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NATIONAL AND INTERNATIONAL STATUS OF SEISMOLOGICAL OBSERVATIONS OVER LAST 25 YEARS

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ABSTRACT

Seismological observations started since the end of last century over different parts of the world are being continuously improved in respect of accuracy of the epicentral parameters and interest to cover a larger frequency band of seismic waves. The improvement has been so rapid that by the time indigenous development of instruments takes place, the model becomes obsolete because of the additional requirements posed by the seismologists. A review of national and international status during the last 25 years shows that wide band seismographs linked with satellite telemetry which have been deployed by USGS, IRIS and a few other regional networks would continue to provide the desired data for years to come. The gaps in this direction highlight the need for endogenous capacity building.

INTRODUCTION

Instrumental seismology started towards the end of the last century. Just prior to 1900, when the seismological instruments were first designed, the epicentral parameters of only great earthquakes could be determined in general due to the sparse network. However, with the technological advancement, more and more sensitive instruments were developed from time to time along with closer network of stations which has enabled us not only to precisely locate earthquakes but also to delineate causative faults. Such networks including those for seismic tomography have provided valuable data for earthquakes source mechanism studies and have revealed heterogeneity and anisotropy inside the earth providing inputs for earthquake risk assessment and earthquake prediction studies. The refinements in the recording techniques have enabled us to produce synthetic seismograms which are invaluable for dynamic source characteristics besides marked improvement in the focal depth of earthquakes. The object of this paper is to present a review of the national and international status of seismological observations over last 25 years.

RATIONALE IN PLANNING SEISMOLOGICAL NETWORK

The seismological stations are planned in such a way that earthquakes above certain minimum detection threshold can be detected over specified regions. Since earthquakes of magnitude 4.0 to 4.5 have occasionally caused some damage particularly in poorly built structures, it has been recognised that the seismological network in India should be capable of locating such earthquakes. The seismological organisations in India are therefore striving to achieve this goal which was first recommended by the Committee appointed by the Planning Commission during 1972 under the Chairmanship of Dr.A.N. Tandon.

It is well known that hypocentral determination depends upon the distribution of seismic stations, knowledge of travel time curves (i.e. how far the assumed velocity model agrees with actual structure of earth's interior and regional anomalies), and accuracy of readings of seismic wave arrivals. The error due to travel time curves gives rise to systematic errors and can be avoided by detailed analysis of travel time anomalies. The errors in reading of seismic waves are random in nature; however, the accuracy in hypocentral determination by these random errors depends on the geometry between the hypocentre and seismic stations. Of these, the travel time curves which were earlier based upon global data like Jefferys Bullen (1946), Herrin (1968) and more recently by IASPEI have been the primary source for epicentral determination of earthquakes. Regional travel times have been worked out in different regions of the world and in particular in Indian region mainly based upon past earthquakes. However, considerable improvements could be made after the DSS programme of National Geophysical Research Institute was undertaken. The IMD operated network of high gain portable seismographs utilising the same DSS explosions and worked out the average crustal structure in different parts of India providing better accuracy in the epicentral determination of local earthquakes (Srivastava, 1988). The accuracy in the timing system could be improved with the introduction of crystal clocks which were introduced in Indian Seismological networks. This work also was indigenously taken up alongwith arrangement to automatically impinge timing signals from the radio broadcast. However, different stations when compared to different broadcasts do occasionally cause some errors. The use of Omega signals has provided better means of taking time signals on the seismograms.

SEISMOLOGICAL OBSERVATIONS IN INDIA : Historical Perspective

The first seismological station in the country was established at Calcutta (Alipore) on 1 December 1898. During 1898-99, seismic observatories were started at Bombay (Colaba) and Kodaikanal using photographic recording Milne seismographs. After the great Kangra earthquake of 1905, a seismological observatory started functioning at Simla with an Omori-Ewing seismograph. In 1911-12, another instrument for recording vertical component of seismic waves, designed by Wiechert, was installed at Simla. This was moved to Agra in 1929. The observatory was also equipped with a Milne-Shaw seismograph. During the 1930s, seismological observatories also started functioning at Dehradun and the Nizamaiah Observatory, Hyderabad. In 1941, the seismological observatory at Agra was shifted to Delhi. The number of seismological stations in the country increased to 8 in 1950, and later rose to 15 in 1960 when more sensitive instruments like Benioff, Sprengnether and Wood-Anderson seismographs were added. At present, the number of observatories under the national Network of stations in the country is 35. The stations at Delhi, Poona, Kodaikanal and Shillong were equipped with sensitive seismographs with known calibration curves since 1962-63 under the Worldwise Standardised Seismograph Network (WWSSN). An observatory with a similar set of instruments was started at the National Geophysical Research Institute (NGRI), Hyderabad, in 1968. Prior to this, the Gauribidanur array station under the Bhabha Atomic Research Centre was put into operation. Out of 18 stations proposed to be set up under the Department of Science and Technology project on "Seismicity and Seismotectonics of the Himalayan Region", eight stations were opened; two by the Wadia Institute of Himalayan Geology, three by the IMD and three by NGRI. The stations by WIHG and NGRI have since increased to about ten and 15 respectively under different programme.

It may be mentioned that the detection capability of earthquakes in the Indian region is generally upto earthquakes of magnitude 5.0. It is expected that a network of 103 permanent stations will be established during the next few years so that the epicentral parameters of earthquakes of M > 4 may be reliably determined over any part.

The detection capability has been increased to reduce the magnitude threshold of earthquakes around several river valley projects and specific regions. Local network of stations have been established in the following regions :

1) Around Pong, Pondoh, Bhakra and Salal hydro-electric Projects : Eighteen seismological stations have been set up to study earthquake risk and reservoir induced seismicity. The detection threshold of the earthquakes has been brought down to magnitude 2.0.

2) Koyna and Bhatsa regions by MERI and BARC respectively and Delhi. Micro zoning Programme has been initiated through the Delhi University.

INTERNATIONAL STATUS

The first attempt to have a standardized system for global monitoring of earthquakes was undertaken by US Geological Survey (USGS) during the years 1963 - 65 with about 120 stations throughout the world equipped with standardized short period Benioff and long period Press-Ewing seismographs providing an immense improvement in the understanding of earth's interior and mapping out the plate boundaries and mechanism of earthquakes. With the design of the electronic systems, commercial firms started bringing out high gain amplifier systems coupled with short and long period sensors with suitable filters. In addition, high gain portable seismographs for micro earthquake studies were developed.

Due to the limited dynamic range of analogue and the improvements in the computerised data processing systems, digital seismographs were designed which enabled us to compute dynamic source characteristics. These were, nevertheless, found to be inadequate to obtain a high resolution image of the earth's interior and therefore broad band seismographs were developed.

In order to obtain a high resolution image of the earth's interior from seismic data, the seismometer must be able to accurately record ground motion over a wide spectrum of the frequency band (from periods of one tenth of a second to several hours) and to respond linearly for a wide range of amplitudes. Presently available systems, such as STS (developed in Switzerland), can accurately record signals with periods from 0.1s to 1 day, and have a dynamic range of atleast 10 . The output of the seismometer is recorded in digital form together with highly accurate timing supplied by a quartz clock. To minimize background noise, broadband, high dynamic range seismometers are usually installed in tunnels.

Digital broadband seismographs make it possible to record signals ranging from a nearby microearthquake to a great earthquake anywhere in the world. They also make it possible to record solid earth tides with high fidelity. Figure 1 shows seismograms recorded by a broadband STS seismograph at the Inuyama Seismological Observatory of Nagoya University. The upper trace is the seismogram for a nearby microearthquake, and the lower trace shows the seismic waves generated by a great earthquake (magnitude 8.2) in the Kermadec Islands. The background solid earth tides can also be seen in the lower figure. In the lower record, the labels R1, R2 and so on, show surface waves (seismic waves which travel along the surface of the earth) which are called Rayleigh waves. R1 is the direct Rayleigh wave and R2 is the Rayleigh wave that arrived 'the long way' after passing the antipode. Similarly R3 is the direct Rayleigh wave after it travels 360° and arrives again. The surface wave denoted by R7 has travelled around the earth more than three times.

The seismic arrays which earlier recorded on magnetic tapes as analogue signals were also modernised to the digital versions. The most recent efforts are, however, to design broad band seismometers linked through satellites so that the data is available in the shortest possible time at several centres in different parts of the world.

Many international organisations joined together to operate recent broadband global networks. The new network under the aegis of the 'Federation of Digital Broadband Seismograph Networks' (FDSN), as founded in 1986 was recommended by the International Union of Geodesy and Geophysics. The founding institutions of this network are :

(i) US Geological Survey
(ii) IRIS
(iii) GEOSCOPE
(iv) ORFEUS
(v) CANDIS (Canada)
(vi) Chinese Digital Seismograph Network
(vii) Bureau of Mineral Resources (Australia)
(viii) Global Seismology Sub-Committee
(ix) Japan National Committee for Seismology and Physics of the Earth's interior
(x) German Research Council (FRG)

OTHER INTERNATIONAL NETWORKS

France has developed and installed the 'GEOSCOPE' global seismic network. The western European countries are developing plans for the ORFEUS seismic network. China has installed a new seismic array. US has planned a large scale global network (IRIS) which aims at a global array of 100 stations since 1986. It is obvious that an adequate network for global seismic observations is too large an endeavour for any one country, and requires the cooperation of all the countries that conduct seismological observations. The FDSN was founded to organise this cooperation.

The special project named POSEIDON (Pacific Orient Seismic Digital Observation Network) set up through Japanese contribution of FDSN Research Programme has been designed to install seismographs in Western Pacific and also South Eastern Asia. It consists of seismic stations on continents and islands, a data centre and development work for a deep ocean seismic network which is expected to remain operational for about 20 years. About 50 new seismic observatories are proposed under this Project. It is expected that high density of stations will greatly improve our ability to resolve finer details of the earth's deep interior. During the second phase, the plan for deploying an ocean botton seismic array is shown in Fig.2. Deploying an ocean bottom seismic array as an integral part of a fibre optic telecommunications cable would have many advantages and in particular the data can be recorded at POSEIDON data centre. The other advantage would be that the power supply for the fibre optic repeaters would be more than sufficient for the power requirements of the seismometers besides allowing substantial enhancement of signal to noise ratio through stacking and other signal processing techniques. POSEIDON Network would help in resolving the following research problems :

(i) Images of the moving plates.
(ii) Anisotropy : 'Seeing' mantle convection.
(iii) Hotspots and the earth's interior.
(iv) Physics of the earthquake source.

The recent plan of US Geological Survey (USGS NEIC 1992) is designed to have approximately 100 seismograph stations under National network in USA to provide the capability to detect and locate earthquakes of magnitude 2.5 and larger. These include :

(i) seismometers
(ii) station processors
(iii) satellite telemetry
(iv) network processor

Figure 3 shows an overview of the placement and interconnection of these elements. The network control centre has been proposed at NEIC in Golden, Colorado. To provide wide band and high dynamic range, both high gain seismometers and low gain accelerometers are required to have a self noise at least 3 dB below the USGS low noise model in the frequency band from 0.03 Hz to 10 Hz and a dynamic range of at least 130 dB throughout this band (with the noise defined in decade intervals). Suitable changes were made to the response of the GURALP CMG-3 broad band seismometer to meet the dynamic range specification. Also the low gain CMG-5 accelerometers form an integral part of US NSN station to provide 210 dB of overall dynamic range with 80 dB of overlap (Ray Buland 1993).

In Southern California, a stand alone type of network called TERRASCOPE is being installed jointly by USGS and CALTECH. It consists of Guralp CMG (.03 to 30 Hz) or Guralp Extended Period CMG-3ESP (.0027 to 10 Hz) or Portable Very Broadband Triaxial Seismometer (.00833 to > 50 Hz). The data loggers include Reftek Recorders.

UPDATING SEISMOLOGICAL INSTRUMENTATION IN INDIA

At present there are about 60 seismological stations maintained by IMD. Other 40 stations are being operated by different institutions. At most of seismological stations maintained by IMD, short-period electromagnetic and Sprengnether seismographs designed in the Department were installed. However, as the optical galvanometers became obsolete, the seismometer signal was recorded through electronic amplifiers/filters. Such instruments were imported as a part of the modernisation of the system and were installed at 17 stations with helicorders and suitable filters.

The four stations at Delhi, Shillong, Pune and Kodaikanal which are under operation as standardised world-wide seismographs systems have also been provided with heated stylus recording mechanisms thus dispensing with the galvanometer.

National Geophysical Research Institute, Hyderabad still continues to operate the standardised earlier system. The Central Seismological Station at Shillong was upgraded to Seismic Research Observatory level under the USGS collaboration programme since June 1978. The main advantage of the SRO system is to lower the threshold of detection in the long period band. Also, because of digital recording, a large number of signal amplitudes can be accommodated. An advanced digital recording system provides at least 110 dB of separation between noise levels and clipping levels in the principal bands. In addition to other equipment the Seismic Research Observatory at Shillong also operates a bore hole seismometer fitted with an advanced recording system and associated equipment of timing, power and control. This equipment produces both anologue and digital records. The seismometer system has been installed at a depth of about 100 metres through a standard 18 cm well casing. The sensors are force balance accelerometers whose output is proportional to the earth acceleration from 0 to 1 Hz. The mass position signal from each sensor is passed through a band-pass circuit with corner frequencies of 0.02 and 16 Hz and a gain of 46 dB.

The seismic filters have parallel outputs. One is used for analogue recording and the other is used for digital recording. Analogue seismograms are produced on helicorders using heat sensitive paper. The digital recording system consists of a gain ranged analogue to digital converter, a station processor with 16 K bytes of memory and magnetic tape recorders. The analogue to digital converter samples the long period signals once each second and the short period signal 20 times each second. Long period data are recorded continuously on tape. Only those events which are detected by the station processor in the short period signal are recorded in order to conserve tape and reduce the volume of data generated by the network. Two tape drives are furnished with each system to maintain uninterrupted recording. These instruments have served a limited purpose due to the limitations of frequency response and the problem of stabilised power supply.

The national network has been further modernised with the addition of digital short period seismometers at Pune, New Delhi and Shillong. A single channel VHF digital telemetry system is being installed at New Delhi. Suitable PC based software has been developed for retrieval of seismic data. Additional digital instruments have enabled us to determine the dynamic source characteristics. About 6 stations out of 40 in India Meteorological Department are also equipped with accelerographs.

The instrumentation at northwest Himalaya around Pong and Pandoh Dams consists of a three component SP Hagiwara electromagnetic seismograph wherein the record on 35 mm film enables us to read out onset time correct to 0.1 s or better, using a film reader. Later kinemetrics SP instruments were installed around Salal dam.

The torsion seismometer, which is a modified version of the original Wood-Anderson instrument designed in IMD is still being used at several stations to standardize the magnitudes of local earthquakes and to record stronger shocks when the other instruments are either saturated or go off the scale. The instrument designed at the IMD has a free period of 0.8 s with critical damping and magnification of 1000. Damping is provided by a permanent horse-shoe magnet. (Tandon 1951).

It may be mentioned that IMD has designed electromagnetic seismometers of various types. The seismometer period was changed from 1.6 to 1.0 s. The galvanometer free periods were kept as 1.5, 1.0, 0.5 and 0.2 s. At the coastal stations and a few inland stations, microseismographs with 7.5 s seismometer period are connected with 7.5 s galvanometer free period to record microseismic and intermediate distance earthquakes. The IMD photographic recorder for an electromagnetic seismometer galvanometer has a translational speed of 60 mm min^{-1} , whereas for the Wood Anderson seismometer, it is set at 30 mm min^{-1} to record two components (north-south and east-west) on the same paper. Efforts were made by CSIO through the funds provided by Department of Electronics to design a portable analogue recorder with smoke paper recording similar to the portacorder RV 320 (Geotech). The recorders were run with S-13 and S-500 seismometers at IMD for field trials. An IMD designed seismometer (Ts=1.0s) connected with the CSIO recorder gave excellent records at a low gain station namely Lodi Road. The performance characteristics of indigenously designed and imported systems have been studied in detail by Srivastava (1989).

A digital seismograph has also being developed by the CSIO. The original version was designed around a 8085 microprocessor but as this sytem consumes more power, it was modified around CMOS technology (Through DST funds). The detection algorithm is based on the STA/LTA ratio and has been modified from a cassette to solid state memory.

Efforts were made by CSIO to design a digital seismic telemetry system (six to eight channels) through the funds provided by DST. Another small aperture six channel telemetry system, designed by Bhabha Atomic Research Centre, has been installed to study seismic activity near Bhatsa reservoir located about 100 km. north of Bombay (Kolvankar et al 1992).

INSTRUMENTATION AT OTHER GEOPHYSICAL INSTITUTIONS IN INDIA

(i) Roorkee University

A short aperture sample digital telemetered seismic array procured from Earth Data, UK was installed in Ganga-Yamuna valley by the Department of Earthquake Engineering, University of Roorkee under the 'All India Coordinated Project on Seismicity and Seismotectonics of the Himalayan Region' of Department of Science and Technology. The array consists of two 3-component and six single-component seismometer stations. The signals in the form of digital time history of ground motion from individual remote seismometer stations are transmitted via radio link to the central recording station. The single component (vertical) seismometer stations are established at Chakrata, Dhargaon, Pauri, Shakumbhari Devi Hill, Surkanda Devi Hill and Roorkee and three-component seismometer stations at Narendranagar and Uttarkashi. The central recording station is located at Surkanda Devi Hill and the operating frequencies are in the rnge of 160 MHZ. (Wason et al, 1986).

The wide band instruments at Roorkee University (Earth Science Department) presently with analogue recording needs conversion to the digital form.

The strong motion array in Himachal Pradesh, Uttar Pradesh and northeast India (of about 40 accelerographs each) has generated acceleration data for moderate earthquakes at several stations which served two purposes. (Chandrasekharan and Das 1992). Since these instruments have timing system, the data along with the local network improved the focal parameters of earthquakes. The working paper by the author (Srivastava, 1989) based on global data enabled International Seismological Centre UK to include strong motion data for epicentral determination in their monthly seismological Bulletins. Also the attenuation characteristics could be worked out for earthquake risk assessment. Several stations for another array sanctioned to Roorkee University by the Department of Science and Technology have been installed in west Uttar Pradesh Hills.

(ii) National Geophysical Research Institute

The digital telemetry system was procured from Geotech, USA. The frequencies used for communication are in VHF range namely around 318 MHZ. The system has a dynamic range of about 120 dB without any gain ranging technique. It has a resolution of 24 bits throughout the dynamic range. The system first installed at Pune faced power supply problems and only analog records could be obtained. Also the problems of high temperature and dust at the top of hills did not enable the operation of computer system for recording the digital data. The system has now been installed in northeast India around Jorhat.

(iii) Bhabha Atomic Research Centre

BARC established seismic array station in 1965 in which 20 short period seismometers, 3 long period and 6 other seismological instruments have been deployed. A triangular network of three sensitive seismographs were also deployed around Delhi not only to detect nuclear explosions but to provide seismic data for development projects. As mentioned earlier, Bhatsa radio telemetered network is operating through the expertise of this department. A few stations around nuclear power stations have also been installed.

SEISMIC INSTRUMENTATION AROUND SPECIAL PROJECTS

The instrumentation around river valley projects was not only modernised but also expanded around river valley projects. Digital and Analogue Seismographs were procured for ten new stations around the Sardar Sarovar Project. The facility of detailed analysis of the digital data was procured using DAC 300 by Govt. of Gujarat.

Keeping in view the monitoring of microearthquakes for local seismicity studies, the Department of Science and Technology funded the procurement of microearthquake seismographs at Delhi University and Wadia Institute of Himalayan Geology. Several other organisations in the country like IMD, Geological Survey of India, Central Water Power and Research Station and State Governments in Maharashtra, Gujarat, Karnataka, Kerala, Andhra Pradesh, Uttar Pradesh, Assam and a few Universities have been operating microearthquake seismographs for specific projects. It is however, noticed that the problems of operation, maintenance and data retrieved from the imported digital micro earthquake records have not been commensurate as compared to the analogue seismographs. However, the updating of technology and indigenous development of PC based software has opened the possibility of their better utilisation.

OPTIMUM NETWORK VIS A VIS MODERNISATION

The following Committees have examined the adequacy and upgrading of the Indian National Seismological Network :

1. Tandon Committee (Planning Commission 1972).
2. Chaudhury Committee 1986 appointed by IMD.
3. Arya Committee appointed by DST.
4. Tandon Committee 198990 appointed by DST.
5. Qureshy Committee 1990 appointed by DST.
6. Detailed Project Report for Seismology Convener (author).

Although the above Committees examined in general the manner in which seismological studies need to be undertaken in future, there was considerable thrust on the modernisation of seismological network and its optimum requirements in the country.

The issues which have been raised in connection with the modernisation of the Indian Seismological Network vis-a-vis international status have brought out the following:

1. During the last two decades the advancement in the seismological instruments and their data generation and dissemination have been so rapid with marked changes starting from analogue recording with amplifier systems to the present broad band systems linked with satellite that by the time indigenous development was taken up, the instrument became almost obsolete. This coupled with the inability to project the future requirements did not bring forth commercial organisations to manufacture the instruments in the country in spite of the efforts made by the IMD, CSIO and other organisations. Now since the systems have been brought to the most sophistication making use of the very small power requirements or solar cells, it appears that the broad band systems with satellite links would stay for a few decades for seismological applications.

2. The next question, however arises, to what extent these broad band instruments linked with satellite telemetry need to be adopted in the national network and whether they are really needed. For the study of simulation of seismograms, it would appear that only a few such systems in the country linked to Global Network would serve the purpose. However, limitations of non-availability of seismographs from across the borders like Tibet and Burma has put severe constraints in the epicentral determination of Himalayan earthquakes. One modern seismograph has started functioning at Lhasa in Tibet recently, but the question of availability of data on real time/semi-real time basis, needs further to be worked out. Although IMD, NGRI and the Department of Space prepared a Project Report a few years back for utilisation of INSAT for the Project called SEQUEX to link the seismographs, a number of problems were foreseen during the practical implementation besides huge cost involved. The VSAT facility, however, makes the feasibility easier. Pilot experiment to link a few stations of IMD, making use of INSAT C-band channel has been examined again to improve our monitoring of earthquakes on real time/semi-real time basis through National network.

3. Continuous efforts are still needed to develop UHF/VHF seismic telemetry systems. Their requirements are expected to be very large around several river valley projects in the near future. Similar is the need for short period digital seismographs for field surveys. In particular, if we decide to study the seismic tomography for specific region, we would need about 200 to 500 seismographs. However, specific requirements of the instrumentation for the country cannot be given. Since considerable foreign exchange has gone into the procurement of analogue/digital instruments and in future the requirements would be much larger, it would be worthwhile to make efforts by the geophysical institutions in the country to encourage commercial firms to take up the manufacture so that reliable products can be brought out.

4. Keeping in view the ease in the analysis, analogue instruments are still needed which have been made by CSIO and ELTEL (Bangalore). Since the requirement of accurate monitoring for river valley is the pre-requisite for estimation of earthquake risk, it may be worthwhile to make it mandatory to instal the minimum network of 5 to 8 stations around such projects which are cleared by the Standing Committee of Central Water Commission. Thus a small fraction of money out of hundreds/thousands crores of Rupees for Dams and nuclear power projects will enable us to collect valuable data to study such aspects as earthquake prediction, induced seismicity and better evaluation of earthquake risk through a denser network.

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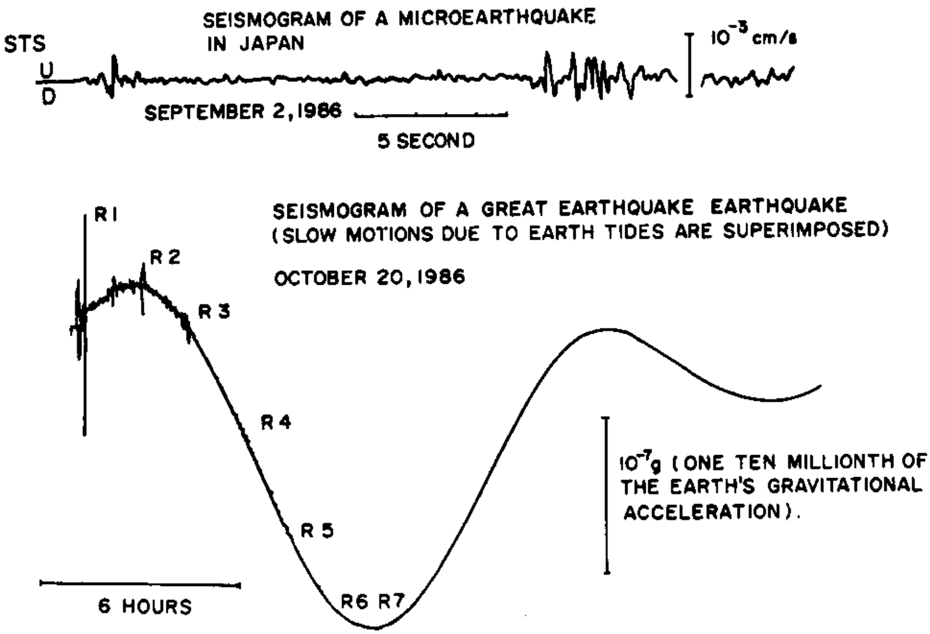
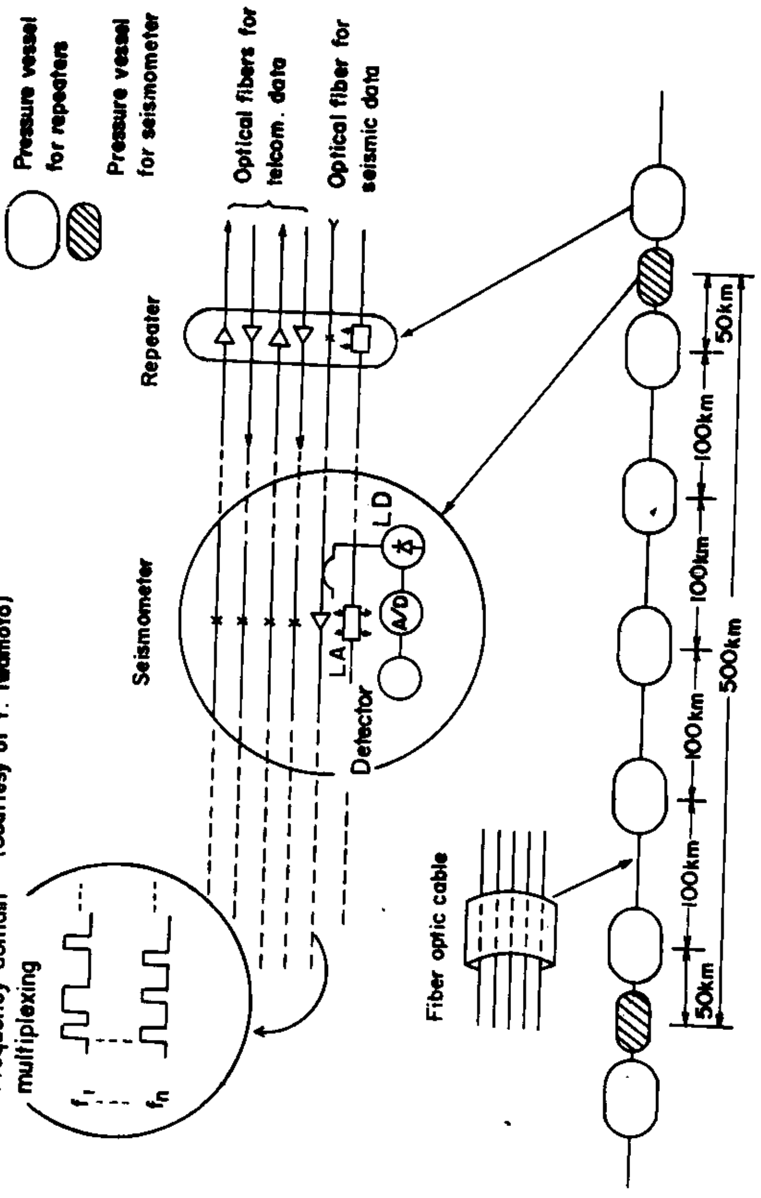

SEISMOGRAM OF A MICROEARTHQUAKE IN JAPAN
STS
U
D
10^{-3} cm/s
SEPTEMBER 2,1986
5 SECOND
SEISMOGRAM OF A GREAT EARTHQUAKE EARTHQUAKE
(SLOW MOTIONS DUE TO EARTH TIDES ARE SUPERIMPOSED)
OCTOBER 20,1986
R1
R2
R3
R4
R5
R6 R7
10^{-7}g (ONE TEN MILLIONTH OF THE EARTH'S GRAVITATIONAL ACCELERATION).
6 HOURS

Figure 1



A possible method by which fiber optic telecommunication cables could be used to transmit data for a permanent array of ocean bottom seismometers (Courtesy of Y. Iwamoto)

Figure 2

U.S. National Seismograph Network

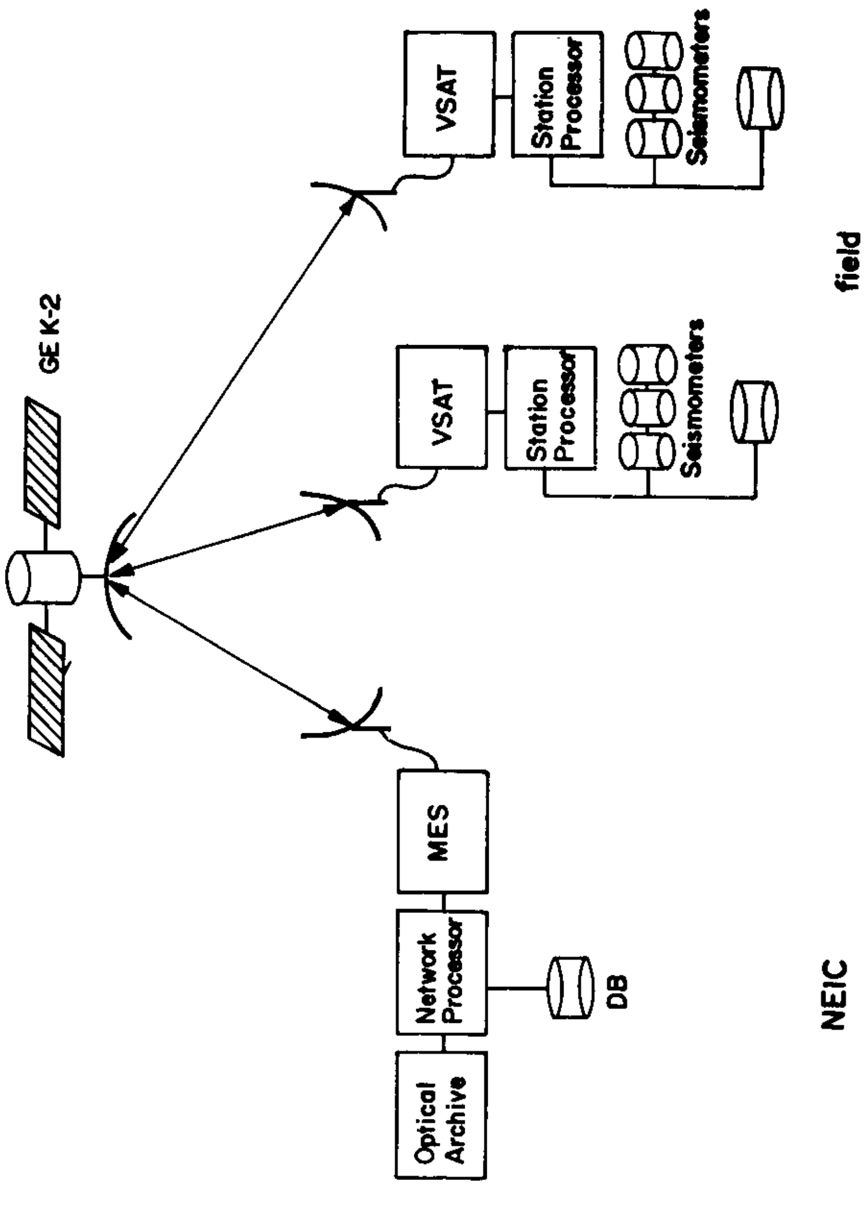


Figure 3

EARTHQUAKES IN AND AROUND INDIA FOR THE PERIOD FROM JANUARY TO MARCH 1992

S. No.	Date	Origin Time (UTC) (USGS/NDI)	Location Lat.°N	Long.°E	Region	Mag. MB/MS	Depth Km.	Remarks
1.	2.	3.	4.	5.	6.	7.	8.	9.
JANUARY'92								
01	01	16 38 17.2	14.3	96.1	Andaman Islands	4.1	33	
02	02	02 35 37.2	34.0	88.9	Xinjiang	4.8	33	
03	04	03 35 21.6	31.9	70.0	Pakistan	5.0 MS 5.1	29	
04	04	14 12 30.1	38.8	69.7	Tajikistan	4.7	33	
05	05	02 14 16.5	21.5	94.4	Myanmar	4.5	97	
06	06	02 25 58.8	36.5	70.1	Hindukush	4.6	219	
07	06	13 20 19.5	23.8	93.4	India-Myanmar Border	-	33	
08	06	15 59 06.9	30.7	66.0	Afghanistan	-	33	Felt at Quetta
10	07	23 52 38.3	36.2	70.8	Hindukush	4.3	261	
11	08	17 41 41.5	30.1	92.5	Xinjiang	4.0	33	
12	09	00 27 42.2	38.2	72.8	Tajikistan	4.0	33	
13	09	13 08 29.7	23.3	94.1	India-Myanmar Border	-	33	
14	11	06 16 55.9	09.3	87.0	Bay of Bengal	5.7 MS 5.0	22	Felt in Madras area
15	11	20 09 18.5	38.8	78.6	Afghanistan-Tajikistan Border	4.8	17	
16	13	18 36 32.1	24.4	92.6	India-Bangladesh Border	4.5	33	
17	15	17 17 39.9	39.9	71.5	Tajikistan	4.3	33	
18	19	11 59 20.3	37.6	72.1	Tajikistan	4.0	33	
19	20	08 58 22.5	27.4	66.0	Pakistan	5.2 MS 5.2	27	
20	20	23 09 45.5	14.5	93.7	Andaman Islands	4.6 MS 3.9	44	
21	21	04 09 08.6	34.4	69.5	Afghanistan	3.7	33	
22	22	10 48 39.2	26.6	67.3	Pakistan	4.3 MS 4.3	33	
23	22	11 25 58.9	36.7	71.3	Afghanistan-Tajikistan Border	3.8	202	
24	22	19 15 31.5	26.4	97.1	Myanmar	-	33	
25	22	23 45 44.5	36.8	71.3	Afghanistan-Tajikistan Border	3.6	33	
26	23	10 26 26.7	34.6	93.2	Quanghai, China	5.2	33	
27	23	15 16 46.8	36.4	71.2	Afghanistan-Tajikistan Border	4.3	244	
28	23	17 56 09.9	36.7	71.3	Afghanistan-Tajikistan Border	3.9	33	
29	23	21 48 13.8	20.4	95.2	Myanmar	4.5	33	
30	24	05 04 47.3	35.5	74.5	Jammu & Kashmir	5.4 MS 4.2	47	Felt at Gilgit Skaradu and Srinagar. Also, felt at Islamabad, Lahore and Rawalpindi, Pakistan.
31	25	15 12 31.9	26.1	98.7	Myanmar-China Border	4.7	33	
32	26	23 48 56.1	32.3	76.4	Jammu & Kashmir	4.5	33	
33	28	03 01 38.0	21.1	94.7	Myanmar	3.6	120	
34	28	16 22 00.4	36.8	71.7	Afghanistan-Tajikistan Border	4.3	33	
35	30	05 55 47.8	29.3	81.1	Nepal	4.6	33	Felt in South Western Nepal.
36	30	17 15 10.6	37.5	70.9	Afghanistan-Tajikistan Border	4.2	10	
37	30	17 54 19.3	22.7	93.6	India-Myanmar Border	4.2	73	

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1.	2.	3.	4.	5.	6.	7.	8.	9.
FEBRUARY'92								
38	01	04 52 24.4	23.5	90.9	Bangladesh	-	33	
39	01	09 26 17.5	36.4	70.7	Hindukush	4.7	196	
40	01	20 07 32.0	26.9	96.6	Myanmar	-	33	
41	01	21 24 24.6	36.5	70.5	Hindukush	-	33	
42	03	03 15 54.3	37.3	82.0	Southern Xinjiang, China	4.1	33	
43	03	15 44 22.6	34.5	93.1	Quinghai, China	4.7	10	
44	04	21 51 36.8	11.1	92.9	Andaman Islands	4.7	33	
45	05	19 36 29.8	31.5	67.0	Afghanistan	4.4 MS 4.2	33	
46	05	23 10 48.6	31.4	66.8	Afghanistan	5.1 MS 5.3	18	
47	05	23 41 36.8	31.4	66.9	Afghanistan	5.0 MS 4.6	33	
48	06	03 35 15.3	29.6	95.5	Eastern-Xinjiang India Border	5.6 MS 5.0	15	
49	06	05 09 10.6	36.7	71.6	Afghanistan-Tajikistan Border	3.6	33	
50	06	18 47 02.3	34.6	72.6	Pakistan	4.1	33	
51	07	14 12 12.2	37.3	70.9	Afghanistan-Tajikistan Border	4.4	33	
52	08	01 48 17.3	29.9	95.2	Eastern-Xinjiang India Border	4.3	33	
53	09	13 11 23.3	37.6	95.9	Quinghai, China	3.9	33	
54	09	14 37 34.7	29.7	95.6	Eastern-Xinjiang India Border	4.8	10	
55	10	07 06 40.1	29.7	95.5	Eastern-Xinjiang India Border	4.1	33	
56	11	10 15 28.1	36.6	71.6	Afghanistan-Tajikistan Border	4.4	33	
57	12	02 45 51.4	36.5	71.2	Afghanistan-Tajikistan Border	4.0	242	
58	13	22 43 34.1	32.6	76.5	Jammu & Kashmir	4.6	33	
59	15	08 14 08.2	37.7	72.1	Tajikistan	4.4	33	
60	15	18 51 09.7	20.1	93.8	Myanmar	3.8	33	
61	17	09 09 05.1	30.2	70.7	Pakistan	4.0	33	
62	20	05 42 37.0 (NDI)	17.3	73.6	Koyna Region	3.8	10	
63	22	01 49 19.9	36.5	71.6	Afghanistan-Tajikistan Border	4.0	33	
64	25	01 57 25.8	25.2	92.2	India-Bangladesh Border	5.0	33	
65	29	21 42 21.0	36.5	71.4	Afghanistan-Tajikistan Border	4.6	185	
MARCH'92								
66	01	06 18 28.6	36.2	73.4	Jammu & Kashmir	3.7	33	
67	01	15 37 23.4	23.4	94.6	India-Myanmar Border	4.0	84	
68	01	21 13 22.3	36.5	71.5	Afghanistan-Tajikistan Border	3.9	33	
69	02	14 48 18.1	30.5	78.5	West U.P. Hills	3.0	33	
70	02	23 06 11.9	36.4	69.0	Hindukush	4.0	33	
71	05	02 14 17.6	35.6	80.6	India-Xinjiang Border	4.7	36	
72	06	01 38 28.7	36.5	71.0	Afghanistan-Tajikistan Border	4.1	212	
73	06	17 42 19.2	36.5	71.0	Hindukush	4.3	221	
74	07	22 41 50.8	29.4	89.4	Xinjiang	4.3	113	
75	07	22 58 12.5	36.3	70.8	Hindukush	3.8	33	
76	08	11 25 33.5	23.2	94.7	India-Myanmar Border	4.6	83	
77	09	16 59 28.6	27.4	66.0	Pakistan	4.9	19	
78	10	05 47 19.7	33.4	73.0	Pakistan	4.5 MS 4.1	33	
79	11	00 23 24.9	36.0	72.9	Tajikistan	4.3	74	
80	12	18 29 05.0	37.6	71.4	Afghanistan-Tajikistan Border	4.7	33	
81	12	18 59 14.9	35.6	70.4	Hindukush	4.4	33	
82	14	05 49 42.4	39.2	72.1	Kyrgyzstan	4.5	33	
83	14	12 [illegible]0 26.0	30.7	78.8	West U.P. Hills	4.8	30	
84	15	23 28 43.6	38.3	70.5	Afghanistan-Tajikistan Border	4.5	33	

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1.	2.	3.			4.	5.	6.	7.	8.	9.
85	16	01	18	55.9	34.3	86.3	Xinjiang	4.7	33	
86	17	02	14	49.9	09.2	92.8	Nicobar Islands	4.8	67	
87	17	23	40	44.4	36.4	71.1	Afghanistan-Tajikistan Border	4.4	228	
88	20	08	39	40.5	36.7	71.7	Afghanistan-Tajikistan Border	4.3	33	
89	21	23	04	56.3	13.5	94.5	Andaman Islands	4.6	33	
90	22	00	00	53.0	10.6	93.8	Andaman Islands	4.6 MS 4.4	33	
91	22	00	26	09.1	10.5	93.7	Andaman Islands	4.5	33	
92	22	01	47	55.0	10.5	93.9	Andaman Islands	4.9 MS 4.7	33	
93	22	14	28	24.0	26.0	95.6	India-Myanmar Border	4.3	33	
94	22	18	59	29.9	14.1	92.9	Andaman Islands	4.4	33	
95	23	08	21	44.2	26.8	97.4	Myanmar	4.9	33	
96	24	02	02	22.0	22.9	94.0	Myanmar	4.7	129	
97	24	18	52	04.3	11.9	92.7	Andaman Islands	-	33	
98	24	19	32	10.3	31.5	81.5	Xinjiang	4.8 MS 4.4	16	
99	24	21	01	47.5	33.8	72.9	Pakistan	5.0 MS 4.2	14	
100	25	22	32	34.8	24.9	95.2	Myanmar	5.3	106	Felt at Silchar and Guwahati.
101	26	08	40	44.8	24.0	93.6	India-Myanmar Border	-	33	
102	27	00	05	20.1	20.9	94.6	Myanmar	5.4	97	
103	27	04	34	49.0	37.5	71.9	Afghanistan-Tajikistan Border	4.2	33	
104	27	07	53	42.4	20.5	93.9	Myanmar	4.1	50	
105	27	10	39	30.6	36.0	72.5	Pakistan	4.9 MS 4.5	35	
106	27	11	50	25.7	35.8	73.0	Pakistan	3.7	33	
107	28	02	50	12.9	21.3	98.7	Myanmar	4.2	33	
108	28	10	17	41.8	26.6	67.3	Pakistan	4.9 MS 4.3	10	
109	28	16	58	10.7	08.1	94.9	Nicobar Islands	4.6	33	
110	29	01	56	06.9	33.6	72.3	Pakistan	5.1	33	
111	30	18	30	06.6	31.9	94.5	Xinjiang	3.9	33	
112	30	19	19	34.8	35.8	72.4	Pakistan	4.4	55	
113	31	00	28	24.4	32.2	80.7	Xinjiang	3.6	33	
114	31	09	16	06.9	31.8	70.7	Pakistan	3.8	33	