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Toward the Development of an Integrated Information System for the Gather, Management and Diffusion of Geodata, at the Service of a Sustainable and Coherent Use of the Geothermal Resource in an Urban Context

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ABSTRACT

In Geneva (Switzerland), GEothermie 2020 Program aims to improve knowledge of the subsurface and establish an institutional framework adapted to a massive and sustainable development of geothermal energy. In its initial stages, the program financed different academic works aiming at gathering, reinterpreting and jointly valorizing large amount of existing but heterogeneous geological data over the Geneva basin. Geological knowledge of the subsurface must therefore be integrated into existing and future energy planning tools in order to meet the need for sustainable subsurface development. As the owner of the subsurface and responsible for the sustainable and intelligent management of the existing resources, authorities of Geneva must be able to manage, process, store and recover all the data providing information on the state of the subsurface. Such management could only be done through an integrative and dedicated information system (IS) able to constitute a robust and coherent dataset, harmonize the regional stratigraphic framework and establish the data model and architecture of a structured information system.

1. INTRODUCTION

Since 2014, a large-scale program for development of geothermal energy has been launched in Geneva (Switzerland) by the local authority. This program, called “GEothermie 2020”, is driven by the Geneva State and the Industrial Services of Geneva (the local energy utility). This program aims at massively develop geothermal energy in order to cover up to 20% of the local heat demand by 2050. To reach this ambitious goal, all kind of geothermal systems are considered, from shallow (20-100m) to medium depth (1500m) aquifers and, at term, greater depths aquifers around 5000m. This approach that gradually goes into depth, as projects and feedback are successful is illustrated in Figure 1. However, this can only be achieved through a sufficient understanding of the basin’s geology accompanied by a robust dataset necessary to characterize its subsurface.

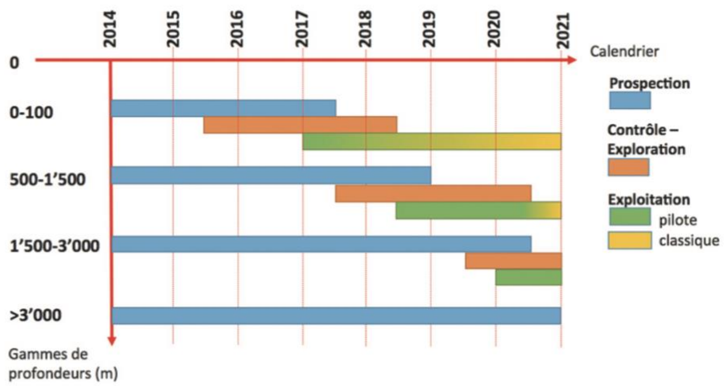

Figure 1: Schedule of geothermal prospection, exploration and exploitation activities with associated depth range within the GEothermie 2020 program in Geneva.

Although existing geological knowledge and dataset could be recovered and valorized through dedicated academic works at the onset of the program, additional data are necessary to fulfill the needs of the basin’s investigation. As part of the prospection and exploration phases of the GEothermie 2020 program, geophysical prospection and medium-depth exploration drilling activities have been initiated and provided new data for academic work to further specify regional geological knowledge (Brentini, 2018; Clerc et al., 2016; Rusillon, 2018). In parallel, shallower aquifers in Quaternary units are also further explored by the geological survey of Geneva and the GEothermie 2020 program to better delineate both their lateral extent and hydrogeological properties. Whereas medium-depths levels are still at an exploration stage, shallow open geothermal systems are now starting to flourish across the territory to complete the numerous geothermal vertical probes already well-developed in Geneva and in Switzerland in general.

The prospecting and exploration activities that have been appeared or have been reinforced since the beginning of the GEothermie 2020 program, generate a very important load of geological, geophysical and hydrogeological data, that sum up with the usual geodata mostly related to the construction activities that need to be gathered and administrated by the cantonal geological survey. Indeed, within the GEothermie 2020 program framework and organization, whereas the Industrial Services of Geneva have the important task to deploy and support the operational prospection and exploration activities , the State of Geneva and more precisely its service of geology, soils and wastes (GESDEC), has the responsibility to collect, administrate, valorize and diffuse the subsurface data in order to ensure, in such densely populated and transboundary area like the Geneva's canton, a sustainable and coordinated use of the subsurface resources without conflict of use and to stimulate the development of the geothermal branch with up-to-date information.

In order to carry out its missions, GESDEC must be able to rely on the most complete and up-to-date information possible. However, these large and heterogeneous data flows cannot be integrated into the current IT system, and are therefore not fully exploitable, due to a lack of tools to enhance them. In addition, the maps and information plans on which the State relies to accomplish its usual missions, particularly in terms of expertise in building land, groundwater protection and use, gravel pit management, and unstable areas, are no longer sufficient. Suitable IT tools are necessary for the three-dimensional representation of the subsurface and its characteristics, as well as the possibility to provide information for all the geothermal plants. In order to support and formalize this task, the canton of Geneva has adopted in June 2017 a new legal framework (Underground resources law, LRSS, L3 05), ensuring in particular the legitimacy of collecting and centralizing geological data for better planning of natural subsurface resources management, promotion of geothermal energy development while avoiding conflicts of use and supporting synergies whenever its possible.

2. INFORMATION SYSTEM FOR GEOLOGICAL DATA AND GEOTHERMAL PLANTS

To ensure a sustainable and coordinated use of the subsurface resources, geological data and energy demand information must be efficiently gathered, stored and administrated in appropriate information system (IS), then valorized and diffused through dedicated platforms. For the development of such an integrated information system, following aspects have been considered: 1) having a robust and scalable data model architecture able to host various types of raw and interpreted data; 2) selecting adapted 2D and 3D IT tools for database administration as well as efficient data collection, valorization and diffusion; 3) defining coherent data workflows for the complete administrative follow-up of geothermal projects, from their planning stage through their entire lifetime (Favre, 2018).

2.1 Data Type and Data Model Architecture

In the field of geology, the primary data that comes from direct observation or physical objects are distinguished from secondary data that consist of models or compilation of several primary data. The following definition proposed by the Ordonnance sur la géologie nationale (OGN, 510.624) is also commonly used by the canton of Geneva to explicit these data types:

- Primary geological data: "raw measurement data, such as drilling profiles, seismic measurements (signals) and geological subsurface field surveys";
- Primary geological data processed: "geological data that has been processed for interpretation";
- Secondary geological data and information: "geological data and information that results from the interpretation of primary geological data and primary geological data processed".

Regarding primary data sets, the GESDEC must mainly manage boreholes data and piezometers with associated data measurements that are coming from engineering firms and operators who carry out work on the subsurface. Data from geophysical acquisitions are less frequent than drilling activities on the Geneva territory but are nevertheless very important to consider for GESDEC. Secondary data are produced through mandates with engineering firms this is particularly the case of the extension of groundwater. Regional Universities and High Schools are also involved in reporting studies and new data for the GESDEC. Such data, primary or secondary, are transmitted to the GESDEC through various formats (paper in the archives, pdf reports, geochemical analyzes, etc.), and have to be stored and managed appropriately. All these data cover a wide range of applications that are representative of GESDEC's missions: geological, hydrogeological, geophysical, geothermal, polluted sites, gravel, soil and waste data.

In order to work transversely between these domains, a relational database model has been proposed. Relational databases require the establishment of a structural model to describe and organize data according to relationships between previously defined tables, called a data model. The first step of modeling consists of representing the objects identified within classes and adding their characteristics as attributes, depending on the use that will be made of the database: boreholes with or without equipment and associated measurements; outcrops; seismic lines acquisition; geothermal plants and associated measurements; soil surveys. These objects are also the most relevant elements to be taken into account for the development of geothermal energy and the issues associated with resource management. The result of this modelling is shown in Figure 2 through a hierarchical diagram of objects.

The structure of the database is designed around a central administrative table, which is the entry point into the database and makes it possible to determine what type of data is involved. Indeed, the “object type” attribute allows the user to select the object that is characterized (borehole, outcrop, seismic line or geothermal plant). Other common tables are linked to the central table and allow the user to add documentation or contact data associated with the described object. Then, specific tables can be used to describe the object and its technical characteristics. Equipments of a borehole are also identified, as well as geothermal plants. The measurements made on these equipments are collected in a specific table. For each of the objects that can be entered into the database, it is also possible to enter different associated geological characteristics, including geological units encountered, geological structures identified, natural resources observed, and samples collected. In addition, a dedicated geological data table describing the Quaternary geological units is proposed in order to detail its composition when possible (Favre, 2018).

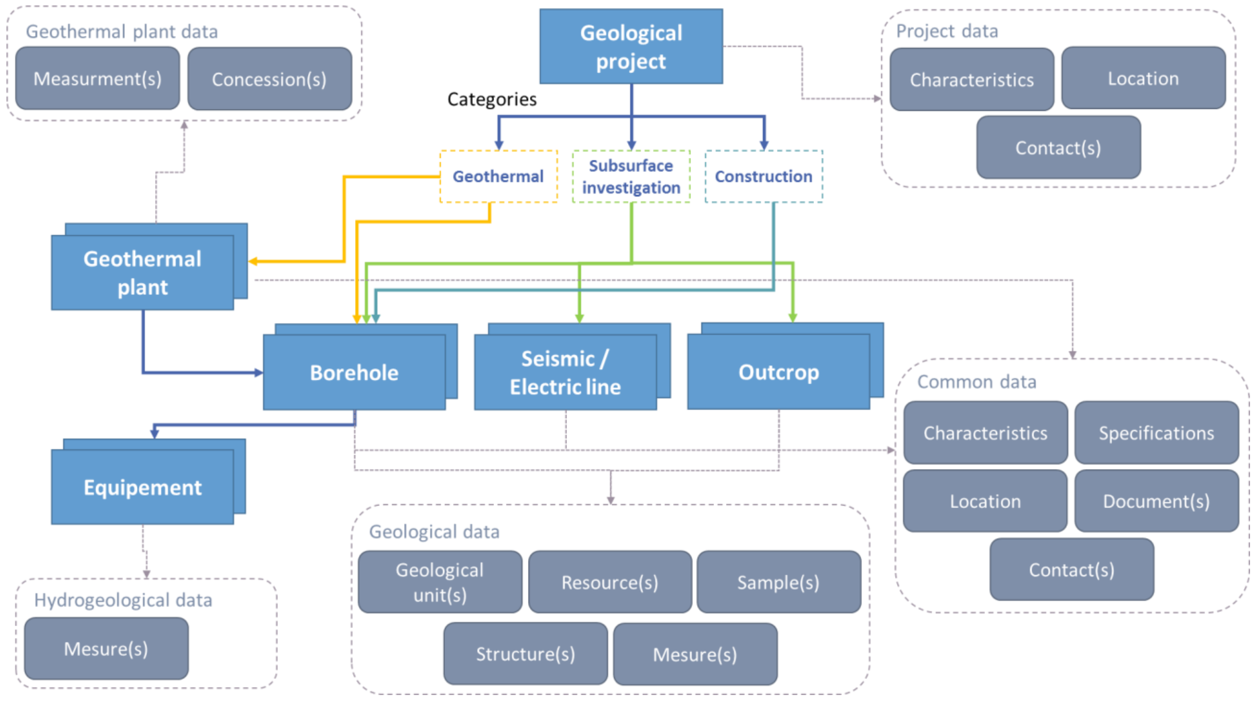

Figure 2: Hierarchical diagram of objects in the database of the GESDEC's information system.

Attributes that can be filled in with predefined values were widely preferred. When entering information, the fields with drop-down menus are used to unify and homogenize the data integrated in the database. This way, new data entry and database querying will be more efficient, and errors are limited regardless of the user.

This new scalable architecture makes it possible to enhance all types of objects related to the subsurface, and thus to populate the many data that can result from it. These datasets of primary data will then be used to generate other cartographic products and geological models (i.e. secondary data). Completeness has not been sought as the database will not replace a complex 3D geological model. However, it must allow existing information to be requested in order to facilitate its subsequent use for the production of new maps and models that are necessary for the GESDEC to meet the needs of subsurface and resource planning and management. Moreover, the correspondence of the attributes and the general structure of the data model was done in order to be easily integrated into the Confederation's minimum data model for boreholes (Oesterling and Brodhag, 2016).

2.2 IT Tools Composing the Information System

Subsurface planning and the need for a comprehensive approach requires a good knowledge of the geology but also of the existing uses of the resources located there. To this end, three-dimensional representations of the local geological conditions are a powerful visualization tool, but it is essential that they be accompanied by systematic data collection using standardized models (Ackermann, 2015). An information system that aims to manage geological data and geodata in 2D and 3D includes several components. The first component concerns the storage of geological data and geodata. The second allows the analysis of geodata for the production of maps and geological models in 2D and 3D. The third one allows the visualization and dissemination of this data across dedicated platforms including processes of data entry and transfer to the storage system and to the distribution platforms (Favre, 2018).

A centralized and indexed archiving system must allow for the safe storage of all documents containing information related to the subsurface. These documents are in various formats: technical documents, hydrogeological reports, administrative decisions, schedules, laboratory analysis results, site plans, survey announcements, maps, models, etc. Fast and efficient access to these documents must be guaranteed to employees in all phases of a project involving the subsurface and whatever the format in which this data is stored. In addition, the durability and security of documents must be ensured, on the one hand for historization purposes, and on the other hand to meet the need to provide legal evidence of administrative decisions or procedures. The storage and management of such data has to be linked with geological geodata in the meantime, so that each borehole point can be referenced with all the document that are related on it.

The mapping analysis and modelling component allows collaborators of the GESDEC working with primary and secondary geological geodata to produce new information through 2D and 3D geological and hydrogeological maps and models. This is the component of the geological information system used to process and analyse geodata. Concerning GIS tools, the State of Geneva uses ESRI suite (ArcGIS, ArcGIS Pro and associated application suites) while 3D models are designed through specialized geological and hydrogeological software (MOVE, Feflow and Isatis).

The component concerning visualization and dissemination in an information system allows geological data and geological models of interest to be shared internally with the main users, but also with actors outside the company. Concerning the dissemination of 2D data, it is the cantonal platform of the Geneva Territorial Information System (SITG) which makes all the canton's geodata accessible through several cartographic tools and counters. Users can access geodata according to the themes that interest them (development, natural waters, energy, geology, soil and waste, surveying, mobility, etc.), view maps on the geographical portal and even download data in different formats (.csv,.gdb,.gml,.kml,.shp), when the data is available in Open Data. A catalogue is also available for searching geodata and their associated metadata (SITG, 2019). For the visualization and dissemination of 3D geological models, the canton acquired GiGa Infosystem's GST software in 2014. GST allows the storage and management of 3D geological models with its desktop application. In this way, GESDEC internal users can manage 3D geological models without the need for full-fledged modelling software. The GST web application also provides a web platform for viewing and sharing models externally, also accessible without the need for geological modeling software or even installing the GST client. This web platform allows users to visualize the 3D models made available, but also to carry out virtual drilling and cross-sections (Gabriel et al. 2015).

2.3 Defining Data Workflows

Regardless of the IT tools used and solutions considered, the definition of data flows through an information system is necessary to ensure effective data management. The integration of data into the geological information system through an online platform will facilitate data management in general. The development of the GESDEC portal application would allow data to be automatically integrated into the GESDEC database, but it would also allow the tracking of requests for survey authorization. Project leaders would therefore have a monitoring tool for requests for authorization, until the work is completed, and the data generated on the subsurface is transmitted. This online platform could also be used to guide project leaders in carrying out a risk assessment.

As illustrated in Figure 3, three main phases have been identified in the creation and life of a geological project: 1) the construction (build), 2) operation (run) and finally 3) decommissioning (dismantling) phase. The first phase, known as the build phase, corresponds to the administrative life of the project and consists of three main stages that are the framing, authorization and then the implementation of the project. The next two phases concern the operation and then the potential end of use of the construction structures (objects) of the project (i.e. boreholes, geothermal plant). On each of the steps of the three phases, data will be collected and decision will be made.

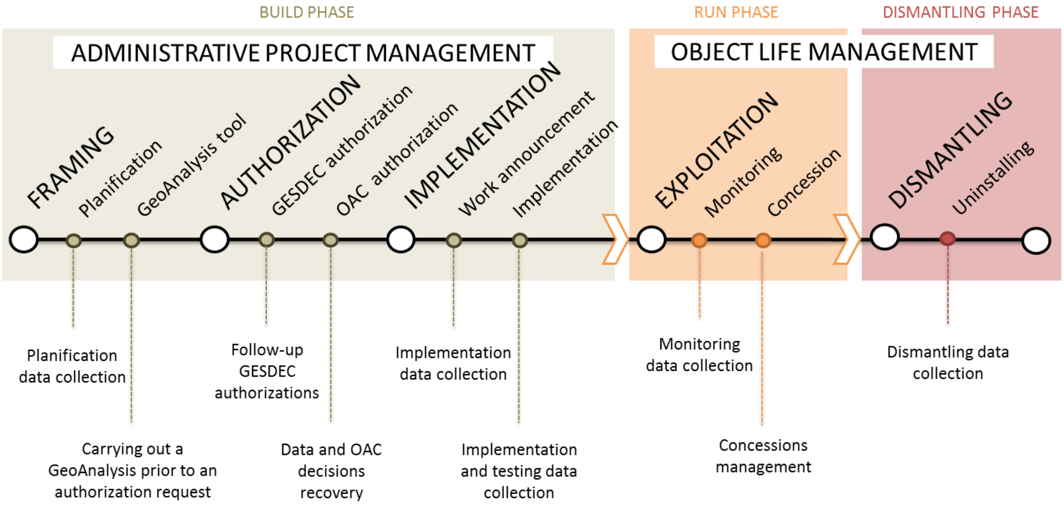

Figure 3: General geological project workflow and data type collection associated.

As described earlier, the data thus integrated into the database can then be used to produce maps or 3D geological models through specific queries to identify and select relevant data. Geological models produced can then be distributed on a dedicated platform, or information plans can be generated to cross-reference this 2D information with other mapping products.

Finally, the cartographic products and 3D geological models are distributed on the cantonal platforms. The legal framework also applies here to define the conditions of publication and confidentiality of data. Apart from the local authorities, other actors will also benefit from the diffusion of subsurface data, including the SIG, as part of its prospecting and exploration activities related to the GEothermie 2020 program, architects and engineers from private offices in the planning and implementation of their projects, universities for research work and knowledge development, the Confederation for the integration of data with federal tools, the cross-border community for coordinated resource planning and also the general public to promote a better understanding and acceptance of subsurface issues. Data should therefore be shared as much as possible with the public and project leaders, in order to promote knowledge sharing and stimulate new projects involving the subsurface while reducing areas of uncertainty thanks to the increasing density of information available.

3 ROLE OF LEGAL FRAMEWORK IN SUBSURFACE RESOURCES AND DATA MANAGEMENT

Laws on geo-resources and geodata are widespread in Europe. However, existing laws are often the legacy of historical mining and therefore do not concern deeper underground resources neither geothermal energy. In addition, data management and IS development issues are rarely addressed. The regulations concerning the data sets to be provided to each geological institute by a private company exploring and producing geo-resources are not systematic. This does not help geological surveys to receive data in a consistent manner and in a consistent format for their IS. The definition of a clear legal framework, concerning data providers, should lead to a systemic data collection and centralization. European geological surveys with advanced IS such as TNO-GSN and BRGM have also defined a clear legal framework (Asch et al. 2004). For example, the new Key Register Act for the subsurface requires that underground data be submitted to the geological survey of the Netherlands and stored in the BRO database (Van der Meulen et al., 2013). In addition, the law stipulates that the government and authorities must consult the database when developing policies or decisions.

3.1 Guideline for Regulations on Data Formats

Following these convincing examples, the canton of Geneva, in parallel of its IS development, has understand the necessity to establish a legal framework to set the principle of underground data management. The mining law from 1940 that was no longer adapted to new uses of the subsurface and its resources has been revised. A new law on underground resources (LRSS) has been in force since June 2017. In this law a chapter is dedicated to data management and prescribe the establishment by the authority of a geological database to reference the subsurface at the cantonal level (art. 17, LRSS). This chapter formalize also the obligation to transmit all the underground data to the authorities and precise the requirements in terms of standards, formats, deadlines and quality of information.

Another important objective of the LRSS and its regulation will be to meet the future requirements of the Land use planning law (LAT) that is currently under review in Switzerland. The development of the federal spatial planning framework aims to require the cantons to make sustainable, "judicious and measured use of the subsurface and to coordinate, both among themselves and with surface planning, the use of groundwater, raw materials, energy and construction areas" (art. 3 and art. 8e LAT). With the increasing use of the subsurface both for natural resources (water, geothermal energy, mineral raw materials) and for urban installations (heating networks, underground car parks, etc.), a coordinated and sustainable development of the subsurface is becoming essential for the cantons.

The new LRSS law provides a general framework for resource management as well as for the management of geological data. However, the definitions and conditions for data transmission still need to be specified in the implementing regulation. Also, the future data flow for the geological IS of the canton should be able to integrate elements under development such as information capture and project monitoring tools, risk assessment methods, production of 2D and 3D geological maps and models, as well as making these data available to the public and handle data confidentiality issues. In this sense, the role of the legal framework is to support the development of the IS and to propose the bases for the definition of coherent data workflows.

3.2 Guiding News Geothermal Projects and Enhancing Data Collection and Centralization

As described in the data workflow, an important point concerns the future obligation to use an automatic cartographic requestor to analyze potential conflict of use of the subsurface environment linked with the ongoing project. The geoanalysis tool indicates the presence and potential of the resources available in the area (i.e. groundwater energy potential, known and forecasted flows rate), specifies the restrictions involved and provides associated recommendations such as the option to study another project alternative in line with environmental conditions. Project leaders will systematically have to submit the synthetic report produced by the geoanalysis during a project submission involving the subsurface.

The role of the geological survey of Geneva is not limited to the regulation of geothermal installations in the territory. It must also ensure the sustainability of the exploitation of resources over time. Quantitative and qualitative preservation of local groundwaters must be evaluated regularly, thus installations monitoring is mandatory. The details of the monitoring data requested by the canton and the time intervals to be respected for the provision of this data are specified through concession agreements and depend of the size of the plant, exploited flows or nominal power. The monitoring data collected in this way will also be integrated into the cantonal database and used to generate hydrogeological models, helping the authorities to make suitable decisions concerning new installation or concessions renewal.

Although many data are requested from project leaders, the objective is twofold: to centralize the canton's geological data and to make this updated dataset available to all for the development of future projects involving the subsurface. This win-win exchange should stimulate projects leaders to participate in the collective effort to transmit the acquired data. In addition, by providing tools for the environmental conditions analysis of the territory, the State aims to support projects in order to promote good practices and optimize authorization procedures. The pilot projects carried out within the framework of the GEothermie 2020 program also contribute to the support and development of a sustainable geothermal energy sector in Geneva.

4 CONCLUSIONS

The development of geothermal energy in Geneva and region raises various questions regarding the management of subsurface resources and data. A good knowledge of the resource and the geological environment of the subsurface will allow the development of geothermal projects by minimizing the risk of failure and damage to the environment. In return, the implementation of such projects will promote and improve knowledge of the local geology and its resources. As owner of the subsurface and its resources, the Geneva state is responsible to collect all data that describe the local geological and hydrogeological conditions. In addition to their role of regulator and data provider, the authorities of Geneva must now also ensure the planning, coordination and administration of a growing amount of data generated by increased use of the subsurface including a fast development of geothermal projects. From this perspective, the question of data management is therefore central and the use of an appropriate geological information system is an invaluable added value. The future information system will guide geothermal project owners and assist the authorities for an optimal management of the subsurface resources in Geneva to guarantee a sustainable and coordinated use of geothermal resources, in line with the cantonal and federal strategy toward extended use of renewable energy. The information system will also be able to gather all information related to the subsurface, answer queries to produce and diffuse up to date information including maps and 3D geological models in order to respond to the growing needs in terms of subsurface information.

An information system for managing geological data cannot be reduced to a single tool or software. The latter includes components that have different roles and functions such as: data storage, mapping analysis and modelling, data visualization and dissemination, and data capture and transfer. This information system must also be able to communicate and exchange with various technological environments. The system architecture has to be designed to ensure the bridges between data and users, i.e. to ensure the interoperability of tools between them. Building an integrative IS implies to have a global view of the outcome and the necessary intermediate steps to achieve it. The ongoing challenges concern the description of detailed business process for each project type identified, that have to be in line with the rules of application of the LRSS currently being drafted. In the meantime, existing data have been transferred from the previous database structure to the extensive one and new data are collected through an input mask directly plugged to the geographical database. Enriching the new database contribute to test the structure developed and will also provide sufficient information to update existing maps and models, and to elaborate new products, such as a geothermal potential map (including temperatures and rate flow expected), a risk map on the presence of hydrocarbons and gas coming during drilling or a faults and fractures map. Moreover, having up-to-date data regarding subsurface projects, boreholes, geophysical acquisition and geothermal plants will help the authorities to adopt a systemic approach to promote synergies and avoid potential conflict of use on the territory.

REFERENCES

Ackermann, T.: Chaos en sous-sol, ou quand règne la règle du « premier arrivé, premier servi » ?. Aqua & Gas, Schweizerischer Verein des Gas- und Wasserfaches (SVGW), Zurich, (2015), 7pp.

Asch, K., Brodaric, B., Laxton, J.L., Robida, F.: An international initiative for data harmonisation in geology. In: Proceedings 10th EC GI & GIS Workshop, ESDI: The State of the Art, Warsaw, Poland, (2004), 23–25.

Brentini, M.: Impact d’une donnée géologique hétérogène dans la gestion des géo-ressources: analyse intégrée et valorisation de la stratigraphie à travers le bassin genevois (Suisse, France). PhD thesis, University of Geneva, Geneva (2018).

Clerc, N., Rusillon, E., Cardello, L., Moscariello, A. and Renard, P.: Structural Modeling of the Geneva Basin for Geothermal Ressource Assessment. Abstract, 14th Swiss Geoscience Meeting, Geneva (2016).

Favre, S.: Systèmes d’information pour les données géologiques 2D et 3D. Perspectives et limites pour l’analyse du sous-sol genevois et ses ressources. PhD thesis, University of Geneva, Geneva (2018).

Gabriel, P., Gietzel, J., Le, H.H., Schaeben, H.: GST: a network based datastore for geoscience data and geomodels and its implementation - ProMine's contribution towards interoperability. In: Weihd, P. (ed.) 3D, 4D and Predictive Modelling for Major Mineral Belts in Europe, Mineral Resource Reviews, Springer International Publishing Switzerland, (2015), pp. 59- 71.

Oesterling, N., Brodhag, S.: Datenmodell Bohrdaten - Module. Bundesamt für Landestopografie swisstopo, Wabern, Switzerland, (2016), 19 pp.

Rusillon, E.: Characterisation and rock typing of medium to deep reservoirs in support of geothermal exploration in the Greater Geneva Basin. PhD thesis, University of Geneva, Geneva (2018).

SITG :[online] http://ge.ch/sitg/ Système d'information du territoire genevois, République et canton de Genève, Geneva (2019).

Van der Meulen, M.J., Doornenbal, J.C., Gunnink, J.L., Stafleu, J., Schokker, J., Vernes, R.W., Van Geer, F.C., Van Gessel, S.F., Van Heteren, S., Van Leeuwen, R.J.W., Bakker, M.A.J., Bogaard, P.J.F., Busschers, F.S., Griffioen, J., Gruijters, S.H.L.L., Kiden, P., Schroot, B.M., Simmelink, H.J., Van Berkel, W.O., Van der Krogt, R.A.A., Westerhoff, W.E., Van Daalen, T.M. : 3D Geology in a 2D Country: Perspectives for Geological Surveying in the Netherlands. Netherlands Journal of Geosciences, 92(4), (2013), 217–241.