APPLICATION OF GEOPORTAL'S WEB-TECHNOLOGIES IN GIS, CASE STUDY: INTERACTIVE GEOLOGY ATLAS

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A unique geoinformation service "The Interactive Geology Atlas" has been created and launched based on the data obtained by the Authors during years of research and evaluation of integrated biostratigraphic, paleomagnetic, and sedimentological data as well as published references materials. The Interactive Atlas includes geological sections comprehensively studied, described, and mapped. Contrary to analogous services, the Atlas covers more territory of Paratethys and time laps and allows for the addition of various content depending on the user requirements. All maps (basemaps) are available for study both individually and joint for comprehensive analysis through the compiling the unified legend to all layers and maps. The combination of different data allows us to track how the paleogeographic conditions of the Paratethys territory have evolved and to highlight the main events associated with fluctuations in climate, salinity, etc. Besides being scientifically interesting, the Atlas can become useful in geologic exploration to evaluate the potential areas of mineral resources. For instance, paleogeographic maps are crucial in this regard. FAIR principles have become the reference criteria for improving datasets: Findability, Accessibility, Interoperability, and Reusability.

1 INTRODUCTION

The creation of systems to collect, store, disseminate and analyze spatial data in geosciences is an important way in the development of modern information technologies. The development of such systems has practical importance for the scientific community. The rise in the intensity of geospatial data (geodata) accumulation is caused by the development of information technologies. Normally it leads to difficulties in the exchange of knowledge between researchers and users. Geoinformation system (GIS) technologies make it possible to significantly simplify the process of interaction with geodata for quick and efficient solutions to various scientific and practical problems [*Krasnoperov et al.*, 2016]. GIS systems have already been successfully implemented in all areas of research. These technologies have existed for more than 10 years. Nevertheless, our era of the fast consumption of data requires new applications that do not miss in its quality but allows easy access with high visibility and well-defined structure.

This is especially true for describing complex phenomena and explaining some global events like paleoenvironmental changes, sedimentation rates, fluctuation of insolation, etc.

According to this point of view, the authors propose to integrate geological and geoinformation methods in solving some important issues related to cyclostratigraphy and paleogeography on the territory of the Paratethys.

The methods of cyclostratigraphy are based on the assessment of astronomical cyclicity and its recording in sediments and are accompanied by detailed lithological and paleomagnetic studies. Global fluctuation of insolation in combination with traditional lithological methods makes it possible to estimate the rate of sedimentation and date the sediments. It is particularly important given the lack of other possibilities to determine the absolute age of the sediments. The influence of astronomical cycles on the sedimentation process is global so this method could be relevant for large-scale correlations.

Nowadays, many web-based systems allow the processing of geophysical and geospatial data in various ways [*Kadochnikov et al.*, 2019; *Kinkade and*

Shepherd, 2021; *Xin et al.*, 2012; *Gvishiani et al.*, 2007; *Dulin et al.*, 2010; *Tkachev et al.*, 2019; *One-Geology*, 2022; *IVIS FEB RAS*, 2022; *SGM RAS*, 2022; *Giovanni*, 2022; *VSEGEI*, 2022], including the data that was stored and shared by Geophysical Center RAS (GC RAS) [*Berezko et al.*, 2008, 2011; *Gvishiani et al.*, 2007; *Nikolov et al.*, 2015].

However, despite the variety of such portals, there is a lack of them in geosciences that allows processing, visualizing, and analyzing data in a united information and communication environment. Here we would like to present a recent achievement in the realization of geoportal web technology in geosciences on the example of "Interactive Geology Atlas" geoportal [*Popov et al.*, 2019; *Kadochnikov et al.*, 2019; *Hu et al.*, 2015; *Kavoura et al.*, 2014].

2   MATERIALS AND METHODS

The goals of creating the system and the underlying geospatial geological data databases are:

- to create a single environment for preparing, displaying, and analyzing the geological data;

- development of intellectual multifunctional geoinformation systems;

- providing system analysis of geodata.

GIS development consisted of several stages:

1. collection and conversion of point, line, and raster source data into a GIS format;

2. creation of a single database for storing initial data and the results of their complex processing;

3. the implementation of a multi-functional custom interface for the possibility of multicriteria queries to the database in the GIS environment.

At the moment, the system is implemented as a standalone desktop application. The infrastructure for working with the database is implemented in the ESRI ArcGIS for the Desktop environment [*Krasnoperov and Soloviev*, 2015; *Soloviev et al.*, 2016]. The geodata is stored in widely used formats, primarily as shapefiles and raster images with georeferencing. The cartographic base is loaded through the online resource ArcGIS Online, which is a cloud-based platform for sharing base maps published by ESRI.

A crucial part of the interactive system of geodata is the GIS server, which stores prepared data for publication as geoportal's application. A set of geodata uses to fill a thematic application with content, also being customized with design elements and base geoprocessing tools. For the moment an ArcGIS Server has been implemented in the system, being a bridge between the developer of the application and a final user, which can be either one within the organization or a user, who has access to the application.

2.1   ArcGIS service

The full process of publishing geodata to different Web services consists of collecting initial data, processing this, adding design, and publishing [*Medolinska et al.*, 2018]. A more detailed description is given in Figure 1.

From the point of view of the step-by-step process of creating an application, the following is a description of steps 1–5 from Figure 1.

Step 1. The general task for the step is data collection. Databases exist as tables, grids, points, lines, polygons, and rasters. These files have the full data – coordinates, parameters of objects/fields, and discretization. The description is accompanying information about the data – coordinate system, source, creation date, and general description of the data in the current database. Field trip data is a local, point-based resource for ground survey geological investigations [*Escalona*, 2011; *Soloviev et al.*, 2018; *Vahidnia and Vahidi*, 2021].

Step 2. At this stage, the full data should be prepared for publishing. Databases should be converted to relevant format to ArcGIS – shapefiles, grids, float, tables. The standard toolboxes of the software package have an opportunity to work with the majority of formats, but sometimes there is a necessity to create some new geoprocessing tools. In such cases, there is a module where the user can program a unique tool in the Python development environment.

A specific item at this stage is data preprocessing. A user can customize the discretization of the file, and parameters of interpolation, which later will influence the quality of a final image. At this stage, when an initial data has been prepared, the user creates the map with the package of all files for future layers. For qualitative visualization of layers, there are a few main aims: setting up a color scale, assigning it to layers with the same physical meaning, and exporting all layers to a special format *.lyr (ArcView Layer Format). The last step there – uploading data to the GIS server. This procedure is carried out by a special tool, which customizes the data's settings for the following publication.

Step 3. After uploading data to the GIS-server, the user should check the visual characteristics of publishing data and the data tree, also the design of layers (such as the color scale with cap-
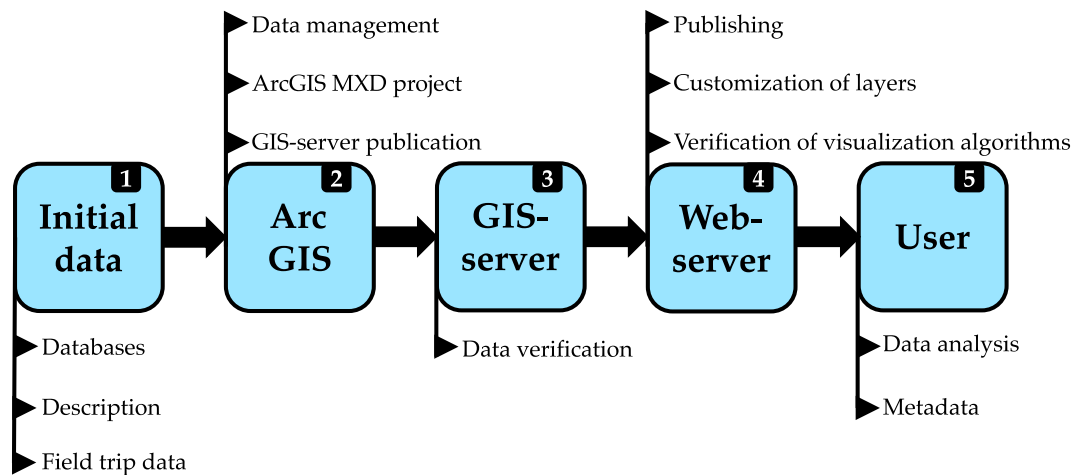
Data management

ArcGIS MXD project

GIS-server publication

Publishing

Customization of layers

Verification of visualization algorithms

Initial data [1] → **Arc GIS** [2] → **GIS-server** [3] → **Web-server** [4] → **User** [5]

Databases

Description

Field trip data

Data verification

Data analysis

Metadata

Figure 1: Scheme of creating the web services.

tions of physical parameters and each data interval). Generally, this step includes database management systems [*Mitsova et al.*, 2013].

Step 4. Includes the visualization of all prepared layers. The user should just add all data from the server, which should be published on the final map. In that case, a person should have permission to modify an app, select layers, and check the final view. Also, at that step, there is a checking of the relevance of metadata, and the existence of layer links in the description. These links allow users to download the ArcGIS projects for subsequent use.

Step 5. The finished app with maps and data can be analyzed by everybody. At that step, users can inspect all information on the map, compare the different physical parameters, and choose data for the region under their study. To provide comprehensive information about layers, there are metadata supporting files that contain a standardized description (ISO 19139 standard).

2.2 The "Interactive Geology Atlas" dataset

A combination of a set of geological geodata has become a basis of the "Interactive Geology Atlas" geoportal. The initial data that forms the basis of the created GIS includes the following set of digital thematic geodata layers:

- Geographical basemap

  - Map of Russian administrative division [*IIASA*, 2002]

- General geology map of Russia with a scale of 1:2,500,000 [*FAIR*, 2019]

- Minerogenic maps of Russia [*Kadochnikov et al.*, 2019]

  - Forecast minerogenic map of Russia 1:2,500,000 (VSEGEI) [*Andrianova et al.*, 2011]

  - Mineragenic map of the Russian Federation and neighboring countries 1:2,500,000 (Aerogeology) [*Rodnov et al.*, 2009]

- Earth's gravitational field maps

  - Gravity Field: Free Air Anomalies (EGM2008) [*Pavlis et al.*, 2008]

  - Gravity Field: Free Air Anomalies (EIGEN-6c2) [*Förste et al.*, 2012]

  - Gravity Field: Bouguer Anomalies (EGM2008) [*Pavlis et al.*, 2008]

  - Gravitational Field: Bouguer Anomalies (EIGEN-6c2) [*Förste et al.*, 2012]

  - Gravity Field: Anomalous field created by the sedimentary cover [*Kaban et al.*, 2012]

  - Gravitational field: an anomalous field created by density inhomogeneities of the consolidated crust [*Kaban*, 2001]

  - Gravity Field: Residual Mantle Gravity Field [*Kaban et al.*, 2004]

  - Geoid anomalies (EIGEN-6c2) (Russia) [*Förste et al.*, 2012]

  - Geoid Anomalies (EIGEN-6c2) (World-wide) [*Förste et al.*, 2012]

- Deep structure of the Earth maps

  - Sedimentary cover thickness [*Tesauro et al.*, 2008]

  - Internal structure of the consolidated (crystalline) crust of Eastern Eurasia [*Stolk et al.*, 2013]

- – Velocity of seismic waves (longitudinal, Vp) in the main layers of the crust of Eastern Eurasia [*Stolk et al.*, 2013]
- – Depths to the surface of Mohorovichich (base of the crust) from sea level [*Stolk et al.*, 2013]

- Mineral Deposits maps

  - – Large and super-large mineral deposits [*Rundqvist et al.*, 2006]
  - – Classification of MD by genetic type [*Rodnov et al.*, 2009]
  - – Classification of MD by rank [*Rodnov et al.*, 2009]

- Hydrocarbon Resources maps

  - – Maps of regional geology: Geology map of the Okhotsk region; Lithological-Paleogeographic maps of Paratethys; Tectonic map of Central-Asian and Pacific Ocean zone scale 1:1,500,000 (ITG FEB, RAS) [*Karsakov and Chunjing*, 2005] (Figure 2).

Data is collected in the framework of this study and published in the form of cartographic web services in GIS geoportal "Interactive Geology Atlas" (https://geology-gis.gcras.ru/). The ESRI Geoportal Server package was chosen as the basis for the development of the geoportal. This software product is designed to organize interactive access to published cartographic web services and metadata using standard protocols for the exchange of cartographic information, including KML, HTML, XML, OGC protocols (WMS, WFS), and others. The geoportal interface implements the possibility of using various options for presenting digital geodata and interactive work with them. These include modern web services such as ArcGIS.com Map and Google Earth, ArcMap or ArcGIS Explorer desktop applications, and the ArcGIS JavaScript API application programming module. In our case, the web interface has been modified to be able to apply to all geological digital layers. For the moment, the geoportal is developing, and recent geological data, both field trip data and geological maps are still being added.

2.3 GIS and Cyclostratigraphy Database implementation

Over the past few decades, geology due to its interdisciplinarity retains a strong association with the

GIS, using tools aimed at data visualization, processing, and analysis. The effective implementation methods for presenting geospatial data offer new opportunities to address the issues of region stage position on the International Chronostratigraphic Chart. Detailed lithological and paleomagnetic studies combined with GIS tools allow to carry out of geological reconstructions and correlation between single-age deposits over a wide area.

The methods of cyclostratigraphy are based on the assessment of astronomical cyclicity reflection in sedimentation processes supported by detailed lithological and paleomagnetic studies. Global insolation fluctuations on the Earth in combination with the traditional lithological approach make it possible to estimate the rate of sedimentation and dating sedimentary rocks. This is particularly relevant in the absence of other possibilities to reliably determine the absolute age of sediments. The influence of astronomical cycles on sedimentation processes is global, which makes this method especially relevant for large-scale correlations. This will lead both to the improvement of the stratigraphic division of the studied deposits, and to the expansion of methods for assessing the paleogeographic environment.

The determination of astronomical cyclicity using geochronological methods, including paleomagnetic reconstructions and analysis of the lithological structure of the strata, is possible by the variability of the magnetic susceptibility of rocks which depends on the amount of Solar radiation reaching the Earth's surface and reflecting climatic fluctuations [*Rostovtseva et al.*, 2016; *Rostovtseva and Rybkina*, 2017; *Rybkina et al.*, 2015; *Rybkina and Rostovtseva*, 2017].

GIS allows for multivariate analysis of cyclostratigraphy through space and time. In this case, an important component of scientific research is the database of geodata formed according to the Systems analysis approach. Its data viewer in combination with the "Interactive Geology Atlas" portal is an important tool for conducting a comprehensive analytical study enabling to display of geodatabase objects, illustrating the tectonic evolution and reconstructing the conditions of the territory in the Miocene.

2.4 FAIR principles

In geological research, because of various restrictions, it is not always possible to carry out fieldwork and research. From this point of view, there is an increasingly urgent need for the creation of an information environment accessible to scientists worldwide to increase opportunities for data sharing. This is particularly important due to actively developing strategies for scientific data management and new ways of effective data processing techniques.

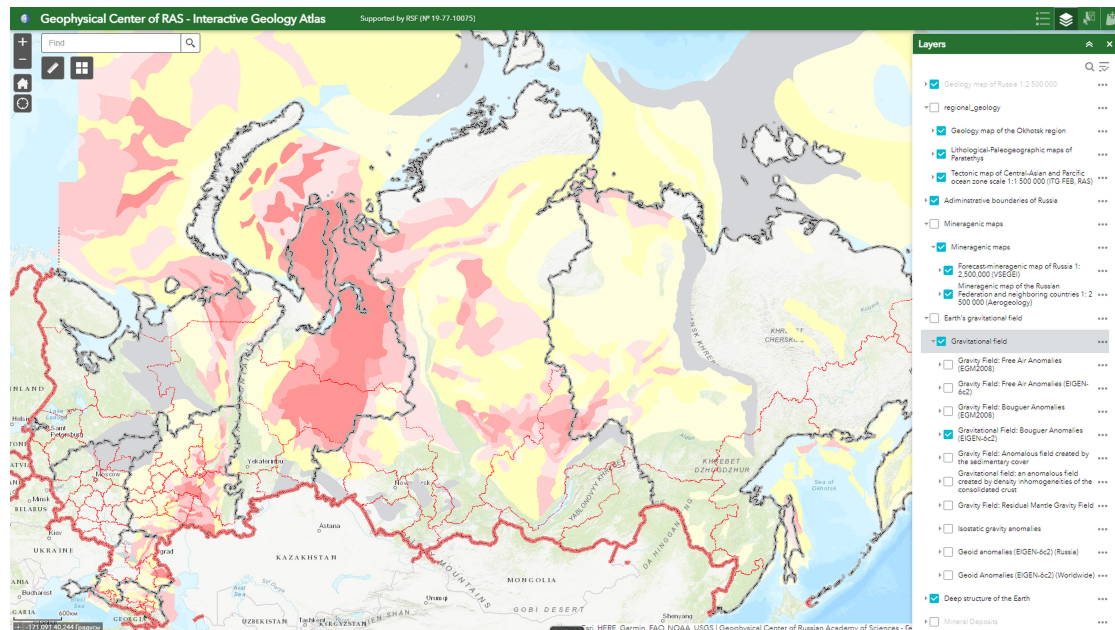Global Science has carried out several actions and efforts aimed at increasing awareness of the

Figure 2: The interface of the core of the "Interactive Geology Atlas" geoportal.

importance of data and the significance of data policy in the scientific community around the world in recent years. It is imperative to recognize the intrinsic link between efficient scientific research and improved approaches to the data systematization, management, and analysis [*Platonov and Naumova*, 2020; *Wilkinson et al.*, 2016; *Berezko et al.*, 2008; *Jacobsen*, 2020; *Bailo et al.*, 2020; *FAIR*, 2019].

The FAIR principles have been endorsed and adopted by authors under this Project. FAIR principles have become reference criteria for promoting and evaluating the openness of scientific data and for improving data. Geological data is not always easy to lead to the FAIR Guiding Principles due to there being gaps in data integration since they come from different sources in various formats and standards. It is therefore special attention in this Project paid to compiling and harmonizing data.

1. *Findability*. Lithological and paleomagnetic data must be easily findable for both humans and machines. The database is equipped with extensive metadata for further detecting the relevant datasets and services as an important component of the FAIRification process;

2. *Accessibility*. The Atlas provides access to data and is comprehensible to humans and machines. Connection with the GIS server is carried out using the HTTP protocol that is open, free, and universal. Moreover, the protocol allows authentication and authorization to access protected data;

3. *Interoperability*. Lithological and paleomagnetic data can be integrated with other data that refer to the same topic using the Atlas to combine both for comparing and improving research. Similarly, when a digital object can be processed by an online service, a machine should be able to detect this correspondence automatically and facilitate interaction between the data and this tool. This requires that the determination of each participating source still clear;

4. *Reusability*. Data are described by rich metadata and equipped with bibliographic references if appropriate to be accessible for both humans and machines to decide whether the digital resource should be reused and under what conditions to optimize reuse.

Based on the FAIR Guiding Principles scientific communities can execute their solutions.

3 RESULTS

The Interactive Atlas developed at the GC RAS formed the basis for the implementation of a mixed-format service for assessing the influence of astronomical cyclicity on sedimentation processes in the Eastern and Central Paratethys.

3.1 Development of datasets

After several years of field research under the Project, a geospatial database to evaluate the impact of astronomical cyclicity on sedimentation processes was developed. To achieve more
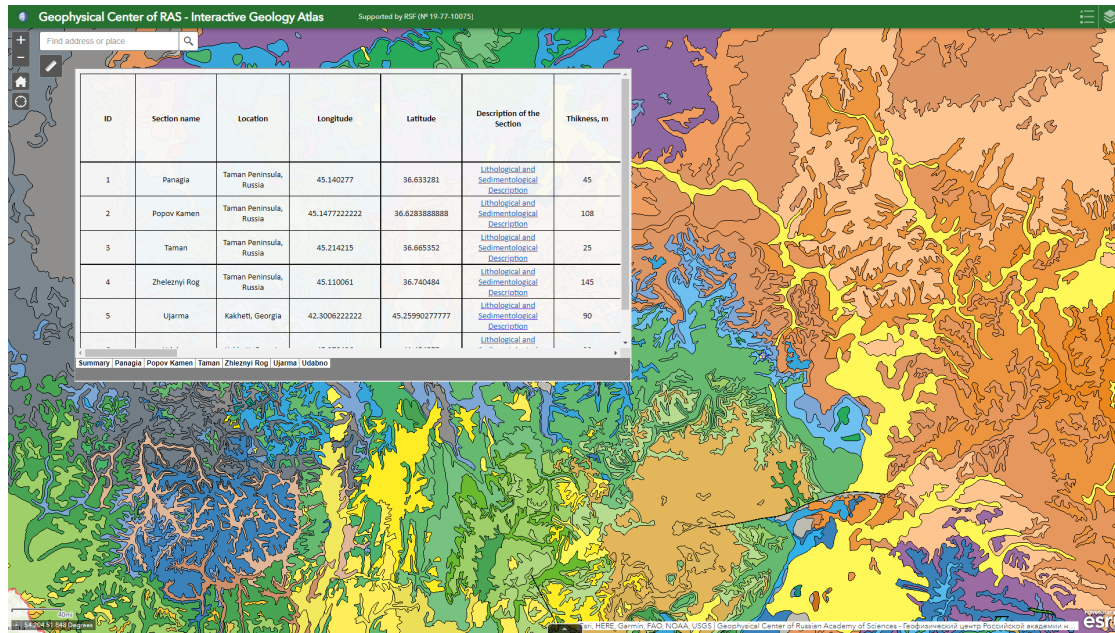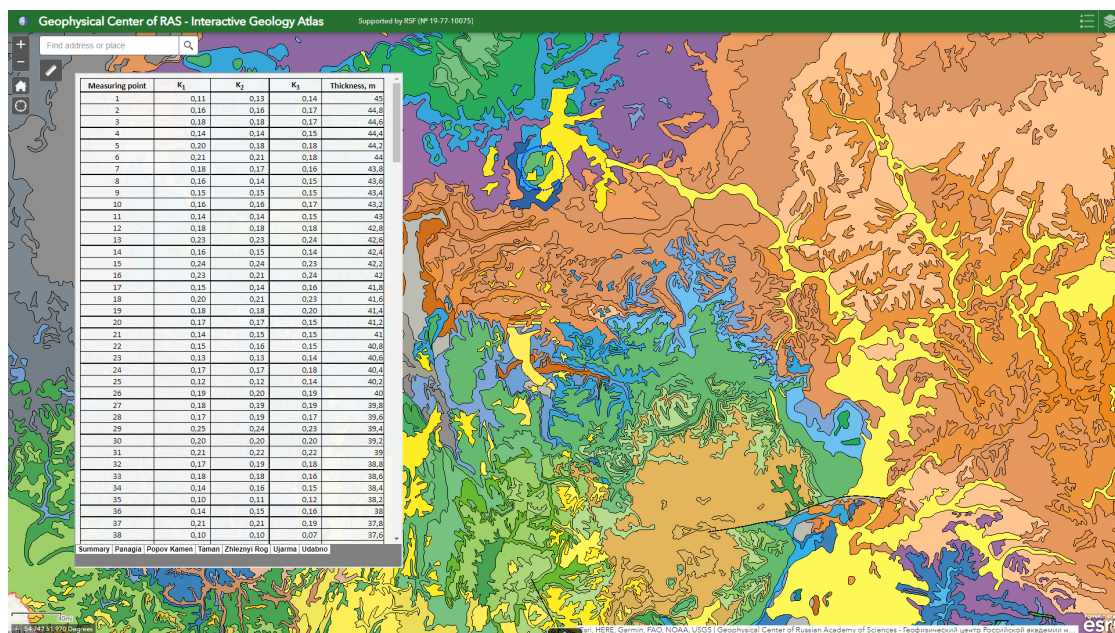
Figure 3: Initial page.

Figure 4: Section "Magnetic susceptibility values of Taman" (extended user workspace).

rapid and effective results several targets are making solid processes, especially for data storage structure for further data processing and mining based on cyclostratigraphy and paleomagnetism approaches, which will make it possible to determine the main trends in the influence of precessional cycles on the lithological record.

The database includes general information about the section, which is represented by the following attributes: ID; Section Name; Location (Country, Region); Coordinates (Longitude, Latitude); Thickness; Section Description; Stratigraphy; Values of Magnetic Susceptibility; Step of measurement; Number of Measurements; Year of the Investigation; Geological Structure; System, Epoch, Stage; Paleontological Finds; References; Additional Information (Figure 3).

4 User interface customization

One of the main goals is to improve the usability of the appearance. In the final field research data collection, each Excel sheet can be exported as HTML pages. For its display and navigation inside the Interactive Geology Atlas portal can be used to

embed web viewer, for example, classic `<iframe>` positioning over the map and resizing by dragging the bottom right corner Figure 3, Figure 4:

```
<iframe id="Paratethys" src="Paratethys.html"
style="z-index:1; position: absolute; top:10%;
left:6%; width:5%; height:50%; resize: both;
background: rgba(250,250,250,0.95)">
</iframe>
```

In this case, it would be possible to connect the events, for example, to click the map's region and update the iframe's content:

```
document.onmousedown = eventParatethys;

function eventParatethys()
{
  if (geoDistance(event.mapPoint,targetPoint)
  < X) window.frames['Paratethys'].src =
  'Paratethys_new.html'
}
```

Alternatively, the ArcGIS API for JavaScript provides an interface for setting up simple UI layouts. Views provide a UI API that allows placing components (widgets or DOM elements) via CSS style [*View UI*, 2022]. This approach may be preferred due to the strong integration of ArcGIS elements.

5   Discussion

The authors upgraded the portal "The Interactive Geology Atlas" that has been created to provide access to the database of field research in an integrated environment to further assessment of the development of the Paratethys in the Miocene. The service is equipped with a series of tools including geodata visualization, selecting underlays, viewing layer legends, accessing metadata, etc. to illustrate the tectonic evolution and reconstruct the conditions of the territory. Data organization, access methods implementation, universal structural cell-level metadata, bringing FAIR Guiding Principles, and the increased visibility were developed as well.

View of the field researches data exported as HTML pages and its navigation can be implemented by embedded web viewer, into which any web application is subsequently built-in, for example, multi-user database with different levels of access (editor, administrator, etc.).

Conflicts of Interest: The authors declare no conflict of interest.

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