SEISMICITY, RECENT SEISMIC OBSERVATIONS AND SEISMOLOGICAL INSTITUTES IN POST-SOVIET CENTRAL ASIAN REPUBLICS

by **Vitaly I. Khalturin, Paul G. Richards, and Won-Young Kim**

Lamont-Doherty Earth Observatory of Columbia University

61 Route 9W, Palisades, NY 10964, USA

(richards@LDEO.columbia.edu, phone 845-365-8389)

PREFACE

This report provides basic information that can be useful in discussion of USA/Central Asian cooperative programs to carry out seismological investigations and observations. The main goals of such cooperation will be an improved understanding and eventual reduction of seismic risk in Central Asia, and improved capability for seismic monitoring of nuclear explosions.

Four post-Soviet Central Asian republics are of principal concern, namely Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan, because they are seismically the ones that are most vulnerable and least instrumented. The southern zone of each republic, where their capitals are located, is associated with earthquake ground shaking that can reach up to seismic intensity **IX** .[1] All these republics have experienced destructive earthquakes with many tens of thousands of victims. Seismic risk is high due to high vulnerability of the Soviet-era style of construction of residential buildings, and to fast growth of urban populations.

Central Asian countries are very favorably placed for seismic monitoring of both earthquakes and explosions in such important areas of the Middle East as Iraq and Iran, and well as Pakistan, India, Afghanistan and North-West China.

The Central Asian republics became independent states after the collapse of the Soviet

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[1]The Modified Mercalli intensity scale has 12 levels. An abbreviated description of three of these levels, taken from http://neic.usgs.gov/neis/general/mercalli.html, is as follows:

VII. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.

VIII. Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.

Union in 1991. Subsequently all four countries have experienced similar economic and political problems of the post-Soviet period: very low standard of living; high level of unemployment; political instability; very low funding of science; and mass emigration of the Russian population, among whom were the majority of local experts in seismology and earthquake engineering.

Kazakhstan is another post-Soviet Central Asian republic that is subject to substantial risk from earthquakes, and we note that it now has a substantial number of high-quality seismographic stations. They are supported by an effective infrastructure that has been built up since independence in 1992, as part of several different joint programs between institutions in Kazakhstan, and academic and governmental organizations in the United States. Both training and modern digital instrumentation were provided, to organizations in Kazakhstan that already had personnel familiar with regional seismicity and with operation of earlier types of instrumentation.

We are of the opinion that successes achieved in Kazakhstan are achievable in Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan. The joint programs to do this will need funding for several years in support of both training and the provision of necessary sensors, data loggers, computer hardware and software, and communications technology.

1. AREA, POPULATION, DESTRUCTIVE EARTHQUAKES

Basic information on the four countries is shown in Table 1. The total population is about 42 million, including about 7.5 million urban population only in the capitals.

Table 1. Areas and populations of Central Asian countries and their capitals (recent estimates)

Country	Area (sq. km)	Population	Capital	Population
Kyrgyzstan	200,000	5,200,000	Bishkek	800,000
Tajikistan	140,000	5,900,000	Dushanbe	1,100,000
Turkmenistan	490,000	4,700,000	Ashgabad	600,000
Uzbekistan	450,000	26,000,000	Tashkent megalopolis	5,000,000
Totals	1,280,000	41,800,000		7,500,000

Table 2. Significant and destructive earthquakes that have occurred in Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan since 1885

Year	Date	Lat	Lon	mag.	Max Intensity	Deaths	Location
1885	Aug 2	42.7	74.1	7.3	IX-X	n/a	Kyrg., 40 km far from Bishkek
1885	Nov 29	41.4	69.5	6.7	VIII	n/a	Uzb., Tashkent
1895	Jul 8	39.5	53.7	8.0	X	n/a	Turk., Krasnovodsk
1902	Dec 16	40.7	72.4	6.4	IX	4,725	Uzb., Andizhan
1907	Oct 21	38.5	67.9	7.8	IX		Taj., 25-40 km from Dushanbe
1907	Oct 21	38.7	68.1	7.3	IX	12,000	a repeat of the above
1911	Feb 18	38.2	72.8	7.4	XI	90	Taj., Sarez, Pamir Giant stoneslide
1929	May 1	37.9	57.8	7.2	IX	n/a	60 km from Ashgabad
1946	Nov 2	41.9	72.0	7.5	X	n/a	Uzb., Chatkal
1946	Nov 4	38.3	55.4	7.0	IX	n/a	Tur., Kazanzhik
1948	Oct 5	37.9	58.8	7.3	X	> 70,000	Tur, Ashgabad totally destroyed
1949	Jul 10	39.2	70.8	7.4	X	20,000	Tad., Khait Giant stoneslide
1970	Jun 5	42.5	78.9	6.8	IX	n/a	Kyr.,Issik-Kul Lake
1974	Aug 11	39.4	73.9	7.3	VIII	n/a	Tad., Pamirs
1976	Apr 8	40.5	63.8	7.0	IX	n/a	Uzb., Gazli
1976	May 17	40.6	63.5	7.2	IX-X	n/a	Uzb., Gazli
1978	Nov 1	39.5	72.6	6.8	IX	n/a	Kyr., Alay Valley
1984	Mar 19	40.4	63.3	7.4	X	n/a	Uzb., Gazli
1992	Aug 19	42.2	73.6	7.4	IX	> 75	Kyrg., Soosamir

The maximum expected seismic intensity in each capital is **IX**. A seismic zoning map of the Central Asian region is shown as Fig. 1.

All four republics have experienced devastating earthquakes (Table 2). The most destructive among them were:

Belovodsk, 1885 and Sousamir, 1992 events (in Kyrgyzstan)

Karadag, 1907 (twice); Sarez, 1911; Khait, 1949 (in Tajikistan)

Krasnovodsk, 1895; Kazandzhik, 1946; Ashgabad, 1948 (in Turkmenistan)

Tashkent, 1886; Andijan, 1902; Chatkal, 1946; Tashkent, 1966; Gazli, 1976 (twice) and 1984 (in Uzbekistan).

Twelve thousand people were killed in a rural area (25 to 40 km from Dushanbe) during the double (M = 7.2) earthquake event in 1907. Ashgabad was completely destroyed in 1948, and about 60-80 thousand people were killed. A giant stone slide and hundreds of landslides killed about twenty thousand people during the Khait earthquake in Tajikistan in 1949.

We note that a recent earthquake in the Kashmir – Pakistan border area (2005 October 8, M = 7.6) killed approximately 80,000 people and has left 400,000 survivors exposed to harsh winter conditions. The building standards in rural Pakistan may be similar to those of rural Central Asia, though buildings and infrastructure in towns, and a limited ability to support rescue efforts, may be better in Pakistan that in villages and towns of Central Asia.

Figure 1 shows the location of nearly 3000 earthquakes that occurred in the area during a 25-year period (1981 to 2005) with magnitude 4.5 or above, with the damaging earthquakes of Table 1 shown as hexagons. Figure 2 shows a somewhat larger area of Central Asia and its surroundings — including nuclear sites in Kazakhstan, China, India, and Pakistan — together with the national network stations of Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan.

In general terms, the seismic hazard for Central Asia as well as for Pakistan and India is due to the tectonic stresses associated with the Indian subcontinent continuing to moving northward against Eurasia. Great earthquakes in this region will continue to occur.

The seismic risk for a given region is a combination of the seismic hazard for that region (expressed, for example, in terms of the probability that dangerous ground shaking due to earthquakes will occur during the next fifty years), and the value of structures in the region (such as building, dams, power plants, pipelines and roads), that would be exposed to this hazard and that could be damaged by it. A seismic hazard map for a region that includes Central Asia is shown in Figure 3.

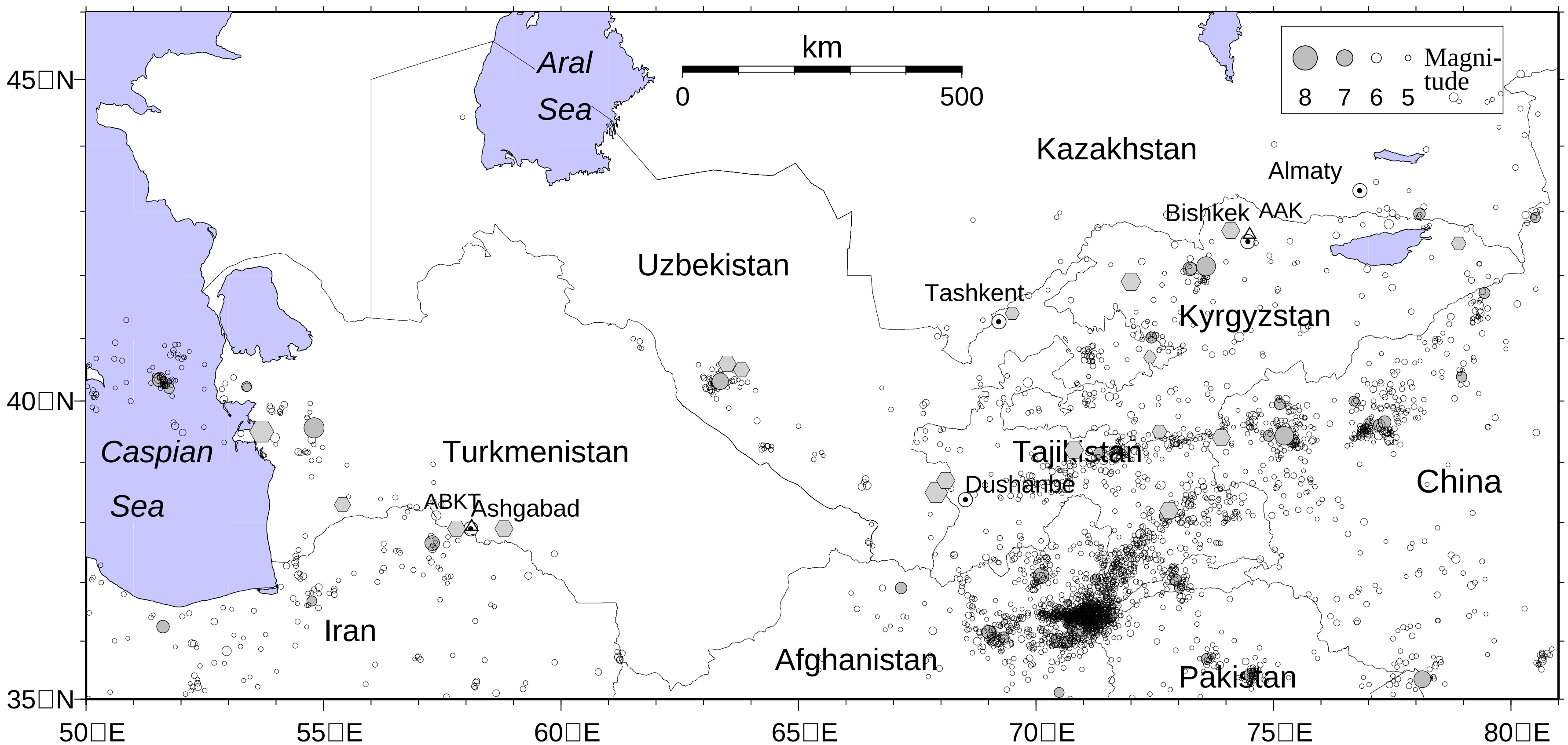

Figure 1. The location of 2850 earthquakes in Central Asia for a 25-year period (1981 – 2005), with magnitude greater than or equal to 4.5, according to the U.S. Geological Survey. Also shown, as hexagons, are the damaging earthquakes listed in Table 1. Many earthquakes are concentrated in the Hindu Kush, near (36ºN, 71ºE), and are at depths greater than 70 km. But shallow earthquakes occur throughout Kyrgyzstan and Tajikistan, and damaging earthquakes have occurred near the capital cities of all four Central Asian republics discussed in this report.

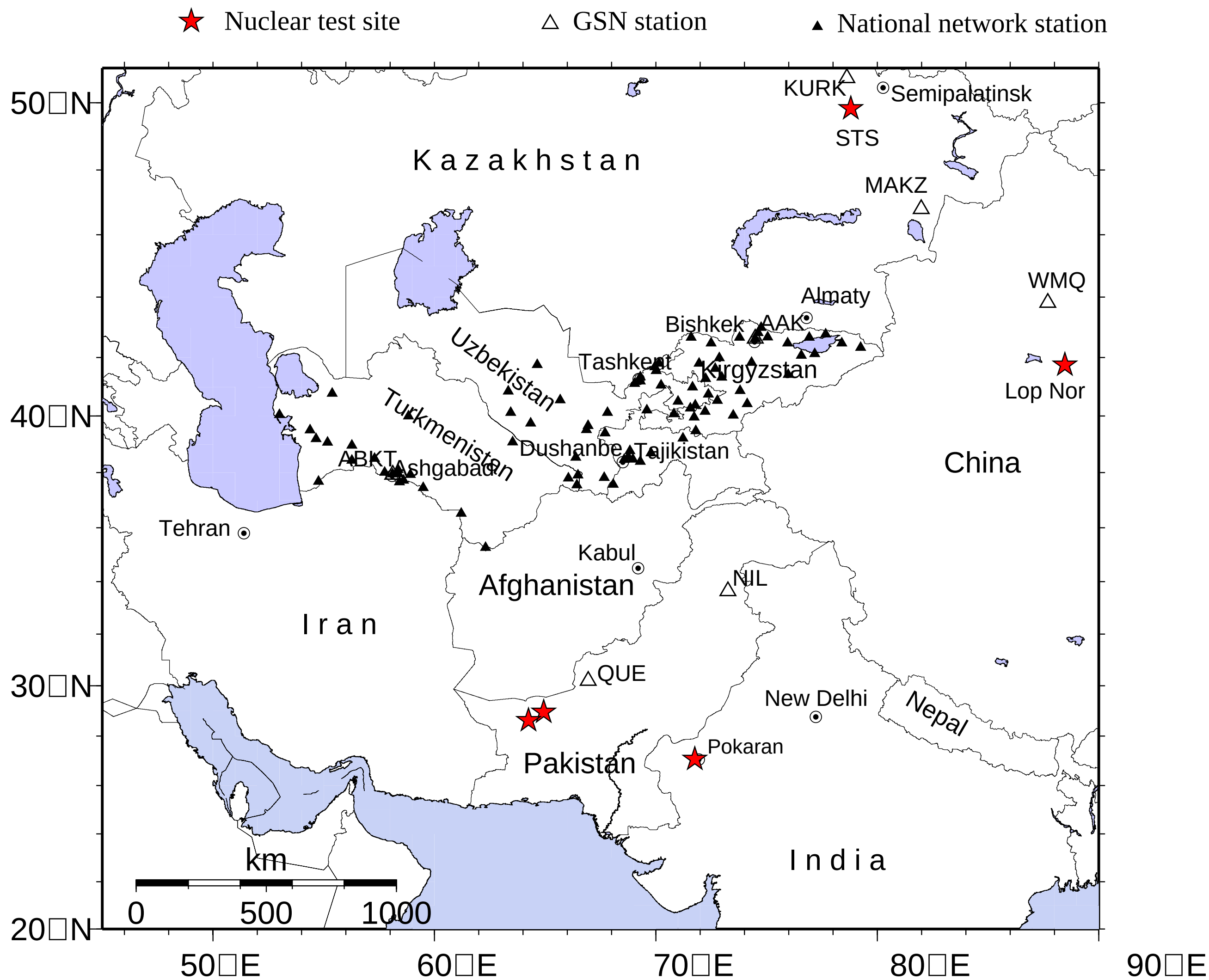

Figure 2. A map of Central Asia and surrounding regions, showing nuclear test sites (red stars), broadband stations of the Global Seismographic Network (open triangles), and national network stations (small black triangles).

Since the early 1900s the population of Central Asia has grown several times, but the quality of rural dwellings has stayed the same. The seismic risk in the region has therefore increased significantly, especially for the capital cities of these four republics. The risk is due to the high growth rate of the population and its supporting infrastructure, and to the vulnerability of Soviet era residential buildings. Though we cannot directly influence the basic seismic hazard, it has long been clear that practical reduction in seismic risk in earthquake-active regions is closely associated with efforts to obtain information on the underlying seismic hazard. As this hazard becomes better known, for example by documentation of the small earthquakes that are occurring all the time, together with measurements of ground shaking for earthquakes that are occasionally felt by the population, it becomes possible to identify active fault structures and to assess their potential for future earthquakes. It also becomes more possible to develop building standards to improve resistance to earthquake damage. In the continual struggle for resources, especially in the lesser-developed countries, it is never easy to develop such standards and to ensure that they are followed. But the operation of seismic monitoring equipment and associated data centers, and publication of the information they provide, is a continual reminder to local authorities of the need to provide earthquake-resistant buildings and infrastructure. The cost of monitoring efforts is a minute fraction of the multi-billion dollar investments in buildings and infrastructure.

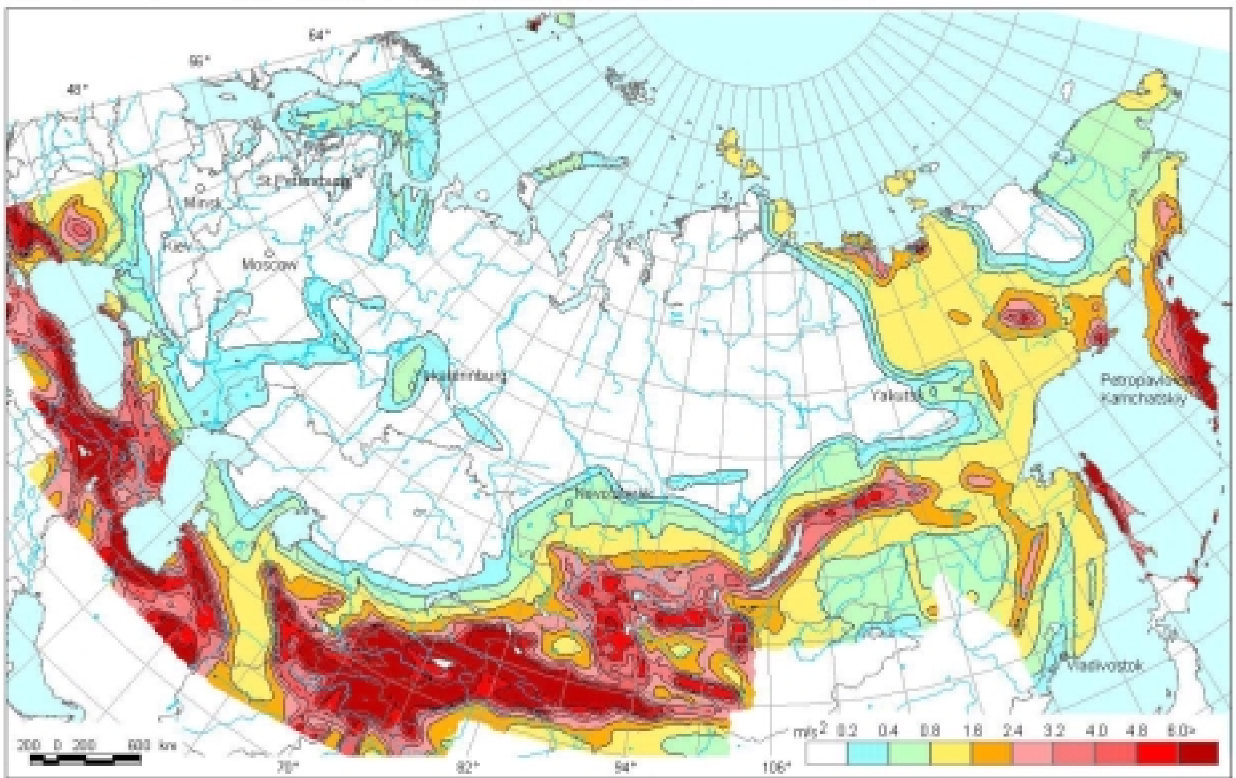

Figure 3. A seismic hazard map of northern Eurasia, including parts of Central Asia which are discussed in this report. The quantity contoured is the ground acceleration estimated to have 10% probability of exceedance in a 50 year time period. Note that a ground acceleration of 1 g corresponds to 9.8 m/s^2. Much of Central Asia is expected to have a 10% chance of more than 6 m/s^2 accelerations over the next 50 years. (Map, developed in the Global Seismic Hazard Assessment Program: see http://www.seismo.ethz.ch/gshap/ .)

2. SEISMIC STATIONS and INSTRUMENTATION

All four post-Soviet republics have a similar structure for their seismological organizations and systems of seismic observations. There is an Institute of Seismology and an Experimental-

Methodical Expedition (EME) in each country. EME manages the seismographic stations and is responsible for all types of seismological and geophysical observations and primary data processing (earthquakes location, calibration and bulletins publication).

The seismographic instrumentation mostly used in post-Soviet republics consists of two standard sets of seismometers, each set responding to three components of ground motion (up-down, north-south, east-west). All six channels have analog recording (pen on paper). One set of instruments, called SKM, has a short period response (pendulum free period, To = 1.5 sec) and the other set, called either SK or SKD, has a relatively longer period (To = 12 sec for SK; To = 20 sec for SKD). Both instruments record a filtered version of ground displacement (rather than ground velocity). The SKM magnification is usually in the range 20,000 to 40,000 (0.2-1.2 sec), SK 1,000 to 1,500 (0.2-10 sec), and SKD 1,000 to 1,500 (0.2-18 sec). There are also low gain channels on a majority of the stations, with magnification about 1,000-2,000 on SKM instruments and about 50-100 on SK-SKD.

The total number of seismographic stations in each country in 1990 (before the Soviet Union collapse), and in 2005, is shown in Table 3 (omitting KNET stations, which are operated by the University of California at San Diego, as described further, below).

Table 3. Total number of seismic stations in each Central Asian republic in 1990 and 2005

Republic	1990	2005
Kyrgyzstan	34	28 (omitting KNET stations)
Tajikistan	47	12
Turkmenistan	24	28
Uzbekistan	27	23

The immediate problem of Central Asia seismology is absence of funding for new equipment. Thus, almost all stations are still using analog recording, which has limited dynamic range and limited bandwidth. Limited dynamic range means that small earthquakes are often not recorded, and large earthquakes may not be recorded correctly because the instrument goes off-scale. Limited bandwidth and analog recording prevent the application of many modern methods of signal analysis such as filtering, stacking to improve signal-to-noise ratios, measurement of ground motion across different frequency bands, and discrimination studies based on spectral content.

Though the immediate problem is amenable to short-term solution by providing appropriate modern equipment with digital recording, in practice the long-term operation of such equipment requires that training be given to local operators, and to the personnel who analyze the digitally recorded ground motions and who can then provide various data products such as earthquake locations, and various measurements of earthquake size.

Tables 4 – 7 give names and locations of all permanent seismic stations operated in each of the four Central Asian republics we are describing. Due the lack of funds almost all stations are still equipped with old type analog instruments that originally recorded on photo paper, but today are more typically use pen-and-ink recording. Only a few digital stations are operated in each republic, the most important being a Kyrgyzstan Network known as KNET. Data from these stations are telemetered in near real time to operators in the USA (at the University of California, San Diego, for KNET), and archives of these stations are maintained by the Data Management Center of the IRIS Consortium.

Figure 4 shows the location of stations listed in Tables 4 – 7, in each of the four Central Asian republics. The geographical boundaries of these countries are often determined by rivers and mountain topography, and are thus quite complicated. Figure 4 indicates how these four countries fit together, though each is shown separately together with the stations of its national network.

Table 4. Seismographic stations in Kyrgyzstan. Status on June 1, 2005. Short-period SKM instruments are installed at all stations. At seven stations (## 2, 8, 9, 19, 20, 21, and 22), long-period SKD instruments are also installed.

#	Station	Lat. N	Long. E
1	Arslan-Bob	41.33	72.98
2	Arkit	41.80	71.95
3	Ak-Kiya	41.62	72.68
4	Aral	41.83	74.32
5	Ala-Kuu	40.42	74.12
6	Ala-Archa	42.63	74.48
7	Ananevo	42.78	77.67
8	Batken	40.07	70.82
9	Bishkek (Frunze)	42.83	74.62
10	Boom	42.48	75.95
11	Daraut-Kurgan	39.48	71.80
12	Erkin-Sai	42.67	73.78
13	Kadzhi-Sai	42.12	77.18
14	Kyzyl-Dzhar	41.28	72.25
15	Ken-Suu	42.33	79.25
16	Kirovka	42.67	71.60
17	Kungei	42.67	76.93
18	Manas	42.48	72.50
19	Naryn	41.42	75.98
20	Osh	40.53	72.78
21	Przhevalsk	42.48	78.40
22	Sufi-Kurgan	40.02	73.50
23	Salom-Alik	40.87	73.80
24	Toktogul	41.98	72.87
25	Terskei	42.07	76.57
26	Yurevka	42.68	75.05
27	Chauvai	40.15	72.22
28	Chumish	43.00	74.75

Table 5. Seismographic stations in Tajikistan. Status on June 1, 2005. All stations operate the short-period SKM instrument. Some stations (## 2, 3, and 7) also operate the long-period SKD instrument.

#	Station	Lat N	Long E
1	Djerino	38.78	68.83
2	Djirgital	39.22	71.22
3	Dushanbe	38.56	68.76
4	Gezan	39.4	67.7
5	Hissar	38.47	68.57
6	Karasu	38.48	68.97
7	Khudjand	40.2	69.6
8	Nurek	38.4	69.3
9	Parhor	n/a	n/a
10	Rogun	38.70	69.78
11	Semiganch	n/a	n/a
12	Shaartuz	37.58	68.08

Table 6. Seismographic stations operated in Turkmenistan. Status on January 1, 1994. All stations operated the short-period SKM instrument. Some stations (##1, 2, 12, 13, 18, and 24) also operated the long-period SKD instrument.

#	Station	Lat N	Long E
1	Ashgabad	37.96	58.37
2	Vannovskaya	37.95	58.11
3	Gaudan	37.67	58.42
4	Gaurdak	37.80	66.05
5	Germab	38.01	57.75
6	Gyaurs	37.93	58.91
7	Dan-Ata	39.07	55.17
8	Kara-Kala	38.44	56.27
9	Karlyuk	37.56	66.43
10	Kaushut	37.46	59.49
11	Kugitang	37.91	66.48
12	Kyzil-Atrek	37.68	54.77
13	Kyzil-Aravat	38.97	56.28
14	Turkmen-Bashi	40.04	53.00
15	Kum-Dag	39.20	54.66
16	Kushka	35.27	62.31
17	Manysh	37.72	58.61
18	Nebit-Dag	39.51	54.39
19	Ovadan-Tepe	38.11	58.36
20	Serniy	39.99	58.83
21	Serakhs	36.53	61.21
22	Suncha	38.50	57.30
23	Chagyl	40.78	55.38
24	Chardzhou	39.08	63.53

Table 7. Seismographic stations operated in Uzbekistan. Status on June 1, 2005. Short-period SKM instruments are installed at all stations. At five stations (## 2, 3, 7, 15, 19, and 22), long-period SKD instruments are also installed.

#	Station	Lat N	Long E
1	Agalik	39.52	66.87
2	Andijan	40.75	72.37
3	Bukhara	39.74	64.35
4	Chet-Suu	41.06	70.24
5	Chimgan	41.55	70.01
6	Chimion	40.27	71.56
7	Fergana	40.37	71.78
8	Gazli	40.12	63.45
9	Dzhangeldi	40.85	63.34
10	Dzhizak	40.12	67.82
11	Zarabad	37.82	67.67
12	Khumsan	41.68	69.95
13	Kokand	40.50	71.00
14	Kumarik	41.20	69.30
15	Namangan	40.99	71.66
16	Nurata	40.55	65.68
17	Pachkamar	38.54	66.39
18	Pskem	41.80	70.14
19	Samarkand	39.66	66.94
20	Shahimardan	39.95	71.73
21	Tamdi-Bulak	41.75	64.64
22	Tashkent	41.34	69.30
23	Yangi-Yul	41.11	69.04

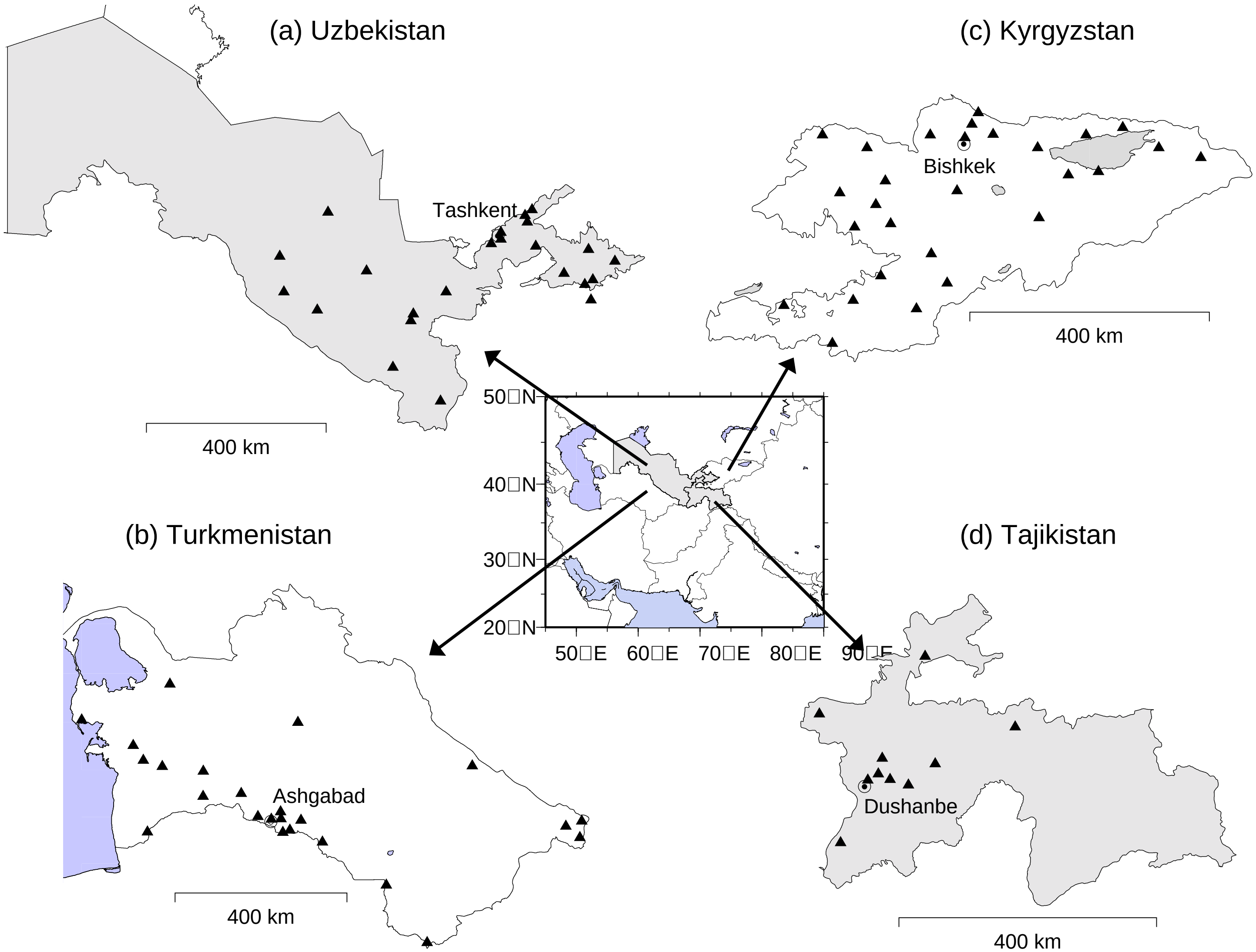

Figure 4. The location of each of the four Central Asian republics discussed in this report, together with maps of the national network stations for each country as listed in Tables 4, 5, 6, and 7.

3. INSTITUTES of SEISMOLOGY

In this section we give short descriptions of the seismological institutes and Experimental Methodological Expeditions (EME) in each of the four Central Asia countries on which we are reporting here, their structure, names of the key persons, their regular mail and e-mail addresses, and their fax and phone numbers.

Additional information about Central Asian Institutes of Seismology (activities, staff and outstanding scientists, biographies) is contained in national reports and institutional reports to IASPEI ,published in the IASPEI Handbook, Part B (2003).

3.1. KYRGYZSTAN

Institute of Seismology, National Academy of Science of Kyrgyzstan

Mail address: m/r Asanby, 52/1, BISHKEK 720060 KYRGYZSTAN

Phone: 996-312-46-18-13

Phone/fax: 996-312-46-28-76

E-mail of Institute and OME: kis@mail.elcat.kg

Director: Kanat ABDRAKHMANOV (excellent English)

Scientific Secretary: Alla Borisovna FORTUNA, phone: 996-312-46-28-82

Institute structure and staff

Department of Regional Seismology and Seismic Zoning

The Head Prof. Kanat ABDRAKHMANOV.

Lab. Regional Seismology. Dr. Kenesh D.DZHANUZAKOV.

Lab. Deep Structure of Seimoactive Zones. Prof. Tamara M. SABITOVA.

Lab. Seismotectonics. Prof. Kanat ABDRAKHMANOV.

Department of Earthquake Prediction

The Head Prof. Ernest MAMIROV.

Lab. Seismic Methods Earthquake Prediction. Dr. Mederbek OMURALIEV.

Lab. Geochemistry Methods of Earthquake Prediction. Dr. Kaliz BAKIROV.

Lab. Hydrochemistry and Tectonophysical Methods of Earthquake Predictions

Prof. Ernest MAMIROV.

Department of Engineering Seismology and Seismomicrozoning

The Head Prof. Asker TURDUKULOV.

Lab. of Engineering Seismology and Seismomicrozoning

Prof. Asker TURDUKULOV.

Total personnel in these laboratories is about 55 researchers and technicians.

The acting Head of the Experimental-Methodological Expedition is Dr. Umetali Shukurovich SHUKUROV. E-mail address: kis@mail.elcat.kg

The staff of Expedition in Kyrgyzstan is 194 employees.

3.2. TAJIKISTAN

Institute of Seismology and Earthquake Engineering, Tajik Academy of Science

Mail address: 121 Ayni St. Dushanbe, 734029 Tajikistan.

Phone: 992-372-24-44-78 and 992-372-25-57-45

Fax: 992-372-21-44-78

E-mail addresses: seismtadj@mail.tj and seismtadj@rambler.ru

Web site : www.tisss.tojikiston.com

Director: Prof. Jahongir NIZOMOV

First Deputy Director: Dr. Farshed H.KARIMOV (English excellent)

E-mail address: farshed_karimov@rambler.ru

Deputy Director: Dr. Nusrat SALOMOV

Scientific Secretary: Dr. Djafar NIYAZOV.

Institute E-mail addresses: seismtadj@mail.tj and seismtadj@rambler.ru

Institute structure and staff

Seismotectonics Dr. Anatoly R. ISCHUK
Recent Crust Movement Dr. Vladimir STARKOV
Seismicity Dr.Alexadra BARINOVA
Hydrogeochemistry Dr. Nusrat SALOMOV
Earthquake Engineering Dr. Mardon JABAROV
Strong Motion Service Dr. Akbar SOLIEV
Hydrotechnical Studies and Dam Observations Dr.Pulat YASUNOV

Total staff of Institute and seismic stations in Tajidkistan: 254 persons, including technical operators, staff of seismic stations, and auxiliary personnel.

3.3. TURKMENISTAN

Research Institute of Seismology, Ministry of Construction

Mail address: 20a, Acad. T. Berdiev St., ASHGABAD 744000 TURKMENISTAN

Director: Dr. Batyr Nazarovich GAIPOV
e-mail: gaipsr@online.tm
Phone : 993-12-39-06-92
Fax: 993-12-39-06-13

Deputy Director: Dr. Odek A. ODEKOV
e-mail: odek_odekov@yahoo.com

There is a lack of informations about Turkmenistan due to difficulties in communication with Turkmen seismologists.

3.4. UZBEKISTAN

This country has an Institute of Seismology, and a separate Institute of Geology and Geophysics.

Institute of Seismology, Academy of Science of Uzbekistan

Mail address: 3 Zulfiyakhonim Street, Tashkent 700128, Uzbekistan
Phone numbers: 998-711-35-75-34; 998-712-41-51-70; 998-712-41-45-51
Fax: 998-711-35-75-31
E-mail: tashkent@seismo.org.uz

Director: Acad. Kakharbay Nasirbekovich ABDULLABEKOV
Phone number: 998-712-41-51-70
Deputy-Director:Dr.Sabriddin HUSAMIDDINOV
Scientific Secretary: Dr. Makhira USMANOVA (exellent English)
Phone number: 998-711-35-75-12 or 998-711-35-75-34.

Main departments of the Institute of Seismology

General Seismicity, Seismic Zoning and Seismic Risk Departments

1. Regional Seismicity and Seismic Zoning
2. Induced Seismicity
3. Seismotectonics
4. Regional Geology
5. Earthquake Engineering
6. Mathematical Modeling and Computerization

Earthquake Prediction Departments

1. Geophysical Fields Time Variations
2. Hydrogeoseismology
3. Physics of the Seimic Source
4. Geodynamics.

A total of 138 persons work in these departments.

The Complex Expedition operates 22 seismic stations, and other facilities making geophysical observations including: 9 sites where multiple types of measurement are made; 32 sites where some type of geophysical measurement is carried out; the Magnetic-Ionospherics Observatory; and the Department of Geography.

Total 164 persons work in the Uzbekistan Expedition.

The Head of Expedition Dr.Mirodil ZAKIROV

E-mail: complex@uzsci.net

Phone: 998-711-41-52-44 and 998-711-41-40-63

Institute of Geology and Geophysics, Uzbek National Academy of Science

Mail address: 49 Khodjibaeva St., Tashkent 700041 UZBEKISTAN

Phone: 998-711-62-68-82   Fax: 998-711-62-63-81

Deputy-Director and the Head of Regional and Applied Geophysics Laboratory

Dr.Bakhtiar S. NURTAEV (exellent English).

E-mail address: nurtaev@ingeo.uz

Main areas of activity in seismology: earthquake hazard and risk assessment, induced seismicity and seismic safety of dams. Studies of crustal structure, remote sensing, and GIS applications.

Leading seismologist: Prof. Lelya M. PLOTNIKOVA. She is expert in seismic hazard and seismic risk assessment, induced seismicity, and seismic safety of unique constructions (historical constructions, high dams, etc.).

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4. SEISMOLOGICAL INFORMATION

The ability to conduct seismological studies in the four countries described in this report, is best in Kyrgyzstan, then Uzbekistan, followed by Tajikistan (which had extensive facilities decades ago, but which has just begun to emerge from years of civil war), and finally Turkmenistan (which has never had significant numbers of seismologists).

4.1. Earthquakes catalogs

In each of the four Institutes of Seismology described above, seismograms for the country are analyzed in the traditional way, working with paper records. That is, the time of arrival of various seismic waves is first measured off the paper records. These arrival times are then interpreted by comparing them with the predicted arrival times of an earthquake located in some geophysical model of the crust-upper mantle structure of the region, and the location and origin time of the hypothetical earthquake in the model is varied until its predicted arrival times, derived from the model, are deemed to be a satisfactory match to the observed arrival times.

Each Institute compiles the regional catalog of earthquakes occurring each year on the territory for which it carries out seismic monitoring. The annual collections, first called *Earthquakes in the USSR* (1964 – 1991), and later *Earthquakes of North East Asia* (since 1992) have been compiled and published by Institute of the Physics of the Earth in Moscow. At the time of writing this report (2005–2006), the latest publication is for earthquakes occurring in 1999.

Many of these earthquakes are quite small. Though such events are not damaging, they are important in the overall work of assessing which regions are seismically active and thus have the potential for damaging earthquakes. Small earthquakes, once they have been accurately located, also allow the identification of active faults, which may also be studied in special field projects.

Table 8 gives the location of 16 earthquakes of significant magnitude in and near Kyrgyzstan in recent years. It may be noted that we received earlier versions of this Table both from Kygyzstan and Uzbekistan (in the latter case, as a list of significant earthquakes in and near Uzbekistan), but these versions had numerous errors, with origin times off by an hour or more for over half the events, and with poor location estimates. Table 8 is based upon hypocenter information published (in the Preliminary Determination of Epicenters) by the U.S. Geological Survey, but with maximum intensity and magnitude information from Central Asia.

Table 9 gives the approximate borders of the area that is seismically monitored by each republic. The Tajik Institute of Seismology, besides the territory of Tajikistan, carries out the seismic monitoring of the Pamir-Hindu Kush zone of deep earthquakes. The deepest earthquake in this zone in recent decades occurred on Apr 20, 1971 and was at a depth of about 380 km.

Table 8. The list of significant earthquakes on or near Kyrgyzstan territory during 1995-2005.

Year	Date	Time	Lat.	Lon.	mb	Maximum Intensity
1995	Feb 20	04:12	39.17	71.12	5.3	VII
1995	Feb 20	08:07	41.07	72.45	5.0	VI
1997	Jan 09	13:43	41.03	74.28	5.6	VII
1997	Aug 13	14:30	41.91	79.70	5.0	V
1998	May 29	22:49	41.17	75.65	5.2	VI
1998	Jun 07	00:05	41.43	77.90	4.7	VI-VII
1998	Nov 04	23:40	39.49	73.62	4.8	VI
1999	Feb 27	17:15	41.24	76.76	4.8	VI
1999	Dec 06	07:33	42.63	76.32	5.0	VI-VII
2000	Aug 08	01:15	42.10	76.97	4.6	VI
2001	Feb 25	02:22	36.42	70.88	5.1	VI
2003	Mar 09	00:32	41.30	72.93	5.3	VI
2003	May 05	06:34	41.05	72.53	5.3	VI
2003	May 22	18:11	42.95	72.76	5.4	VII
2004	Jan 16	09:06	42.53	75.35	4.7	VI
2005	Jan 19	06:28	41.92	79.17	4.8	VI

Table 9. The sizes of seismically active zones monitored by Institutes of Seismology in each Central Asian republic

	Area of monitoring	Number of events located each year ($m > 3.0$)
Kyrgyzia	39.5-43N and 69-81E	2,500
Tajikistan	35-40.2N and 67-75E	2,300*
Turkmenistan	35-42N and 51-67E	2,500
Uzbekistan		572

* 810 surface events plus 1,500 deep events in the Pamir-Hindu Kush zone.

4.2. Measurement of Earthquake Size

All Central Asian seismic networks use the energy class *K* (Rautian, 1960, 1964; Fujita et al., 2005) to characterize the size of local and regional earthquakes. The *K* value is an estimate of the logarithm of the radiated seismic energy in joules. The relation between *K* and m_b and between *K* and M_S is slightly different in different regions (see Table 10 for this relationship in the Kopet Dag mountains of Turkmenistan, as compared to an appropriate average value for Central Asia). This can be explained by regional variations of the spectral content of earthquakes, the regional law of attenuation, and amplitude losses in the aesthenosphere (for m_b). In general the m_b value for the same *K* will be larger by 0.15 – 0.20 magnitude units in stable regions than in seismically active and thickly sedimented areas. Station corrections *dK* are used for stations located on thick sediments (Mikhailova et al., 1999).

Table 10. Relationship between energy class *K* and ISC magnitudes m_b and *Ms* (from Fujita et al., 2005)

Region	$m_b(K)$	$M_S(K)$
Central Asia	$m_b = 0.41K - 0.33$	$M_S = 0.54K - 2.15$
Kopet Dag	$m_b = 0.37K - 0.29$	$M_S = 0.66K - 3.71$

Besides the *K* value for stronger events (*K* > 10), alternative measures of the size of seismic events have included the following:

(1) a regional magnitude *MPVA* (Mikhailova et al., 1999), based on the amplitudes of *P* waves recorded by the SKM instrument;

(2) a surface wave magnitude *MLV* based on surface waves recorded by SK or SKD instruments; and

(3) a coda magnitude *Mc* based on regional curves that give the attenuation of SKM-coda and SKD-coda as a function of time (Rautian, Khalturin et al., 1981; Khaidarov, 1983).

4.3. Regional phases observed in Central Asia

At distances less than 180 – 200 km, direct *P*-waves and direct *S*-waves propagate within the crust and are observed as first and secondary arrivals. At larger distances these trend into *Pg*- and *Lg*-waves, which propagate within the crust as a sum of multiply-reflected waves.

The velocity of direct *P*-waves and *Pg*-waves is about 5.8 – 6.0 km/sec; direct *S* and *Lg* - about 3.5 km/sec. *Pg*-waves are observed in the Central Asia region typically out to about 600 – 700 km. *Lg*-waves propagate efficiently in Central Asian territory and usually provide the strongest signals on SKM and SKD records. However they are partially or completely blocked on paths that cross the Tibetan plateau, the Kopet-Dag mountains, and the southern part of the Caspian Sea.

Pn- and *Sn*-waves propagate beneath the crust and appear as first and secondary arrivals at distances greater than 180 – 220 km. Their velocities are 8.0 – 8.2 and 4.5 – 4.6 km/sec respectively, out to distances about 800 – 900 km.

The surface wave *Rg* is recorded by SK or SKD instruments with period 7 – 12 sec and group velocity about 2.8 – 3.0 km/sec, at distances greater than 500 – 600 km.

Regional phase travel times are shown in Table 11, based on observations of small magnitude (m_b = 3.6 – 4.6) underground nuclear tests (UNTs) at the Semipalatinsk Test Site, recorded by Central Asian stations. Where *Pg* can be observed beyond 800 km it is quite weak.

Table 11. Travel time table of main regional phases observed from UNTs at the Semipalatinsk Test Site on Kazakhstan and other Central Asian seismic stations at distances up to 1000 km.

distance, km	*Pg*	*Pn*	*Lg*	*Sn*
		times in seconds		
100	16.8	-	28.3	-
200	32.9	33.0	56.4	56.5
300	49.0	45.3	84.5	78.0
400	65.0	57.6	112.5	99.5
500	81.0	69.9	140.5	121.0
600	97.0	82.2	168.5	142.5
700	113.0	94.5	196.5	164.0
800	129	106.8	224.5	185.5
900	145	119.1	252.5	207.0
1000	161	131.4	280.5	228.5
Velocity, km/s	6.25	8.13	3.57	4.65

The regional seismic signals become more complicated at greater distances, in that additional phases besides the main phases *Pn* and *Sn* are present. Thus the *Pn* group has multiple arrivals, and teleseismic *P* and *S* also become apparent. This is illustrated by a more detailed travel-time table (Table 12) for additional phases observed for underground nuclear tests at Lop Nor, recorded at Central Asian stations.

Table 12. Travel time of regional phases from events in North-East China and surrounding territories from observations at stations in East Kazakhstan and elsewhere in Central Asia. (V. Khalturin, A. Lukk, A. Ruzaykin, unpublished report CSE, 1978). Symbol "e" denotes a weak (emergent) signal, and "ee" is doubly weak.

distance, km	*Pn2*	*Pn3*	*Pn4*	*P1*	*P2*	*Sn*	*S*
	times in seconds						
800	106.5	-	-	-	-	187.5	-
900	118.8	-	-	-	-	208.7	-
1000	131.0	131.0	141.0	-	-	229.9	-
1100	-	142.8	150.0	-	-	251.1	-
1200	-	154.6	159.5	-	-	272.3	-
1300	-	166.4	169.8	-	-	293.4	328.0
1400	-	178.2	180.5	194.5	-	314.4e	345.6
1500	-	190.0	191.7	202.9	-	335.4e	363.2
1600	-	201.8	202.9	211.7	219.0	356.4ee	380.8
1700	-	213.6	214.2	220.8	227.3	-	398.4
1800	-	225.4	225.5	230.1	235.8	-	416.0
1900	-	-	236.8	239.5	244.4	-	433.6
2000	-	-	248.0	249.0	253.2	-	451.1
2050	-	-	253.6	253.8	257.6	-	459.9
2100	-	-	-	258.6	262.0	-	468.6
2200	-	-	-	268.2	270.8	-	486.0
2300	-	-	-	277.8	279.6	-	503.3
2400	-	-	-	287.4	288.4	-	520.5
2500	-	-	-	297.0	297.2	-	-
2600	-	-	-	-	306.0	-	-
2700	-	-	-	-	314.8	-	-
2800	-	-	-	-	323.6	-	-
2900	-	-	-	-	332.4	-	-
3000	-	-	-	-	341.2	-	-

5. ASPECTS OF SEISMIC MONITORING

5.1. Central Asian seismographic stations are well placed for monitoring many countries in Asia including Iran, Pakistan, India, and parts of Russia and China. The locations of nuclear testing by in China, India, and Pakistan, are shown in Table 13 to the nearest tenth of a degree in latitude and longitude. Further information on these test sites, and explosion locations, is given by Barker et al. (1998) and Waldhauser et al. (2004). The approximate epicentral distances from each test site to some Central Asian seismographic stations are in Table 14.

Table 13. Location of previous nuclear testing by India, Pakistan and China

Country	Test Site	Lat ºN	Lon ºE
China	Lop Nor	41.5--41.8	88.3--88.8
India	Pokhran	27.1	71.7
Pakistan	Chagay	28.4--28.9	63.8--65.0

Table 14. Distances (*R* in km) of some close Central Asian stations from three test sites:

From China test site Lop-Nor

	Kyrgyzstan					Tajik.	Uzbekistan
Station	Ken-su	Przhev.	Ananevo	K. Say	A-Archa	Dzhirg.	Andijan
R, km	860	920	950	1000	1250	1500	1800

From Indian Test Site Pohran

	Kyrgyzstan	Tajikistan	Turkmenistan		Uzbekistan	
Station	Ala-Archa	Shaartuz	Serakhs	Kushka	Zarabad	Gazli
R, km	1760	1500	1100	1275	1250	1635

From Pakistan test site Chagay

	Turkmenistan			Kyrgyzstan	Tadjik.	Uzbekistan
Station	Kushka	Serakhs	Vannov.	Ala-Arch.	Shaartuz	Zarabad
R, km	740	910	1,150	1,800	1,100	1,100

5.2. The seismic stations located in Central Asian countries can be used for monitoring the territory of neighboring countries including Iran, Pakistan, India, and China. The utility of these stations is sometimes greater than might be expected on the basis of distance alone.

For example, note that Iran and parts of Pakistan are located in a zone of high attenuation of seismic waves and low efficiency of *Lg*-wave propagation. In such cases the epicentral distance should not be the sole criterion for selecting monitoring stations. The stations located at distances in the range 800 – 1,400 km from the epicenter can be less efficient, than stations located at 1,600-3,000 km. The reason, is that for the more distant stations the seismic rays propagate under the high-temperature layer of strong attenuation (asthenosphere), whereas the closer stations record the rays propagate along the high attenuation layer itself.

This result follows from our study of amplitude-distance curves for Iranian earthquakes recorded by stations Vannovskaya (in Turkmenistan near the Iranian boder) and Zerenda (in North Kazakhstan). In many cases amplitudes at Zerenda (R = 1,600 – 2,200 km) were larger than amplitudes at Vannovskaya (600 – 1,200 km).

Besides the high attenuation of seismic waves in this region, partial or full blockage of the *Lg* -waves is also observed. Since the *P*/*Lg* spectral ratio (especially at high frequencies) is becoming widely used for effectively discriminating between the seismic signals from earthquakes and explosions, blockage of *Lg* from Iranian earthquakes could lead to false indications that these events are explosions.

The main need, is to build up archives of high-quality broadband signals and thus to acquire practical experience with both earthquake and explosion monitoring over the broad region.

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