justification of the project

Induced seismicity research in Erdenet, Mongolia

proposed to the

Grant Agency of the Academy of Sciences of the Czech Republic

1 Introduction

1.1 Induced seismicity

Induced seismicity deals with earthquakes related to human activities in mines, around water dams, geothermal power plants, underground gas storages etc. The investigation of induced seismicity is important not only for the mitigation of direct damage caused by induced seismicity: it also contributes to our knowledge of natural earthquakes. Short-range forecasting of strong earthquakes is one of the most challenging problems of the present-day science. Its solution could save millions of lives in the twenty-first century and prevent huge material damage. One of the methods is a detailed investigation of induced seismicity, especially the triggering effects of seismic events (Gupta, 2002). Induced earthquakes are controlled by the same physical phenomena as natural tectonic earthquakes and, at the same time, conditions for the study of induced earthquakes are much better. Locations of induced earthquakes can be predicted quite well, moreover, the factors leading to induced earthquakes are known. Induced seismicity is usually shallow which implies a better accessibility for measurements. The problem of induced seismicity forecasting has not been solved yet, but it is much more promising than the forecasting of natural earthquakes.

1.2 Geophysical research in Mongolia

Research in Mongolia provides excellent opportunities in many respects: famous localities for archaeological, geological and wildlife observation, and also favourable conditions for seismological observations. Mongolia is a seismically active country with strong events exceeding $M = 6.0$ occurring each year (see Fig. 1). The strongest seismicity is connected with Mongolian Gobi Altai mountain range, which was formed during the Indian – Eurasian lithospheric plates collision. Seismicity in Mongolia is also connected with the Siberian Lake Baikal rift system which continues south to the Mongolia region – a deep rift valley now filled with Lake Khovsgol in Northern Mongolia.

Geophysical research started in the 1950s. Although the support from Mongolian government is low, there are several institutions in Mongolia engaged in geology and geophysics. The most important is the Mongolian Academy of Sciences with its Research Centre for Astronomy and Geophysics (RCAG). Petr Kolínský, the proposed project applicant, visited the RCAG last year (2005). He had the opportunity to discuss the problems concerning the projects in geophysics. He met many young researchers willing to advance the present research methods. The RCAG has a strong interest to collaborate with foreign institutions. The Centre proved its abilities during the project with US Geological Survey and several French and Russian institutes. As an attachment of this proposal, see the short report written by one of the young researchers from RCAG.

The Mongolian RCAG has a lack of instrument equipment. Due to the insufficient budget, there is no chance to improve this situation. The only way for the RCAG to obtain new equipment is to get it as an aid from abroad. In such way, the RCAG was equipped with good computing facilities from Japan. It has also several seismic stations deployed near Ulaanbaatar and throughout the whole Mongolian territory. The seismic network is very sparse yet. Mongolia has the area 20 times larger than the Czech Republic and much stronger seismic activity, but only 9 seismic stations or local networks are operated. Data transfer is arranged only occasionally and the accessibility of these stations and their maintenance suffers from weather conditions, poor road conditions and other phenomena not met during geophysical research in Europe.

One permanent USGS station is placed near Ulaanbaatar, and the RCAG is responsible for data transfer to the United States. A seismic array was built by French seismologists 80 km from the city within the CTBT (Comprehensive Test Ban Treaty) project. The RCAG is responsible for maintaining the array under the supervision of one French engineer.

As a consequence of the above mentioned phenomena, Mongolia is one of the most challenging countries for seismologists. It belongs among the largest areas which are still to be surveyed. Several projects held by the RCAG in cooperation with foreign institutions were the first attempts to fill the gap of knowledge of this vast seismoactive country.

The mines are the most economically active companies in Mongolia. There are several ore mines, especially gold mines. Most of them are open-pit mines. Blasting is generally used for rock disintegration. These blasts can be used for geophysical structural studies, which is one of the main topics covered by the IRSM in the Czech Republic. During his visit at RCAG in 2005, Petr Kolínský studied several quarry blast seismograms. There are several large blasts each week in the area of hundreds of kilometres around Ulaanbaatar city, and good quality records are available due to the charge size (several tons). Despite the good quality and easy accessibility of sources of seismic events, no processing has been done yet.

1.3 Mongolia in the scope of interest

Mongolia belongs among the eight developing countries of the world which are set as the most important for the Czech official development cooperation. Therefore, several projects are supported by the Czech government to be conducted in Mongolia. These projects concern environmental protection, politics, economy and culture. Their goals should pose a benefit especially for Mongolian partners, but should consequently also bring some contributions to the Czech Republic and to the mutual Czech – Mongolian relationships. Unfortunately, no geophysical projects are supported at present.

The most important projects concerning geology, geophysics and science in general include the survey of minerals, fossils and petrified wood by Czech students from Masaryk University and Mendel University of Agriculture and Forestry (2000–2005), the Geological mapping of the Mongolian Altai held by the Czech Geological Survey (2003–2006), the New Odyssey project studying migratory birds by the Czech Radio (2002–present), geological and geochemical mapping, environmental survey including hydrogeological investigations by Geomin (since 1997) and drinking water supply project by Geotest Brno (2002–2005). Other projects involve economic cooperation and exchange of government service employees.

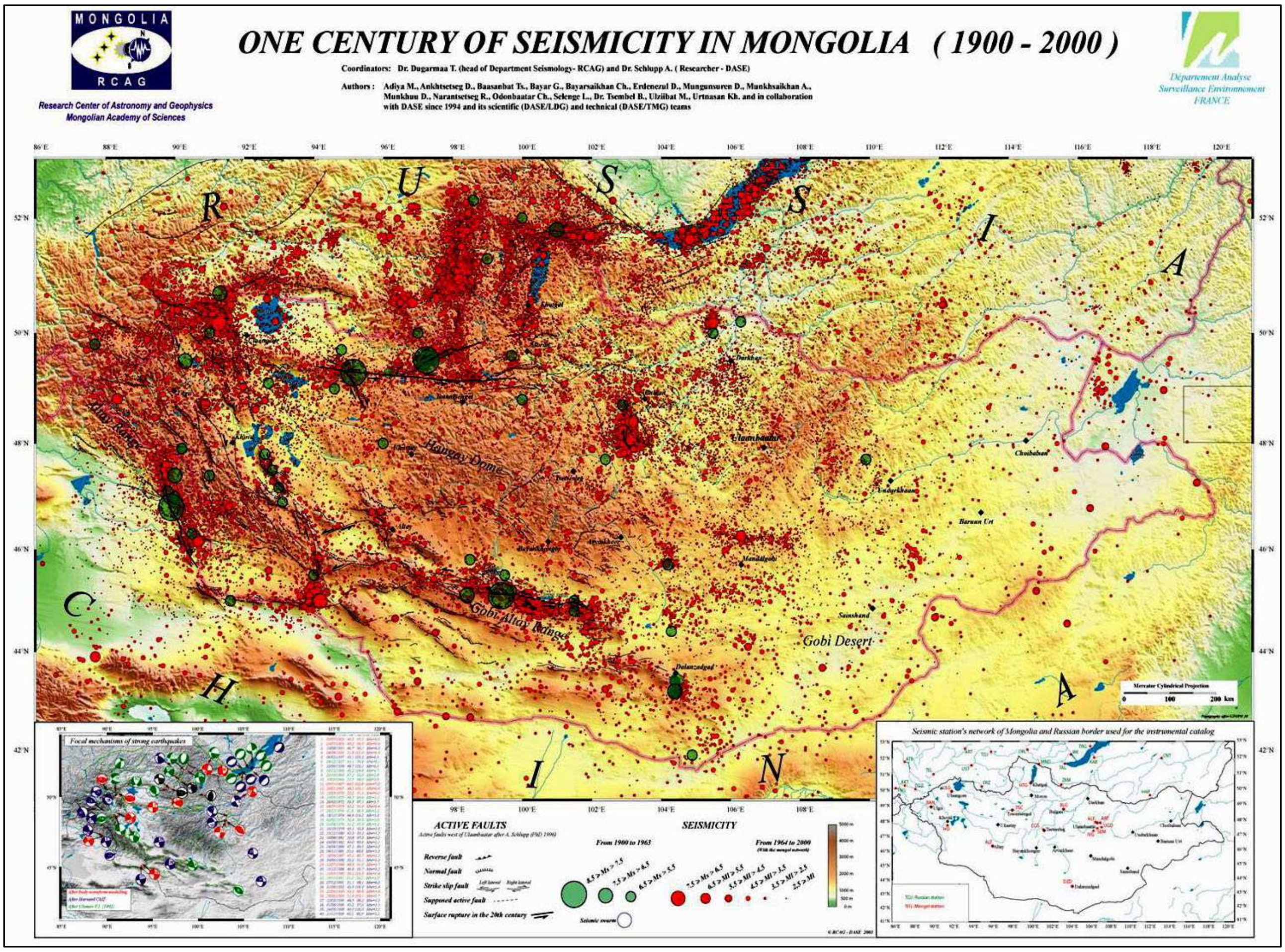

Fig. 1.
A map of the Mongolian seismicity. Red dots are events measured by modern instruments, green dots present the historical events not recorded by seismometers. Printed with permission of RCAG.

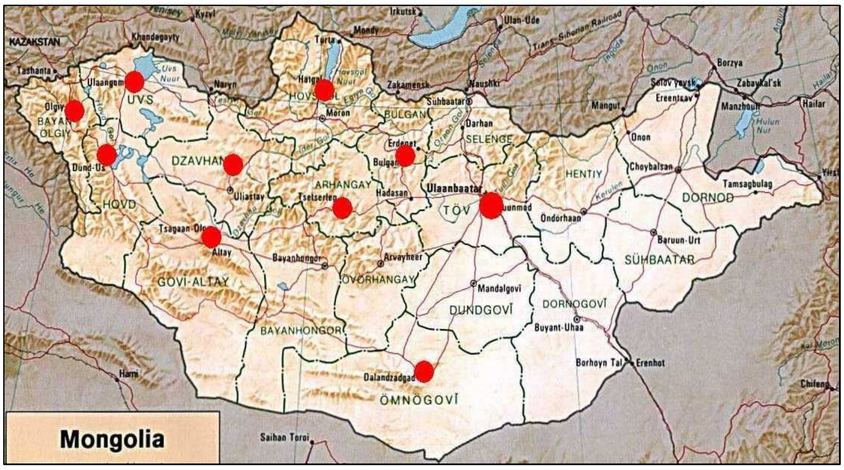

Fig. 2
Seismic stations operated by Research Centre for Astronomy and Geophysics, Mongolian Academy of Sciences.

Not only due to these projects but also to the former Czechoslovak geological survey in Mongolia, Czech scientists are always welcomed in the country. The Czech–Mongolian scientific cooperation was encouraged by the Czech government during official visit of Czech politicians to Mongolia and Mongolian politicians to the Czech Republic in the last years.

2 Erdenet copper mine

The copper mine near Erdenet City, 250 km northwest of Ulaanbaatar, is one of the world's largest of its kind. It produces nearly 40 % GDP of Mongolia. Mining started about 150 years ago, when natives mined copper in the gossans. In the 1940s–1960s, Russian geologists explored the area, but it was the Czechoslovak geologists in the 1960s who found the underground deposit to be much larger. Massive exploration began in the 1970s. The mine was conducted by a joint Russian–Mongolian company. The principal metals are copper, molybdenum and silver with some gold, selenium and rhenium.

The deposit is a late Neogene stockwork in a belt of Permian volcanic and plutonic rocks stretching east–west. The ore body is located in an uplifted fault block dipping to the northwest. Geological survey was conducted around the deposit but no seismic measurements were held in the vicinity of the mine as it is planned by the proposed project.

3 Aims of the project

3.1 General goals

The project will use up-to-date methods of local seismological investigations and especially methods developed at the IRSM recently. The main goal is to use these methods of measurements and processing of data in the unexplored terrain, and to gain new knowledge about the natural and induced seismic events generation and wave propagation. The software for analysis used at the IRSM needed for data processing will be adjusted for particular problems, but no new methods will be developed. The use of approved methods and equipments will ensure that no major problems are expected during data acquisition and processing.

Geophysical research comes, as a part of its results, with mapping of the local fault zones. Fault zones and especially their intersections are perfect sites for boreholes and possibly also excavated wells. This might be another great benefit for the arid Mongolian countryside with its chronic lack of good-quality, productive, unpolluted water sources.

3.2 PhD thesis

Five members of the team are postgraduate students at three Czech faculties: Faculty of Mathematics and Physics, Charles University in Prague, Faculty of Science, Charles University in Prague, and Faculty of Electrical Engineering, Czech Technical University. Their PhD theses are in close relation to the proposed project, and the field work in Mongolia and subsequent data processing will help them to complete their studies. Five of the members of the team work together in another grant project "Hydrogeological effects of seismicity in the Hronov-Poříčí fault zone area" funded by the Czech Science Foundation, and they have formed a compact team.

3.3 Induced seismicity

The most important goal is to study induced seismicity. The Erdenet copper mine area seems to be an excellent "laboratory" for such purpose. Huge amount of soil, rock and copper ore was mined out, many blasts are performed there. The derogation of the terrain is extraordinary – the mine occupies an area of 4 x 6 kilometres. We plan to set one or two seismic stations in the vicinity of the quarry in 2007 to find out where the induced events take place, and to suggest station locations in the main measurement campaign to be performed next year. During the main campaign, we will measure at several places around the mine. We will use a continuous record to capture even very weak events. We also plan to build one small-aperture array to record and distinguish the smallest events down to the magnitude of -1 in the technological noise. Exact locations of events, both absolute and relative, will be emphasized (using a double difference algorithm).

Fig 3:
Part of the Erdenet copper mine open pit quarry where blasts are performed.

3.4 Natural events

Several faults are situated in the vicinity of the quarry – some of them are active, what can be also seen in Fig. 1. We plan to measure microearthquakes around the quarry. Although the border between natural and induced seismic events is not sharp, we will try to distinguish between natural and induced ones. We will look for a correlation between induced events and quarry mining activity. Comparison of focal mechanisms of natural and induced events will be performed.

3.5 Quarry blasts

The methods and equipment for measuring and interpretation of seismic effects of quarry blasts will be also used in Mongolia. These methods include precise measurements of origin times using special seismographs placed about 50 m from the blast. It has been already proved (see Fig. 4) that high-quality records of huge blasts used in Mongolian mines can be obtained at distances of as much as 150 km from the explosion. We will measure blast origin times also at other mines situated in northern part of Central Mongolia to estimate the basic seismic properties of the upper crust using first arrivals of P and S waves, arrivals of reflected waves and using surface wave analysis. We also plan to use permanent stations built by RCAG in the region (see Fig. 2).

3.6 Seismic hazard assessment

Mongolian government asked the RCAG to ensure the seismic hazard assessment (SHA) for Ulaanbaatar and other populated urban areas of Mongolia. Some work has been already done for the capital. The project for SHA starts in Erdenet city in 2006 and in Darkhan city in 2007. The SHA projects are of major importance for Mongolia since large faults with high probability of earthquake occurrence cross the country, and no anti-seismic engineering was implemented in urban planning. We plan to cooperate with our Mongolian colleagues to help them with measurements and data processing (Buben, Málek 1995, Málek, Buben 1996). They will use several geophysical methods for SHA, and our seismic data will be available for them to complement their results. The head of RCAG expressed a strong interest in cooperation in the SHA project.

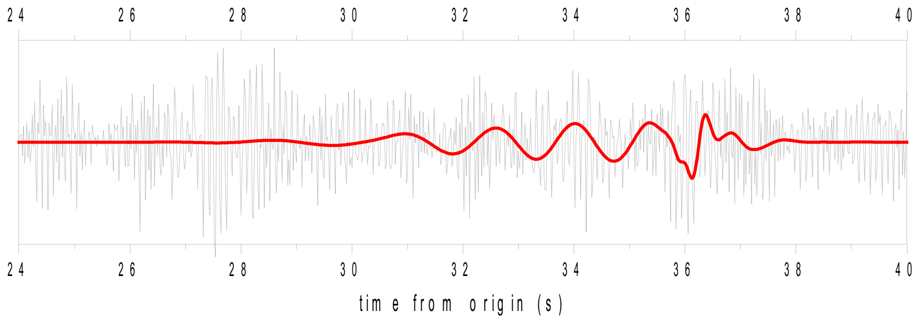

Fig. 4
Transversal component record of the Boroo Gold Mine blast (black), ALFM station near Ulaanbaatar, epicentral distance 91.3 km, with surface wavegroup marked (red). (P-waves are not shown)

3.7 Shallow seismic measurements

To complement our study and to determine a detailed crustal structure (for example, in close vicinity of seismic stations), we plan to use shallow seismic exploration. The IRSM is well equipped for this kind of work: this method is routinely used during our field measurements in the Czech Republic.

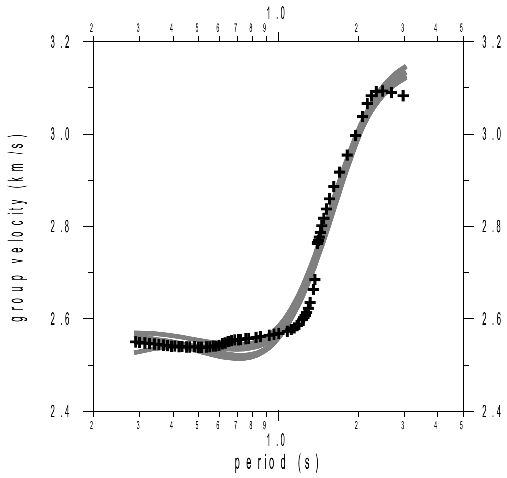

Fig. 5
Surface wave dispersion curve of the presented record (crosses) and theoretical fitted dispersion estimated for 1D upper crust model.

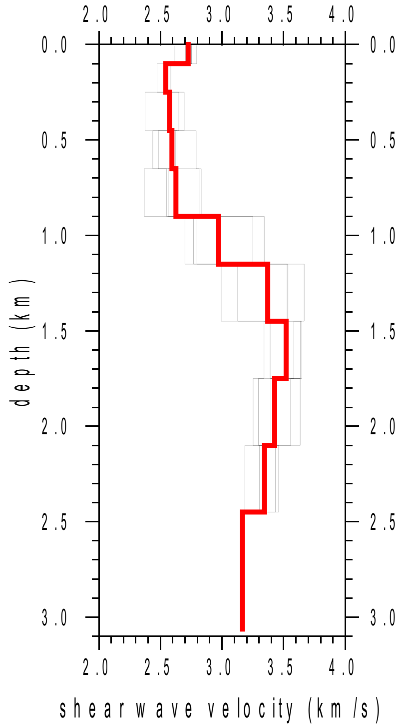

Fig. 6
Inversions of the dispersion curve (black lines) and average 1D model (red).

3.8 Very low frequencies (VLF) method and gravimetry

We propose to employ yet other geophysical exploration methods together with our seismic measurements. A combination of different methods gives more precise and reliable results than a single method. For example, seismic methods are not the most efficient for the detection of local faults. In such case, it is advisable to employ some electromagnetic method. The VLF method is known as one of the most efficient geophysical methods for fault mapping. It is fast and highly portable and therefore well suited to be a complementary method in this case. A combination of seismic and gravimetric methods should yield higher resolution, especially at the boundaries of geological blocks.

The knowledge of a local fault system is essential for any geological or tectonic interpretations. The knowledge of dislocation planes enables the construction of well suited input models for seismic inversion methods, thus providing better results.

Gravimetry is commonly used in combination with seismic methods in exploration geophysics, especially for deep structure investigations. Relations between seismic and gravimetric models are described, e.g., in Kozlenko and Kostukevich (1994).

3.9 Training of Mongolian PhD students

Last but not least, we plan to involve the Mongolian researchers and especially PhD students in data processing. This is beneficial of two reasons: first, some preliminary results will be available during the stay of Czech researchers in Mongolia which means that some computations and data processing will be done there; secondly, the RCAG researchers are interested in methods used by the Seismological Department of the IRSM. We use many methods which are not common at RCAG and we have also developed software for standard and special methods which can further improve the ability of the RCAG to fulfil its mission within the framework of the Mongolian Academy of Sciences and Mongolian government programs. In addition to this, several young researchers apply for their PhD degree and new methods and software will help them in their educational problems.

4 Research team of the IRSM

The Department of Seismology of the Institute of Rock Structure and Mechanics has a long tradition in the study of local seismic problems. Seismic methods have been developed and used both in mining regions and seismoactive areas of the Czech Republic (Janský, Málek 2004, Málek, Janský, Horálek 2000, Málek, Horálek, Janský 2005). The data interpretation is mainly targeted to velocity models evaluation (local seismic tomography and surface wave tomography). Special attention is given to the anisotropy of seismic waves. Effects of technical seismicity (e.g. quarry blasts) and methods for shallow structure investigations are other topics in the department.

Several local seismic networks are operated by the Department of Seismology in the territory of the Czech Republic to study both induced and natural seismic activity. The study of natural seismicity is predominantly focused on seismic swarms in western Bohemia and on the events around the Hronov-Poříčí Fault in eastern Bohemia. The study of mining-induced events continues from the 1950s. Nowadays, induced and technical seismic events are studied in the vicinity of the underground gas storage of Příbram-Háje (Brož et al. 2001), in open-pit coal mines in northwestern Bohemia and in quarries around the Czech Republic. (Brož et al. 2000, Málek, Žanda 2004) We also co-operate with the University of Madrid (Spain) on induced seismicity in the vicinity of water reservoirs.

The IRSM operates broadband seismic stations in eastern Bohemia with a small-aperture array, the WEBNET local seismic network in western Bohemia (in cooperation with the Geophysical Institute, AS CR) and other broadband seismic stations in the Bohemian Massif (Málek, Janský 2003).

Not only seismology but also other geophysical methods are used and developed at the IRSM. At present, the IRSM takes part in a grant project called “Hydrogeological effects of seismicity in the Hronov–Poříčí Fault zone area”, a complex geophysical project combining several methods of observation, such as shallow seismic survey, small-aperture array measurements, body wave tomography, surface wave analysis, measurements of groundwater level changes, precipitation data analysis, geological observations as well as other phenomena and their relation to the earthquake occurrence.

Since 2006, we have been also involved in the PASSEQ international passive seismic experiment. The Department of Seismology also in the international experiments studying the lithospheric structure in Europe. We have taken part in the refraction experiments CELEBRATION 2000, ALP 2002 and SLICE 2003 and in the international seismic experiment BOHEMA (Málek et al. 2004, Vavryčuk et al. 2004).

We are ready to solve all possible problems and tasks connected with measurements in Mongolia. The most important tasks include the positioning of the seismic station, building a complete station equipment such as energy sources, data transfer, seismometer placement, computer hardware connection, GPS installation, software installation and security arrangements. Members of the team have experience with complex seismic experiments both in the Czech Republic and in central Europe (see above) employing large-scale equipment distributed over long distances, transfer and storage of huge amounts of data, organization of special quarry blasts and measurements of origin time near the blasts by special seismometers.

The members are also accustomed to work in a small team and solution of their particular tasks within the team. They have previous experience with organizing expeditions to remote and deserted parts of Europe, North America and Asia. Petr Kolínský, the main investigator, visited Mongolia for six weeks in 2005. His journey was organized within an international academic agreement. He had the opportunity to work with Mongolian researchers, face their problems and to visit several seismic stations. He also experienced the peculiarities of Mongolian life and travelling as well as problems concerning the equipment and possibilities of what material can be acquired in Mongolia and what has to be brought from the Czech Republic.

Two team members, Petr Kolínský and Jan Valenta, plan to visit Mongolia again in June 2006. This journey is partly covered by the international agreement between the Czech and Mongolian Academy of Sciences and partly supported directly by the IRSM. These preparatory works give a good chance to detect all problems before the main project starts in 2007.

All fieldwork in Mongolia will be carried out in cooperation with the Seismological Department of the Research Centre for Astronomy and Geophysics. The department suffers from lack of seismometers and money, but has modern computer equipment, and researchers and engineers who will join the project. An agreement will be signed between our IRSM and RCAG to specify which work will be done by the Czech and Mongolian parties, respectively. The overall agreement was made during Kolínský's visit in 2005. Signing of the treaty document is one of the goals of the 2006 journey to Mongolia. The realization of the bilateral treaty will be conditioned by financial support demanded in this project proposal.

It is supposed that the Mongolian side will be responsible for the logistics of fieldwork, for the seismic station support and supplies, for the accommodation of Czech scientists and for the transportation of equipment across the country. The facilities of RCAG will be also used: computers, internet connection and other devices placed in the Centre in Ulaanbaatar will be at hand for Czech researchers.

A preliminary data processing will be performed in Mongolia: first, the Czech researchers will have the opportunity to check all the necessary equipment and station and to fix possible problems; secondly, the Mongolian researchers will be introduced into the way of processing the data and the methods used at IRSM.

5 Equipment

5.1 Hardware and instruments

During the last few years, several broadband seismometers (Guralp) and many short-period ones (Lennartz and SM6) were purchased and used by the IRSM for various measurements in the Czech Republic and other countries. Portable device (Bumprecorder) for measuring the quarry blast origin time was developed and successfully used.

We are going to buy a new VLF receiver and gravimeter from the funds of IRSM to complement our seismic studies. To ensure a safe and smooth coordination of fieldwork in Mongolia, two satellite phones will be needed since GSM network operates only in the Capital and a couple of smaller towns in the country. Also a several walkie-talkie transmitters will be useful for communication in vast Mongolian plains as well as one new GPS receiver since our current receivers are slow and out of date.

5.2 Software

The Seismological Department of the IRSM manages many computer programs. Most of them were developed in the IRSM in recent years and are to be used for our current projects in the Czech Republic, other international projects our Department is involved in, and for the proposed project in Mongolia. Unlike the commercially distributed software, they have many advantages: clear and accessible source codes, special design for our purposes, no copyright problems etc. It seems to be necessary to make some insignificant changes in the codes with respect to the instruments used and other local conditions, but the main amount of programming work has been already done at the IRSM and the programs were developed with the intention to be used for such type of project.

6 Time schedule

6.1 Preparatory stage

2005 **visit of Petr Kolínský at the RCAG**
- mutual agreement on future cooperation between RCAG and IRSM
- checking of the Mongolian computational and measuring equipment (already done)

2006 **visit of Petr Kolínský and Jan Valenta at the RCAG**
- a visit at the Erdenet copper mine
- gathering of geological maps and information
- planning of seismic station placement
- choosing other possible destinations for seismic survey
- specification of possibilities of material and equipment supplies in Mongolia
- signing of a bilateral treaty between the IRSM (Czech Republic) and RCAG (Mongolia) (supported partly by the bilateral academic agreement between AS CR and MAS, partly by the IRSM internal funds)

6.2 Project

2007
- expedition of three Czech researchers to Mongolia
- two weeks of measurement at min. two seismic stations near the Erdenet copper mine
- measurement of quarry blast origin times and epicentre coordinates
- preliminary evaluation of measured data
- final conclusion about the optimal measurement position and seismometers needed for the next year project main measurement campaign

2008
- expedition of four Czech researcher to Mongolia
- main measurement campaign, 3 months of terrain work, continuous measurement
- periodical measurement of quarry blast origin times and epicentre coordinates both at the Erdenet copper mine and other mines within hundreds of kilometres from Ulaanbaatar
- visit of one or two Mongolian researchers in the Czech Republic

2009
- data evaluation
- visit of two Mongolian researchers in the Czech Republic
- publication preparation
- presentation of results

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Appendix 1

Research Centre of Astronomy & Geophysics Mongolian Academy of Sciences

P.O.Box – 152 Ulaanbaatar – 51
Mongolia

Brief Introduction of the Organization

The Research Centre of Astronomy and Geophysics (RCAG) has determined its mission and objectives and carried out its activities within the present framework of organizational structure since 1997. Research activities in astronomy and geophysics started during the International Year of Geophysics in 1957. The RCAG is conducting research activities in the basic four fields (sectors): astrophysics, astrometry, seismology and geomagnetic investigation. Each sector has its own history, main directions of research work and results. The future trends are based on Mongolian specific problems and advantages: research equipments, working experience and database.

The RCAG has been carrying out its activities continuously since 1960s. The centre has comparative advantages in terms of professional staff resources and knowledge of local problems and terrain. The RCAG has collaborated with several foreign institutions (France, USA, Russia) during international projects.

The main topics of seismic investigation

- investigation of seismic wave propagation in the deep Earth and on the Earth surface by means of seismological survey
- determination of earthquake fault size, source time duration, magnitude and origin time
- evaluation of seismic effects on Earth surface
- studying of rock condition by the means of engineering seismology
- seismic hazard assessment (SHA) of urban areas

The main results

Determination of both dynamic and kinematic parameters like arrival time (To), epicentre distance (Δ, km), hypocentre depth (φ, λ), magnitude (M) and energy class (K) by interpretation of seismic network data. These results are summarized in an annually produced catalogue of seismic data (bulletin). The RCAG exchanges the seismic data with international seismological organizations.

The RCAG has produced the **Mongolian seismic microzoning map** (M 1: 2.500,000) by the investigation of strong earthquake source mechanisms, seismic activity, regional seismic regime and seismicity of whole Mongolia. The result is that 75 % of Mongolian territory have an experience with MSK-64 intensity 7 and more.

The century's strong earthquakes and the tectonic activity of Mongolia are caused by the collision of Indian and Eurasian plates. These tectonic forces have resulted in many features to be seen both on the surface and in the deep structure of Mongolian territory – big surface faults are among them.

We have determined the crustal thickness and seismic velocity distribution.

We have determined – by the complete engineering seismology investigation – that the seismic energy propagating through different rock types result in acceleration with intensity varying within 1 – 2 orders of magnitude. Hence we determined the seismic hazard for Ulaanbaatar city area, which is located in the seismic activity region.

Future plans

We will update the seismic stations to modern electronic digital equipment. We plan to expand our seismic data bases, to precise the Mongolian seismicity evaluation and to develop methods for deep structure model estimation by means of the seismic wave propagation. The main goal is to interpret the seismological, geological and engineer-seismological investigations in Mongolia according to the modern hypothesis concerning the Baikal Rift and Central Asia geodynamic processes.

Equipment

In Mongolia we have 9 analog seismic stations SKM-3 with galvanometric registration operating in short-period range. There is also a small local seismic network in the vicinity of Ulaanbaatar city. The data from this network are digitally telemetered to the RCAG. We have also a broadband seismic station.

International cooperation

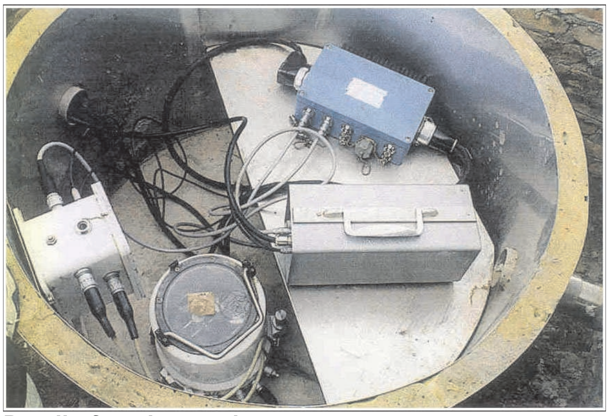
We participated in important projects in close cooperation with scientists of the Institution of Earth Crust, Russian Academy of Sciences, Irkutsk; the Department Analyse et Surveillance de l'Environement, Commissariat a l'Energie Atomique, France and the U.S. Geological Survey, US, for conducting a new technology, making a field work in the seismic activity region, to do the complete engineer-seismological investigation and for publishing the results. We have also conducted the research and field work in close cooperation with scientists of DASE, France (Seismic Hazard Laboratory) and Institute of the Earth Physics, Russian Academy of Sciences, Moscow.

Staff

The research team of the Seismological Department of the RCAG consists of about 20 workers. These include a seismologist, theoretical physicist, geophysicist, engineering geologists, engineering geodesist, electronic engineers, and construction engineers. We have two Ph.D. research workers and three young research workers candidates, who are Mr. M. Ulziibat, Mr. Ch. Odonbaatar and Mrs. D. Ankhtsetseg.

T. Dugarmaa	Doctor of Philosophy, head of the Seismological Department of the RCAG, e-mail:dugarmaa@csg.mn
B. Tsembel	Doctor of Philosophy
D. Munkhuu	research worker
G. Bayar	research worker
M. Adiya	research worker
L. Selenge	research worker
M. Ulziibat	research worker
Ch. Bayarsaikhan	research worker
D. Ankhtsetseg	research worker
Ch. Odonbaatar	research worker, responsible for cooperation with the Institute of Rock Structure and Mechanics, Academy of Sciences of the Czech Republic, e-mail:odon@csg.mn
B. Battulga	electronic engineer
B. Sergelen	electronic engineer
A. Munkhsaikhan	research worker
D. Mungunsuren	research worker
Kh. Urtnasan	research worker
D. Erdenezul	research worker
Ts. Baasanbat	research worker
R. Narantsetseg	assistant-research worker

Seismic station in Mongolian mountains powered by solar energy.



Detail of station equipment.

Future cooperation with the Czech Republic

The Mongolian Government expressed the intention to improve seismic monitoring in Mongolia and to make seismic hazard assessment (SHA) of Mongolian urban areas. Therefore the RCAG started the SHA project of Ulaanbaatar city in the year 2000. In this project, we use temporary seismic stations from France. In the year 2006 we start the same SHA project in Erdenet city. To complete the results of these projects at an up-to-date level of international geophysical methods and publications, we need some seismic equipment, a higher number of measurements and know-how.

We also started to replace our analog (photo paper based) stations by broadband digital stations. Now, we plan to install BB stations at each point where a short period or analog station operates at this moment. Nevertheless, Mongolian research suffers from insufficient financing. We plan to buy two BB Guralp seismometers in 2006. Other analog stations will be replaced by digital short period stations. We will highly appreciate any kind of help from the Czech Republic concerning the measuring equipment and methods of data processing.

Last year (2005) Petr Kolinsky visited our Research Centre within the bilateral exchange program of Mongolian Academy of Sciences and Czech Academy of Sciences. We discussed the future cooperation of our two institutions and Kolinsky's surface wave inversion study. The software he had developed was very interesting. If we apply his method and programs in a blast area of some quarry, it would allow not only to study the Earth structure but also solve theoretical aspects.

Odonbaatar Chimed
RCAG, Ulaanbaatar, Mongolia
January 2006

Appendix 2

MONGOLIAN ACADEMY OF SCIENCES

Date: 4 April, 2006
Ref: 6/160

Mrs. ALENA SOLNICKOVA
HEAD
INTERNATIONAL DEPARTMENT
ACADEMY OF SCIENCES OF
CZECH REPUBLIC
FAX: + 420 224 24 0531

Dear Mrs. Solnickova,

Warm greetings from the Mongolian Academy of Sciences!

Hereby, I am pleased to inform you that we are ready to receive **Mr. Petr Kolinsky** for the period of **21** days, starts from 26 May, 2006 at the Center of Astronomy and Geophysics of the Mongolian Academy of Sciences under the terms of the Cooperation Agreement between the two Academies.

Please kindly inform us the arrival date of Mr. Petr Kolinsky to Mongolia.

Thank you for kind cooperation and looking forward to hearing from you.

Sincerely yours,

J.KHISHIGJARGAL
INTERNATIONAL RELATIONS DEPARTMENT