RESULTS OF ENGINEERING-SEISMOLOGICAL STUDIES OF THE ZANGHEZOUR EARTHQUAKES IN 1968

by

A.G.Nazarov[I], B.K.Karapetian[II], N.K.Karapetian[III], V.L.Mnatsakanian[IV], S.A.Pirouzian[V], D.N.Roustanovich[VI] S.A.Shahinian[VII], L.V.Shahsouvarian[VIII]

SYNOPSIS

A macroseismic investigation has been made of the effects of earthquakes in Zanghezour; it has been established that the seismic stability of buildings and structures is secured provided the norms of earthquake-proof construction are observed.

An analysis of devices in the Zanghezour earthquakes has been carried out by recording the vibrations of the earth in the epicentral zone and registering the reactions of buildings and structures with the help of multi-pendulum seismometers. The dynamic characteristics of a nine-storey monolithic reinforced concrete building in nature have been

---

I Academician, Doctor of engineering sciences, Professor; Institute of Geophysics and Engineering Seismology, Academy of Sciences, Armenian SSR.

II Doctor of engineering sciences, Professor; Yerevan Polytechnic Institute , Institute of Geophysics and Engineering Seismology, Academy of Sciences, Armenian SSR.

III Candidate of physico-mathematical sciences; Institute of Geophysics and Engineering Seismology, Academy of Sciences, Armenian SSR.

IV Candidate of engineering sciences; Institute of Geophysics and Engineering Seismology, Academy of Sciences, Armenian SSR.

V Candidate of engineering sciences; Institute of Geophysics and Engineering Seismology, Academy of Sciences, Armenian SSR.

VI Candidate of engineering sciences; Institute of Physics of the Earth, USSR Academy of Sciences.

VII Candidate of engineering sciences; Institute of Geophysics and Engineering Seismology, Academy of Sciences, Armenian SSR.

VIII Candidate of engineering sciences; Armenian Institute of Building Materials and Structures, Yerevan, Armenian SSR.

determined. A spectral analysis of the vibrations has been conducted, and the values of reactions for rigid, averagely flexible and flexible structures have been derived analytically.

INTRODUCTION

In the south-east of the Armenian SSR earthquakes corresponding to Intensities VII and VIII by MSK-64 scale took place in Zanghezour on June 9 and September 1 1968; they were accompanied by a large number of aftershocks.

Those earthquakes were studied from the geological, seismological, geophysical and engineering-seismological standpoint, by the joint complex expedition of the Institute of Geophysics and Engineering Seismology of the Armenian Academy of Sciences, The Armenian Institute of Building Materials and Structures, The University of Yerevan, The Institute of Physics of the Earth of the USSR Academy of Sciences and so on. We should like to dwell below on a number of results of the engineering-seismological investigation.

RESULTS OBTAINED

An investigation of the effects of the Zanghezour earthquakes of 1968 revealed that most damage was done and partial destruction caused in the populated areas of the district of Kafan in Armenia. In parts located nearest to the epicenter the Intensity of the earthquake was as high as VII by the MSK-64 scale. In particular local areas the tremors amounted to Intensity VIII resulting from the unfavourable conditions of the ground. Tremors of Intensity V-VI were recorded over an area of about nine thousand sq. km. Apart from the damage to buildings and structures, the earthquake caused also residual deformations on the surface of the Earth. Rock screes formed in the canyons of mountain rivers. Earth rifts with an opening of 0.3-1.0 m, a vertical displacement of 0.3-0.4 m and from ten to several dozen meters long have been discovered in the epicenter of the earthquake. Cracks in the diluvial layer on the hill-slope in the epicenter of the earthquake are shown in Fig.1, while Fig.2 illustrates heavily damaged two-storey hospital building in the town of Kajaran. Analysing available macroseismic evidence, a map of isoseists of the earthquake of June 9 1968 has been drawn up [1] which is shown in Fig.3.

One-two storey houses with bearing walls of rubble masonry and wooden roofs were greatly damaged. Cracks, at times unbroken, developing in all directions, were as wide as 0.5-1 cm. As a rule the corners and connections of walls were damaged. Subsequently artificial consolidation of the wall constructions of those buildings failed to yield the

desired effect; therefore most of them were torn down.

Two-five storey stone buildings are constructed of volcanic tuff of the Artik type. The walling is layered by the "midis" system. The intermediate floors are of reinforced concrete iron hollow slabs. The buildings were designed with antiseismic measures to counter an earthquake danger of Intensity VIII. The first floors of some four-five storey buildings were damaged; thin cracks appeared mainly in the corners and connections of walls as well as in the corners of window and door openings. Those damages resulted from the poor quality of the masonry and, specially, from the improper choice of the construction site (hill-sides, embankments). Construction measures made it possible to restore those buildings completely. An analysis of the behaviour of multi-storey stone buildings indicated that they are rather aseismic and can withstand earthquakes of estimated intensity with negligible damage provided they are built of good standard and according to earthquake-proof norms.

Six-storey carcass monolithic reinforced concrete buildings with precast boards proved their earthquake stability in full measure. No appreciable damage has been done to them. Only thin cracks appeared in joining places of the fill and the carcass as well as in the vertical joints of ventilation blocks.

In the designs of Finnish-type one-storey wooden houses no damage has been discovered. In some cases the brick stoves were isolated from the walls and small cracks appeared in the walling. Two-storey multi-flat apartments of prefabricated wooden panels remained intact. However, cracks could be seen in the outer plastering of some houses.

Industrial buildings, made of prefab or monolithic reinforced concrete and also those of metallic carcass, completely withstood the earthquake, with no damage at all.

Thus our macroseismic observations have led us to the conclusion that buildings and structures of good quality, where the aseismic norms of construction required in the USSR are observed, withstood the earthquakes adequately, with insignificant damage and small cracks basically in the joints of various designs.

The dynamic characteristics of a nine-storey monolithic carcass building of reinforced concrete have been determined. The period of the fundamental tone of free vibrations proved to equal $T = 0.50-0.58$ sec, the logarithmic decrement $\delta = 0.17$. The vibration parameters of the building under consideration in microseisms, tremors and

the subsequent tremors of the earthquake are of a form where the bending strains prevail.

In the epicentral zone of the Zanghezour earthquakes at the stations of "Kajaran" and "Gyard", a special equipment was installed to record strong earthquakes of intensity VIII. The set of devices consisted of oscillographs ISO-2 ans seismometers C-5-C, that operated in expecting conditions and were switched on during earthquakes of Intensity III and upward. The horizontal component N-S in three canals with increases were recorded: 2.5; 10 and 50. As a result a great number of recordings of recurrent tremors were made that occurred after the earthquake of June 9 1968. Fig.4 shows the recordings of earthquakes made at the station "Kajaran", where K indicates the class of energy, λ_0 is the maximum displacement of the vibrations in mm, while J is the Intensity by the MSK-64 scale.

Making use of the recordings of the epicentral zone, a spectral analysis of the seismic vibrations is made, and it has been established that the prevailing period of vibrations varies within the range of 0.2 - 0.3 sec which, according to the constructed amplitude spectra in time, takes place almost from the very start to the end of the vibration process. Most of the buildings erected in the epicentral zone showed nearly the same periods of free vibrations. That is why the vibrations grew considerably in them during earthquakes, which fact is accountable in terms of the resonance.

With the help of multi-pendulum seismometers [2,3] installed, with definite tasks, in Kajaran, in various conditions of the earth (on the rock, on pebble beds with a high level of ground water, on diluvium, on embankment ground) fourteen consecutive tremors of the Zanghezour earthquake were registered, of Intensity III to VIII. Spectral curves $\tau(T)$ were plotted based on the obtained values of reduced seismic accelerations. When those curves are analysed they all prove to be of a sharply declining neture; this holds specially for relatively weak tremors of up to Intensity V. In the case of tremors of greater Intensity (VI-VIII), the drop of the curve is less sharp. This difference is most noticeable in periods T = 0.3 - 0.6 sec. In the generally declining curve $\tau(T)$, approximating the hyperbole, in most cases peaks are also to be seen on the curves. Those peaks correspond to the various periods of vibration within the range of 0.1 - 0.3 sec and depend on the site where the device had been installed and on the particular nature of the tremor.

Relying on the obtained values of the reduced seismic accelerations, estimations were made of the reduced velocities, reduced displacements (spectra of action) and respec-

tive spectral curves were plotted which intersected at characteristic points conforming with the definite periods of vibrations.

An estimation of the Intensity of the recorded tremors was made by the value of the mean reduced velocity, which served the basis in establishing intensities of all the fourteen subsequent tremors of the Zanghezour earthquake of June 9 1968, ranging from Intensity III to VIII. In this way the values of mean reduced seismic speeds obtained with the help of multi-pendulum seismometers can serve a measure for determining the intensity of the earthquakes.

The reduced seismic accelerations were also specified analytically, by elaborating the recordings of vibrations in time of some of the subsequent tremors of the Zanghezour earthquake of June 9 1968. The recordings of vibrations of the ground were tabled and, in accordance with the method worked out [4] , the values of reduced seismic accelerations for periods of 0.5 to 2.5 sec and the logarithmic damping decrements were determined on the computer "Hrazdan-2" by means of a specially compiled program: 0; 0.05; 0.1; 0.2. Spectral curves $\tau(T,\lambda)$ were plotted in conformity with the reduced seismic accelerations obtained.

An examination of those curves showed that they are all of a decreasing nature and can be described by the hyperbole. However, in some points those curves have particular peaks. It should be noted that the effect of the damping decrement makes itself particularly felt in those peak points.

Next, graphs of dependence of the reduced seismic acceleration on the logarithmic damping decrement were drawn. Their analysis indicates that the damping decrement has, first of all, a great impact on the short periods and, secondly, the greatest effect of the decrement is observed in small dampings (0.05-0.1).

The reduced seismic velocities were based on the obtained values of reduced seismic accelerations. The greatest reduced seismic velocity was obtained for rigid buildings where the period of the fundamental tone of free vibrations varies in the range of 0.1-0.4 sec. Those are the commonest buildings in seismic areas. For buildings with periods of 0.6 - 1.0 sec the reduced seismic velocity proved considerably less. Such value of periods is typical of multi-storey buildings. As to the flexible constructions the reduced seismic velocities are of quite small value to them.

Of the next five tremors, for which values of reduced seismic velocities were obtained analytically, by the recordings of vibrations in time, two tremors (23.06 and 27.07)

were also registered with the help of multi-pendulum seismometers. A comparison of the values V_c derived analytically and directly with the help of multi-pendulum seismometers, shows that they differ but insignificantly. The curves of reduced seismic accelerations in both cases are similar in nature.

An investigation by devices of the subsequent tremors of the Zanghezour earthquakesof June 9 1968, of Intensity III to VIII, indicates that the reaction of the structures under different intensities of seismic vibrations, manifests itself in different ways; particularly the curves of reduced seismic accelerations are of varying nature. However, general regularities have also been revealed, viz. an established constancy of the peculiar points of intersection of the spectral curves of reduced accelerations, velocities and displacements regardless of the intensity of the earthquake as well as ground conditions. It has also been established that an acceleration in the relatively high frequency part of the spectrum of vibrations exceeds several times the estimated values of accelerations adopted in the norms regulating seismic stability. In this way this general conclusion, that is in the focus of investigators of many countries, is confirmed in the case of the given earthquake too. The major task of specialists in earthquake engineering lies in the specification of the methods of estimated structures. A most reliable token of the accuracy of calculations on earthquake stability is the identification of estimated accelerations, adopted in the rules of estimation, with the actual accelerations observed during earthquakes.

REFERENCES

1.Nazarov A.G., Pirouzian S.A., Shahsouvarian L.V. The Zanghezour earthquakes of 1968. DAN, Armenian SSR, v.XLIX, No 2, 1969.

2.Nazarov A.G. A method of engineering analysis of seismic forces. Izd. Acad.Sci.,Armenian SSR,Yerevan,1959.

3.Karapetian B.K. Multi-pendulum seismometers and the effect of their application in earthquake engineering. Izd. Haypethrat, Yerevan, 1963.

4.Karapetian N.K. The method of determining reduced seismic accelerations by the seismograms of earthquakes and explosions DAN, Armenian SSR, v.XIII,No 5,1966.

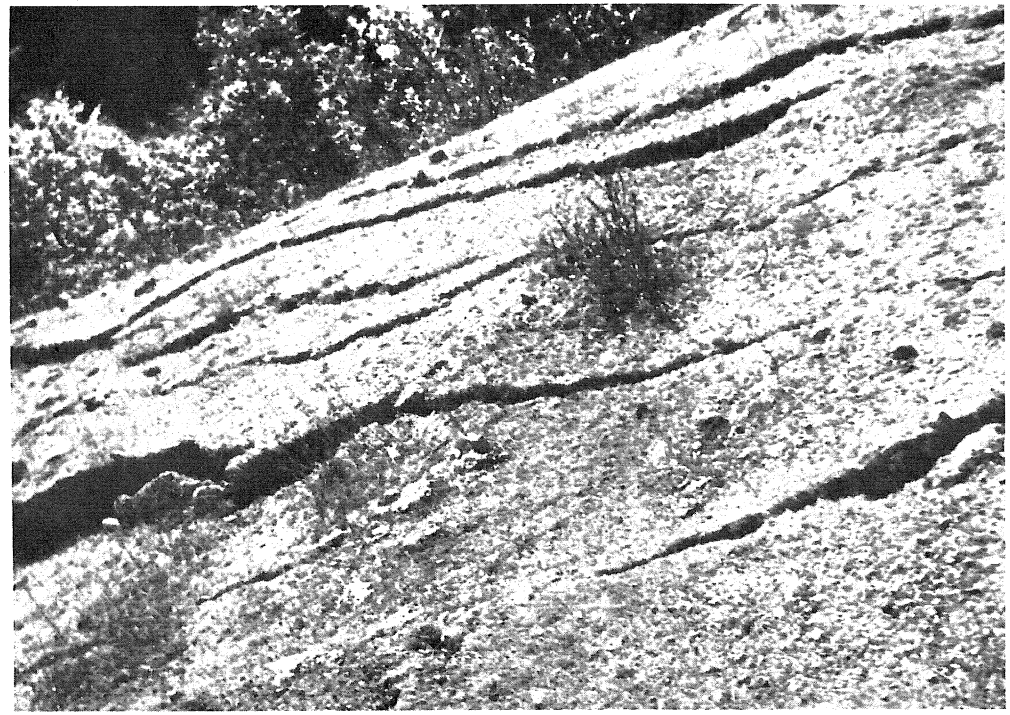

Fig.1 Cracks in the diluvial layer on the hill-slope in the epicenter of the earth-quake

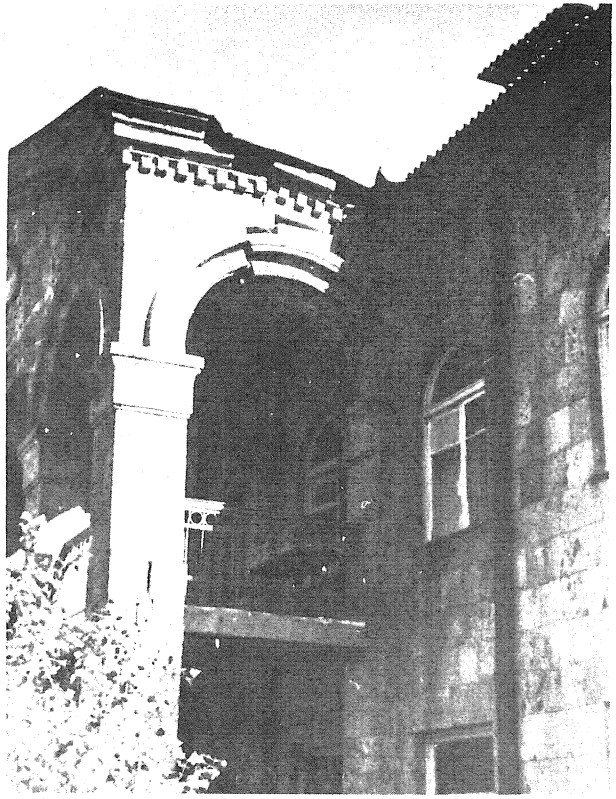

Fig.2 Heavily damaged two-storey hospital building in the town of Kajaran

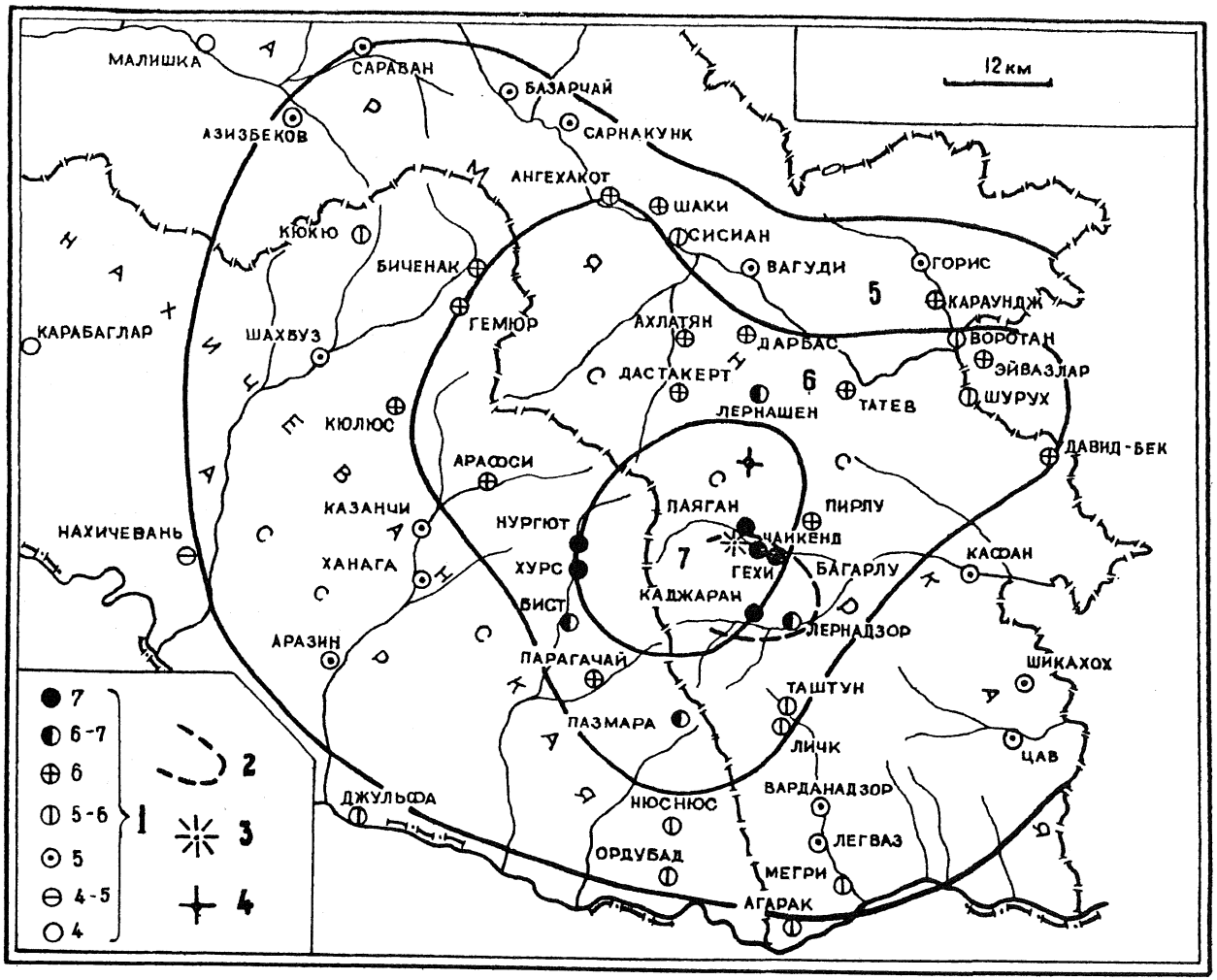

Fig.3 Map of isoseists of the Zanghezour earthquake of June 9 1968: 1.Intensity by the MSK-64 scale; 2.Outlines of a strong tremor,September 1, 1968, of Intensity VII-VIII; 3.Macroseismic epicenter; 4.Instrument epicenter.

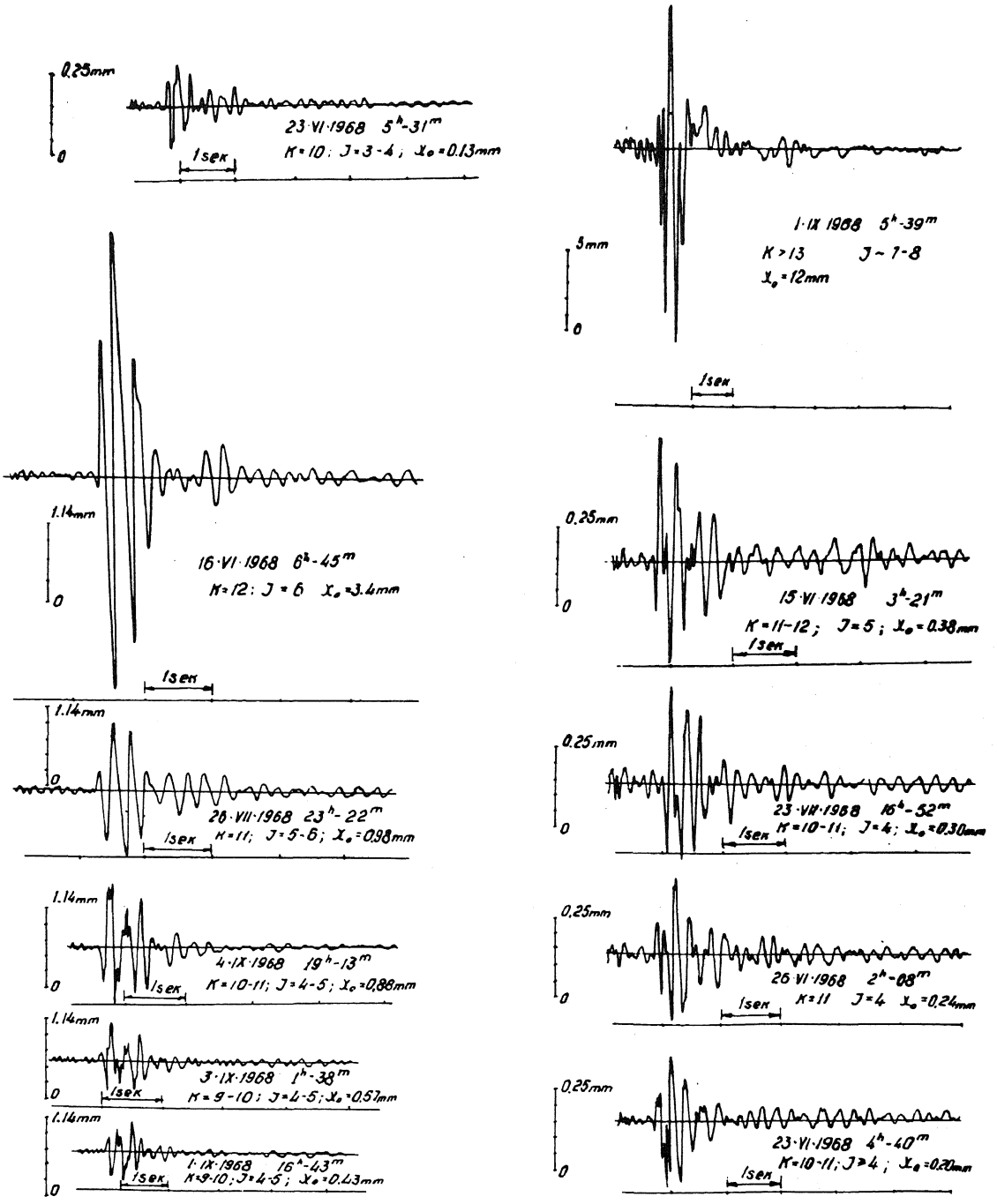

Fig.4 Recordings of the Zanghezour earthquakes made at the station "Kajaran"