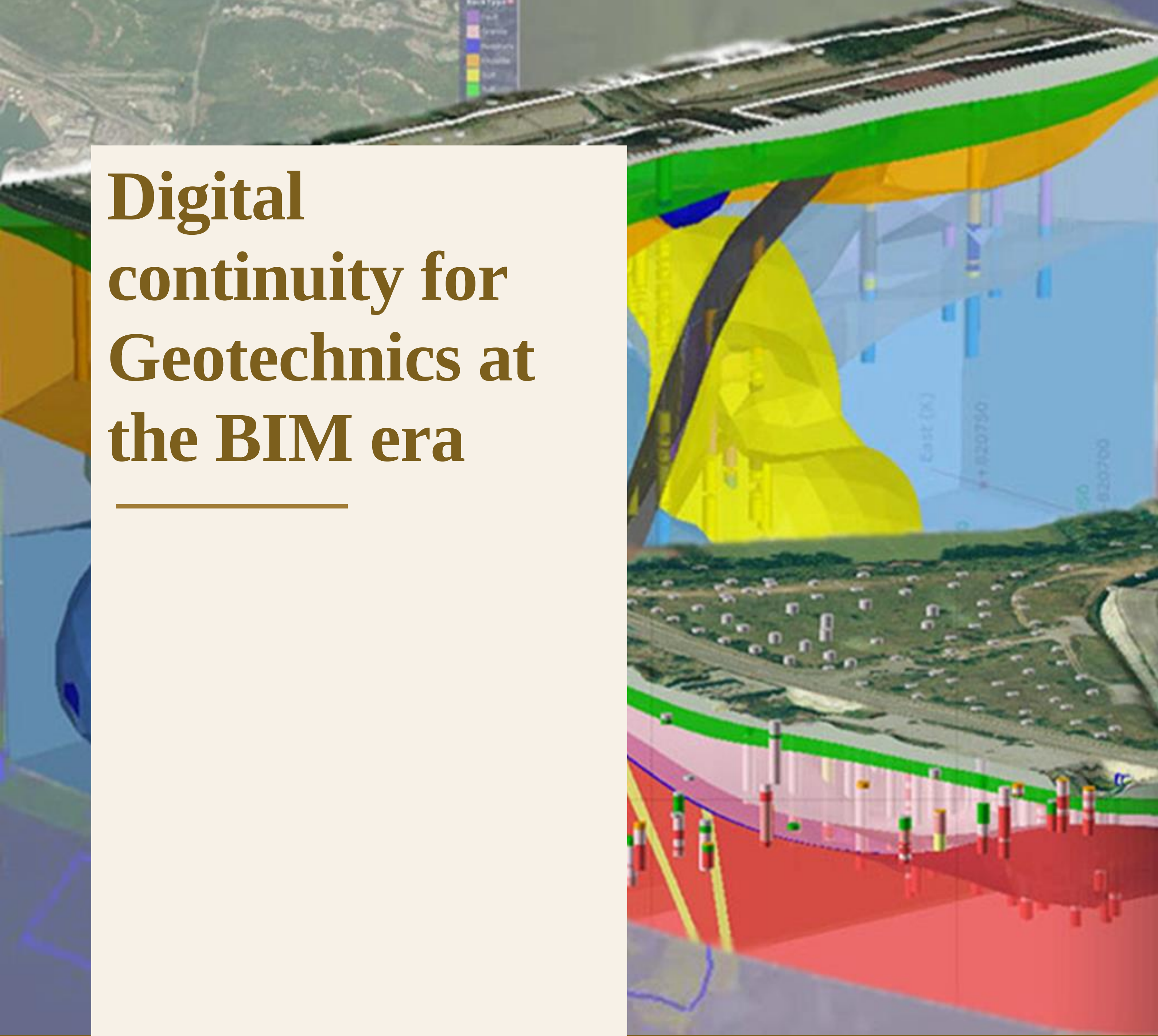

Digital continuity for Geotechnics at the BIM era

22 January 2022

V1

Paper objective

This paper exposes a position regarding Digital Continuity for Geotechnics at the BIM era. It introduces challenges and also envisions solutions to address it.

The co-authors listed below share this vision and propose to collaborate to develop or support this initiative.

Co-authors / supporters

Confirmed:

Scott Simmons, OGC, Chief Standards Officer

Richard Petrie, buildingSmart International, Chief Executive

Mickaël Beaufils, BRGM, OGC GeoScience DWG Chair

Michel Rives, Vianova Systems, IFC Tunnel Project Leader

Jonas Weil, IC-Group, IFC Tunnel Geo-Subgroup Leader

Neil Chadwick, AGS Data Management Working group

Dan Ponti, DIGGS Steering Comitee

Magnus Romoen, NGI, ISSMGE TC222 Chair

Harvey Thorleifson, Minessota Geological Survey, CGI-IUGS Chair

Andrew Hugues, BGS, OGC MUDDI SWG Co-chair

Isabelle Halfon, BRGM, Geotechnical Engineer

Elodie Vautherin, COLAS, Geotechnical Engineer

Pierre Garnier, COLAS, Geotechnical Engineer

Sylvie Bretelle, Antea Group, Geotechnical Engineer

Contents

What is geotechnics?

"Natural Soil is never uniform, and its properties change from point to point while our knowledge of its properties are limited to those few spots at which the samples have been collected".

Karl von Terzaghi (1883 - 1963)

This quote sums up the global difficulty for the geotechnical engineers to assess ground conditions to build safe & persistent infrastructures. Through centuries, geotechnical engineers developed numerous & various tests to extend the knowledge of nature & mechanical behavior of soil and translate them using physical theories compatible with classic mechanical structural models. The step from raw measurements to mechanical model is a subjective process which is, as geotechnical data, often forgotten after project realization.

Therefore, digital modeling and digital twins offer a unique opportunity to define numerical data exchange format for raw data and interpreted features. Used as widely as possible, this format would provide a common, evolutive but persistent tool to allow communication and exchange between geotechnical engineers and civil engineers in order to define a specific geotechnical model, related to a unique project. This model will be merged with interoperable projects BIM models to make calculations and designs, according to various standards.

Joining efforts for geotechnical data standardization

Standardizing geotechnical data is not a new topic. Several organizations have undertaken initiative to work on this topic. Figure 1 introduces the different national or international bodies involved in the project. At the ISO level, standards for OpenBIM and OpenGIS are respectively addressed by TC59 and TC211. Those two TCs themselves consolidate upon pre-standardization specifications provided by bSI and OGC. The IFC Tunnel GeoSubgroup from bSI and the MINnD project (in France, supported by the ATLAS initiative) are the main co-builders of a joint proposal for geotechnical data standardization. Both identified the OGC standards and other formats like AGS as a suitable base for a cross BIM-GIS standard for Geotechnics. In parallel, ISSMGE has recently launched a Technical Committee (#TC222) to address the topic of "BIM and Digital Twin for Geotechnics". The main envisioned activities are to provide a forum to disseminate and exchange knowledge and practice on BIM and DigitalTwins in Geotechnics, and support the standardization activities.

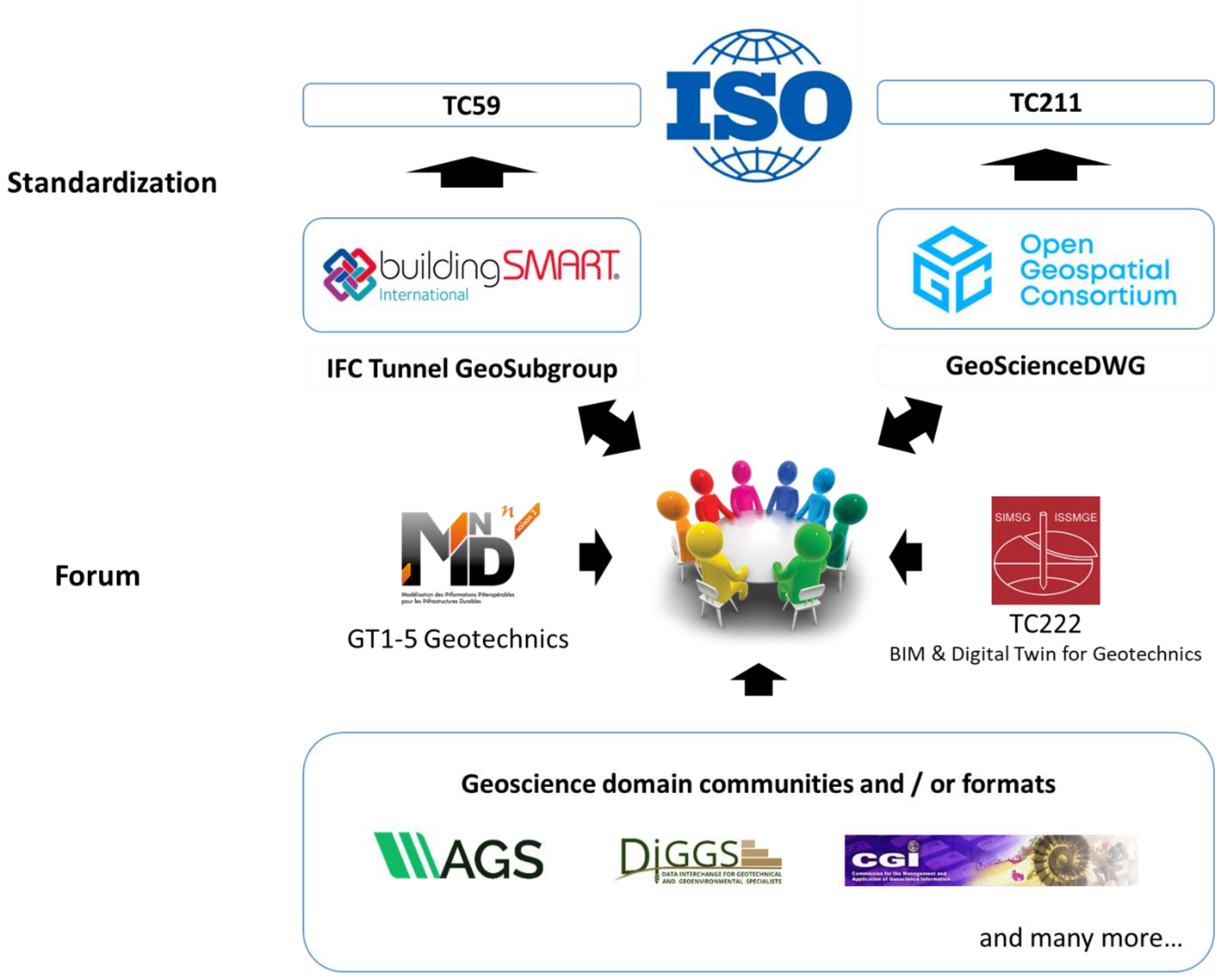

Figure 1: Different bodies are involved to enable Digital Continuity for Geotechnics.

Although different exchange data formats are already developed, little has been done to link the geotechnical data to the geotechnical model and the infrastructure to be built, through the associated design. The next sections will develop this topic.

Answering the requirements of Digital Continuity for BIM and GIS in Geotechnics and the relationship with the FAIR principles

BIM, GIS & Digital Twins introduce or emphasize several requirements regarding the data. This mostly concern the built environment but also orientate the way the geoscience data are expected to be delivered.

Semantic coherence for Geotechnics and the necessity of models federation

The main concern is about semantics. As also identified as the main criteria of interoperability in the FAIR principles, data shall be described in a non-ambiguous way. Those definitions shall be shared by the community independently from the standard that is used.

For that purpose, a federation of model is needed. Then OGC and bSI will derive logical models for OGC based and bSI based (IFC) standards.

This effort would fit into the ongoing collaboration between OGC initiatives and bSI projects on georeferencing, infrastructures alignments, procedural geometries, voxels, etc...

Richard Petrie (bSI), Scott Simmons (OGC)

Although, this project is the opportunity to align with other standards. A non-exhaustive list of them include AGS/AGSi, DIGGS, Geo3DML, GeoValML, BoreholeML, ResqML...

On the OGC side, this project is identified as the main contributor to leverage the OGC based standards. For the moment, the IFC schema extension for Geotechnics is mainly supported by the GeoSubgroup of the IFC Tunnel but it aims to serve all the IFC infrastructure projects. As illustrated by Figure 2, regular cross meetings between those two groups are necessary to enable OpenGIS <> OpenBIM interoperability.

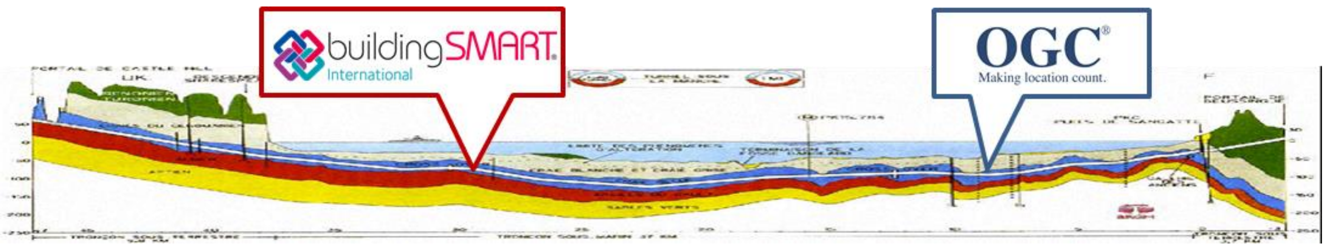

Figure 2 : Semantic alignement and tunneling. Same objectives: meet each other.

Handling of geometries: continuity between representations

The second main concern is about geometry. When available, association to geometric representations (in particularly georeferenced representations) shall be made possible. This is commonly assumed that in geoscience several kind of representations enable to map the subsurface: 3D volumes, 2D longitudinal profiles or cross-sections, maps. As a model engage the geomodeler vision of the subsurface, they pay a real attention to the kind of model they agree to build. 2D longitudinal profiles are then still a very common situation, even with big projects.

Figure 3 gives an overview or usual representations for geoscience objects.

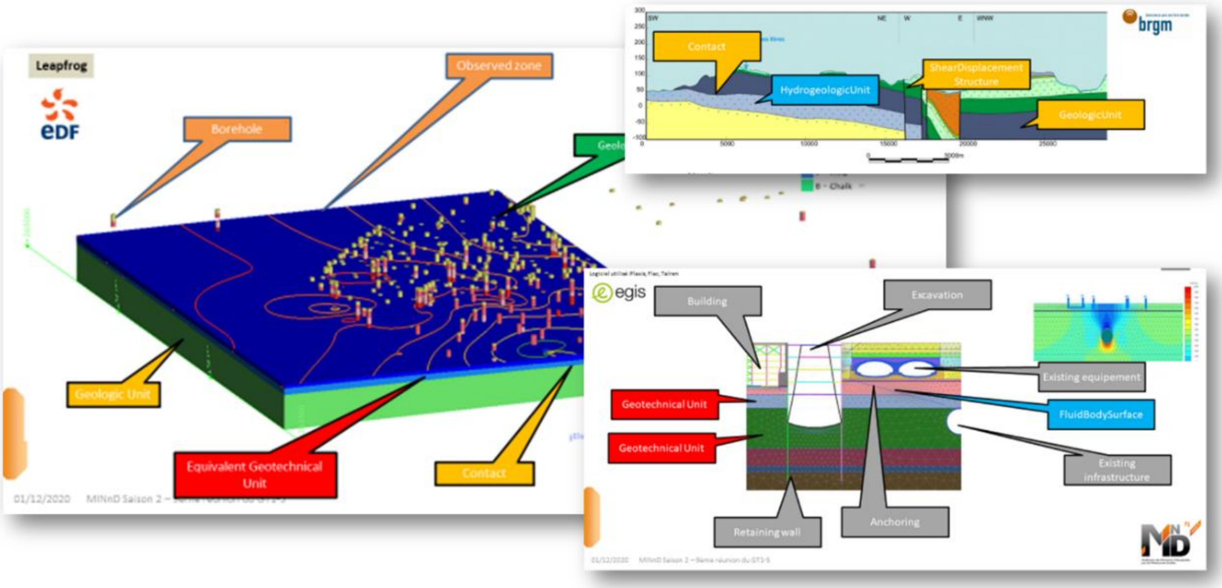

Figure 3: Some usual representations for geoscience objects. Source: MINnD GT1-5

Proposed actions

Leveraging the existing OGC based geoscience standards

The objective is to define the suitable extension of GeoSciML, GroundWaterML2 and other OGC based standards to cover the topic of Geotechnics.

This basically consists in defining new concepts or extend the existing ones by adding new properties to them.

Figure 4 drafts the expected impacts on several OGC based standards concepts. Different fill and border colors enable to highlight different kind of evolutions are expected:

- Colored box without border: a concept from an existing model has been identified as a suitable basis. The expected evolution it to propose additional properties to that concept;
- Colored box with a border: a more generic concept exists. The expected evolution is a specialization of that concept and attach associated properties;
- White box with dashed lines: this concept does not exist yet in an existing data model. The expected evolution is to create it (with associated properties) and connect it to the existing data models.

Note that the topic of observations, measurements, tests, analysis and interpretations (including geophysics) are all expected to be covered thanks to the ISO19156 standards / Observations & Measurements.

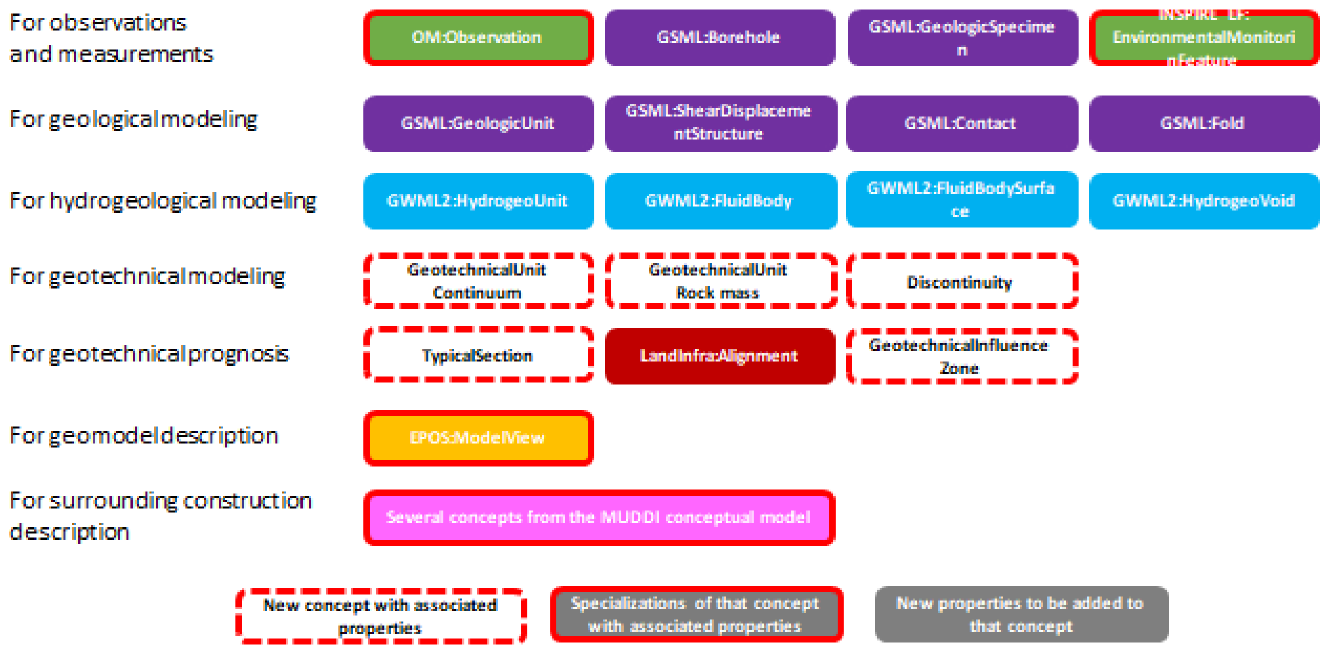

Figure 4: Expected evolutions on OGC based standards (draft)

Facilitating access to geotechnical data thanks to APIs and encourage linked data

Several standards or at least formats already exist to provide geotechnical data. As some are more compatible with some software, the geotechnical engineers often have to proceed data conversions in order to enable interoperation of systems. This action is not only time consuming but can lead to mistakes, loss or duplication of information.

In the meantime, solutions like web services or APIs have been developed in order to facilitate data access. The OGC is quite famous for being the author of some of them in the domain of geospatial. This includes the well-known Web Map Service (WMS) to provide maps, but more recently Sensor Things API for observations or OGC API Features for objects. Linked data also enable to explicit relationships between objects and/or properties.

Figure 3 illustrates the possibility to use OGC APIs or Web Services to describe objects or properties and also link them. This system offer a cross platform solutions enable to bridge between BIM, GIS or domain specific software.

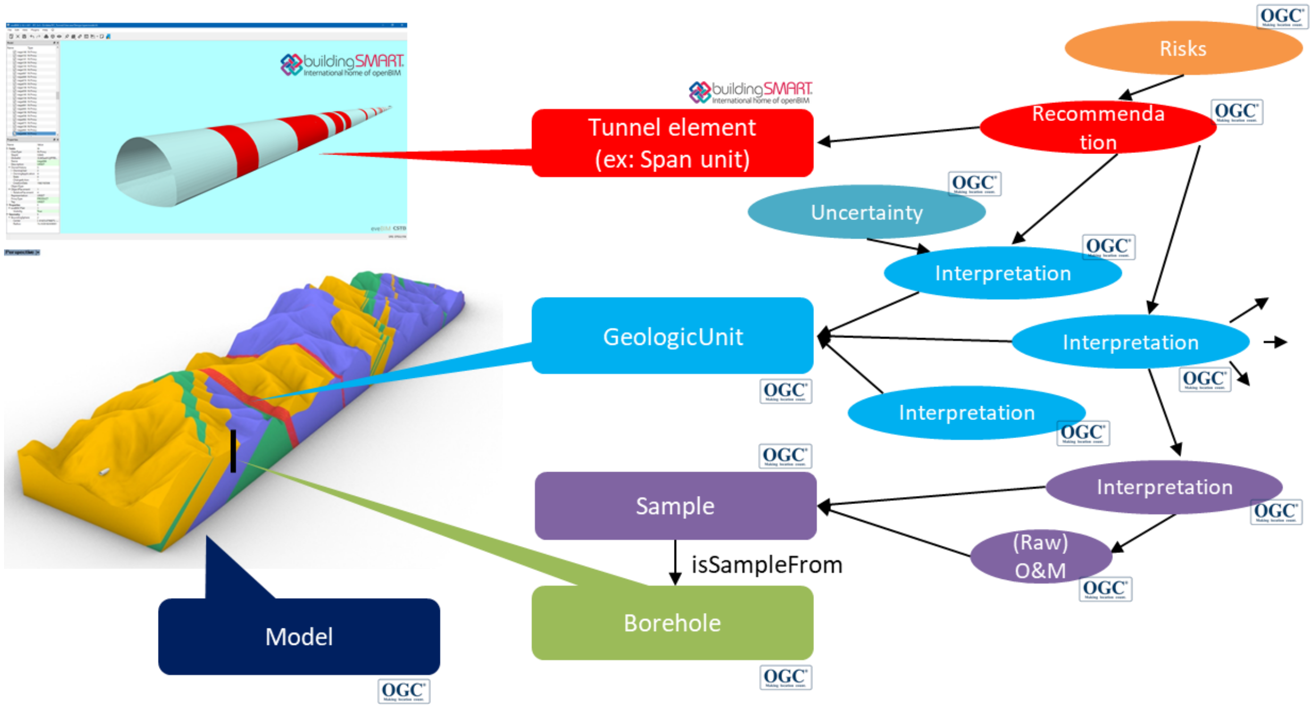

Figure 5: An illustration of the principle of linked data applied to geotechnics thanks to OGC APIs

Such approach has been demonstrated in the Beijing bSI Summit 2019 by a joint working group between BRGM, CSTB and OYO.

Accessible and shared vocabularies for Geotechnics

As stated above, semantics is a key point for interoperability and does not only concern the objects description but also the values that can be used to fill the properties. Each term that is used shall be associated to an unambiguous definition that one can freely access. Those terms form registers that can together be part of a registry. In that domain, the work made in Web Semantics in the W3C shall be mentioned and taken as a structure to follow.

In geoscience, the Registry of Geoscience in France (https://data.geoscience.fr/ncl/) or the Registry of the CSIRO in Australia (http://registry.it.csiro.au/_def) are based on those principles. Other organizations, like the Geological Survey of Austria propose some thesaurus (https://thesaurus.geolba.ac.at/).

In civil engineering, the buildingSmart Data Dictionnary (bSDD) is the reference for sharing vocabularies regarding building and civil engineering works. It offers an online service that hosts classifications, standards, dictionaries and their properties, allowed values, units and translations (https://search.bsdd.buildingsmart.org/).

Of course, coherence between vocabularies (same definition for the same concept) shall be encouraged when possible, but at least registries, thesaurus and data dictionaries offer solutions to enable someone to do some reference to unambiguous definitions.

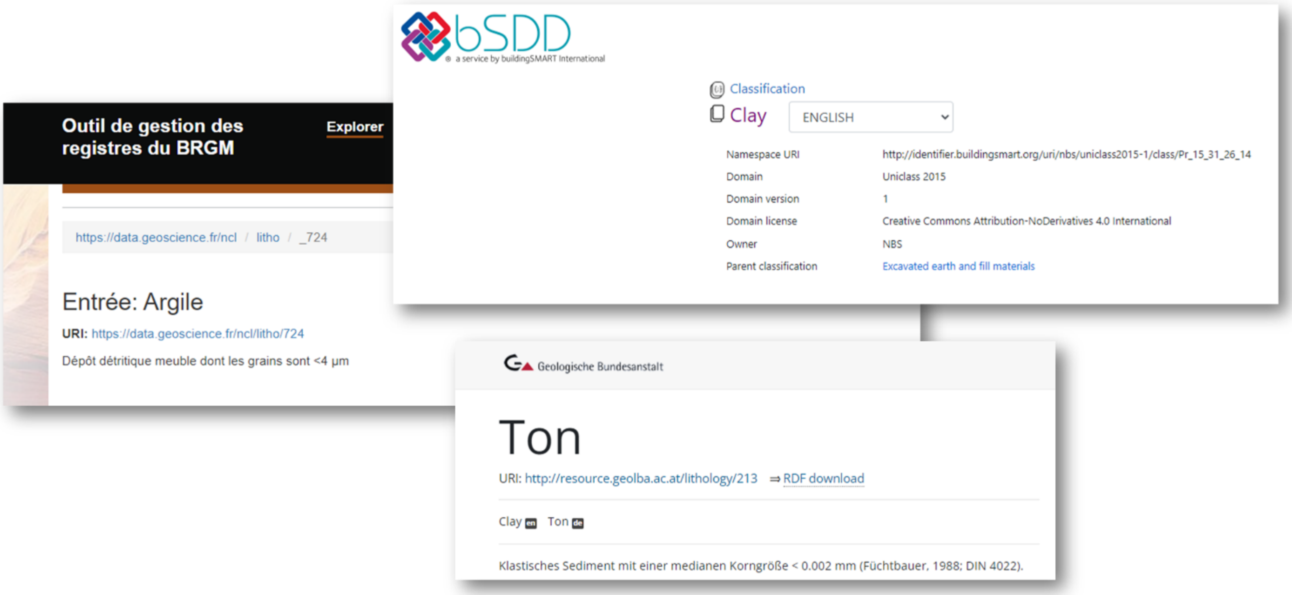

Figure 6: Clay in English / Argile in French / Ton in German: beside the language, several definitions exist. Reference to registries, thesaurus or data dictionaries enable to clarify the one that is used by the data provider.

Glossary

Scientific terms

Geology: study of the planet Earth, the materials of which it is made, the processes that act on these materials, the products formed, and the history of the planet and its life forms since its origin (ISO 22932-2)

Hydrogeology: the study of the interrelationships of geologic materials and groundwater (CIRIA C515)

Geotechnics: application of scientific methods and engineering principles to the acquisition, interpretation, and use of knowledge of materials of the Earth's crust for the solution of engineering problems; the applied science of making the Earth more habitable. Geotechnics is the field of civil engineering which studies soil-structures interfaces as well as natural risks to assess feasibility & to adapt and design human constructions.

Geoscientific model: A geoscientific model is defined as the result of geoscience data processing and interpretation. Proposing either a spatial distribution of geoscientific objects with properties of interest (feature) or attempt of retranscribing natural/man-made soil behaviour through mathematical functions or algorithms (process).

Conceptual model (informatics): A conceptual schema or conceptual data model is a map of concepts and their relationships. This describes the semantics of a domain and represents a series of assertions about its nature. Specifically, it describes the things of significance to a domain (entity classes), about which it is inclined to collect information, and its characteristics (attributes) and the associations between pairs of those things of significance (relationships). This model's perspective is independent of any underlying data format or application.

FAIR principles: Introduced in 2016, the 'FAIR Guiding Principles for scientific data management and stewardship' provide guidelines to improve the Findability, Accessibility, Interoperability, and Reuse of digital assets. The principles emphasize machine-actionability (i.e., the capacity of computational systems to find, access, interoperate, and reuse data with none or minimal human intervention) because humans increasingly rely on computational support to deal with data as a result of the increase in volume, complexity, and creation speed of data.

Organizations and standards

ISO: The International Organization for Standardization develops and publishes International Standards. Several Technical Communities enable to address a large domain of activities. TC59 is dedicated to Building and Civil Engineering works (including BIM). TC211 is dedicated to Geographic Information/Geomatics (including GIS). Since the emergence of BIM, TC59 and TC211 collaborate in order to achieve compatible standards between BIM and GIS. The work made by buildingSmart International (bSI) and the Open Geospatial Consortium (OGC) are largely supported and promoted in TC59 and TC211.

CEN : the European Committee for Standardization, is an association that brings together the National Standardization Bodies of 34 European countries. Its actions are strongly connected with ISO activities.

Open Geospatial Consortium (OGC): OGC is an international industry consortium participating in a consensus process to develop publicly available interface standards. The geoscience standards, especially GeoSciML have been designed jointly with CGI-IUGS, giving them the status of reference standards for geology. Efforts from OGC have also been made to extend those standards to address the topic of hydrogeology. The result was the standard GroundwaterML2 that is an extension of GeoSciML. The geoscience standards also rely on the ISO19156 standard that is a cross domain model for Observations, Measurements and Sampling.

---

buildingSmart International (bSI): bSI is an international organization committed to creating and developing open digital ways of working for the built asset industry. buildingSMART standards help asset owners and the entire supply chain work more efficiently and collaboratively through the entire project and asset lifecycle.The Industry Foundation Classes (IFC), ISO 16739, are the official standards for OpenBIM. Major evolutions have been made on them, especially with IFC v4.x, to extend their capacities: IFC 4.0 introduces the extension of IFC from building to infrastructure. IFC 4.3 is having another step forward in the direction of environmental modeling. It introduces the capacity of describing non-man-made objects and also georeferencing. Two major and necessary improvements to envisage the description of geotechnical objects or even earthworks. The IFC Common Schema is identified to offer a cross-infrastructure support to address those domains. Major evolutions in that direction are made through the IFC Tunnel project.

MINnD: The MINnD National Project in France is since its creation in 2014 is the French initiative to push openBIM extensions for infrastructure description. Majors contributions from MINnD have been brought to the development of IFC Bridge, IFC Road, IFC Rail. IFC Tunnel is largely influenced by the work made by the MINnD Tunnel (WG1-4) and MINnD Geotechnics (WG1-5) projects, that are themselves part of the wider MINnD Underground Infrastructure. MINnD Geotechnics emphasized the importance of building on and connecting existing standards.

ISSMGE: The International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE) is the pre-eminent professional body representing the interests and activities of Engineers, Academics and Contractors all over the world that actively participate in geotechnical engineering. The aim of the International Society is the promotion of international co-operation amongst engineers and scientists for the advancement and dissemination of knowledge in the field of Geotechnics, and its engineering and environmental applications.

IAEG: The International Association for Engineering Geology and the Environment (IAEG), is an international scientific society that aims to promote and encourage the advancement of engineering geology through technological activities and research. At the same time it strives to improve teaching and training in engineering geology, and to collect, evaluate and disseminate the results of engineering geological activities. IAEG is affiliated with the International Union of Geological Sciences (IUGS).

IUGS-CGI: The Commission for the Management and Application of Geoscience Information (CGI) is a working subcommittee of the International Union of Geological Sciences. Its mission is to enable the global exchange of knowledge about geoscience information and systems. CGI is the governing body responsible for the XML-based exchange languages Geoscience Markup Language (GeoSciML - in collaboration with the Open Geospatial Consortium) and EarthResource Markup Language (EarthResourceML). The CGI and its members also play a significant role in the OneGeology initiative.

AGS and AGSi: AGS is the association of geotechnical and geoenvironmental Specialists based in UK. In 1991, the AGS set up a method for transferring data between industry organizations. This is known to many simply as ‘AGS Format’ or ‘AGS Data Format’ and provides a standard way to transfer ground investigation, laboratory testing and monitoring data between the contributing parties of a project which involves geotechnical or geoenvironmental elements. AGSi has been developed recently to fit with IFC format and to be used more specifically for ground models and interpreted data.

DIGGS: Data Interchange for Geotechnical and Geoenvironmental Specialists. DIGGS is used in the United States. It has been based on the AGS data format, yet using IT technologies like XML and GML. DIGGS supports any language, and any unit system and it can reference any codes, units, or language conventions. It is currently being expanded to handle other types of geotechnical data from sources such as pile load testing, performance monitoring instrumentation, and geo-environmental site monitoring.