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The Lurbach system (Central Styrian Karst - Semriach, Austria) - a complex (but) instructive karst aquifer to evaluate predictive modelling capabilities of rainfall - runoff approaches

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Predicting the hydrodynamic behavior of alpine spring catchments under changing environmental conditions is highly relevant in Austria and elsewhere, regarding drinking water supply, flood predictions and construction works (e.g., tunnels). Especially the effects of climatic changes are of growing concern. Appropriate hydrogeological tools able to capture the system responses outside calibration ranges are required. On the one hand, process-based distributive models might suffer from the lack of information about the spatial variability of hydraulic and geometric aquifer properties. Thus, the model calibration is expected to be ambiguous, suggesting high prediction uncertainty. On the other hand, global models use a group of parameters to reproduce from a given input function the observed system responses. These models are able to cope with the scarcity of input data but often do not adequately account for the physics of flow. Thus, process-oriented global (grey-box) approaches appear to be preferable, in particular, if conditions change beyond those considered by the model calibration.

Keeping these limitations in mind, the predictive capabilities of various global and distributive modeling approaches are tested using a well known and understood field site: The Lurbach system. Located in the Central Styrian Karst (Highland of Graz), the system serves as ideal test site for the evaluation of model performance and prediction uncertainties. Ample hydrogeological as well as speleological data are available (Behrens et al. 1992) and a profound understanding of the whole karst aquifer is established. The system behaves very differently as recharge conditions change. It is decoupled at low rates where the two springs (Hammerbach and Schmelzbach) act individually, but flow from one system to the other occurs at higher flow rates. Further, it seems that the proportion of flow in the conduit and matrix system changes with recharge as well. At extreme flood conditions a single conduit (the Lurgrotte cave) acts as the main flow path. Thus, this site provides an ideal framework to test models under strongly changing boundary conditions and aquifer characteristics. Limits in prediction-making capabilities and their uncertainties are addressed from synergies of the two model approaches (grey-box versus distributive) using differential split-sample tests of this complex aquifer system. The lessons learned will serve as a basis for other field sites where predictions outside the calibration ranges are needed.

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Geophysical prospection of subsurface monuments in a highly noisy environment

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The investigated area in Semlach near Knappenberg (Carinthia) was a Roman iron production site between the 1st and the 4th century A.D. Due to the long period of industrial utilization, a considerable number of relics (walls, melting furnaces, slag heaps, etc.) have been preserved in the subsurface. The delimitation of such monuments by means of geophysical prospection is based on contrasts in their petrophysical parameters compared with the natural soil or under laying rock. In general, relics of iron production processes with a high magnetic susceptibility can be identified with relative ease in a magnetic survey, e.g., by high (dipole) anomalies. The variations of the total magnetic field exceed 2000 nT for huge slag heaps and reach up to 500 nT for smelting furnaces. Contrastingly, minor decreases of about 250 nT, may give evidence for buried walls.

Recent archaeological excavations on the site Semlach yielded remains of a large building, which is assumed to be a roman depository. For the prediction of the further extension of the external walls, a combination of different geophysical methods was applied. A magnetic survey with an extension of 34x45 m and a grid of 0.5x0.5 m was executed using GEM proton precession magnetometers. The apparent conductivity and the inphase response of the soil were measured with a Geonics EM38 electromagnetic instrument. Additionally, the resistivity method (geoelectric mapping and multielectrode geoelectrics) and the self potential method (SP) were applied on selected profiles crossing the excavation area.

The new results from the site Semlach yielded several zones of relative minima of the magnetic field over the suspected areas, which were indicative of walls. However, the interpretation was complicated by a highly noisy background, which was caused by deposits of slag from the iron melting process. Such slags were extensively distributed in the surrounding environment. They are characterised by high magnetic susceptibility values (max. 3796 x 10^{-3} SI) and, thus, has a significant effect on the magnetic survey results, as well as on measurements of the electric conductivity and related parameters. The presented susceptibility models are based on an integrative interpretation of the different geophysical survey results and petrophysical measurements.

Data treatment for a hydrothermal reservoir assessment

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The main components of a hydrothermal system are the availability of a fluid to carry the heat, a conducting or heat producing basement, a reservoir to accommodate the fluid and specific reservoir parameters, e.g., thickness, lateral extension, porosity, permeability and thermal conductivity. Essential fluid parameters for a hydrothermal reservoir assessment are temperature, chemistry and quantity. The properties of a feasible geothermal object are partly measurable, but the geothermal potential depending on its recoverable volume has to be derived from the interpretation and modeling of geological and geophysical data and in a further step by geothermal modeling and simulation. The geological data framework is almost entirely derived from the hydrocarbon exploration and production. For demonstrating the methods of the geological and geothermal exploration the Calcalpine basement of the Vienna Basin is chosen as an example.

The reservoir is represented by dolomitic complexes of the northern frontal parts of the Calcalpine nappe system. In the area of Vienna, the prevailing hydrothermal reservoir rocks are Norian Hauptdolomite and to a minor degree Upper Carnian dolomites of the Lunz-Frankenfels-nappe. The structural features of the dolomite complexes are fold structures, forming two large anticlines (Höllenstein- and Teufelstein-anticline) and a syncline (Flössel syncline), detected by drilling in the areas of Kaisermühlen, Kagran and Hirschstetten, and geometrically analysed (Brix & Schultz 1993). The delineation of the reservoir in a 3D-model showing the structural features, the stratigraphic succession and the complex fold and fault system (Wessely 2006) is performed by application of the geological modeling software Petrel, developed by Schlumberger Co. The given geological sections and maps are imported as images and as grid files. Interpretation is performed directly on the geological profiles. For surface generation also information from wells is regarded. The generated surfaces are used as input for the modeling process. The model consists of regular, rectangular cells with a grid size of 100x100x50 m. Each of these cells is filled with reservoir parameters to obtain a 3D property model (Eichkitz et al. 2009). This property model is the input for the reservoir simulation.

Lithological, facial and petrophysical analyses are carried out using core samples and log analyses. For determination of the essential thermal properties, measurement of porosity, density, thermal capacity and thermal conductivity takes place under several different conditions (in a dry state and under saturation by high saline water). Regarding the dolomitic reservoir rocks different thermal properties have to be taken into account according to facial and diagenetic variations, whereas correlation between diagenetic processes, depositional environments and thermal properties can be created. Intercalations of claystone and the presence of evaporite have to be considered. From the analyses of the disposition of the permeable and impermeable zones the drainage system and fluid path are identified (Wessely 1983). Based on preceding information about temperature, pressure and salinity of the reservoir fluid gained by formation tests in the wells Kaisermühlen and Hirschstetten, the hydrothermal reservoir assessment shows the suitability of this area for exploiting heat respectively balneologic utilisation by means of the fluids of the Calcalpine basement.

The verification of the possibilities for the exploitation of hydrothermal energy depends on implication of an extensive database, which supplies the preconditions for energy- and economic calculation to assess the method of energy extraction and the estimation of the energy gain. The advanced methods to treat existent data of petroleum exploration for hydrothermal purposes in combination with additional investigations might assure a better selection of hydrothermal objects.

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Nutzungsmöglichkeiten tiefer Geothermie in Österreich

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Die Intentionen zur Nutzung tiefer geothermaler Energie in Österreich gehen in Richtung hydrothermale Nutzung (Wärmeentnahme aus zutage geförderten Lagerstättenwässern mit anschließender Wiederverpressung), aber auch