

Modernizing Geological Information Services: Architecture and Capabilities of the Slovak G-Portal

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Abstract

The paper presents the architectural evolution and technical implementation of the Slovak G-Portal, a comprehensive web-based geological information system developed for the State Geological Institute of Dionýz Štúr. The study analyses the transition from legacy desktop GIS workflows to a distributed, configuration-driven WebGIS platform supporting national geological registers and statutory processes defined by the Slovak Geological Act. Particular attention is given to the bi-directional modular architecture, distinguishing between data-centric modules, where datasets dynamically trigger specialized interfaces, and process-centric modules that digitize reporting of geological works, administration of prospecting areas, and preparation of official spatial-planning statements. The system is based on a declarative JSON configuration core integrated with Vue.js and the ESRI ArcGIS Maps SDK for JavaScript, enabling scalable deployment and modular expansion. Integration of high-resolution 3D subsurface geological models using Scene Layers is also evaluated. The results demonstrate that a configuration-driven WebGIS framework can successfully integrate geological registers, administrative workflows, expert analytical tools, and 3D visualization within a unified platform accessible to both professionals and public users.

Keywords: WebGIS, Modular Architecture, 3D Geomodeling, Geoprocessing, Digital Geological Archive

Introduction

This article explores the architectural evolution and technical implementation of the G-Portal, a comprehensive web-based geological information system developed for the State Geological Institute of Dionýz Štúr (ŠGÚDŠ) within the Geofond digital archive environment. The platform represents a transition from legacy desktop-based GIS workflows to a modern distributed WebGIS application designed to support national geological registers, public access to geological data, and statutory processes defined by the Slovak Geological Act.

The research highlights a bi-directional modular architecture that distinguishes between data-centric systems, where datasets dynamically invoke specialized functionality (e.g. DEKAM for decorative stones or MEZ for monitoring of environmental burdens), and process-centric modules, where web applications generate new legally relevant outputs (e.g. OGP for reporting geological works, SKUP for spatial-planning statements, and PU for the administration of prospecting areas).

The paper also describes the integration of high-resolution 3D subsurface geological models using Scene Layers technology and outlines a configuration-driven system design based on centralized JSON configuration files. This approach enables rapid scalability, modular deployment, and long-term sustainability of national geological information services

Research contribution

The contribution of this study lies in the design and implementation of a configuration-driven WebGIS architecture capable of integrating national geological registers, statutory administrative workflows, and advanced 3D geological visualization within a single platform. Unlike conventional geological data portals focused primarily on map visualization, the Slovak G-Portal introduces a bi-directional modular architecture that connects geological datasets with specialized analytical interfaces while simultaneously enabling web-based tools to generate legally valid outputs required by national legislation.

Data and Method

The area of interest includes national geological datasets and statutory registers managed by the State Geological Institute of Dionýz Štúr within the Geofond system. These datasets comprise geological maps, monitoring datasets, exploration territories, environmental burdens, borehole registers, and high-resolution 3D subsurface geological models. Particular attention was given to registers related to prospecting areas (PU), reporting of geological works (OGP), and preparation of official statements (SKUP) required under the Slovak Geological Act (Act No. 569/2007 Coll.) and related regulations.

The system integrates spatial data services hosted on ArcGIS Server with PostgreSQL/PostGIS databases, configuration-driven JSON files (map.sk.json), Scene Layers for 3D visualization, and server-side geoprocessing services for automated spatial analysis. The frontend architecture was implemented using Vue.js and the ArcGIS Maps SDK for JavaScript, allowing scalable deployment within the G-Portal platform.

Modular web applications were used to digitize statutory workflows. The OGP module enables legally required reporting of geological works by defining exploration areas and automatically identifying affected cadastral units. The PU module supports administration of prospecting areas by analysing spatial overlaps, legal constraints, and validity periods. The SKUP module generates automated spatial-planning statements by intersecting requested territories with protected geological zones and producing legally valid outputs.

The research method consisted of architectural analysis, implementation of standardized data models for national geological registers, integration of archival geological documentation through OCR-assisted metadata extraction, and functional testing of modular components in operational deployment. Both data-centric and process-centric modules were evaluated to assess scalability, interoperability, and suitability for long-term digital archive management within Geofond.

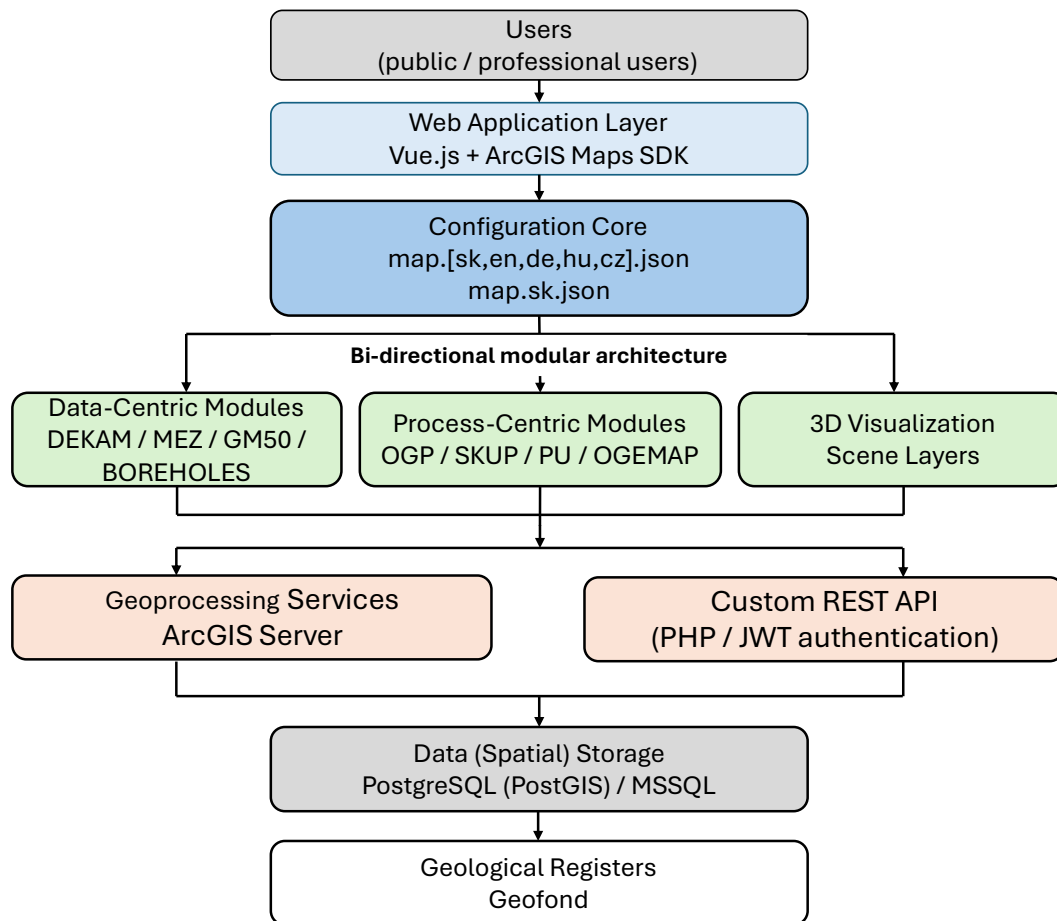


Figure 1: Architecture of the Slovak G-Portal showing the configuration-driven WebGIS framework and the bi-directional modular architecture integrating data-centric modules, process-centric workflows, and 3D geological visualization.

Results

The evaluation demonstrated that the configuration-driven architecture enables dynamic module loading and scalable expansion of the G-Portal without structural modification of the core application. The central JSON configuration file controls map extent, coordinate systems (including dual support for Web Mercator and the national S-JTSK grid), hierarchical layer catalogs, and modular logic injection, allowing rapid deployment of new geological datasets and statutory registers within the Geofond environment.

Two complementary architectural paradigms were successfully implemented:

1. **Data-centric modules**, where specific datasets automatically trigger specialized user interfaces. Examples include
 - DEKAM (Decorative Stones), transforming geological layers into an interactive encyclopaedic interface, and
 - MEZ (Monitoring of Environmental Burdens), applying regulatory limit criteria to monitoring datasets and visualizing contamination trends.
2. **Process-centric modules**, where application workflows generate legally valid outputs required by the Slovak Geological Act. Examples include

- SKUP (Statements for Spatial Planning), producing automated PDF statements and SHP data packages through server-side geoprocessing,
- OGP (Online Reporting of Geological Works), enabling digitized statutory reporting with role-based access control and automatic identification of affected cadastral units, and
- PU (Prospecting Areas), supporting administration of exploration territories through analysis of spatial overlaps, legal constraints, and validity periods.

The platform also integrates high-resolution 3D geological models, including the Nováky brown coal basin, the TransEnergy Danube Basin model, the Bratislava environmental burden model, and the Turiec Basin model. SceneView rendering enables direct web-based visualization of complex subsurface structures without external plugins, improving accessibility of expert geological models for both professional and public users.

Operational Framework and Comparative Perspective

The operational model of the G-Portal was designed to support long-term sustainability of national geological information services while minimizing maintenance complexity. The system operates on a distributed WebGIS infrastructure consisting of a Vue.js frontend integrated with the ArcGIS Maps SDK for JavaScript, ArcGIS Server services providing map, feature and scene layers, and PostgreSQL/PostGIS and Microsoft SQL Server (MSSQL) databases storing spatial datasets and national geological registers.

A key element of the architecture is the configuration-driven design based on the central JSON configuration file (`map.sk.json`). This declarative configuration approach allows the system to dynamically define map layers, datasets and application modules through configuration parameters rather than hard-coded application logic. This approach allows administrators to integrate new datasets, activate application modules, or modify the layer structure without modifying the core application code. As a result, expansion of the platform can be performed through configuration updates rather than software redevelopment, which significantly reduces operational maintenance requirements.

Maintenance activities primarily involve updating geological datasets and statutory registers, managing ArcGIS services and geoprocessing tools, and maintaining the configuration files that define system behaviour. Because most application logic is modular and configuration-based, new thematic applications or registers can be integrated with minimal development effort.

Compared with many national geological WebGIS platforms, which primarily function as visualization portals for geological maps and datasets, the Slovak G-Portal integrates both data dissemination and workflow automation. While systems such as national geological map portals typically focus on data access, the G-Portal additionally supports legally mandated geological processes through modules such as OGP, SKUP and PU. These modules not only display spatial information but also generate new datasets and legally valid outputs through automated geoprocessing.

Another distinguishing feature is the integration of web-based 3D geological visualization using Scene Layers, allowing complex subsurface structures to be explored directly within a web browser without specialized desktop software. This combination of configuration-driven architecture, modular workflow tools, and integrated 3D visualization positions the G-Portal as a comprehensive digital infrastructure for geological information services rather than a conventional geological data portal.

Several national geological surveys operate WebGIS platforms providing public access to geological maps and datasets through web-based geospatial infrastructures. A simplified comparison of selected systems is presented in Table 1.

Table 1. Comparison of Selected Geological WebGIS Platforms.

Organization / System	Architecture Type	Main Purpose	3D Geological Visualization	Workflow Automation	Legal Process Integration
Slovak G-Portal (ŠGÚDS)	Configuration-driven modular WebGIS	Geological data + statutory workflows	Yes	Yes	Yes
Czech Geological Survey	WebGIS data portal	Geological maps and datasets	Limited (3D models)	No	No
GeoSphere Austria	WebGIS data portal	Geological and geoscientific map services	Limited (3D viewer)	No	No
Geological Survey of Slovenia	WebGIS data portal	Geological datasets and national geological maps	Limited (3D geological model)	No	No
Mining and Geological Survey of Hungary (MBFSZ)	WebGIS data portal	Geological and geothermal data services	Limited	No	No
Polish Geological Institute – NRI (PIG-PIB)	National geological data portal	Geological maps and national datasets	Yes (national 3D geological model)	No	No
British Geological Survey (BGS)	WebGIS data services	Geological datasets and map services	Yes (3D modelling and visualization systems)	No	No
United States Geological Survey (USGS)	Distributed data portals	Geological and environmental datasets	Yes (3D model inventory)	No	No

The comparison shows that most geological WebGIS platforms primarily focus on visualization and dissemination of geological datasets. In contrast, the Slovak G-Portal integrates data services with workflow automation and legally mandated geological processes within a unified WebGIS infrastructure.

Conclusion

The G-Portal demonstrates that a configuration-driven WebGIS architecture can effectively modernize national geological information services managed by the State Geological Institute of Dionýz Štúr. The distinction between data-centric and process-centric modules provides a scalable framework supporting both expert geological datasets and statutory administrative

workflows, including registers of prospecting areas, reporting of geological works, and automated spatial-planning statements required by the Slovak Geological Act.

The operational model based on modular components and centralized configuration significantly reduces maintenance complexity while enabling continuous expansion of the platform through the integration of new datasets and applications. Compared with conventional geological WebGIS portals focused primarily on data visualization, the G-Portal integrates data dissemination, workflow automation, and legally relevant geoprocessing within a unified digital infrastructure.

The integration of high-resolution 3D subsurface geological models further bridges the gap between expert desktop GIS applications and publicly accessible web platforms, improving the accessibility of complex geological information for professionals, decision-makers, and the general public.

Future development will focus on offline field data collection, AI-assisted metadata extraction from archival geological reports, and advanced simulation approaches, such as voxel-based modelling of groundwater contamination and other subsurface processes.

Abbreviations

DEKAM – Decorative Stones Information System
 MEZ – Monitoring of Environmental Burdens
 GM50 – Geological Map 1:50 000
 BOREHOLES – Borehole Register Database
 OGP – Reporting of Geological Works
 SKUP – Statements for Spatial Planning
 PU – Prospecting Areas Register
 OGEMAP – Old Geological Map
 REST – Representational State Transfer (web service architecture)
 JWT – JSON Web Token authentication mechanism
 GIS – Geographic Information System
 WebGIS – Web-based Geographic Information System
 3D – Three-dimensional
 SDK – Software Development Kit
 API – Application Programming Interface
 PostGIS – Spatial extension for PostgreSQL database
 MSSQL – Microsoft SQL Server database system

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