PS Bridging Information Gaps in Reservoir Studies – Archiving and Providing Information for Reservoir Studies (APIRS)*

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Abstract

Archiving large amounts of geoscientific data from reservoir studies in a permanent yet accessible manner can be expensive and time-consuming. Access to relevant digital geoscience data is however increasingly important to describe the complex relationships encountered in reservoir characterization and modeling within the energy industry and related fields of research. Hereby, disparate data from different geoscientific disciplines, scales of investigation and various sources must be queried, compiled, and validated before populating numerical reservoir models.

To enable a centralized data archive for reservoir studies and to ensure sophisticated connections between geoscientific disciplines, the database application APIRS (*Archiving and Providing Information for Reservoir Studies*) has been developed with a Relational Database Management System. The purpose of APIRS is the expeditious input and output of complex geoscientific data in a user-friendly client-server model interface. While data management in reservoir characterization is often performed via spreadsheet applications, APIRS saves time, users need to load, inquire and sort single, unconnected spreadsheets. Data input can be done either manually or by spreadsheet file import. Hereby, APIRS automatically links imported data to relating geological features.

APIRS enables field geologists and petrophysicists to enter multidimensional types of directional data from field surveys, drilling campaigns, laboratory information systems, and 2D/3D geological models. In addition, reservoir geologists can conduct common workflows like creating various types of sections (stratigraphic, sedimentological) and defining facies associations directly within the application. For further analysis, interoperability to other software is provided via Open Database Connectivity. Working on the entire scale of reservoir characterization, APIRS contributes to solving problems in computational reservoir up- and downscaling through facilitating access to highly complex and disparate data.

As a case study, outcrop analogue data for a deep geothermal reservoir from the northern Upper Rhine Graben in Germany has been acquired and processed with APIRS. For this example, data is derived from sedimentology (lithofacies analysis), petrophysics (field and laboratory measurements), and 2D/3D models. By this contribution, the advantages of extensively linked geoscientific data in reservoir characterization are visualized.

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Introduction

Reservoir studies build an important step of hydrogeothermal energy and heat production workflows. Thereby, quality of a spatially restricted geological reservoir is assessed by multiple investigative methods gathering disparate types of data.

Detailed evaluation of the geothermal potential of reservoirs especially demands comprehensive knowledge of **lithologic composition and spatial heterogeneity/ anisotropy of petrophysical properties** (Bär et al. 2017). Due to missing data management systems and a small number of abstracted data models, reservoir information is often managed in unconnected, distributed file systems.

To encounter the broad information spectrum of academic fields contributing to geothermal reservoir studies, the software application **APIRS** has been implemented based on the relational database management system (RDBMS) technology. An RDBMS as data storage component in a software application ensures data integrity, connectivity and accessibility.

Entity–relationship model (ERM)

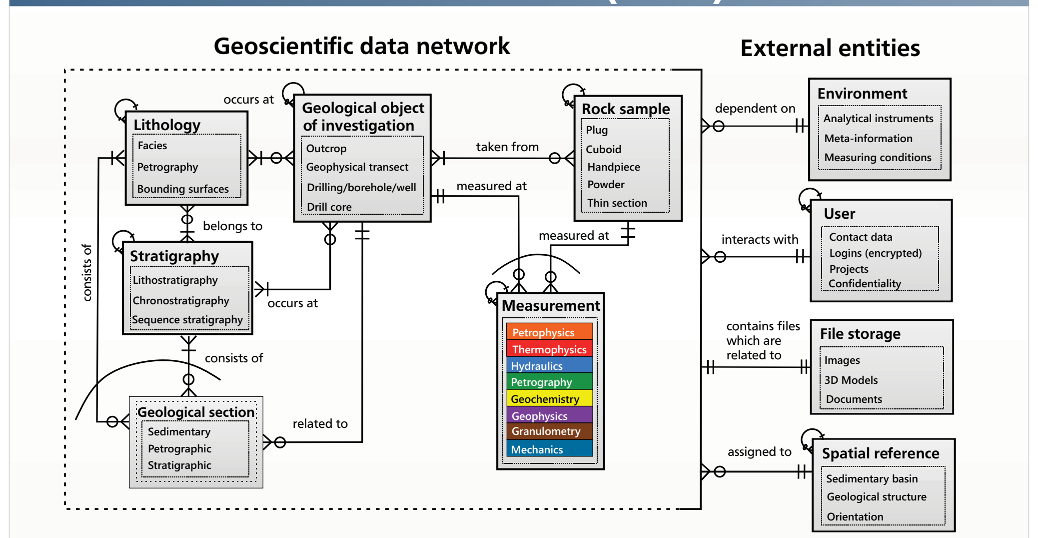
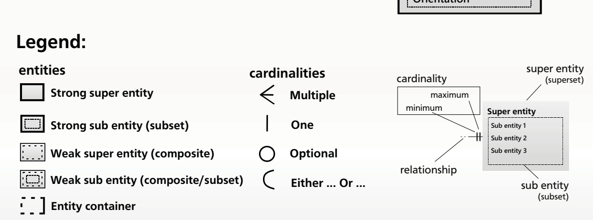


Figure 1: Simplified entity–relationship diagram (ERD) using the U3D approach (Tillmann, 2017) for the back-end database of APIRS. The model is restricted to the most important entities. Every entity is representative for one or more tables storing data in attribute columns.

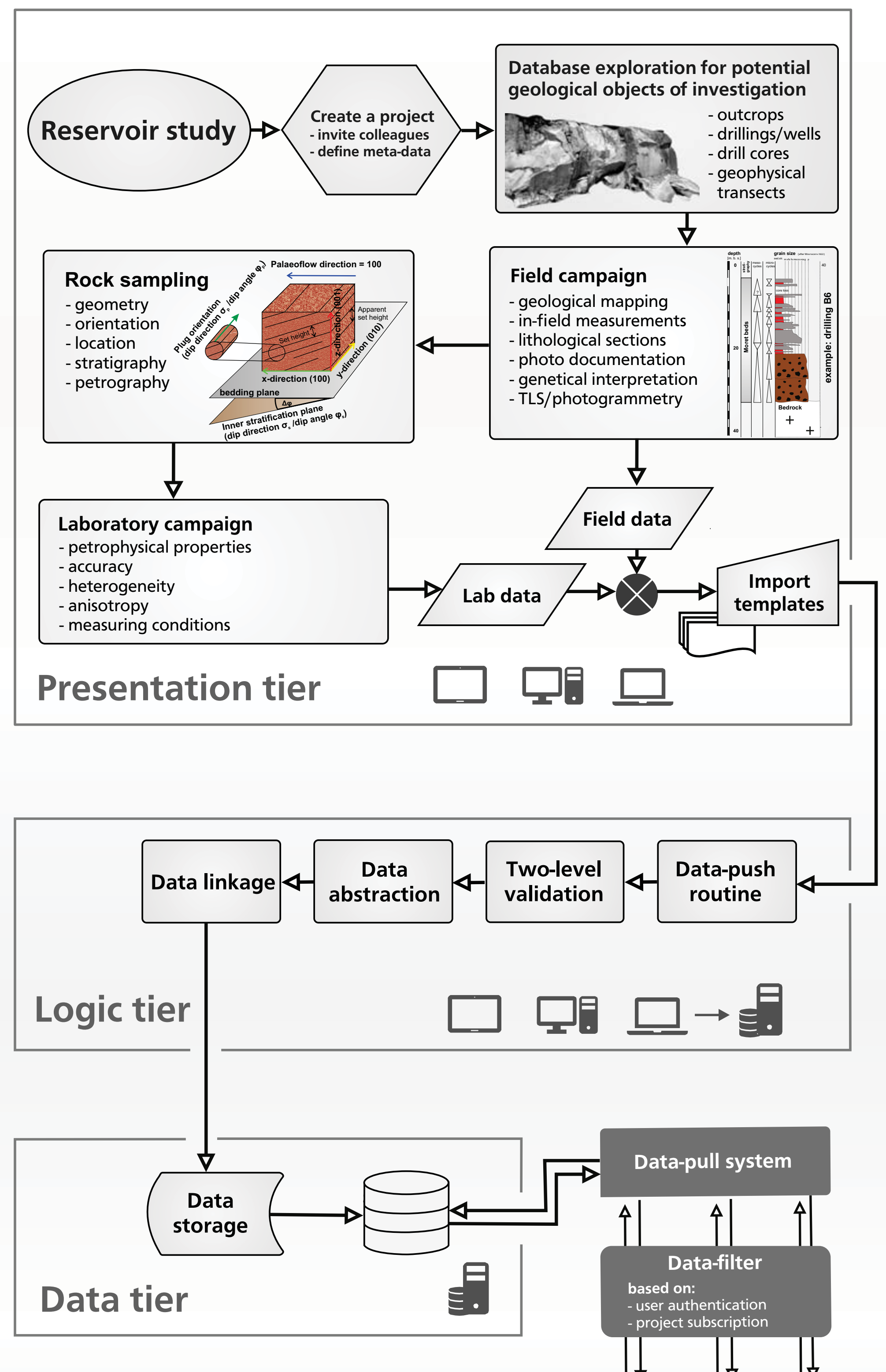


Software architecture

Our application provides a three-tier-architecture (figure 2) divided into presentation, logic and data tier. This setup simplifies the abstracted data model and facilitates scientists to handle complex data yet providing a high level of data consistency and integrity.

As database back-end (data tier) we decided to run a Microsoft SQL Server Express instance providing updatable views and stored procedures (logic tier) for the client application (presentation tier) and an integrated file system based on the Filestream technology. Connection to the front-end is provided using the ODBC (open database connectivity) respectively ADO (ActiveX Data Objects) database APIs.

Workflow



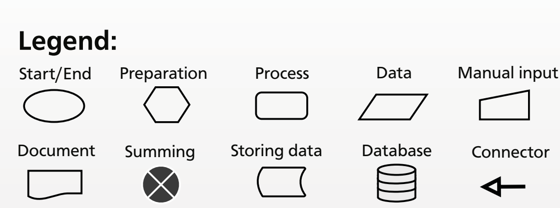


Figure 2: Flowchart representing data production, import, storage, and output stages during standardized reservoir studies using the APIRS database application system.

Case study

An outcrop analogue study testing APIRS has been conducted on the Eastern Graben flank of the Upper Rhine Graben, which represents a potential hydrogeothermal reservoir in Hesse (Germany).

Six drill cores containing Permian sedimentary strata from the Donnersberg formation of the European Rotliegend group have been investigated in terms of their hydrogeothermal potential.

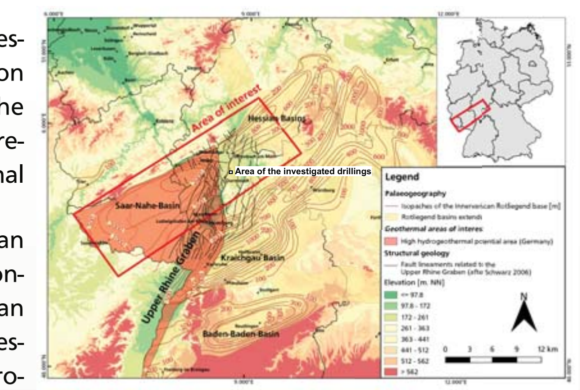
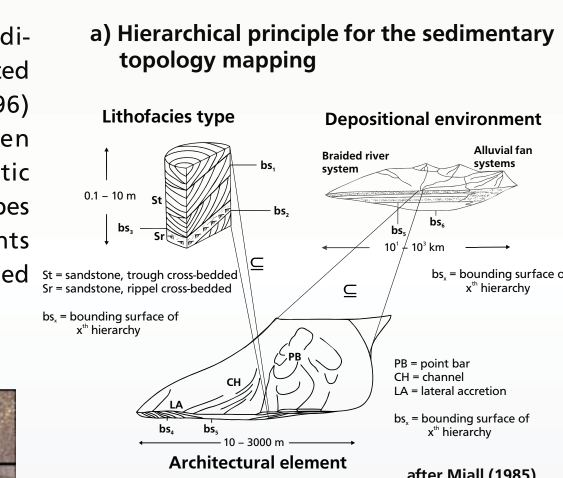


Figure 3: Working area of the case study in the Saar-Nahe-Basin and the Sprendlinger-Horst-Basin (Germany, after Bär 2012, Boy et al.2012).

1. Lithofacies quantification and rock sampling

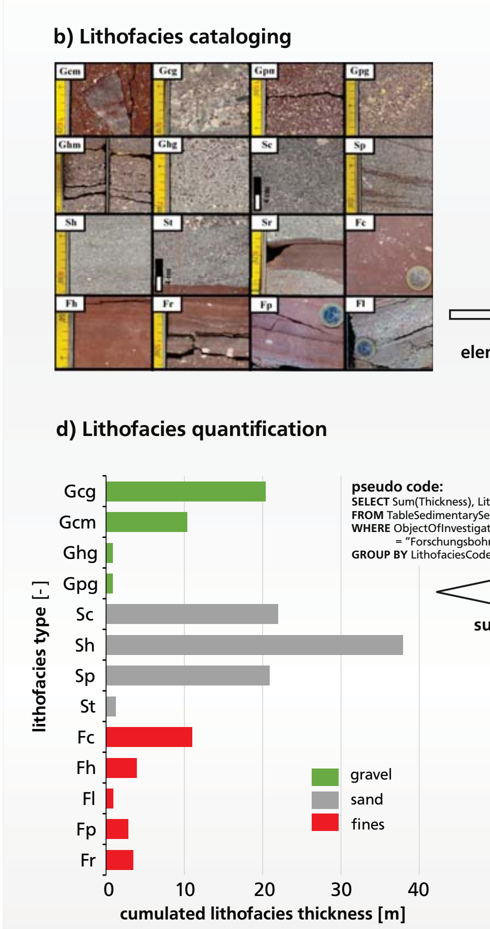
150 m of highly detailed sedimentary sections using an adapted approach of Miall's (1985, 1996) lithofacies concept have been constructed with 16 siliciclastic lithofacies types. Lithofacies types build up architectural elements from an alluvial fan and braided river depositional environment.

a) Hierarchical principle for the sedimentary topology mapping



b) Lithofacies cataloging

d) Lithofacies quantification



c) Sedimentary section preparation ("Forschungsbohrung Messel GA 1" 3–4 mbgs)

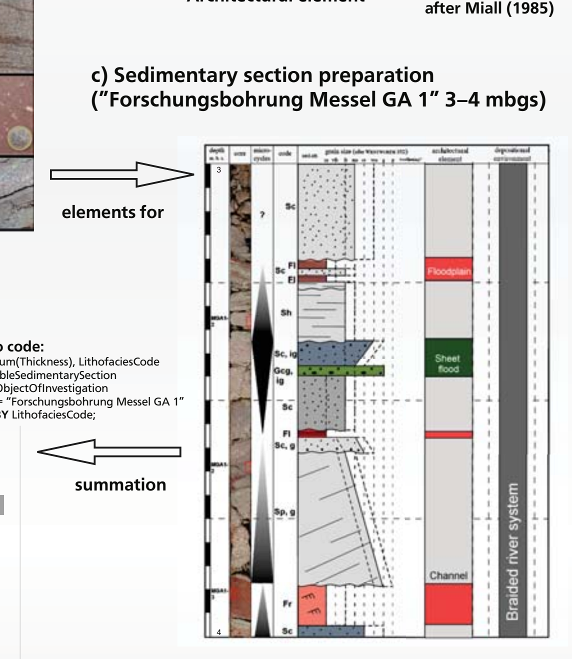


Figure 4: Hierarchical principle of lithofacies analysis applied in the case study (a), observed lithofacies types in the investigated drill cores (b), sedimentary section of a representative drill core in the "Forschungsbohrung Messel GA 1" (3–4 mbgs) (c), cumulated lithofacies thicknesses in the drill cores (d).

2. Petrophysical characterization

Sedimentary topologies were attributed by measurements of six geothermal reservoir properties on 115 cylindric rock samples. Statistical analysis reveals a low hydrogeothermal potential of the rock matrix.

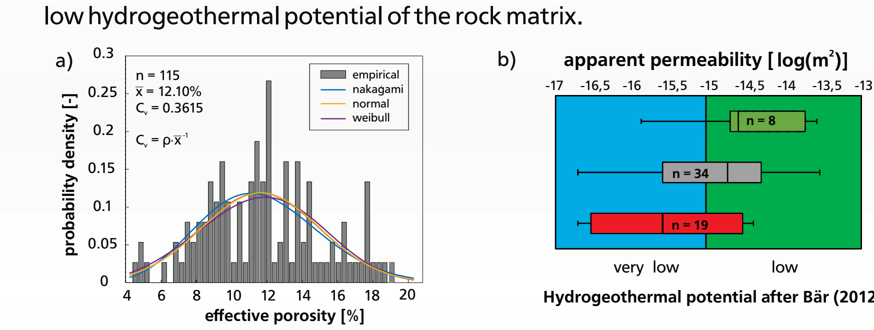


Figure 5: Empirical histogram with fitting functions for the effective porosity values measured at the extracted rock samples (a) and hydrogeothermal potential assessment of the empirical apparent permeability (b).

3. Statistical and spatial analysis

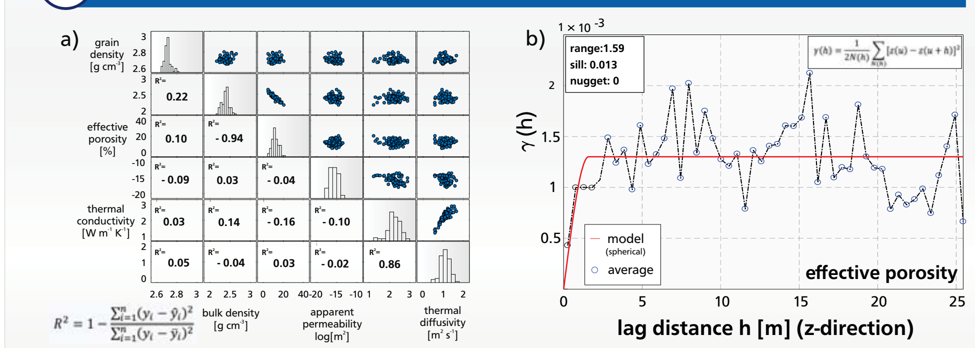
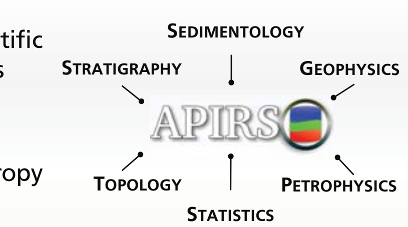


Figure 6: Cross-correlation matrix with empirical histograms and 2D scatterplots of the observed reservoir properties (a) and empirical semi-variogram analysis of the effective porosity in positive z-direction (b).

Conclusions

APIRS provides

- a dense yet extensible data model of geoscientific data for (geothermal) reservoir characterizations
- predefined data rules and workflows following **international standards**
- full control of spatial heterogeneity and anisotropy of lithological reservoir properties



Outlook

- APIRS is currently getting migrated to a web-framework and will be extended by data visualization, mapping and analysis functionality
- The software is intended to be publicly available after user acceptance testing (UAT)

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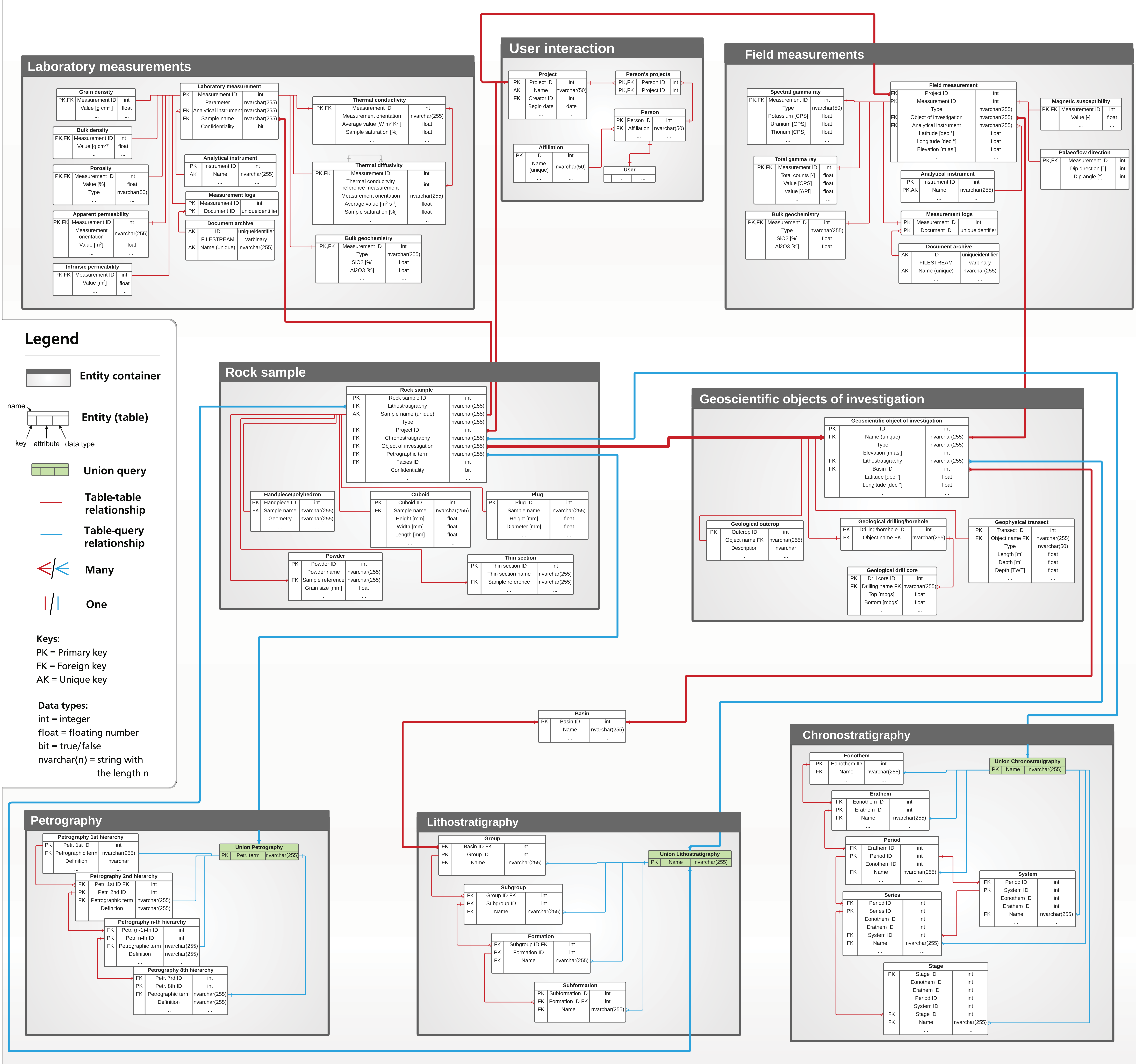
EXTRACT OF THE RELATIONAL DATA MODEL IMPLEMENTED IN APIRS



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