SEISMOLOGICAL OBSERVATIONS AND GEODYNAMIC ZONING PREDICTIONS

O.E.Starovoit
Geophysical Survey, Russian academy of sciences: Lenin str., 189, Obninsk, : 249020, Russia

S.L.Yunga
United Institute of physics of the Earth, Russian academy of sciences. B. Gruzinskaya,10, Moscow, 123810, Russia

Keywords: earthquake, seismic station, seismogram, network, lithosphere, asthenosphere, mantle

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Summary

The main objective of this chapter is to illustrate to readers the problems and solutions in earthquake observations. To achieve this objective, a discussion of modern seismic observation systems is presented. Briefly, it can be summarized as follows. Earthquakes are recorded at seismic stations operating in networks . The main coverage of the earth's surface is provided by world-wide permanent seismic stations which ensure the observation of earthquake waves over teleseismic distances.

Today more than 4,000 stations are operating in the world, and the number is increasing. These stations compose the world network and operate for the benefit of seismology as a whole. Each seismic station in the network detect the movement of the ground at the site. The fundamental observations used in seismology are seismograms which are a record of the ground motion at a specific location as a function of time. Seismograms are in different forms, on "smoked" paper, photographic or standard paper, in digital format and the seismological basic data. These data are used to study the earthquakes and to learn more about the structure of the Earth. In addition to their value in monitoring and studying Earth interior, seismograms can be used to probe the geodynamic zones of the Earth. The geodynamic aspects of seismicity are of special interest. Emphasis is placed on the geodynamic zoning as it follows from plate tectonic theory.

1. Historical overview

Earthquakes as natural phenomena have attracted great interest throughout history. The history of seismological observation has been traced about 2000 B.C. since man first recorded literally the earthquakes. A rational explanation of earthquake phenomena and even classification of earthquakes according to the nature of the observed earth movement has been given by Greek philosopher Aristotle, some 340 B.C. The earliest instrument which was made to reveal earthquake ground motion is the seismoscope, invented by the Chinese scholar Chang Heng in 132 A.D. Catalogs of earthquakes felt and earthquake observations have appeared intermittently for many centuries. Since the nineteenth century earthquake catalogs were being regularly published. As early as 1855, a number of seismographs using electromagnetic recording had been constructed in Italy by Palmieri. The prototype of the modern seismograph was developed in Japan by British seismologist John Milne and his associates James Ewing and Thomas Gray about 1880.

The modern instrumental seismology in its worldwide sense was born in 1889 when the first teleseismic seismogram was recorded and identified by Ernst von Rebeur-Paschwitz at Potsdam. The earliest known list of instrumentally recorded earthquakes with computed times of origin and epicenters is that for the period 1899-1903. Cardinal improvement in the design of seismograph was made in 1906 by Russian academician Boris Borisovich Golitzin, who designed the first electromagnetic seismograph with photographic recording. A principal development was associated with Golitzin's idea of recording ground motion by means of a light ray reflected from the moving mirror of a galvanometer. The motion of the mirror is excited by an electric current generated by electromagnetic induction when the pendulum of the seismometer moves. In subsequent years the number of instrumentally recorded earthquakes began to accumulate and cataloging of earthquakes has become increasingly more uniform and complete.

Essential progress in seismological observations has been made through first half of the twentieth century. By 1940, where were about 250 seismographic stations around the globe. During the late 1950's there already existed worldwide about 700 seismographic stations equipped with seismographs of various types and frequency responses. But only few instruments were calibrated, so that actual ground motions could not be measured and timing errors of several seconds were common.

World-Wide Standard Seismographic Network (WWSSN) began to form in the 1960's. By 1967 the WWSSN consisted of about 120 stations distributed over 60 countries. Timing and accuracy are maintained by crystal clocks, and a calibration pulse is placed daily on each record. The resulting data provided the basis for significant advances in research on earthquake mechanisms, global tectonics, and the structure of the Earth's interior. By the 1980s further upgrading of permanent seismographic stations began with the installation of digital equipment. Digital Global Seismographic Network (GSN) is responsible for the deployment and maintenance of permanent digital seismic recording stations around the globe. By 1998 the GSN had over 100 stations with affiliations to IRIS and several other national and international networks (Fig. 1). Among the global networks of digital seismographic stations now in operation are the seismic research instruments in deep boreholes; modified high-gain, long-period (surface) strainmeters; and digital worldwide standardized seismographic network stations. In addition, a number of gravimeters capable of digital recording and response to very long wavelengths have been installed throughout the world as part of the International Deployment of Accelerographs (IDA) network. The main goal of this program is to equip global observatories with seismographs that can record seismic waves over a broad band of frequencies.

Today more than 4000 stations are operating in the world, and the number is increasing. More than 100 stations are equipped with internet connected computers, and large amount of seismic data are now available on the Internet. Already constructed are the so called "virtual networks" where seismologists are able to collect data from a subset of stations that enhance the specific goals of individual projects.

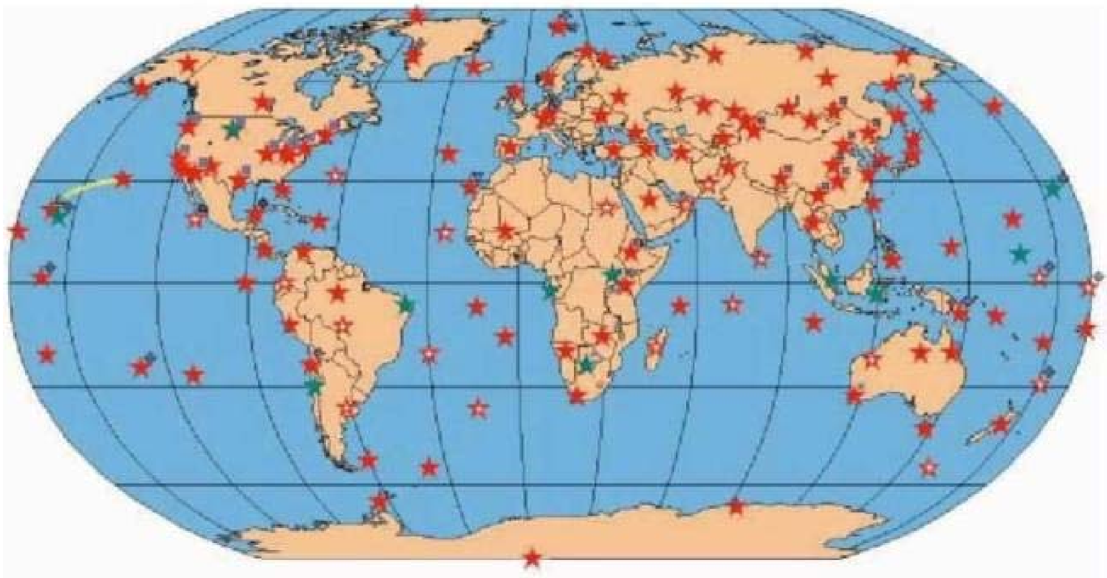

Fig. 1. Global seismographic network. Seismic stations are shown by stars, green stars indicate stations of 1999 year.

2. Current seismological observations

2.1. Global seismic net

The many thousands of earthquakes occurring world-wide each year pose a scientific and practical problem of their reliable observation and identification. Thus National Earthquake Information Center of the USA currently locates more then 15000 earthquakes yearly. Especially valuable is the service provided by the International Seismological Centre (ISC) at Great Britain. Each month it receives about 80,000 readings from worldwide seismic stations from national and regional agencies and observatories and preliminary estimates of the locations of earthquakes. The ISC publishes monthly (with about a two-year delay), a bulletin that provides all available information on each of about 1,500 to 2,000 earthquakes.

In the broad sense, earthquake observations obviously have fundamental significance in

the practical solution of the problems arising due to damaging earthquakes, i.e. in planning, designing, constructing and managing earthquake-resistant structures and facilities.
The substantially international character of the world-wide stations has been emphasized by the Committee for the International Seismological Summary, the UNESCO Missions, the Committee for the Standardization of Seismographs and Seismograms, and the Intergovernmental Meeting on Seismology and Earthquake Engineering. The stations of the global network are placed in all parts of the world. Europe, most of Asia and North America are already covered to an appropriate density, within 1000 km of each other. The areas which have much less than optimum cover are South America, Africa, Antarctica and the oceans.

The seismograph is the primary sensing instrument which provides the seismologist with almost all the data. The instruments are installed on simple cement block or may be placed directly on flat surfaces of hard rock. Generally, seismographs are divided into three types: short period; long (or intermediate) period; and ultra-long period, or broad-band, instruments.

World-wide stations usually are equipped to record three components (N-S, E-W, Z) of short-period and three components of long-period earth motion. The long- or intermediate-period instruments of the type used by the WWSSN have a response maximum at about 20 seconds. In order to provide as much flexibility as possible for research work, the trend has been towards the operation of very-broad-band seismographs, often with digital representation of the signals. This is usually accomplished with very-long-period pendulums and electronic amplifiers that pass signals in the 0.005 to 50 Hz band.

The signals recorded at a seismograph station show different characteristics depending upon the distance from the source. Teleseismic signals (distance 3000-9000 km) are simpler in nature than the signals at regional distances (less than 3000 km) which are rather complex. Seismic signals are recorded both from earthquakes and underground explosions. A typical earthquake seismogram and an explosion record have different characteristic features, which may be used to discriminate between these two types of sources. A permanent building is used on a particular recording site. A station site must fulfil several conditions according to the type of station, taking into consideration such factors as remoteness from local disturbances (large rivers, heavy machinery, traffic etc.), stable underground like hard crystalline bedrock and low relief.

Station equipment, operation and reporting procedure are determined by special world standards as described in the manuals of seismological observatory practice.

Global permanent stations should guarantee a continuous recording of all seismic signals that are observable above the threshold level determined by local noise conditions. Seismic noise usually includes regular continuous seismic disturbances in the typical range of periods from 0.01 to 10 seconds, although microseisms with longer periods have been observed. In highly seismic areas, the traces of the most sensitive instruments are overlapped by events close to the station, so additional equipment for recording at lower sensitivity are provided. In sites where destructive earthquakes are to be expected, the range of intensity may require as many as three levels of instrumentation at stations. In such cases accelerometers are installed, to measure the rate at which the ground velocity is changing; these instruments are capable of recording strong-motion because they allow integration to be carried out to estimate ground velocity and displacement. The ground accelerations to be registered range up to 2g, where g is the acceleration due to gravity. Recording such accelerations can be easily accomplished with short torsion suspensions or force-balance mass-spring systems.

Global seismic stations operate with a high reliability and with regularly calibrated instruments.

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Biographical Sketches

Dr.Starvoit is one of the leading Russian seismologists who has worked extensively on various aspects of seismic observations. In addition to his scientific investigations, Dr.Starvoit devote much time to the management of the national net of seismic stations. At the same time he is the director of the institute of Geophysical Survey, which is the Russian foremost research center for seismological observations.

He had published more that 100 works in Russian and international seismological geophysical journals. He constantly participate in most I mportant international meetings,conferences and workshops.He has close scientific relations with seismologists of the U.S.A.,Great Britain, Germany,France,Japan and other countries. For many years Dr.Starovoit is the national coordinator of international research projects devoted to seismic data acquisition.

Dr. Sergei Yunga is one of the leading Russian seismologists who has worked extensively on various aspects of earthquakes, including focal mechanisms, seismic moment release, maximum magnitude evaluations, and earthquake prediction. He was involved for 20 years in seismological research in Tadjikistan and Kazakstan, in Central Asia. He is currently the principal scientist of the United Institute of physics of the Earth, one of foremost Russian research centers for earth sciences, and a corresponding member of the Russian Academy of Natural Sciences.

Sergei Yunga graduated from Moscow Physical-Technical Institute in 1973, in the department of applied mathematics and space investigations, specializing in the theory of elasticity, theory of plasticity, and fracture mechanics. He received his formal training in geology and seismology as a post-graduate student. He holds both candidate (equivalent of Ph.D.) (1977) and doctorate degrees (1989) from the Institute of physics of the Earth, USSR Academy of sciences. His works have been published in international, Russian and American seismological and geophysical journals. Dr.Yunga is the author of one monograph of his own and several monographs with co-authors. His scientific results have been discussed at international meetings, conferences and seminars in the U.S.A., Great Britain, France, Egypt, Germany, Bulgaria, China.