An integrated information environment to support geophysical research of the Baikal Rift Zone

Ludmila P. Braginskaya[1,2], Andrey P. Grigoruk[1,2] and Valery V. Kovalevsky[1]

[1]*Institute of Computational Mathematics and Mathematical Geophysics SB RAS, Novosibirsk, Russia*
[2]*Institute of the Earth's Crust SB RAS, Irkutsk, Russia*

Abstract

In this paper it is proposed to organize information support for geophysical research of the Baikal Rift Zone by organizing an integrated system available on the Internet. The system provides access to experimental data and their computational analysis, and also provides systematization of information objects of the subject area based on the ontology of the subject area.

Keywords

Geophysical monitoring, knowledge portal, ontology.

1. Introduction

The Baikal Rift Zone (BRZ) is the largest in Russia and the second largest on the planet. BRZ is located in the interior of the continent Eurasia. Rift structures stretch for 2500 km from northwestern Mongolia to southern Yakutia. The rift system consists of a series of depressions (the largest of them is Baikal) and uplifts separating them. The process of formation of the Baikal rift continues at the present time, manifesting itself in increased seismic activity [1, 2, 3]. Up to several thousand earthquakes, mostly weak, are recorded on the territory of the BRZ per year. Tangible events with a magnitude of 5.0 or more occur in the Irkutsk region every one to two years. Over the past 295 years, more than 15 large seismic events have been registered here, the intensity of which was above seven points. In 2020–2021, there is a significant increase in the seismic activity of the BRZ [4].

Possible negative consequences of earthquakes are associated with the dense population of large cities located on the territory of the BRZ and the presence of large industrial enterprises. In addition, earthquakes can provoke landslides and mudflows in areas of active nature management. The task of forecasting earthquakes becomes especially important in connection with the growth of seismic activity in the region.

The concept of an approach to solving the problems of earthquake prediction and the organization of multidisciplinary monitoring of the BRZ using vibroseismic technologies was proposed in the Siberian Branch of the Russian Academy of Sciences by academicians A.S. Alekseev and S.V. Goldin [5, 6]. Seismological studies have shown that precursor complexes can change over time within one source zone [7]. The earthquake preparation process manifests itself in

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ludmila@opg.sscc.ru (L. P. Braginskaya); and@opg.sscc.ru (A. P. Grigoruk)

variations of geophysical fields of different nature and covers larger areas than destruction zones. One of the factors of pre-fracture is fracturing, which manifests itself in most physical fields: seismic, electrical, gravitational, affects hydrological and geochemical indicators. One of the indicators of earthquake preparation is an increase in seismic wave dispersion. The dynamics are most actively observed in the destruction zone (50–150 km for large earthquakes). At the same time, the characteristic time for preparing an earthquake is not so long — from a year to tens of years. In this regard, the proposed concept is based on the integration of various types of information obtained as a result of many years of geophysical experimental work covering large areas or long observation profiles.

In the concept of monitoring observations, the emphasis is on the search for complexes of multidisciplinary precursors, which implies the creation of observation points in order to identify and track a number of physical parameters of the lithosphere and underground hydrosphere. Changes in the variations in the characteristics of the seismic wave field are supposed to be monitored as a result of the sounding of source zones with a 100-ton seismic vibrator.

A vibratory source, unique in power, which allows obtaining high-quality seismograms at distances up to 400 km, is mounted on the shore of Lake Baikal, near the village of Babushkin. The geographic location of the vibrator and the network of seismological stations make it possible to study at least three focal zones that pose a threat to cities in such cities as Ulan-Ude, Irkutsk, Angarsk. The vibrator has precision accuracy and stability in frequency, phase and amplitude of radiation from session to session. The high power of the source makes it possible to use the network of digital seismic stations located around the southern part of Lake Baikal as receivers of vibroseismic signals. Correlation processing of digital records allows you to extract vibroseismic signals from microseismic noises and obtain vibration seismograms similar to the action of an explosion or an earthquake. It is theoretically substantiated that the high stability of the radiation and registration systems makes it possible to record changes within the identified focal zones: wave travel speed, frequency changes, oscillation phases, etc.

In addition to recording the probing signals of a 100-ton seismic vibrator by a network of seismic stations, numerous experiments on vibroseismic monitoring were carried out using profile and areal observation systems [8, 9, 10].

At present, the complex monitoring of the BRZ is carried out by several institutes of the Russian Academy of Sciences. IZK SB RAS has organized points for complex monitoring of dangerous geological processes of modern crustal movements, seismic activity, rock mass deformations, radon activity at the Priolkhonye, Buguldeika and Listvyanka test sites.

The Internet contains a large amount of knowledge and information resources on various types of geophysical monitoring, including those related to BRZ monitoring. However, access to these resources is significantly limited due to the fact that they are poorly structured, insufficiently systematized and, moreover, scattered across all kinds of Internet sites, libraries and archives. The authors of the article believe that the organization of effective access to experimental data obtained during vibroseismic monitoring of the BRZ, their computational analysis, as well as to the results of numerical modeling of the vibroseismic wave field will significantly increase the efficiency of scientists who use the results of active seismology research to interpret data obtained in other areas of geophysics. No less important is the systematization and integration of information resources reflecting the methods and results of all methods of geophysical monitoring of the BRZ.

This paper proposes an approach to the organization of an integrated environment, presents a scientific Internet resource in which the experimental data of vibroseismic monitoring and the Knowledge Portal are integrated. Knowledge Portal provides navigation and meaningful access to information resources that are relevant for researchers developing theoretical and experimental methods for monitoring the BRZ.

2. Knowledge and data integration principles

Today there is no strict definition of data, metadata, information and knowledge. In the presented concept of the scientific environment, we define that data are records of signals obtained in the course of field and computational experiments and represented by files that make up a directory tree. Metadata — description of experiments (type of seismic source, parameters of the signal emitted by it, recorder parameters, geographic coordinates of the source and recorder, etc.), represented by relational databases. It should be said that the description of data is reduced to a certain limited set of parameters. In our case, these are 18 parameters: Source Type, Source Number, Experiment Number, etc. The relational database management system provides high performance of requests for access and analysis of experimental data [11].

We refer to information objects the individual sites, publications, reference information, etc., located on the Internet.

We refer to knowledge about the subject area (geophysical monitoring) the totality of information about the objects of this subject area, their essential properties and relations connecting them. There are many knowledge modeling methodologies, and there are some general requirements for any domain information model. The model should adequately reflect the structure of the subject area, the formalization used in the model should unambiguously describe the structure and functioning of the subject area, graphic or other means of displaying the model should be understandable to the user.

Nowadays it has become a common practice to describe domains using ontological models. The main purpose of ontology creation is to provide support for the accumulation, sharing and reuse of knowledge. The term “ontology” was first introduced into knowledge engineering by Thomas Gruber [12]. According to its definition, an ontology is an explicit specification of conceptualization. Conceptualization here means a simplified description of some part of reality, built for a specific purpose. With regard to a specific subject area, this description should consist of terms and rules for the use of these terms, limiting their meanings within a specific area. At the formal level, an ontology is a system consisting of a set of concepts and a set of statements about these concepts, on the basis of which concepts can be combined into classes and relationships between them can be built.

An ontology can form a framework for a knowledge base, create a basis for describing the basic concepts of a subject area, and serve as a basis for integrating databases containing factual knowledge necessary for the effective work of researchers.

Each information object must be assigned to a certain class of ontology, i.e. be an instance of it. Relationships can exist between information objects, the semantics of which is determined by the relationships specified between the corresponding classes of the ontology. In the ontology, databases or their separate individual elements can be described as information objects.

Ontologies are used in the development of knowledge-based systems. In this case, it is possible to use previously developed ontologies. To integrate knowledge and data on geophysical monitoring of the BRZ, we built a Knowledge Portal in technology developed in the artificial intelligence laboratory of the ISI SB RAS [13].

3. Ontology and knowledge portal for geophysical monitoring of the BRZ

The ontology of geophysical monitoring of the BRZ is based on the reengineering of the "Active seismology" ontology. According to the methodology for constructing knowledge portals, the subject area is described in the form of two basic ontologies: Ontology of scientific knowledge and Ontology of scientific activity [13].

The ontology of scientific activity includes basic classes of concepts related to the organization of scientific and research activities, such as Person, Organization, Event, Activity, Publication, Information resource. The ontology of scientific knowledge is, in essence, a meta ontology. This ontology creates the structure of the domain under consideration. The ontology of scientific activity contains such meta-concepts as Section of Science, Method and Object of Research, Research Means, Scientific Result. The concepts of the ontology of scientific knowledge are related to each other and with the concepts of the ontology of scientific activity by associative relations. For example, an instance of the Person class "Kovalevsky" is associated with an instance of the "Vibration sounding" subclass of the Methods class by the relationship "develops", and the relationship "describes" sets the relationship between the Publication class and the Scientific result class.

When developing the Ontology, the choice of associative relations was carried out based on the structural patterns of ontological design and proceeding from the convenience of navigation through the information space of the portal [14].

Figure 1 shows an ontological graph that shows the relationship between classes and objects of the ontology of geophysical monitoring. Classes of concepts on the graph are depicted by an oval, Base classes — in red, objects of classes — by rectangles.

Ontology is the information core of the Knowledge Portal. The chosen technology allows one to develop the knowledge portals without the participation of artificial intelligence specialists. Experts, carriers of knowledge of the modeled area, having experience in object programming, are able to independently cope with the task of building portals.

To build basic hierarchies, a corpus of publications, containing a systematization of concepts related to geophysical monitoring was worked out, and interviews with experts working in various areas of the subject area were done. When ordering the concepts, each of the built hierarchies was assigned to one of the meta-concepts of the knowledge ontology.

The structure of the technology for building knowledge portals includes editors of data, ontologies and relations. With the help of the ontology editor, a formal specification of an ontology is created, including: hierarchies of concepts; a set of relations defined on the basis of concepts; many attributes describing the properties of concepts and relationships; set of domains that define attribute values; set of restrictions and axioms that describe the properties

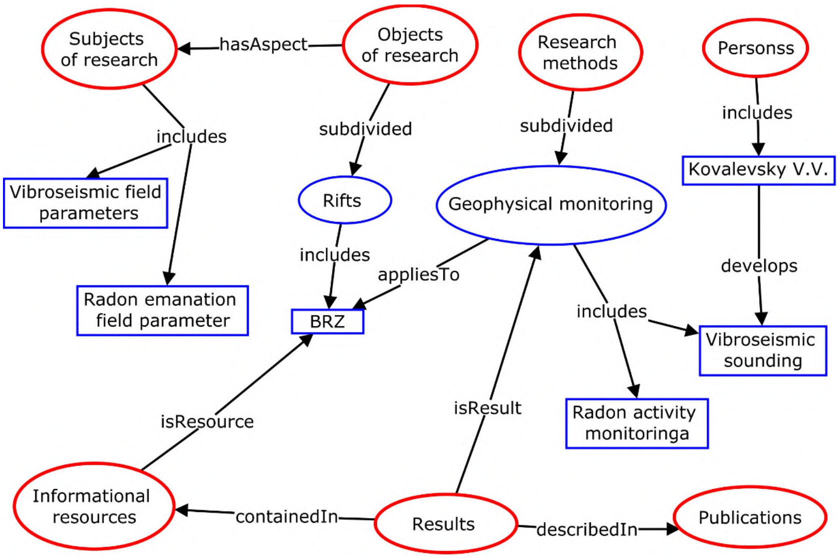

Figure 1: Ontological graph.

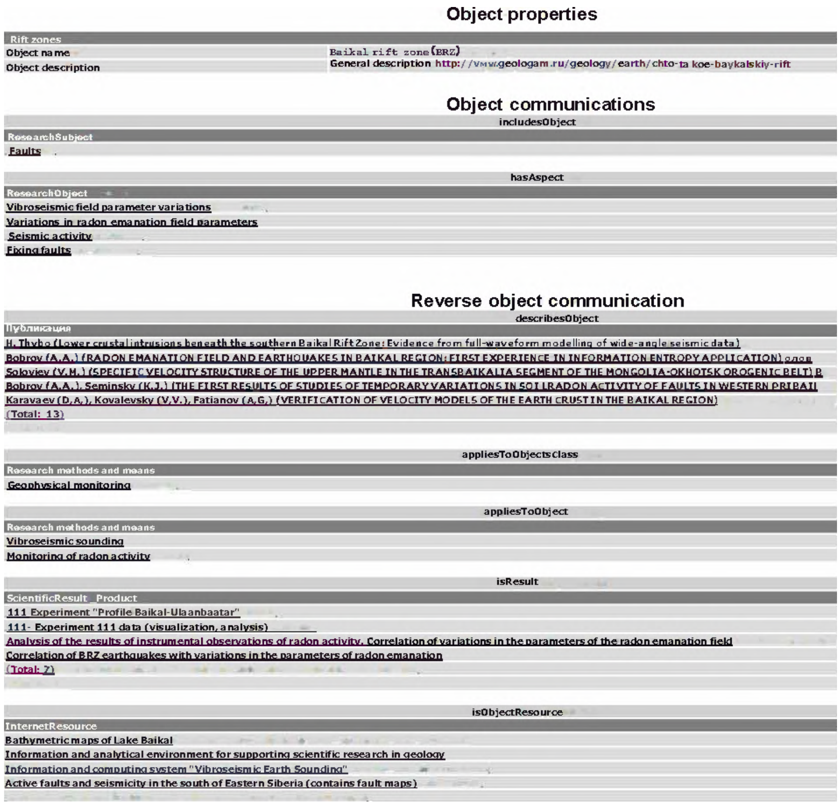

Figure 2: Portal page.

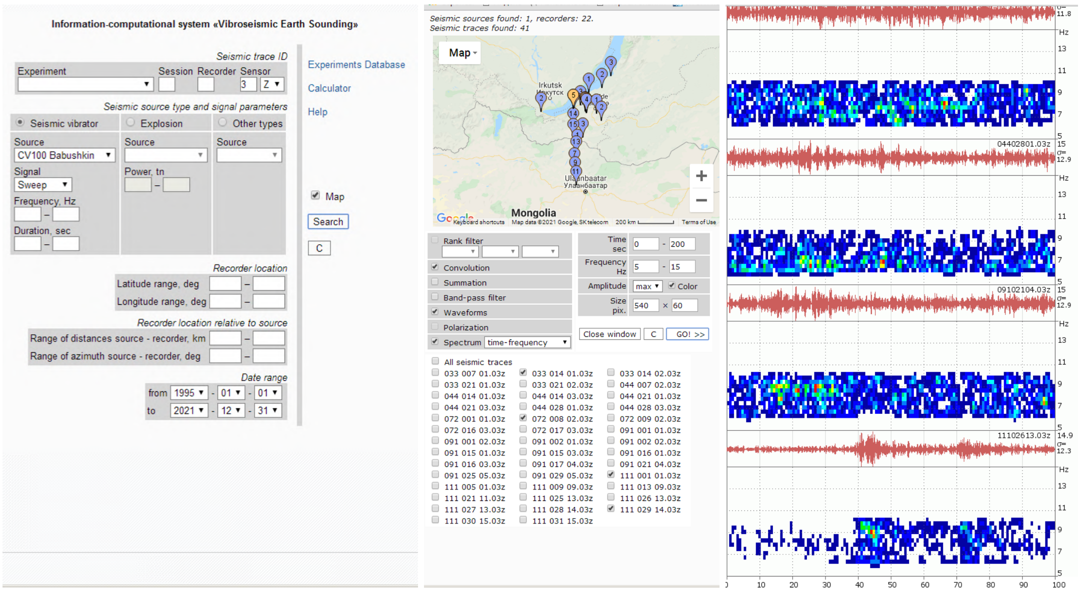

Figure 3: User request to Information-computing system "Vibroseismic Earth Sounding" and result of execution.

of classes and relationships.

Introducing formal descriptions of concepts in the form of classes of objects and relationships between them, the ontology of the portal defines structures for representing real data and relationships between them. Knowledge portal content is created using the data editor. The information object of the Portal is a formalized description of some object of the subject area. All information about a specific object and its links is displayed on the Portal page.

Figure 2 shows the Portal page containing the description of the "Baykal Rift Zone (BRZ)" object, belonging to the "Rifts" subclass of the "Research Objects" class. All objects related to "BRZ" are presented on its page in the form of hyperlinks, by which you can go to their detailed description. By clicking on the link "Information-computational system" Vibrational sounding of the Earth users get access to experimental data on vibrational sounding and means of their computational analysis.

Figure 3 3 shows an example of a custom query for and the result of execution. Request parameters: Vibrator CV 100-Babushkin, signal type — Swip, recorder number — 3, component — Z. Request to the analysis module — spectral-time functions of the marked seismograms.

4. Conclusion

The infrastructure for supporting geophysical research of the BRZ has been created. Effective access to visualization and computational analysis of experimental data of vibration sounding of the BRZ by a 100-ton seismic source has been organized. On the basis of the ontology developed by the authors, the Portal is built, which provides integration and meaningful access to information resources related to the subject area. When searching the information, the user has the opportunity to specify a query in terms of the portal subject area. The ontological approach to the systematization and integration of information objects forms a common space of knowledge for researchers working in various areas of geophysical monitoring, forms a common view on the research object and promotes better interaction of all participants of the process.

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