IMPLEMENTATION OF GEOLOGICAL MODELS AND GEOSCIENCE DATA INTO BIM PROJECTS

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ABSTRACT: From January 1, 2027, BIM will be mandatory for all large-scale public construction contracts in the Czech Republic. Its key component is a digital building information model based on the ISO 16739 (IFC) standard, which, however, does not yet systematically cover geological information. Nevertheless, this information is essential, especially for large-scale and underground constructions. In recent years, we have therefore developed procedures for integrating spatial geological data into IFC models at several specific locations. The benefit is the standardization of geological objects and their easy combination with IFC models from other professions in the BIM environment. This improves the quality of design, planning, and risk management and reduces costs during exploration and construction. Typical examples of using the proposed approach include not only transport tunnels and other linear structures, but also nuclear power plants and deep repositories for highly radioactive waste, which are currently being intensively developed

1. INTRODUCTION: BIM AS DATA-ORIENTED CONSTRUCTION INFORMATION MANAGEMENT

In technical terms, BIM (Building Information Modelling) is understood not as the creation of a 3D model, but as a system for managing information about a building throughout its life cycle, typically in connection with the processes defined by the ISO 19650 series (ISO 19650-1, 2019). BIM assumes that data is created during project preparation, continuously validated during construction, and subsequently used in the management and operation of buildings. A decisive condition for this approach is a formalized data structure and data sharing in an environment that allows clear interpretation across disciplines.

In the Czech Republic, BIM is currently institutionally recognised as a tool for increasing the efficiency of public investment. Information on the effectiveness of the legal framework from 1 January 2027 is available in public administration sources and related information portals (Zákon o správě informací o stavbě 2025, Zákon o správě informací o stavbě a vystavěném prostředí 2025). This significantly increases the demands for standardization of data structures not only for "classic" construction disciplines, but also for disciplines that influence the design, safety, and operational reliability of buildings, such as geology and geotechnics.

2. DIMS: BASIC BIM DATA SOURCE AND REQUIREMENTS

In Czech terminology, an essential component of BIM is the Digital Building Model (DiMS), which "connects graphic and non-graphic information" and serves as a digital representation of the spatial arrangement and selected properties of a building and its elements (Koncepce BIM.gov.cz). For the purposes of interdisciplinary coordination and subsequent object management, it is critical that this model is not reduced to geometry, but also carries:

- unique identification of objects and their relationships,
- properties (including data types and physical units),
- metadata about the origin and quality of data,
- links to documentation.

In the case of constructions with a significant impact on the subsoil (deep foundations, linear structures, underground excavations), these requirements naturally extend to the rock environment. If geological information is kept outside DiMS, the project reverts to a document-oriented practice, where 3D knowledge is reduced to 2D sections and text interpretations, which impairs the reproducibility of analyses, change management, and information integration.

3. OPEN STANDARD IFC (ISO 16739) AND THE LIMITS OF CURRENT SUPPORT FOR GEOSCIENCE DATA

The ISO 16739 standard defines IFC as an open international format for exchanging BIM data between software applications (ISO 16739-1, 2024). Its benefit lies in the fact that it allows the transfer of object-oriented data, including properties and relationships, thereby supporting interoperability and long-term data sustainability.

However, it is necessary to precisely distinguish between two levels of "coverage" of geology in IFC:

- Existence of basic entities: IFC 4.3 includes elements for geotechnical/geological concepts, e.g., IfcGeotechnicalStratum and IfcGeoslice, which explicitly refer to geological interpretation and cross-sectional models (IFC 4.3 dokumentace-IfcGeotechnicalStratum; IfcGeoslice). Furthermore, there are higher-level concepts such as IfcGeoScienceElement as a framework for geotechnical and geological entities (IfcGeoScienceElement). However, currently available software tools often do not have the latest version of IFC 4.3 fully integrated and therefore do not include even these basic geological concepts.
- Ability to standardize complex 3D geological models: the mere presence of entities does not solve the issue of a uniform methodology, data templates, consistent parameterization, links to source data (boreholes, profiles, etc.), or the representation of, for example, volume or voxel models to an extent that would enable reliable data exchange between different tools without loss. In the field of underground construction, it also appears that even with the "semantic adequacy" of IFC, an implementation guide is necessary to achieve interoperability (HUYMAJER, M. et al. 2024).

It follows that the practical application of IFC for geology requires additional standardization: the definition of object types, properties, relationships, and representation rules that will be interpreted consistently across tools.

4. THE INTEROPERABILITY PROBLEM: PROPRIETARY MODELS, LOSS OF MEANING, AND "2D DEGRADATION"

Geological and geotechnical models of the subsurface are traditionally created in specialized (often proprietary) environments (Fig. 1) and are exchanged by exporting them to various "intermediate formats." This process leads to three typical losses:

- Geometric loss (generalization, triangulation without topology, breakdown of volumes into surfaces),
- Semantic loss (loss of object meaning: unit/structure/boundary → "nameless network"),
- Information loss (attributes, parameters, uncertainties, metadata of data origin).

In extreme cases, 3D information is transmitted only through 2D sections, which significantly limits the possibility of combining geoscience data with other profession models. In the BIM environment, geology thus becomes an "external document" rather than a data layer that can be actively worked with—to perform queries, automatic checks, variant analyses, etc.

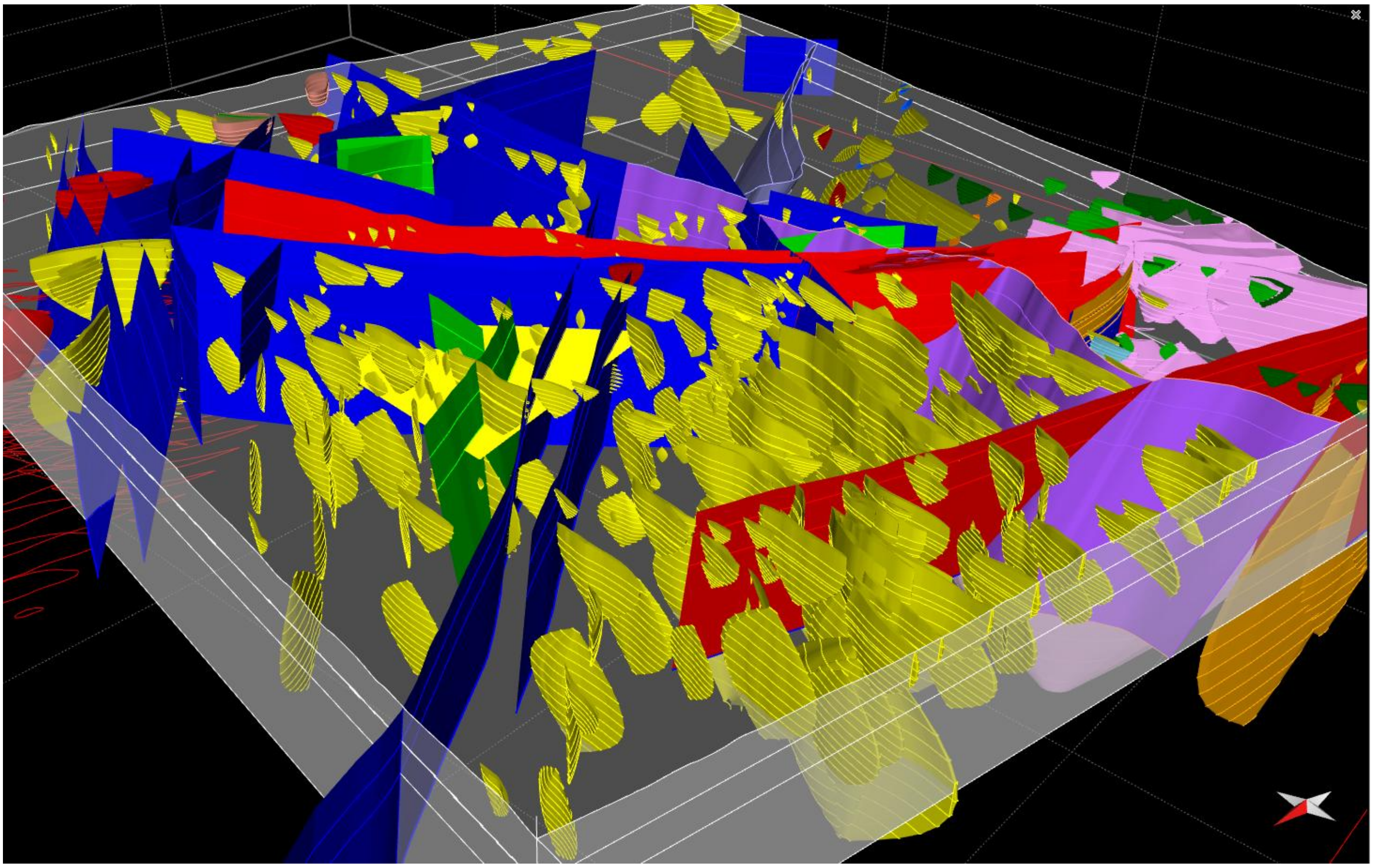

Figure 1: Example of a native geological model in specialized software that cannot be effectively shared with other disciplines.

5. EXTENSION PROPOSAL: STANDARDIZED GEOLOGICAL OBJECTS IN IFC

The proposed approach aims to supplement and unify geological IFC objects so that the geological layer can be integrated into DiMS as an equivalent part of BIM (KoncepceBIM.gov.cz-2026, ISO 16739-1-2024). Conceptually, the geological IFC model which we propose consists of the following elements:

- Volume models of lithostratigraphic units/quasi-homogeneous entities (Fig. 2). These are formed by irregular and geometrically very complex meshes. They represent the basic 3D context of the rock environment. It is crucial to preserve the identity of geological units, their boundaries, and links to interpretation and classification.
- Voxelized geological bodies (Fig. 2). These enable the representation of spatially variable parameters (e.g., strength, permeability, weathering degrees, risk indices) in a discrete manner and support connection to numerical and probabilistic analyses. However, due to the necessary discretization, they simplify the original shapes of geological bodies.

Planar geological objects (Fig. 3). These include discontinuities and interfaces (faults, fracture sets), groundwater levels, etc. In IFC 4.3, these needs can be partially addressed through geotechnical/geological entities (e.g., IfcGeoslice for sections; IfcGeotechnicalStratum for layers), but for 3D practice it is crucial to unify the rules of geometric representation and links to parameters (IFC 4.3 dokumentace-IfcGeotechnicalStratum; IfcGeoslice).

- Input geoscience data (Fig. 3). Boreholes, geophysical profiles, and other surveys must be part of the model. This enhances auditability and the ability to continuously update the model as new findings emerge.

The standardization we propose focuses on data structures and non-graphical information (parameters, names, types, relationships, units, hierarchies) so that geological data is "readable" in BIM tools in the same way as objects from other professions, i.e., filterable, queryable, versionable, and combinable across disciplines (ISO 16739-1, 2024,) .

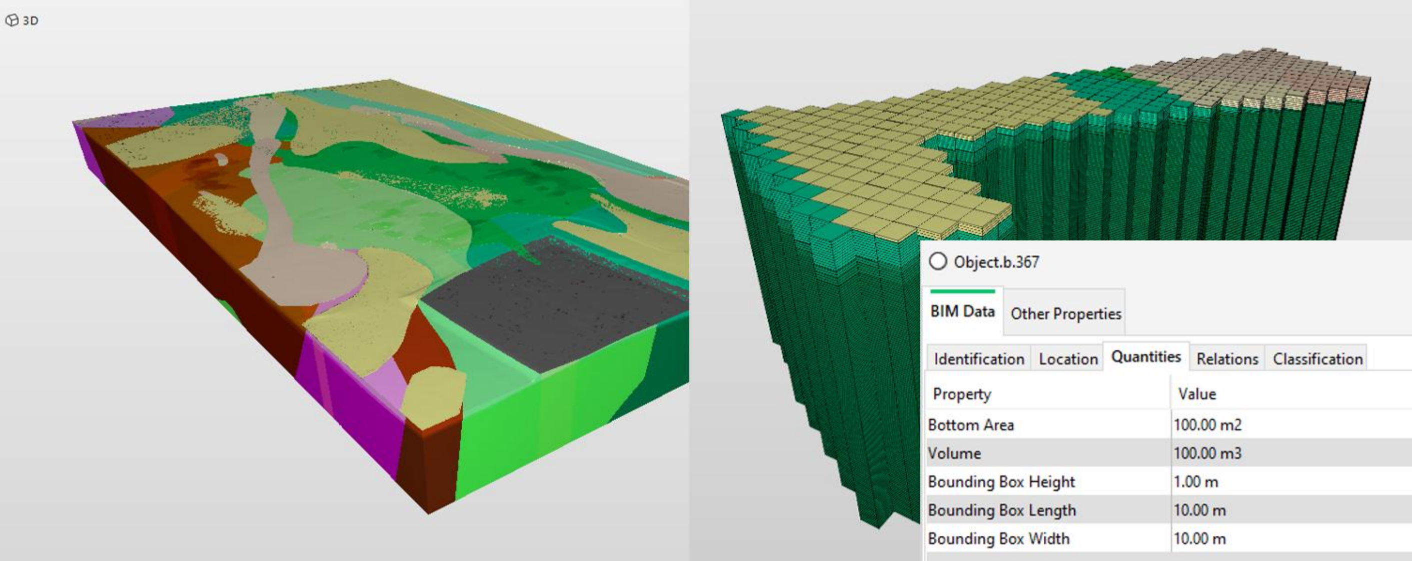

Figure 2: The resulting DIMS representing volumetric models of lithostratigraphic units/quasi-homogeneous units (left) and a detail of their voxelized equivalent (right). In the case of voxels, a table of basic geometric parameters of 1 voxel is provided.

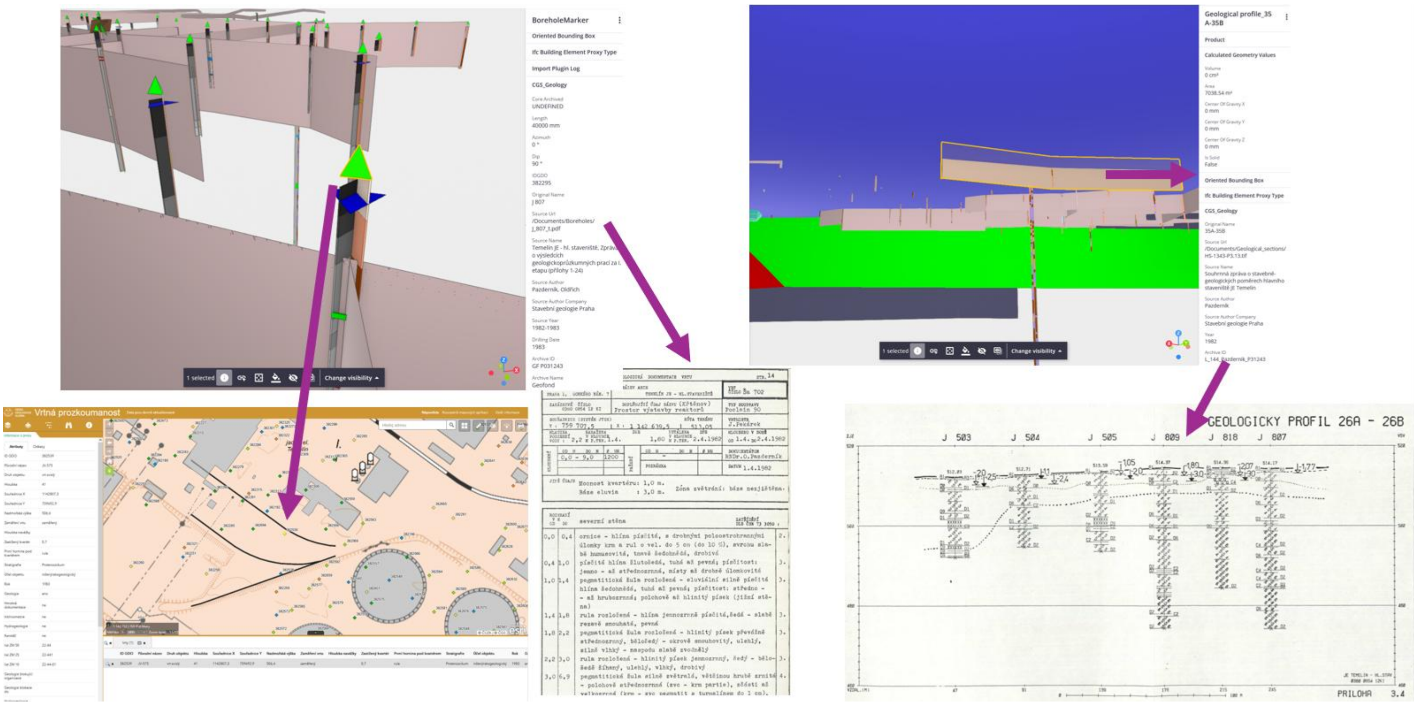

Figure 3: Representation of boreholes (left) and geological vertical sections (right) together with brittle geological structures and model of groundwater table. Both types of objects contain a wealth of non-graphical information which, in addition to their classification and references, includes active links to scans of original exploration reports and, where applicable, web links to publicly accessible archives.

6. DISCUSSION: IMPACTS ON DISCIPLINE COORDINATION, RISK MANAGEMENT, AND PROJECT ECONOMICS

The integration of geological IFC into a common BIM environment (Fig. 4) creates the conditions for:

- interdisciplinary consistency: geotechnics, foundations, statics, and underground construction work with the same reference geological model instead of parallel interpretations,
- faster change management: new survey data can be projected into the data model and the impacts on the design and schedule can be assessed transparently,
- reduction of geological/geotechnical risks: risk zones can be explicitly mapped in 3D and linked to structural elements and technological processes,
- better interoperability: IFC as an open standard reduces dependence on proprietary formats and supports long-term data preservation (ISO 16739-1, 2024) .

- More efficient management not only of construction, but also of long-term operation and decommissioning (demolition) of buildings

At the same time, it is necessary to realistically acknowledge that "IFC entities" alone are not enough: experience to date shows the need for implementation rules to achieve repeatable interoperability (HUYMAJER, M. et al. 2024). In geology, this requirement is even stronger due to data heterogeneity, the partial absence of standards, uncertainties, and different types of representation (surface, volume, voxel).

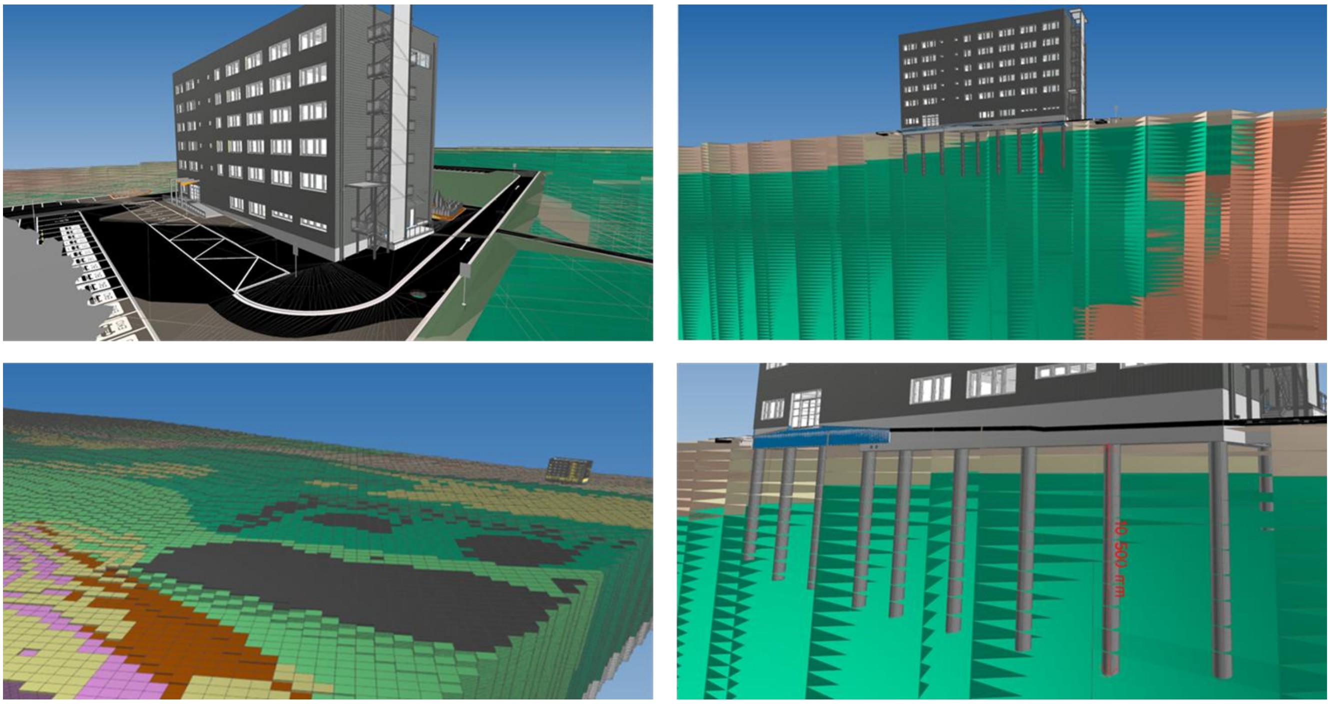

Figure 4: Optimization of position of the administrative building with respect to the bedrock – voxelized geological bodies supplemented with non-graphical information (geotechnical parameters), combined with the design of the administrative building (architectural-construction model)

7. CONCLUSION

The implementation of the Czech legal framework for construction information management from January 1, 2027 (Zákon o správě informací o stavbě 2025, Zákon o správě informací o stavbě a vystavěném prostředí 2025) creates pressure for the practical standardization of information even outside traditional construction disciplines. Although IFC (ISO 16739) provides a robust framework for open information exchange (ISO 16739-1, 2024), geological objects require the addition of consistent object types, parameters, links, and representation rules in order to integrate 3D geological models into DiMS without loss (KoncepceBIM.gov.cz 2026; HUYMAJER, M. et al. 2024). Standardized geological IFC objects (unit volumes, voxels, planar structures, and input data) represent a way to make the rock environment a shared, queryable, and versionable part of project documentation. This improves coordination quality, reduces risks, and promotes the economic efficiency of the project throughout its life cycle (ISO 16739-1, 2024; ISO 19650-1, 2019; HUYMAJER, M. et al. 2024). The proposed approach can be used for transport tunnels and other linear constructions, as well as nuclear power plants and deep repositories for high-level radioactive waste. These are currently the subject of intense development and related research and development work, presently being held e.g. in the Josef Underground Laboratory (CEG ČVUT)

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