithological units.

Individual rock types or petrographies typically exhibit a great variability in related properties due to heterogeneous mineral compositions, variable textures and different porosity distribution (Schön 2015). Existing collections of rock properties are proof for this high variability (e.g. Cermak and Rybach 1982, Clark 1966, Clauser and Huenges 1995, Landolt-Börnstein, PetroMod, Schön 2004, 2011, 2015, Hantschel and Kauerauf 2009, Aretz et al. 2015). Since the compiled properties are mostly complemented by limited meta-information, it is difficult to use these data for regional applications. This is aggravated by the limitations of such compilations as these are usually covering only certain rock types or geographic areas and not providing the same set of information on all samples.

To avoid (i) time-consuming literature research, (ii) problems arising from unwanted generalisations and (iii) missing complementary information needed for further interpretation of the measured values, a database is under development within the scope of the IMAGE project. This database is filled with data from both IMAGE research partners and literature.

2. CONTENTS AND STRUCTURE OF THE DATABASE

According to our motivation, the IMAGE rock property catalogue will be publicly accessible and only containing rock properties measured in laboratory experiments. Furthermore, it will only contain measurements that are associated with lithological descriptions of the corresponding sample and a proper reference to the original citation.

The data thus has to be publicly available for all researchers, meaning that only data from scientific publications (books or peer reviewed journals) or proceedings (e.g. IGA Geothermal Papers/Conference Database) as well as published research reports (e.g. dissertations or publicly available student's theses) were included.

For each measured value, a set of meta-information is required to ensure that the data can later on be used for interpretations, generalisations or modelling. The minimum associated input therefore is the reference to the original source (citation), the location of the sample (including a radius of uncertainty) and information on the petrography for the allocation of a possible lithotype.

The database is thus structured into three main pillars (Fig. 1). The first, named sample information, contains all the meta-information on the sample including the sampling location, the sample type and dimensions as well as information on its petrography and stratigraphy. The second pillar contains the actual measured property value(s), the information on the measurement (parameter, method, conditions etc.) and a field for specific remarks. Finally, the third named quality control includes all information relevant for the quality assessment of a data set.

The properties included in the database are displayed in Fig. 1 and were chosen due to their high relevance for geothermal exploration (including the fields of geophysical exploration techniques and subsurface numerical models).

Figure 1: Schematic structure of the IMAGE rock property database illustrating the main three pillars: sample information, rock properties and quality control. Different input parameters (small font) are grouped according to the property they belong to (italics).

The petrography or rock type classification is defined in a separate table directly connected to the database. Its internal structure is based on a hierarchical subdivision of rock types, where the rock description becomes more detailed with increasing rank of petrographic classification. This hierarchical subdivision is based on international convention (e.g. Bates & Jackson 1987, Gillespie & Styles 1999, Robertson 1999, Hallsworth & Knox 1999, Bas & Streckeisen 1991, Schmid 1981, Fisher & Smith 1991). Thus, the classification also corresponds to the subdivision used in existing property data compilations such as e.g. Hantschel and Kauerauf (2009), Schön (2011), Rybach (1984) and Clauser and Huenges (1995).

The stratigraphy of each sample can be inserted into the database in two complementary ways. The first way is to use the definitions of the international chronostratigraphic chart of the IUGS v2015/01 (Cohen et al. 2013, updated). Alternatively, a more detailed description of the local stratigraphic unit can also be documented if provided in the primary reference.

To provide information on the quality of each data point (excellent, average or poor), a set of key criteria is automatically analysed: (i) uncertainty of the geographic location, (ii) the rank of petrographic classification, (iii) the stratigraphic rank, (iv) the completeness of information on measurement conditions and, (v) the statistical type of a value (e.g. single value, mean value etc.).

3. STATUS OF THE DATABASE

Up to now, data that entered the catalogue are either from published data collections or scientific papers (234 references including student's theses and scientific reports). So far, more than 60,000 data points from more than 35,000 sample locations from all over the world (Fig. 2) have been collected. The amount of samples from different petrographies shows that all main rock types are represented: 13,576 samples from magmatic rocks, 7,585 samples from metamorphic rocks, 12,798 samples from sedimentary rocks (thereof 1,294 samples from clastic sediments). Since this catalogue has been filled to follow the goals of the IMAGE project and it still represents work in progress, its data entries are unevenly distributed among the different properties. Moreover, the entries for some properties derive from only one single source, such as e.g. the values of radiogenic heat production that are taken from the compilation of Vilà et al. (2010).

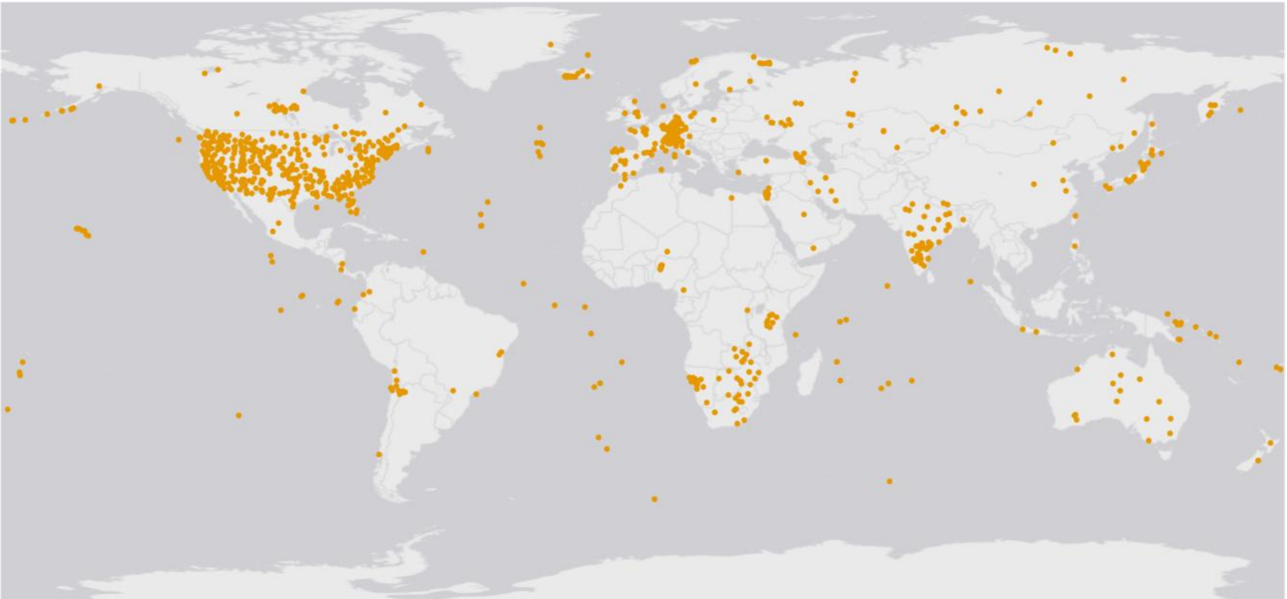

Figure 2: World map showing the locations of all data points currently included in the IMAGE rock property database (May 2016).

4. DISCUSSION

The current status of the database already shows a lot of benefits that such a compilation brings along, but also some limitations in utilisation.

The defined minimum requirements for a datum to be integrated in the database guarantee its usability in terms of statistical, spatial, petrographic and stratigraphic analyses. Direct correlations with other data and properties are facilitated, which may help identifying new empirical relationships and, on the other hand, contribute to a better understanding of the limitations of generalisation and upscaling approaches. Thereby, the partly automatic quality assessment allows for a quick evaluation of single data within a group of selected entries. The possibility of cross-correlating data also simplifies and accelerates the identification of key references for rock parameters in specific regions, for specific rock types, or stratigraphies. Furthermore, the database allows to systematically analyse the dependency of property values on the corresponding measurement conditions.

Thus, the most important added values of this database compared to conventional databases are its dimensions (large number of entries corresponding to a large number of petrophysical properties) and the abundance of given meta-information.

On the other hand, such a database can never be complete and is always prone to some uncertainties. To identify errors in the original publications (in terms of property values and meta-information) is beyond the scope of this compilation, while data-input errors cannot be totally excluded. Additionally, this database includes values generated with different measurement methods usually delivering data of different quality and uncertainty. Thus, data comparability is not necessarily given. For example, due to diverse effects (such as temperature, pressure, weathering etc.), properties measured from outcrop analogue samples might differ considerably in quality from those of the same formation at in situ conditions of the deep reservoir.

5. CONCLUSIONS AND PERSPECTIVES

A database of diverse petrophysical rock properties has been developed. It has been designed to be as transparent as possible through the integration of multiple meta-information (including the original source) for each data point. The database already comprises a great variety of properties, petrographies, stratigraphies etc. that derive from laboratory measurements on samples from all over the world. The current compilation of samples, however, largely reflects the project goals of the geothermal project IMAGE (Van Wees et al., 2015), while the applicability of the catalogue certainly can be seen in various geoscientific fields focusing on subsurface utilisation.

A first release of this database will be published soon. Since such a database can never be complete, a further extension through newly published data is foreseen. We also plan to develop a publicly accessible web-based interface to facilitate external users to perform specific queries on petrophysical properties. In addition, external users shall also be given the opportunity to complement the database for a better visibility of their own measured rock properties. Thus, the database will be continuously updated and at certain stages newly released by the editors.

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