PB82-225020

Engineering report on the Muradiye-Caldiran, Turkey, Earthquake of 24 November 1976

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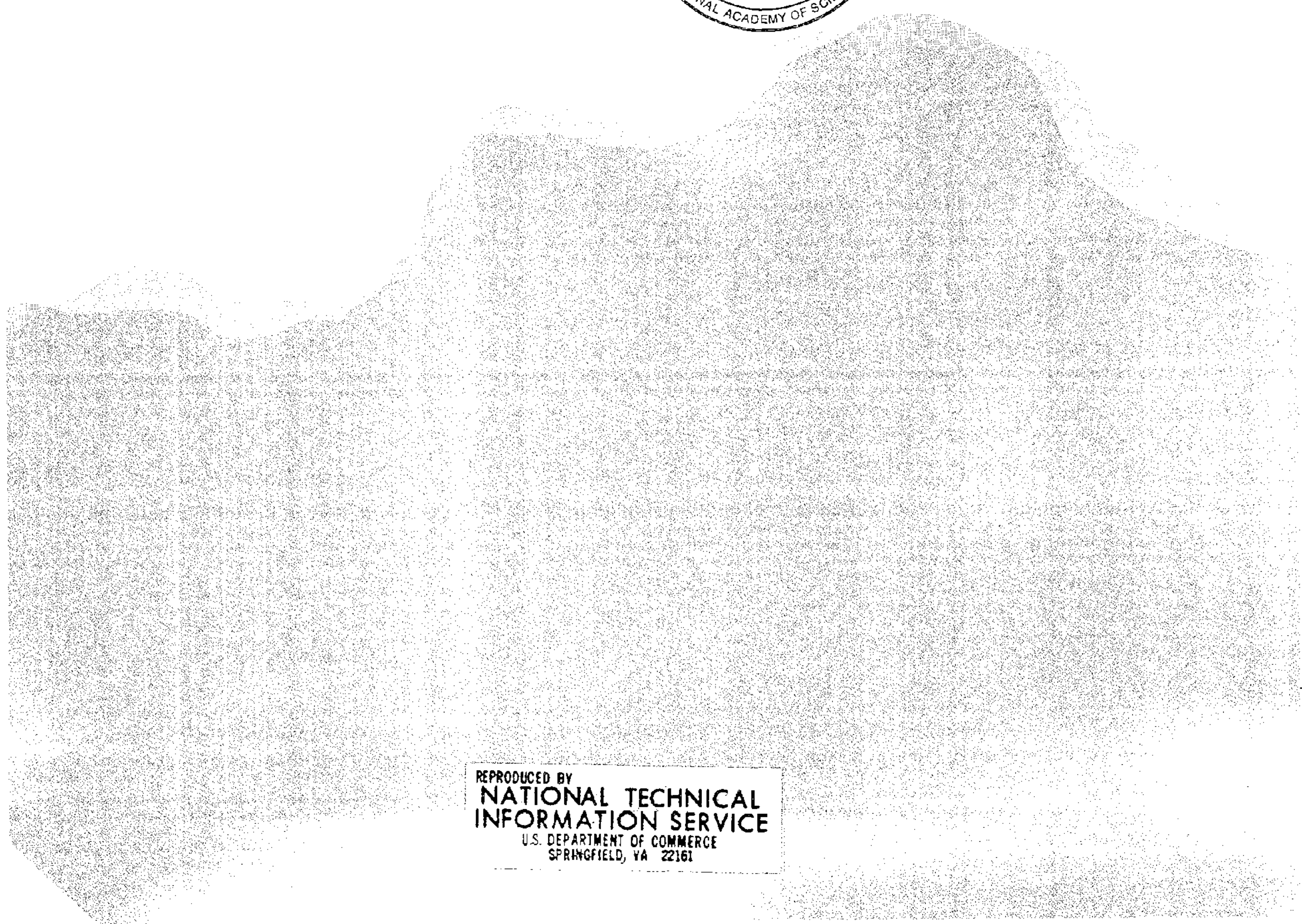

ENGINEERING REPORT
ON THE
MURADIYE-ÇALDIRAN, TURKEY, EARTHQUAKE
OF
24 NOVEMBER 1976

by

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submitted to the

Committee on Natural Disasters
Commission on Sociotechnical Systems
NATIONAL RESEARCH COUNCIL

National Academy of Sciences
Washington, D.C.
1978

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This report has been reviewed by a group other than the authors according to the procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

Financial support for publication of this report was provided by the National Science Foundation.

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Printed in the United States of America

FOREWORD

The National Research Council Committee on Natural Disaster was formed to study the engineering aspects of natural disasters, including floods, earthquakes, tornadoes, hurricanes, and major fires. The objectives of the Committee's studies are to improve the protection against disaster and to stimulate research needed to understand the hazard posed by these extreme events of nature.

This report is sponsored by the Committee's Panel on Earthquakes and describes the effects of the Muradiye-Çaldıran, Turkey, earthquake of November 24, 1976. The report was prepared by a team of Turkish engineers and scientists with editorial and technical assistance from Professor Mete A. Sozen of the University of Illinois and Professor James O. Kirsa of the University of Texas at Austin, who visited the affected region shortly after the earthquake.

P. C. Jennings, Chairman
Committee on Natural Disasters

ACKNOWLEDGMENTS

The work of the various inspection teams was aided greatly by the Central Disaster Coordination Committee in Van. The individuals comprising the various teams cooperated to produce independent field reports which are liberally quoted in this report. In particular, it must be mentioned that much of the information on the geology of the region and the tectonic structure of the fault is abstracted from the field report of Arpat, Saroğlu, and İz (1977).* A number of photographs and figures given in this report were provided by the Ministry of Reconstruction and Resettlement team headed by Sinan Gencoğlu. Mr. Oktay Ergünay, Head of the Earthquake Research Institute, generously made available all information and aid at their disposal, and also provided the two strong motion recordings given in this report.

*Publications referred to in the report appear in the Bibliography.

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INTRODUCTION

Object and Scope

As soon as it appeared that the magnitude 7.3 earthquake which occurred on November 24, 1976, at 12:22 GMT or 2:22 pm local time in eastern Turkey had caused widespread life and property damage, various institutes in Turkey responded by dispatching teams of experts for investigations. Preliminary indications released by the news media suggested that the most heavily affected center was the city of Van (population 50,000), the provincial capital. However, it quickly became apparent that although the earthquake had been felt rather strongly in Van, there were no collapsed buildings or fatalities in the city. The heaviest toll in terms of property and life occurred in the towns of Muradiye, 80 km north of Van, and Çaldıran, 25 km further north, and in the numerous villages administratively linked to these two centers.

This report contains brief descriptions of the geology and physiography of the affected region as well as the preliminary studies and observations on the earthquake made by the members of several inspection teams. One team, consisting of Esen Arpat, Fuat Şaroğlu, and Huseyin B. İz from the Mining Research and Exploration Institute of Turkey, concentrated its observations on the geological and tectonic features of the event. A second team from the Earthquake Research Institute of the Ministry of Reconstruction and Resettlement, consisting of Sinan Gencoğlu, Ahmet Tabban, Nejat Bayülke, Murat Köylüoğlu, and Ziya Bozer, collected the bulk of the data on the extent of damage and supplied complementary information on the geological aspects of the earthquake. The Middle East Technical University group was comprised of Aybars Gürpınar, Mehmet Çelebi, and Polat Gülkan whose impressions of the structural damage constitute the corresponding section of this report.

There were no strong motion instruments in the epicentral region. Two instruments, one of which was located in Van and the other in Ağri, about 80 km northwest of Çaldıran, received shocks large enough to trigger them and a seismoscope located on rock in Van yielded a recording. Various estimates of the intensity of the epicentral motion are derived from these recordings.

From the viewpoint of structural engineering, the damage resulting from the November 24, 1976, event is not of major interest because of the scarcity of engineered structures in the area. The earthquake response of indigenous housing is, however, a problem of world-wide interest and the implications of the newly formed, and previously unmarked, fault along which most of the damage was concentrated are enough to warrant a detailed description. The studies given in this report are limited to preliminary evaluations only, and are intended to relate the first-hand impression of a significant, magnitude 7.3 earthquake.

THE AREA AND THE EARTHQUAKE

The effects of ground shaking during the November 24 earthquake were most visible in centers of habitation within the administrative boundaries of Van and Ağri provinces in eastern Turkey (Figure 1). Life and property losses were concentrated along the fault break located in northern Van province. Indirect evidence suggests that the ground shaking was not as severe as one would expect in the epicentral area of a 7.3-magnitude earthquake, and that there was a rapid attenuation of ground motion in the north-south direction, approximately normal to the direction of the fault. Heaviest damage was concentrated in Çaldıran located midway between the two ends of the fault rupture and in Muradiye, 25 km to the south of Çaldıran. Numerous small villages dotting the landscape also received heavy damage, although the cumulative statistics of collapsed dwellings and fatalities originating from these were more dramatic than the individual contributions.

Van

Van, the central city of the province of Van in eastern Turkey has been the center of many different civilizations. Its history can be traced as far back as the tenth century B.C. when it was the Urartu State. In late times the Assyrians, Cimmerians, Persians, Romans, Armenians, and Arabs ruled the area in addition to others whose dominations were brief. The Turkish Emoire captured the city early in the sixteenth century. It has been under Turkish rule almost without interruption since then.

The city is at an elevation of 1720 m above sea level on the eastern coast of Lake Van, and is located on lake deposits of sand and gravel overlain by clay and organic soil layers (Figure 2). It is a typical Anatolian provincial center with relatively few reinforced concrete structures over three or four stories. The 1970 census credited the province with a population of 326,000 and Van with approximately 50,000.

Muradiye and Çaldıran

The two centers of habitation where significant numbers of collapse and fatalities occurred during the November 24 earthquake were the towns of Muradiye and Çaldıran, the sub-district center, shown in Figure 1. Within the administration structure of the Turkish State, Muradiye is one of the seven districts centers "linked" with the provincial capital, Van. Çaldıran is "linked" similarly to Muradiye.

Although Muradiye was probably founded before the domination of the Turkish Empire, its development is rather recent. Its name in the seventeenth century is recorded as Bargiri and was given its present administrative status in 1910. The town is located on a small alluvial plain created by a river flowing between mountains on the east and west into Lake Van (Figure 3). The population has risen from 1,380 in 1927 to 6,750 at the time of the earthquake. The number of buildings in the town was listed as 561, of which the greatest majority were single story, adobe-rubble stone dwelling units with thick walls and a soil roof. A few engineered buildings where state services are run were brick masonry or reinforced concrete. At the time of the earthquake there were no buildings in muradiye of more than four stories. The economy is based on agriculture and animal breeding and there is no significant industry.

Çaldıran was totally obliterated by the earthquake (Figure 4). Located about 25 km north-northeast of Muradiye on the edge of a plain bearing the same name, Çaldıran was directly on the path of the fault rupture formed during the earthquake. The town had a population of 3,300 and of the 532 dwellings it contained, 505 either collapsed or were damaged beyond repair. One out of every six persons was killed. There was one building with three stories (officers' housing) and several others for government services with two. The remaining units were typical for eastern Turkey, which is relatively poorer and less developed than the rest of the country. Although a few dwellings were constructed partially of hollow concrete blocks, almost all the remaining were of adobe or rubblestone held together by mud, with little vertical reinforcement by timber and the typical heavy mud roof underlain by unfinished poplar trunks (Figure 5).

Physical Geography of Van Province

The province borders Iran on the east and Lake Van on the west (Figure 6). The general tendency of the topography is to decrease in elevation from the mountains in the east towards the lake. From the eastern flank of the volcanic Tendürek Mountain (3,542 m elevation) in the north a series of sharply defined peaks, none of less than 2,400 m elevation, run southward along the Iranian border. Another mountainous region exists between the Bendimahi river in the north and the Karasu river which flows into the lake northwest of Van. To the northeast, Alikelle Mountain rises to 2,850 m and is flanked on the west by the Çaldıran plain at an elevation of 2,100 m. Between the Çaldıran and Muradiye plains, there are several peaks, among which Pirrasit (3,200 m) and Geregamiş (3,020 m) Mountains are the more prominent. The Muradiye plain is bordered on the eastern edge by the 3,000 m high Isabey Mountain. Between these youthful and craggy peaks, spring rivulets have etched deep valleys and gorges which are usually dry in the summer. Fast moving streams, which drain the volcanic Tendürek and Aladağ mountains in the north, join to form the Bendimahi river which flows southeastward, first through Çaldıran and then Muradiye plains. The stream empties into the triangularly-shaped Lake Van at its northern tip. Further to the south, several other streams such as Kara and Memedik flow into the lake after following an east-west course.

There are also a significant number of lakes in the area, many of them small. Among these, Kaz, Şor, Hasantimuran, Akgöl, and Engiz in the east, Hıdırmentes and Sarıgöl in the north may be cited. Lake Erçek to the east of Lake Van is 92 km^2 in area and is at an elevation of 1,890 m. Lake Van from which the province derives its name is the largest in Turkey with a surface area of 3,765 km^2. It lies at an elevation of 1,720 m above sea level and has a maximum depth of about 100 m.

The province experiences a harsh inland climate alleviated somewhat by the presence of the large body of water in the lake. The average temperature varies between -4 and 22°C. On the average, snow remains on the ground for 80 days every year and on 130 days the temperature falls below freezing. The average annual rainfall is 400 mm.

Geological Features and Soils of the Area

The area affected by the earthquake consists of the recent volcanic formations in eastern Turkey and the wide melange farther to the east in the Van and Hakkari provinces. It is known that Nemrut, Süphan, Tendürek, and Ağri (Ararat) Mountains, which form a series of volcanic centers in east Anatolia (Figure 1) have been active during the Quaternary. Of these, Tendürek has two craters approximately 20 km from the fault rupture. Tendürek has been active until very recently and appears to be in a quiescent stage at the present. Basaltic outflow from Tendürek has extended to within 3 km of Çaldıran from the north. Basaltic formations of the same origin occupy a small area west of Lake Hıdırmentes (Figure 7). However, the volcanic formations covering the area to the west of Çaldıran intersected by the fault rupture are largely not Tendürek in origin. Basaltic and at times andesitic layers, whose origins can be traced to the Aladağ, Azizan, and Esrük volcanic centers which are judged to be upper Miocene-Pliocene in age, cover most of the western portion of the scarp. Although Esrük Mountain has been active for the longest period of time, its outflow is observable principally north of Ercis (see Figure 4) and not in the fault zone. On the western flank of Azizan Mountain, which is an extinct volcano on the western tip of the fault line, one can observe a syenite mass underneath volcanic cover. Also, to the north of this mass green schist and marble layers with a partially weathered volcanic cover on top extend as far north as Taşlıçay (Figure 7).

Although not visible in the immediate vicinity of the fault zone, lower and middle Miocene limestone and shale sediments are observed to have been trapped below the volcanic layers. However, these rocks which overlie the eastern portion of the fault zone are really part of a characteristic melange. In the fault area, serpentinites constitute the largest percentage of such rock types. In addition to the serpentinites, red pelagic mudstone, grey shale, tuffites, and limestone blocks with varying degrees of metamorphism are the most commonly encountered rock types.

The oldest geological unit in the area consists of Paleozoic crystalline limestone. In the Muradiye-Çaldıran area, Paleozoic formations rarely exhibit outcroppings. In the Çaldiran plain between the villages of Yukarimutlu and Burçakalan (see Figure 7) light pink, finely crystalline, Permian limestone can be observed. To the northeast of Çubuklu and Umuttepe villages (east of Çaldıran) there are occasional quartzite and sericitic schists. Further to the south toward Özalp (Figure 6), the Paleozoic is represented by schistic formations.

Upper Cretaceous formations constitute the Mesozoic structure in the area. These are generally intermixed with Paleocene formations and ophiolites. At various places one observes greyish, competent limestone on top of 1 to 3 m thick conglomerates overlying Paleozoic schists. Also, it is common to observe reddish limestone intermixed with ophiolites and radiolarites. To the south and east of the area, it is observed that Upper Cretaceous limestones containing greyish calcite veins have been weathered and are intersected by serpentinites.

A Paleocene-age Flysch formation consisting of marly limestone, sandstone, and conglomerates is visible locally on top of the upper Cretaceous limestones. Eocene formations are represented by massive greyish limestone. Since this formation is covered by recent basaltic overflow in the entire area, outcroppings can only be observed in zones of extensive weathering such as that in the vicinity of Soğuksu in the north. Between Umuttepe and Çubuklu villages (Figure 7) basal conglomerates are founded on metamorphized rock. These deposits overlie radiolarites with a complex and jointed structure in the Üçgözeler village area. Andesitic series cover these locally. Miocene formations in the area are generally calcereous in composition. The limestones are relatively soft, greyish and contain many fossils. Similar weathered formations northeast of Erciş reach a depth of 150 m on the Lake Van shore. Additionally, on the eastern coastline of the lake, gravel size Pliocene deposits up to 50 to 60 m in depth are visible. These formations are usually covered with a 40 to 50 m thick organic soil layer.

Quaternary deposits carried by streams have formed large plains such as Muradiye, Çaldıran, and Erciş. The thickness of these alluvial layers shows significant local variations. While the thickness of the alluvium in the Muradiye plain is generally 10 to 20 m, it reaches 70 m in the Çaldıran plain. Borings have indicated that the soil layer in both plains is underlain by basalt and basaltic tuff. While the upper layers of the alluvial deposits consist of sand and gravel containing basalt and limestone pebbles, lower layers are generally greenish grey plastic clays.

Observations on the Contemporary Tectonics of the Area

The earthquake of November 24 occurred in an area about which there is a paucity of geological information. The fault break which was formed during the event was previously unmarked in the tectonic maps of Turkey although past indications for its existence can be recognized at the present with the obvious benefit of hindsight. In this section a general overview of the tectonics of the area to the east of Lake Van will be presented with the objective of bringing into discussion various descriptions that have been offered. Whether the new fault is an extension of the North Anatolian Fault system cannot be answered with certainty, and requires further study.

The eastern tip of the North Anatolian Fault can be extended only as far as Varto (see Figure 1) as documented by observed tectonic movements during earthquakes. Ketin (1976) suggests a possible further extension to the east over Malazgirt, although there are objections raised to this proposition. Preliminary investigations in the area between Ahlat on the western shore of Lake Van (Figure 1) and Varto have suggested that such an extension of the North Anatolian Fault, definitely not as active as its western portion, may indeed exist. However, a detailed examination of satellite and aerial photography to discern a possible extension of the North Anatolian Fault in the vicinity of Van and further east has yielded a negative answer as no major active fault could be traced between Muradiye in the north and Hakkari in the south. During these studies a significant number of discontinuous lineaments exhibiting strike-slip morphology were noted between Van and Muradiye in the northwest-southeast direction. Although no major fault could be discovered to the south of Çaldıran, a significant active fault in the north passing between Diyadin and Doğubeyazıt could be traced as far as the Iranian border. This right-lateral strike-slip fault is indicated in both Figures 1 and 7, and in this text will be referred to as the Balık Gölü fault after the lake it intersects.

Assuming that the tensile activity that gave birth to the Nemrut, Süphan, Tendürek, and Ağri volcanoes continues to this day, tension formations that should have accompanied this activity could not be discerned from the photographic studies.

The recently published seismotectonic map of Iran [Berberian (1976), and Nowroozi (1976)] does not permit a clear relational interpretation to be made between active faults in eastern Turkey and those in western Iran. It is, however, possible that the North Tabriz Fault shown in a grossly simplified version of the seismotectonic map of Iran in Figure 8 is connected with the newly formed Çaldıran fault. Figure 7 indicates a fault continuing into Iran from the north of the eastern tip of the recently formed Çaldıran rupture. Since aerial photographs of this particular sector have not yet been studied, no statements can be made at the present time on the degree of activity of this particular fault and on whether it is a continuous line extending far enough into Iran to link up with the North Tabriz Fault. However, it has been established from field observations and aerial photographs that the Çaldıran Fault does not extend further east than is indicated in Figure 7. This, in turn, makes it probable that the Çaldıran Fault extends into Iran through an "en echelon" jump continuity through the northern Balık Gölü Fault in the direction of Üçgözeler village (Figure 7). In such a continuation, however, there ought to have been a zone of compression between the two faults considering their right-lateral character. This zone has not been clearly identified in the field. It is possible, however, that local landslides in the area have produced an obscuring effect.

On the other hand, one can observe Quaternary-age faults running in the same general direction as the Balık Gölü Fault in Iran (Figure 8).

Whether these faults are related to the Balık Gölü system is debatable and deserves further study.

Seismic History of the Area

Historical records attest to the fact that Van and its vicinity have had a series of tremors in the past including a number of major earthquakes. Since Van has always been the most important center of settlement in the area, the effects of earthquakes, as they are felt in the city, are often described and there is a paucity of data for other towns. The most comprehensive source for historical events is the catalog compiled by Pınar and Lahn (1952). The following descriptive information for seismic events in and around Van has been abstracted from that source. It must be pointed out, however, that, although more recent catalogs [e.g., Ergin et al. (1965, 1971)] quite often quote from Pınar and Lahn (1952), there are occasional discrepancies on the dates of occurrence. Also, faults which are cited by Pınar and Lahn as the sources of the seismic events in their catalog do not always receive universal acceptance.

Date	Event
1111	Earthquake in Van and around Lake Van; very intense with widespread damage. It is reported that wide cracks were formed in the ground.
1245	An earthquake in Ahlat (Figure 1) related to a fault system in the north of Lake Van.
1276	Earthquake swarm felt strongly in Ahlat, Erciş, and Van. Tremors which caused widespread damage lasted for a year.
1441	Earthquake in the Van and Nemrut areas, possibly related to the north Lake Van fault system. Abich (1878) mentions 30,000 deaths. According to Oswald (1912), Nemrut erupted in 1440. It is likely that this is related to the earthquakes.
1646 or 1648	In the Van region tremors lasted from April to June. Walls of the old fort in Van collapsed. At that time the city was founded on lake deposits in a small area around this fort.
1701	A very strongly felt earthquake in Van and western Iran. People lived in tents "for months."
1704	Shaking in Van again caused damage.
1715	Shaking in Van and Erciş.
1791	A very strong tremor felt in Van and as far north as Erzurum and east as Tabriz, Iran.

Date	Event
1871 March 5	Van area: this intense earthquake activity began in Van and Aşkale region and extended north to Erzurum.
1871 June 7	Van and Nemrut area: 400 buildings collapsed in around Van, and 95 deaths were reported. Damage also in the Nemrut mountain area where an earthquake-triggered landslide obliterated a village. This is possibly related to the fault system north of the lake.
1900 June-Sept.	Van, strongly felt.
1902	Erciş, moderately strong.
1904 or 1905	Strongly felt in Van and Hamidiye; Ağri province also reported feeling the tremors.
1906	Strong shaking in the Nemrut area; Erzurum again reported feeling the tremors.
1924	Light damage in the Özalp area.
1932-1933	Moderate damage in the Özalp area.
1941 Sept. 11	Damage in Van and Başkale.
1945 Jan. 15	Moderate damage in Van-Özalp-Muradiye-Erciş area, light damage in Çaldiran
1945 March 2 and 9	Bitlis-Tatvan-Erciş-Muradiye area affected, insignificant damage in Muradiye.
1945 Sept.	Following an earthquake swarm which began on June 30 and lasted into March 1946, 2,000 dwellings in villages around Van collapsed. Maximum intensity was judged to be VI (MM). A strong aftershock in the Van swarm caused the collapse of a significant number of homes in Erciş. In Kocapınar (Figure 1) 300 deaths were reported.
1948 Oct. 12	Light damage reported in Muradiye.

In order to complement the seismic "history" with "instrumentally" recorded events since 1900, several catalogs were studied and cross-checked by members of the Earthquake Research Institute. These events, covering the period from 1900 to 1973, are listed in chronological order in Table 1. The Table is necessarily incomplete, but it is believed that no truly major earthquake has been omitted. It is noteworthy that no earthquake larger than M = 5.9 has occurred during this 74-year period within 100 km of Çaldıran. This may explain the reason for both Muradiye and Çaldıran being in Zone 3 of the 5-zone earthquake map of Turkey in which Zone 1 corresponds to the highest risk.

The Event of November 24, 1976

The major shock occurred on November 24, 1976, at 2:22:17 pm local time. Information concerning the magnitude of the major shock as given by the European Mediterranean Seismological Center in Strasbourg is summarized below.

MLH 7.4 (SKO,GS), 7.3 (UPP,PAS), 7.2 (KRA,CLL,HFS), 7.0 (DBN), 6.9 (TRI)

MLV 7.2 (MOX), 6.9 (ZST), 6.8 (BNS)

MPV 6.9 (NNS), 6.3 (KRA), 6.1 (BRA,ZST)

M 7.9 (ATH), 7.6 (UPP), 7.2 (PAS), 6.7 (HFS), 6.5 (LDG)

MSV 7.1 (BNS)

MAW 7.6 (ISK,ATH)

The magnitude has since been finalized by the National Earthquake Information Service of the U.S. Geological Survey to be 7.3 from an examination of the long-period surface waves.

For the epicentral coordinates of the earthquake, information from the following sources has been received (see Figure 1).

a) National Earthquake Information Service (U.S.G.S.): 39.7°N-44.3°E (vicinity of Doğubeyazıt); later revised to 39.1°N-44.0°E.

b) European Mediterranean Seismological Center, Strasbourg: $39.12^{\circ} \pm 0.03$ N - $44.19^{\circ} \pm 0.03$ E (East of Çaldıran).

Field observations, on the other hand, indicate the macro-coordinates of the earthquake to be 39.15°N - 43.9°E, just to the west of Çaldıran. On the basis of field observations, an intensity I_o of IX(MSK) was assigned to the epicentral region of Çaldıran. Large ground deformations observed just to the west of Çaldıran were the primary reason for assigning the epicentral intensity; structural damage alone was insufficient in this case to assign very high intensities due to the vulnerability of the feeble construction in the area. The isoseismal map is presented in Figure 9. As can be observed from this map, the affected area to the south is larger than the one to the north. This may be explained by the presence of mountains north of Çaldıran, which impose a geological discontinuity, whereas southward from the epicentral region one finds alluvial plains.

The question of focal depth has still not found a definite answer at the time of preparation of this report. Observational evaluations on this are contradictory in character. Stated briefly, there is observational evidence for justifying both a deep and a shallow focus. The fact that the 7.3-magnitude earthquake was felt and caused damage in such a small area would normally indicate that the event had a shallow focus. For example, in the village of Köşk, only 30 km from the epicenter, a garden wall of mortarless rubble stone was untouched (Figure 10). On the other hand, one would expect a shallow 7.3-magnitude earthquake to show effects of very strong shaking in the near field. Therefore, it is surprising to find some adobe and stone houses of mediocre quality, even by the standards of the region, only several meters from the surface faulting, to be standing after the earthquake, almost undamaged (Figures 11 and 12). An instrumental evaluation by the Strasbourg center gives the focal depth as 60 km. (Surface wave analysis and static displacements determined from the tilt of Lake Van have indicated a focal depth of 15 - 25 km. The National Earthquake Information Service value for the focal depth is listed as 36 km.)

It is possible to arrive at some descriptive values to indicate the dimensions of the event of November 24. Using empirical relations and variables which have been observed mostly in the field, values may be obtained for the focal depth, seismic energy, length of the causative fault, area subjected to significant ground deformation, maximum ground displacement, epicentral acceleration, and duration of strong shaking. In some cases empirical equations are used in the inverse form to arrive at orders of magnitude for the variables in question. Until more detailed analyses are made of the source parameters from available seismograms, these values are intended to yield preliminary information on the relative size of the earthquake. For some parameters utilized in the empirical relations given below, the following values were taken: epicentral intensity, $I_o = 9$; magnitude, $M = 7.3$; epicentral distance to the vicinity of Muradiye where intensity, I_1, was judged to be 7 to 8, $\Delta_1 = 20$ km. In the following no attempt has been made to make use of an exhaustive array of empirical relations; the intent is simply to obtain plausible results for the variables in question.

a) Focal Depth

An estimate of the focal depth, h, using the empirical relation derived by Inglada (1948), which considers the decay of the intensity with distance, yields h = 3 km. Using the equation suggested by Blake (1941) in inverse form, one arrives at values for h between 7 and 12 km. Given the benefit of hindsight, both relations provide poor estimates of h.

b) Energy Released

The Gutenberg-Richter (1956) equation

$$\log E = 1.5\ M + 11.8$$

yields an E of 5.62×10^{22} ergs. Likewise, the updated Gutenberg-

Richter equation

$$\log E = 9.4 + 2.14\ M - 0.054\ M^2$$

gives $E = 1.39 \times 10^{22}$ ergs. Employing the Bath (1960) relation

$$\log E = 7.2 + 2\ M$$

one determines $E = 6.31 \times 10^{21}$ ergs. These values indicate an energy release on the order of 10^{22} ergs.

c)Length of the Fault Rupture

According to Iida (1969), the relation between the length of the fault rupture , L, and the magnitude, M, may be expressed as

$$\log L = 1.32\ M - 7.99$$

which yields L = 44.3 km for an M of 7.3. If, on the other hand, L = 60 km is substituted for the possible value of L, then M = 7.4. Use of the relation

$$\log L = 0.6\ M - 2.91$$

suggested by Umemura et al. (1977) yields L = 29.5 km. Again, the reverse operation in which L = 60 km is used gives M = 7.8. The first of these relations is more nearly consistent with field results.

d)Fault Rupture Area

According to Berckhemer (1961)

$$\log F = 1.75\ M + 0.45$$

which indicates $F = 1.679 \times 10^{13}\ cm^2$ or 1679 km^2 for M = 7.3. Based on field observations with L = 60 km, and h = 15 km, F = 900 km^2 is determined, which is roughly consistent with the equation.

e)Epicentral Acceleration

The maximum epicentral acceleration, a, is a highly controversial issue and very large "a" values in excess of 1 g have been recorded during events of comparable magnitude (e.g., 1971 San Fernando; 1976 Kysyl Kum). The Gutenberg-Richter (1956) relations

$$\log a_o = (I_o/3) - 0.5$$

and

$$\log a = -2.1 + 0.81\ M - 0.027\ M^2$$

yield a = 0.32 g and 0.24 g respectively.

f) Maximum Ground Displacement

Umemura et al. (1977) have proposed

$$\log D = 0.60\ M - 3.91$$

which yields D = 2.95 m, a value in good agreement with field observations.

g) Duration of Strong Ground Motion

The Saragoni (1977) equation

$$\Delta t = (\exp 0.80\ M)/d^{0.86}$$

yields Δt = 6 seconds for the duration of strong ground shaking.

A strong motion accelerograph in Van at an epicentral distance of 100 km and another at Ağri, located at a similar distance in the north-east (see Figure 1) were triggered into recording the earthquake. Those traces are shown in Figure 13. Also, a seismoscope located in Van recorded the ground motion and this record is presented in Figure 14. The instrument in Van is located on reather deep lake deposits in the south of the city and the Ağri instrument on several meters of talus overlying basaltic formations. These traces have not been reduced, but peak-to-peak readings indicate a maximum of about 0.07 g in Van and 0.03 g in Ağri. Another accelerograph located in Mako, Iran, reportedly recorded a single peak maximum of 0.12 g (A. A. Moinfar, verbal communication). Although measurable, the accelerations obtained at Van and Ağri are too far away to be informative about the stron shaking in the epicentral region.

Description of the 1976 Çaldıran Earthquake Fault

Length: - The fault scarp formed during the 1976 Çaldıran earthquake can be visually traced from near Baydoğan in the east, close to the Iranian border, to about 3 km west of Sarıkök in the west. It has been established that the fault does not continue further in the eastern direction, but it is possible that the break is a few kilometers longer in the western portion, where it disappears into the snow covered Azizan mountains, than has been visually verified. Field work on the western flank of Azizan has revealed no visible fault trace. The likelihood of its continuation into Iran, by means of a possible linking with the Balık Gölü fault in the north, has been suggested; however, no satisfactory mechanism for this has been established. Aerial photographs have yielded no evidence for an active fault in the area.

The fault break formed during the 1976 event is approximately 55 km long and is exceptionally linear in the vicinity of Lake Hıdırmentes (Figure 7). It exhibits and "en echelon" configuration in several locations, the most notable being near Çaldıran.

Near the Eastern tip, in the vicinity of Sorgun, a village founded on serpantinite, no surface trace of the fault has been formed (see Figure 7). Inaccessible land has made it impossible to observe the portion between Güngören and Bezirhane villages. Unfortunately, aerial photographs taken after the earthquake accidentally missed the same area, resulting in the question mark in Figure 7.

Direction: - Excluding local deviations west of Çaldıran, the fault formation is approximately N 70° W in direction. To the east of Çaldıran, the sub-district center, the general direction is first N 55° W, and 15 km later N 45° W. The fault scarp is not really a single line but consists of a number of smaller cracks at various angles of inclinataion with the general trend.

Sense of Displacement: - The sense of the displacement which took place along the fault trace is definitely right-lateral. This rightward motion is clearly manifest along intersected roadways (Figure 15), stream beds (Figure 16), water conduits (Figure 17), and vehicle tracks (Figure 18). As opposed to this consistent lateral throw, it was not possible to identify significant vertical movement. On relatively steep slopes cut by the scarp, it was observed that the side on the lower elevation had moved downward relative to the portion above. An inference on the direction of the vertical movement cannot be built upon this observation since it is related to the stability of the slope material. Where the trace has cut through flat topography, there was no definite consistency in the sense of the vertical displacement since both the north and the south blocks were observed to have shifted up at different places. Nevertheless, weakly consistent observations have indicated a slight upward displacement of the northern block [Arpat et al. (1977)].

Magnitude of the Lateral Slip: - It was possible to gather data from various locations for the evaluation of the magnitude of the lateral slip which took place during the earthquake. In Sarıkök, a village near the western tip of the fault (Figure 7), a 225 cm right-lateral slip was noted on the roadway sitting on basaltic rock. At a distance of 1.5 km to the east of Alaçayır in the same general area, lateral displacements of 330 and 370 cm were measured on a meandering stream bed intersected at several points by the fault (Figure 16). Since the stream was frozen at the time of the earthquake, the shifted banks were not eroded, thus permitting accurate measurements to be made. Two kilometers west of Çaldıran where the scarp cuts through flat alluvial deposits, a set of intact vehicle tracks had moved 238 cm sideways (Figure 15). Also, an oxcart track had shifted 210 cm laterally to the right (Figure 18), and a water canal evidenced 206 cm lateral movement in the same direction.

Inside Çaldıran's bounds, a 250 cm lateral movement was measured on closely spaced parallel breaks formed in basaltic rock. Yağbasan, another village east of Çaldıran was the scene of a 170 cm slip in a basaltic outcrop. In an alluvial deposit at Yukarıgülderen, near the eastern extremity of the fault, the lateral displacement was of the order of 60 cm. Slightly further east of Aşağıgülderen, thsi value was 10 cm.

The following general statements apply to the lateral motion of the fault: (1) over thick alluvial formations, observable displacements showed a significant decrease, and (2) the magnitude of the lateral slip appeared to decrease toward the eastern end.

Configuration: - Figure 7 indicates that the fault break makes significant deviations from a linear path in the Eşekbatan area in the west, within and around Çaldıran in the middle, and in the Kalkandelen and Yağbasan area in the east. Where these deviations occurred, tensile cracks and compression ridges were formed in conformity with the right-lateral motion. Figure 19 is a schematic description of this event. Case A reflects a situation frequently observed to the west of Çaldıran; Figures 20 and 21 are visual examples of this effect. Case B in Figure 22 depicts the state of the ground deformation immediately east of Çaldıran where the tip of the break extending from the west turned northward and terminated. This bend naturally resulted in the formation of compression ridges as shown in Figure 22. Inasmuch as the main rupture continued for about 1 km to the north, tensile cracks, several hundred meters long, with no particular lateral slip, were observed between the two main lineaments in the north-south direction.

Although the fault scarp defines a fairly linear, single line as shown in Figures 23 and 24, on close inspection it really consisted of a large number of small scale tension cracks and compression bumps. Figure 25 depicts this situation. Perfect examples of a rightward slip could be observed along the fault in many locations. Samples in the Çaldıran plain west of the town (Figures 26 and 27) and in the snow covered eastern edge (Figures 28, 29, and 30) are textbook perfect.

Earthquake Triggered Landslides, Settlements, and Rockfalls

Landslides: - Inasmuch as the affected area is based upon stable volcanic rock formations, no large scale landslides developed. The only location where minor landslides were observed was north of Devetaş which is north of Muradiye (Figure 7).

Settlements: - Settlements were observed, especially in youthful alluvial formations in stream beds. Fills behind bridge abutments were often subject to small amounts of settlement. There were no examples of dramatic settlements and no structural failure could be related to soil instability.

Rockfalls: - Some cases of rockfalls were observed along the steep slopes of the valley through which the Muradiye-Çaldıran road passes (Figure 31). In view of the likely sites along this valley, however, the number of actual rockfalls was below the expected figure. This can perhaps be explained in terms of significant local variations in the maximum acceleration experienced at different sites.

Damage Statistics

The consequences of the November 24, 1976, earthquake in terms of the number of deaths and collapsed houses is summarized in Table 2.

STRUCTURAL DAMAGE

Local Construction Practice

From the viewpoint of structural engineering, the event of November 24, 1976, did not provide a test case for the assessment of the relative merits of either structural systems or codes. The reason is the paucity of engineered construction in the area. Within the obvious limitations of a single drawing, an artist's rendering of the typical rural dwelling in the Muradiye-Çaldıran area is shown in Figure 32 [Arioğlu and Anadol (1977)]. Indeed, there were almost no buildings, in any of the hundreds of villages affected by the earthquake, other than variations of the general type shown in this figure. Çaldıran, being a sub-district center, contained several buildings of more than a single storey, one of which was reinforced concrete; Muradiye had even more. The "average" person in either center, however, was likely to live in a dwelling unit consisting of a few rooms, with thick rubble masonry walls and mud mortar binding. Quite often, a layer of adobe is placed on the outside of the rubble walls to give a smooth-finish appearance to the building. Lack of forest products or brick, adverse climatic conditions necessitating a flat and heavy earth roof supported by unworked poplar tree trunks, absence of qualified construction people, and economic hardship all combined to produce the scene in Figure 33, essentially the remains of the residential section of Çaldıran. An individual sample is provided in Figure 34.

Experience with previous earthquakes in eastern Turkey [e.g., Varto (1966), M = 6.8; Lice (1975), M = 6.9; Earthquake Research Institute (1967, 1976)] indicated that the typical rural dwelling will be heavily damaged or collapse, even when the local effects of the grond shaking produce an intensity rating of VI MM. The total destruction of Çaldıran where the intensity was judged to be IX due to a nearby magnitude-7.3 earthquake is therefore not totally surprising.

Military complexex and government buildings housing functions such as local administration and mail and health services had had engineering planning and supervision in their construction. Although such buildings clearly constitute a minority, a meaningful discussion of the severity of ground shaking at different localities can only be made in terms of their behavior. These official buildings were constructed of either reinforced concrete or brick masonry, but the quality of workmanship and materials often exhibited significant variations. The following list is a selective description of the behavior of several of the more important structures in each category. The assessments made are qualitative in nature and constitute reasonable bounds of their earthquake response based on keen hindsight.

Reinforced Concrete Structures

The Mobile Gendarmerie Platoon Building, Çaldıran: - This two-storey structure served as the base of the military unit in Çaldıran and was located on loose topsoil approximately 100 m from the fault rupture traversing the town. The T-shaped building contained the sleeping and general services quarters in the rear portion; official business was conducted in the front half (Figure 35). If reinforced concrete design philosophy is geared against total collapse and no deaths in case of "very strong" earthquakes, this building fulfilled those functions. The filler walls were unreinforced, hollow concrete block, ordinarily very weak and brittle when subjected to in-plane loads. The inside of the building was a shambles, but sign of structural distress were limited to the upper ends of some columns in both stories. The stiffness effect of the filler walls apparently created a condition in which no single column was overly stressed. In zones of obvious force concentration, such as beam-column joints with filler panel walls, there were cases of shear failure (Figures 36, 37, and 38), but as a whole, the building was essentially intact. Circles in Figure 35 indicate the directions in which the following three photographs were taken. In spite of its unfortunate proximity to a capable fault, this building was judged to be repairable after the earthquake.

Local Government Services Building, Muradiye: - A general view of the basement-plus-two-storey structure is provided in Figure 39. Filler walls were again concrete block tiles which appeared to have worked loose from the main structural system during vibration (Figure 40), allowing the reinforced concrete frame to be easily identified. There was no damage to the component stone masonry walls of the basement level. Walls parallel to the long axis of the building in the other floor levels were surprisingly free of diagonal cracking related to in-plane forces. This probably related more to the nominal bond between the structural framing and the walls than to the direction in which vibrations took place. The plan of the building was simple: there were twelve column lines in the long (north-south) direction, with a window opening between each as shown in Figure 40, and four in the short direction.

The overall quality of materials and workmanship in this building appeared to be poorer than the military building in Çaldıran. Hinging had been initiated at the ends of columns in the second storey facing north (Figure 41), and a panel wall had toppled outward (Figure 42). An interior column which had failed in shear on the next column line adjacent to a chimney conduit appeared to have no transvers reinforcement (Figure 43).

Other Buildings in Muradiye: - Several other reinforced concrete structures in Muradiye generally faired well and there was no major failure in any of them. The district gendarmerie building, a two-storey structure shown in Figure 44 lost its chimneys, but there was no evidence of significant structural distress. A brick masonry version of the same building built according to the same plan had collapsed during the 1975 Lice earthquake [Earthquake Research Institute (1976)] . The single storey, trading store buildings built at the foot of the Muradiye Fort, from which the picture in Figure 45 was taken (the rear of the district gendarmerie building is visible in the upper right side), showed no evidence of even small amounts of cracking in structural elements.

The two-storey, brick walled, Agriculture Bank building (Figure 46) located opposite the government building also performed quite well, although a cantilevered portion on the northern face showed signs of excessive sagging (Figure 47). A four storey bank employees' housing building next to the bank (Figure 48) also remained intact and serviceable immediately after the earthquake. It is to be noted that a traditional structure adjacent to this building suffered total collapse (right of Figure 48). The post office building shown in Figure 49 is on the same side of the main road; is showed no evidence of having been subjected to severe ground motion, The meteorological observations building shown in Figure 50 had a penthouse-like appendage, stiffened by brick walls, on top of the ground storey. Although concrete quality was visibly poor and contained large pieces of aggregate, the structural framing system had enough strength to withstand the dynamic forces created during the earthquake.

The following generalizations can be made with respect to reinforced concrete structures in Çaldıran and Muradiye: average-to-poor concrete quality and workmanship notwithstanding, no reinforced concrete building in either town collapsed. Although the two-storey military building in Çaldıran was practically on the fault rupture which gave rise to the 7.3-magnitude earthquake, it did not contain a significant number of individual structural element failures. Viewed as a whole, it also did not seem irreparably damaged. Whether the survival of this and other buildings in Muradiye was the result simply of good luck cannot be answered without detailed analyses. Nevertheless, the fact that reinforced concrete structures with two to four stories founded on different soil formations all did well suggests that either the severity of the ground motion was not as high as one would expect in a comparably sized earthquake or that the capacity of the structure was larger than might be expected.

Brick or Stone Masonry Structures

Officers' Housing, Çaldıran: - This three-storey building served as the lodging for the officers of the mobile gendarmerie unit. It was reported to have been completed a few months before the earthquake, and was located a few hundred meters to the east of the military building. This building also showed no outward sign of excessive structural distress (Figure 51) in spite of its closeness to the fault line. Inspection of the staircase area did not indicate significant cracking in the reinforced concrete slab, but it was not possible to inspect the rest of the building from the inside as the individual apartments had been vacated and were locked.

Two single-story dwellings for non-commissioned officers fared badly (Figures 52 and 53). The walls were hollow concrete block and a reinforced concrete slab underneath corrugated metal roofing material served as the ceiling.

Post Office Building, Çaldıran: - Located partially on an artificial embankment held in check by stone walls around the garden perimeter, the two-storey brick masonry building suffered heavy damage (see Figures 54 and 55). There were large settlements of the loose material and the eastern face of the building had tilted because of these settlements. Corners of the building subjected to force concentrations had fallen away leaving conical openings. The state of the structure four days after the main event suggested that collapse could become imminent during a fairly strong aftershock.

Health Center, Çaldıran: - The one-storey concrete-block health center which served as the local hospital was located on alluvial deposits close to a small stream passing from the south of the town. The center and the adjacent lodging unit for its personnel both suffered heavy damage. Figure 56 depicts the health center after the earthquake. Naturally, no relief or care for the injured could proceed in the building; being an essential facility, it should have remained functional.

Government Employees' Housing Muradiye: - This three-storey brick masonry building, very similar to the officers' lodging building in Çaldıran shown in Figure 51, suffered far greater damage in spite of the fact that the intensity rating for Muradiye was judged to be two units less. Figure 57 shows a general view of the building. Shear failure in the upper ends of the brick wall panels of the ground floor destroyed structural continuity, as shown in Figure 58. A second floor balcony turned downward a full right angle and its parapet wall fell on the balcony below (Figure 59). The poor behavior of this building can be partially explained in terms of the excessive openings for windows (see Figure 58). Single-storey units nearby, built reportedly in 1946 for government employees, came through without damage (Figure 60).

High School and Junior High School, Muradiye: - Both of these schools were built as two-storey brick masonry units. Some two-directional diagonal cracking developed between the window openings in the high school building (Figure 61); its roof was observed to have shifted slightly toward the east. Although inclined cracks joined at the corners, no gaping holes were formed. The junior high school building immediately on the back showed similar behavior and was judged to be in no danger of collapse.

Stone Masonry House, Muradiye: - A one-storey stone masonry house built with angular stone pieces held together by cement mortar and reinforced by horizontal timber lintels came through in perfect shape (Figure 62). Although the more common samples of local construction around it collapsed, these simple precautions were apparently sufficient to save this house from destruction. This observation has been made time and time again after earthquakes in Turkey.

Glossing over individual differences in the behavior of masonry buildings in the area, the following general statements may be made. Because of their lower strength, brick or concrete block masonry units performed more poorly than reinforced concrete structures. Even nominal observance of basic requirements with respect to architectural layout, materials, and workmanship was often the deciding factor with respect to the binary collapse or no collapse condition of the structure. The survival of the three-storey officers' lodging in Çaldıran is difficult to explain in terms of available attenuation relations and observed behavior of other similar buildings in the area.

Engineered Structures

Several industrial buildings in Van were not affected by the earthquake. The absence of any industry in Çaldiran or Muradiye and the lack of large civil structures, such as dams or large bridges, in the epicentral region confined the adverse effects of ground shaking almost totally to dwellings. A very short span, reinforced concrete bridge in Caldıran and culverts on the Muradiye-Çaldıran road were observed not to have been affected at all. On the southern backfill of a reinforced concrete bridge on the Van-Erciş highway crossing over the Bendimahi river (Figure 6), tension cracks had formed (Figure 63). Also, the southern abutment had rotated slightly, but whether this rotation occurred during the earthquake or was the product of long-term settlements could not be determined. The superstructure of the bridge was otherwise intact.

SUMMARY AND CONCLUSIONS

The Earthquake

On November 24, 1976, a 7.3-magnitude earthquake associated with surface fault rupture of approximately 55 km completely devasted the town of Çaldıran and some hundred villages closely spaced along the fault trace within the provincial bounds of Van in eastern Turkey. Intensity of ground motion was IX (MSK) in Çaldıran and VII in Muradiye, a larger district center some 25 km from the epicenter. Damage in Muradiye was also heavy, particularly in the traditional dwelling units whose poor behavior took a significant toll of human lives during many previous earthquakes in eastern Turkey. About 9,000 homes either collapsed or were declared unrepairable. The number of dead approached 4,000.

There were no direct measurement of the ground motion in Çaldıran or Muradiye. However, a strong motion accelerograph located on lake deposits in Van, 100 km from the epicenter, and another founded on "stiff" soil in Ağri at a similar distance were triggered into recording. A seismoscope record, not yet reduced, taken in Van may give an indication of the "predominant" sense of the motion and the displacement maxima.

Judging very crudely on the basis of damage to engineered and non-engineered structures, it would appear that the severity of the ground motion was not as great as would be predicted for a 7.3-magnitude event. The distribution of damage in villages where the quality of construction is approximately uniform seems to indicate that the attenuation of the ground motion in the east-west direction was less rapid than in the north-south direction.

Tectonic Features

The causative fault of the November 24, 1976, earthquake had not previously been identified on tectonic maps of Turkey. Geologically, the affected area is underlain by volcanic formations which have been discharged from several youthful volcanoes in the region. Based on the present state of knowledge on the tectonics of eastern Turkey, it cannot be definitely established whether the recent right-lateral fault rupture is a continuation of the North Anatolian Fault system or is solitary extension of the fault systems in western Iran.

The surface fault, which was exceptionally straight in configuration, could be visually traced for about 55 km. There were measured lateral displacements of more than 2 m in the western half of the approximately east-west trending rupture. However, toward the east, the magnitude of the lateral slip was noticeably less. Vertical displacements were much less in magnitude and there was no consistency in the sense of the movement.

Structural Damage

The "traditional" type of dwelling in the area, a sketch of which is shown in Figure 32, has almost no resistance to lateral loads. In Çaldıran and the villages in the immediate vicinity of the fault rupture these buildings collapsed totally and caused bu far the largest number of deaths. A two-storey reinforced concrete building in Caldıran serving as the headquarters of the local military unit survived the earthquake with some structural damage but was in no danger of collapse. Considering the proximity of this building to the fault and the fact that it was not designed particularly against earthquake effects, its survival points to the advantages of well-designed reinforced concrete structures for the saving of human lives. Other reinforced concrete structures in Muradiye also exhibited similar behavior. Masonry buildings showed a more erratic damage distribution. For example, a three-storey building in Çaldıran, only a few hundred meters away from the fault trace, showed no outward signs of structural distress, while a very similar building in Muradiye, 25 km to the south, suffered significant damage. The scarcity of a large number of engineered buildings in the area makes it difficult to derive lessons of structural importance from the earthquake effects.

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Table 1

Catalogue of Earthquakes within a 100 km Radius of Çaldıran
1900 - 1973, M 4.2

Date D	M	Y	Epicentral Coordinates (N-E)	h(km)	M
13	9	1900	38.47 - 43.30	-	5.1
-	3	1901	39.53 - 44.10	-	4.5
-	-	1902	39.00 - 43.30	-	5.1
1904/1905			38.74 - 43.35	-	5.1
-	-	1906	38.80 - 43.40	-	5.1
31	3	1907	39.10 - 42.90	-	4.9
-	-	1914	39.93 - 44.00	-	4.5
-	-	1916	39.95 - 43.70	-	5.1
3	8	1930	38.46 - 44.70	80	5.0
21	5	1931	39.00 - 44.50	-	4.2
-	-	1933	38.66 - 44.00	-	5.1
6	11	1933	38.68 - 43.85	10	5.5
19	4	1935	39.60 - 43.10	-	4.9
18	8	1935	39.60 - 43.10	-	5.0
1	5	1936	39.60 - 43.10	-	5.6
2	5	1936	39.80 - 43.50	-	5.0
18	10	1940	38.57 - 44.30	20	5.5
28	10	1940	39.04 - 44.17	50	5.0
9	9	1941	39.24 - 42.85	-	5.2
10	9	1941	39.45 - 43.32	20	5.9
13	9	1941	39.70 - 43.00	-	4.9
14	9	1941	39.70 - 43.00	-	4.9
15	9	1941	39.70 - 43.00	-	4.9
15	1	1945	38.75 - 43.89	10	5.1
11	7	1945	38.80 - 43.30	-	4.6
21	7	1945	38.41 - 43.76	60	4.9
9	8	1945	38.80 - 43.30	-	4.9
12	8	1945	38.80 - 43.00	-	4.9
-	9	1945	39.00 - 43.30	-	5.8

Table 1 (Continued)

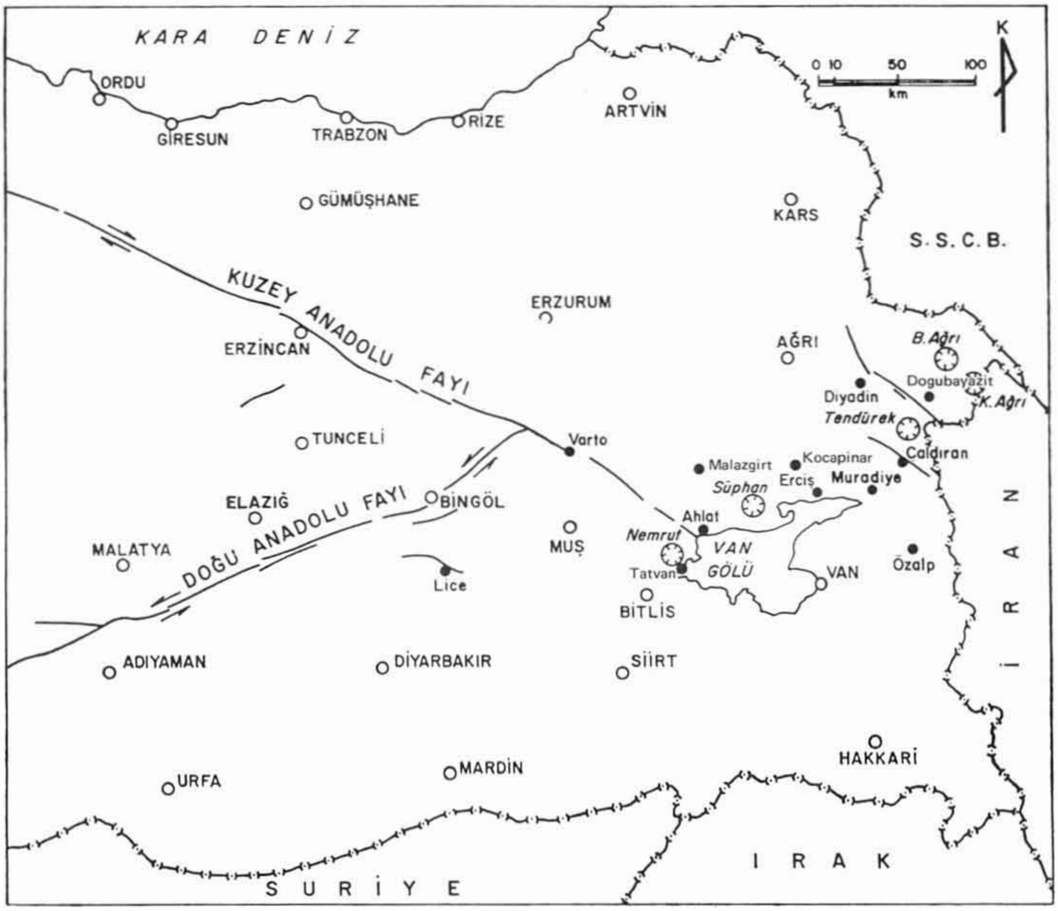
Catalogue of Earthquakes within a 100 km Radius of Çaldıran
1900 - 1973, M 4.2

Date D	M	Y	Epicentral Coordinates (N-E)	h(km)	M
20	10	1945	39.00 - 43.00	-	5.0
20	11	1945	38.63 - 43.33	10	5.5
15	12	1945	38.80 - 43.30	-	4.3
3	10	1946	39.50 - 44.12	50	4.9
28	12	1946	39.00 - 43.30	-	4.3
2	9	1948	38.50 - 43.30	-	4.3
15	3	1951	38.40 - 44.00	-	4.8
3	9	1952	39.00 - 43.00	-	5.5
30	9	1952	38.91 - 44.09	10	5.0
9	1	1955	38.50 - 43.90	-	4.5
28	4	1958	39.31 - 44.78	40	4.4
1	6	1962	38.50 - 43.30	-	4.3
19	4	1962	38.74 - 44.19	40	4.7
4	9	1962	39.96 - 44.13	40	5.3
16	9	1962	39.90 - 44.00	-	4.3
21	11	1962	39.90 - 44.00	-	5.2
3	12	1962	39.90 - 44.00	-	4.6
5	6	1964	39.13 - 43.19	42	4.6
17	5	1967	38.69 - 44.29	54	4.7
29	4	1968	39.24 - 44.23	17	5.7
17	2	1970	38.65 - 43.36	47	4.6
1	3	1970	39.10 - 44.50	-	4.2
14	3	1970	39.10 - 44.50	-	4.2
21	9	1971	38.60 - 44.14	17	4.3

Table 2

Damage Statistics, 24 November 1976 Earthquake

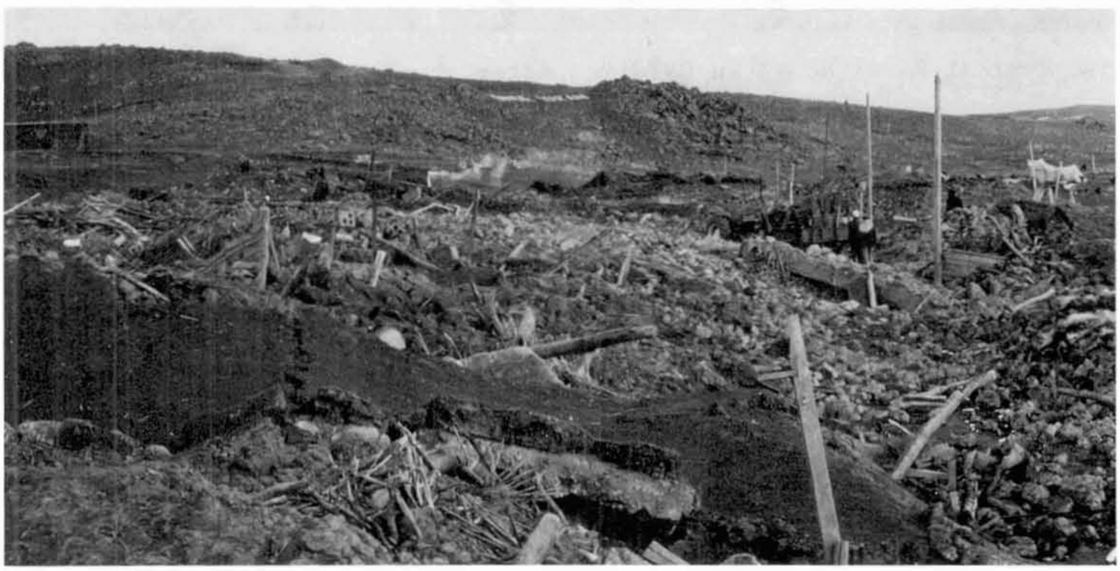
Locality	Total Population	Number of Deaths	Number of Dwellings	Damaged Buildings Total Collapse	Partial Damage
Çaldıran	3,304	615	532	505	27
Çaldıran Villages (24)	27,587	2,313	4,045	3,327	642
Muradiye	6,753	159	561	470	87
Muradiye Villages (37)	22,654	479	2,940	1,593	847
Erciş and 11 Districs	24,143	3	3,563	771	1,802
Ercis Villages (33)	19,647	31	2,573	751	1,198
Deliçay and 14 Villages	9,406	87	1,298	614	428
Kocapınar and 30 Villages	15,976	-	1,943	77	1,247
Özalp and 29 Villages	18,357	19	2,324	202	1,723
Timar and 7 Villages	3,329	3	413	35	290
Diyarbakır (Ağrı) and 28 Villages	22,448	121	2,773	795	1,597
Taşliçay (Ağrı) and 12 Villages	5,630	-	701	86	262
Doğubeyazıt (Ağrı) and 2 Villages	1,500	-	190	6	25
TOTAL	180,761	3,840	23,856	9,232	10,175



1. Major Faults in Eastern Turkey

2. View of Van, Looking Southwest

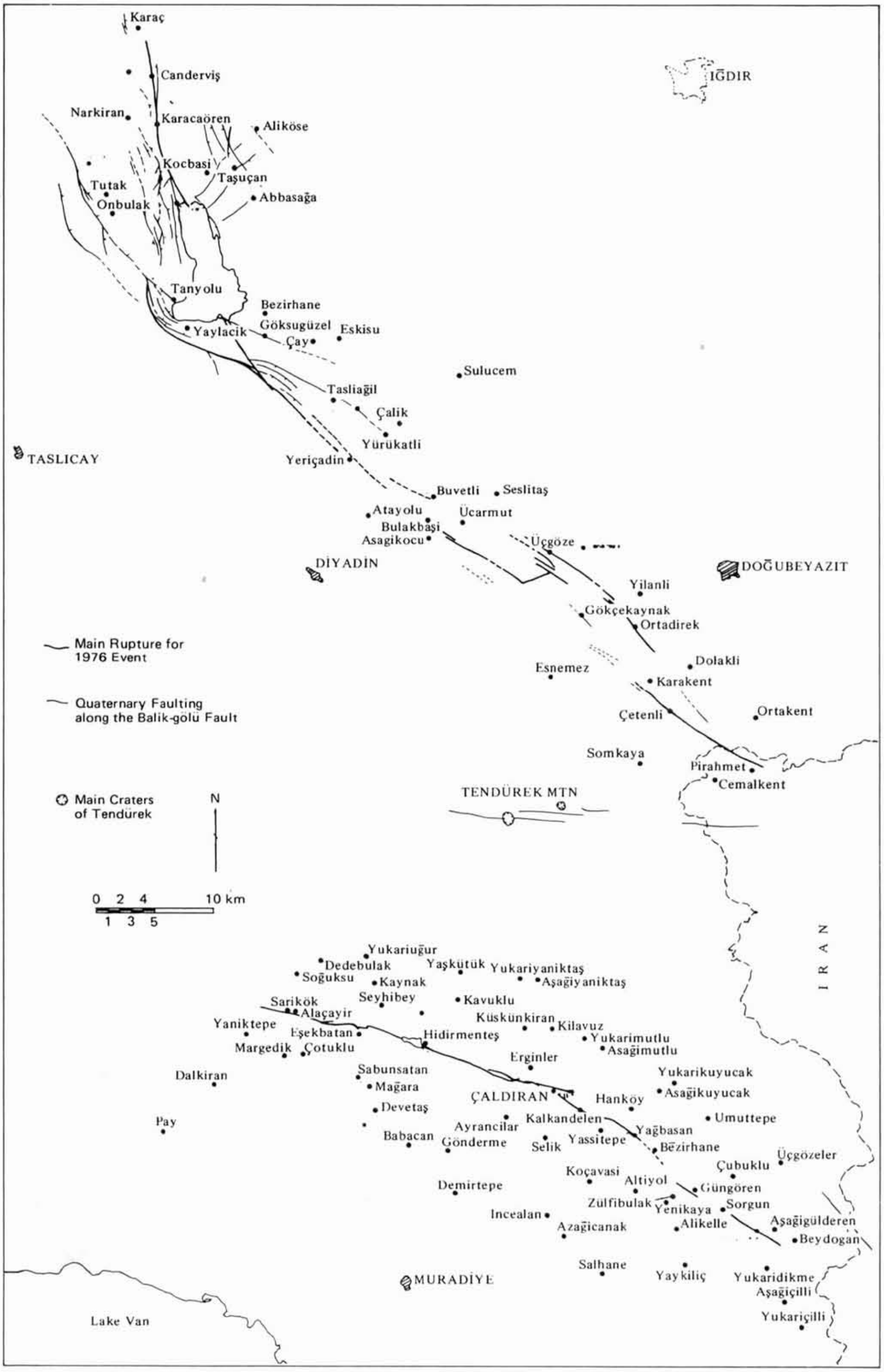
3. View of Muradiye, Looking Southeast



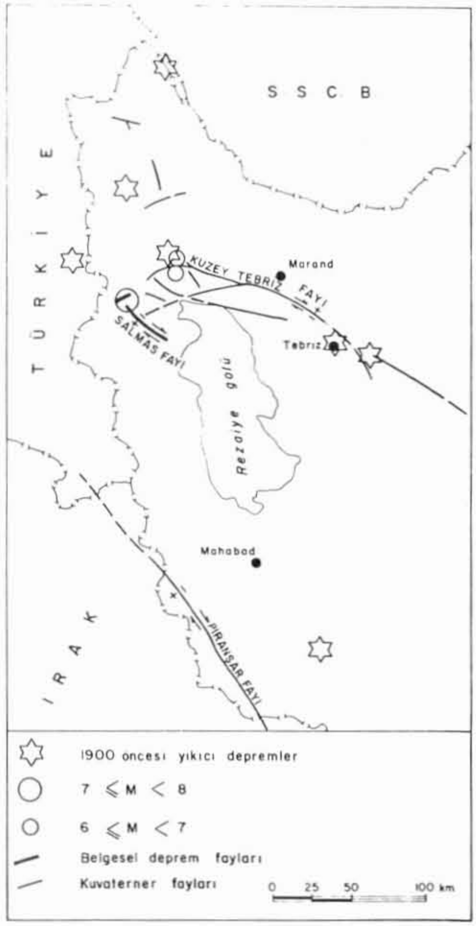
4. View of Çaldıran, Looking Northwest

5. Typical Rural House in Çaldıran after the Earthquake

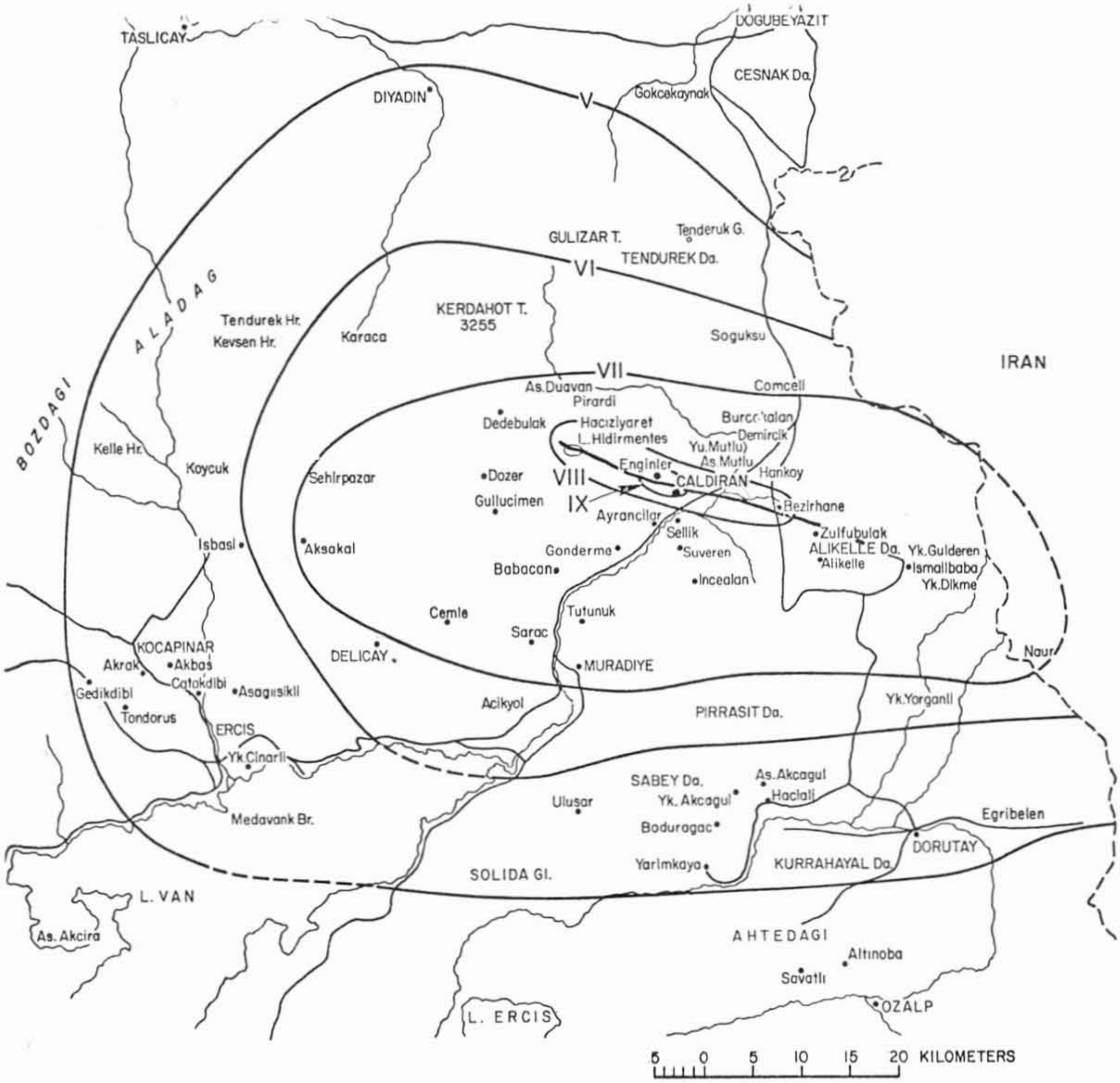
6. Physiography of Van Province



7. Çaldıran and Balık Gölü Faults



8. Active Faults in Western Iran

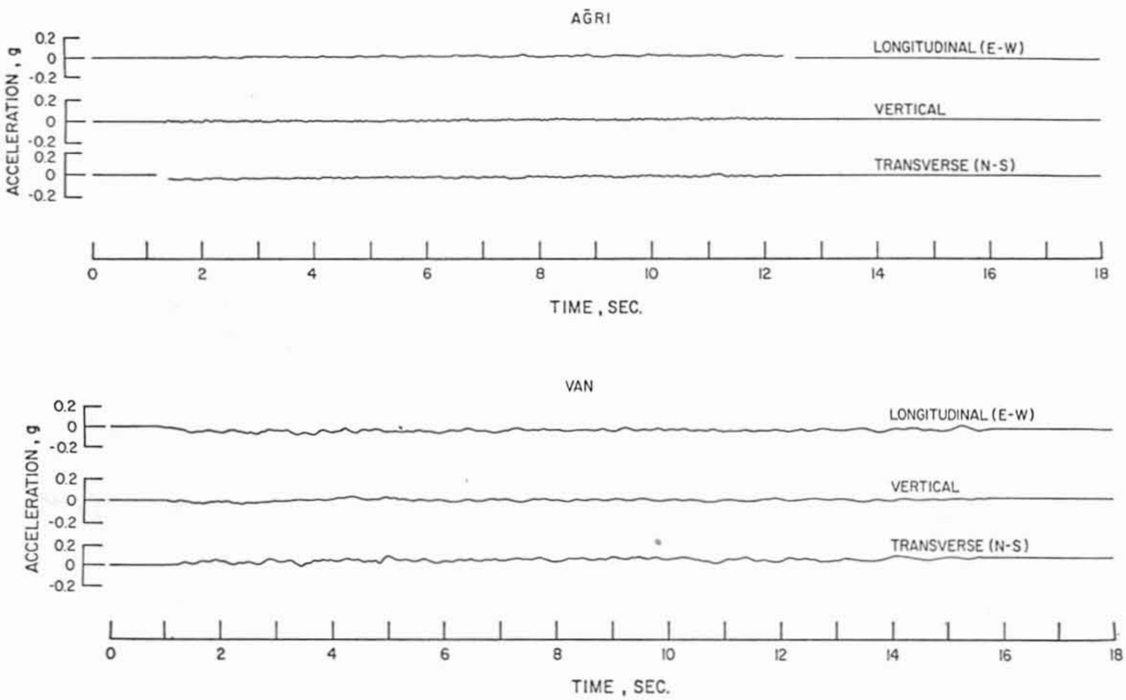


9. Isoseismal Map of the Muradiye-Çaldıran Earthquake

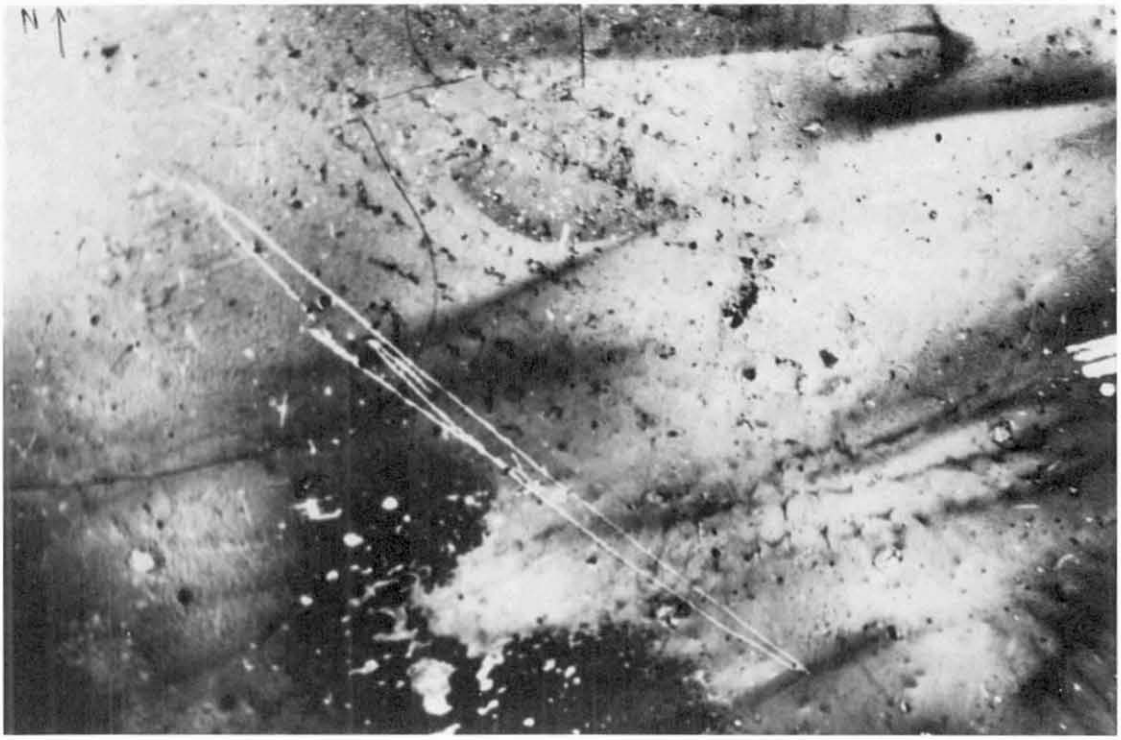
10. Rubble Wall 30 km from Epicenter

11. Surviving Adobe Dwelling in Çaldıran

12. Surviving Rubble Masonry Shed in Çaldıran



13. Accelerograph Records, (a) Van, (b) Ağrı



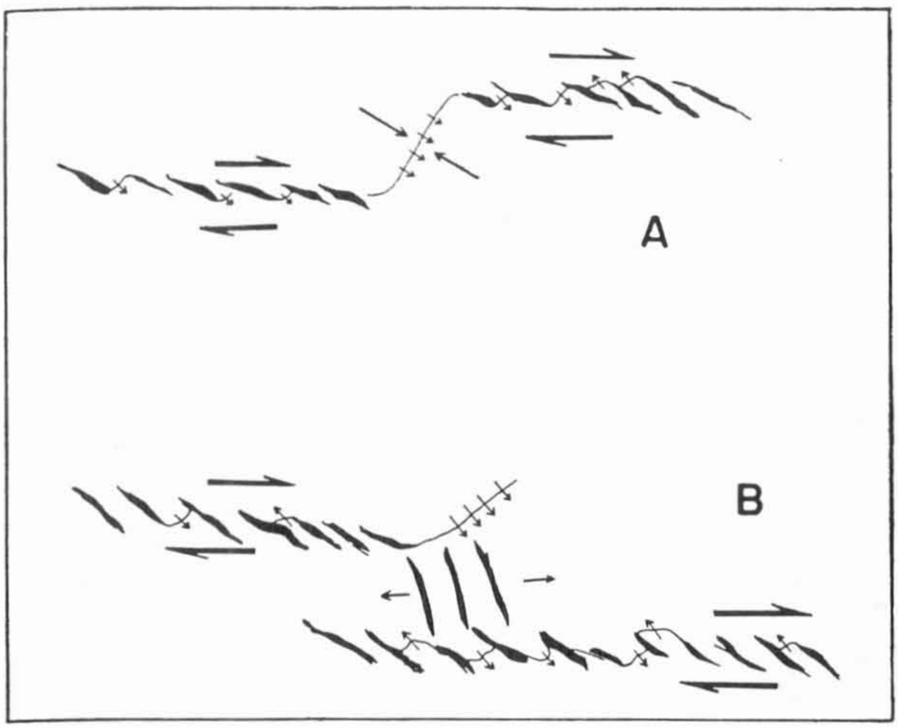
14. Seismoscope Record Taken in Van

15. Roadway Displaced 238 cm, 2 km West of Çaldıran

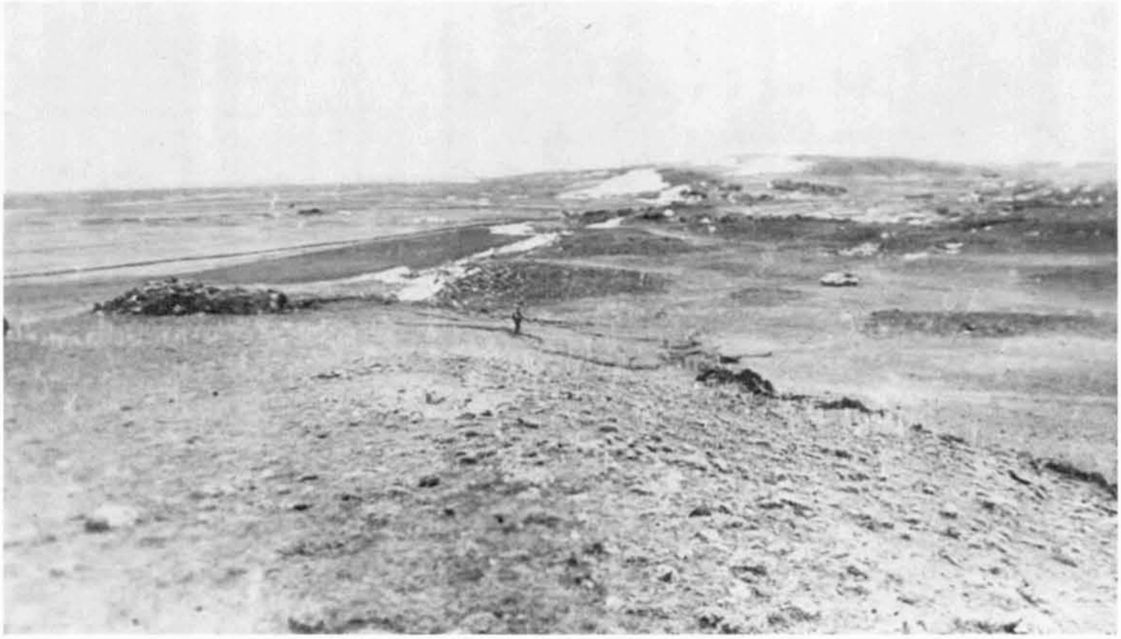
16. Stream Bed Displaced 230 cm, 1.5 km East of Alaçayır

17. Water Trench Displaced 206 cm, 1.5 km West of Çaldıran

18. Oxcart Tracks Displaced 210 cm, 2 km West of Çaldıran



19. Schematic Description of Local Ground Deformation

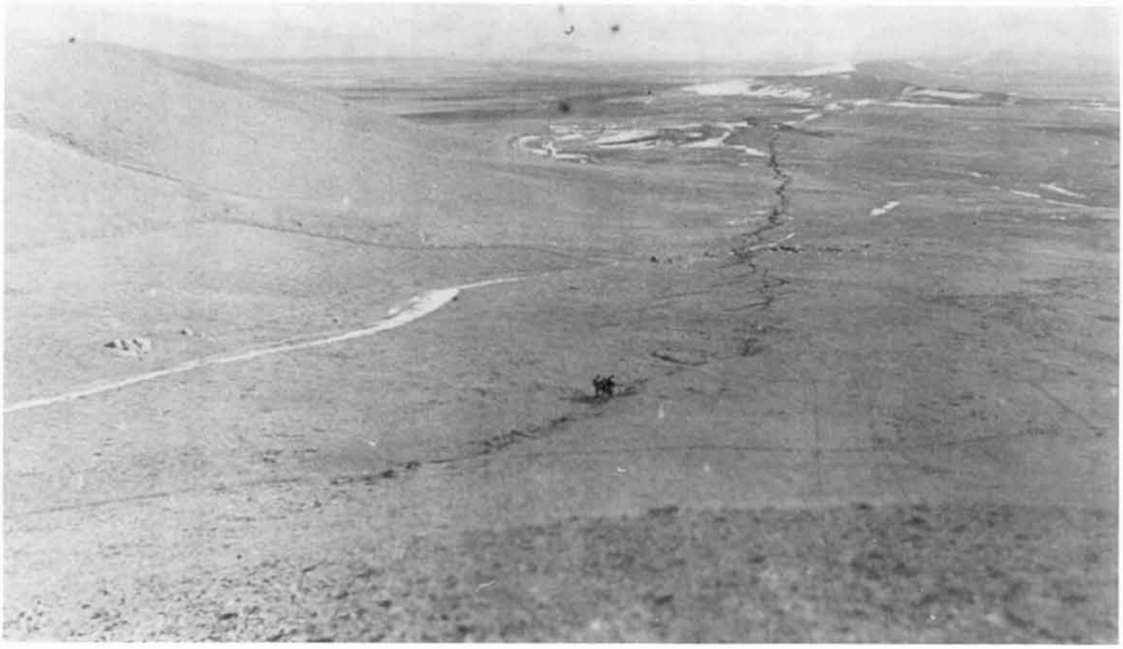


20. Compression Ridge 500m West of Çaldıran

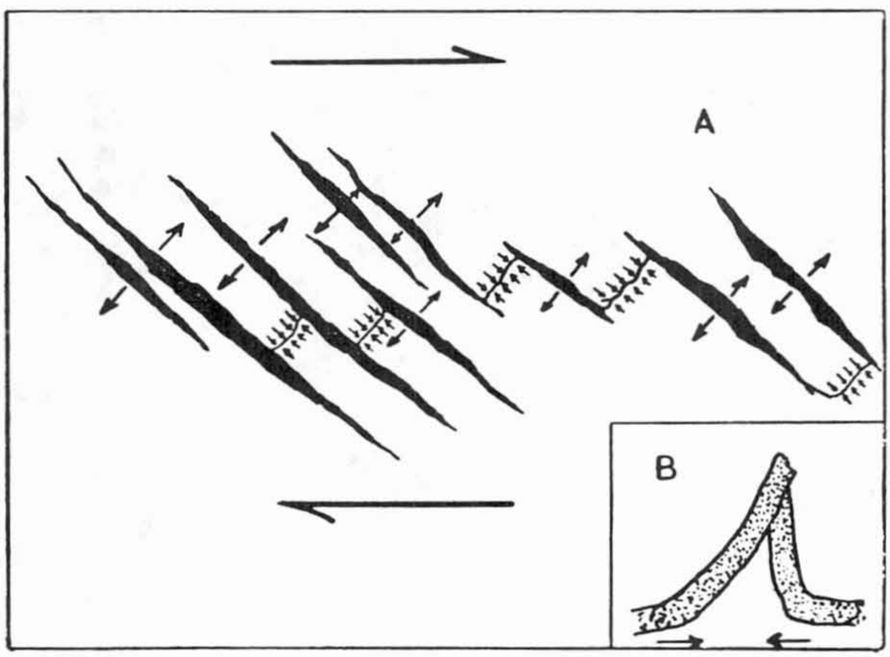
21. Compression Ridge 2 km West of Çaldıran

22. Compression Ridge 1.5 km East of Çaldıran

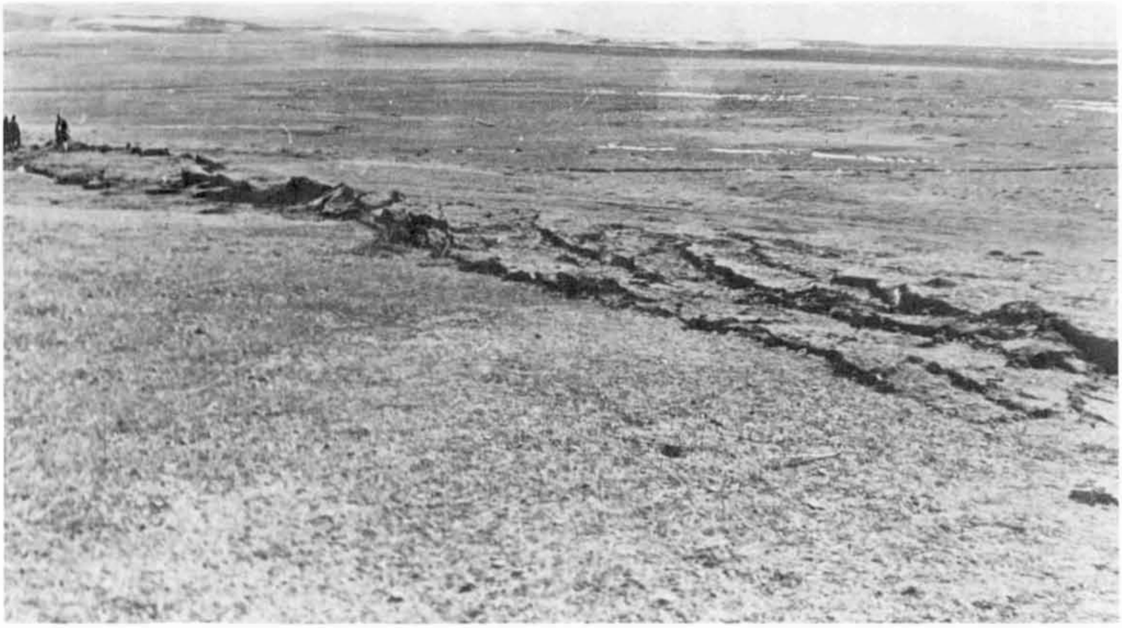
23. Fault Scarp between Eşekbatan and Alaçayır



24. Fault Scarp 3 km West of Çaldıran, View to the East



25. Tension Cracks and Compression Bumps, (a) Plan, (b) Elevation



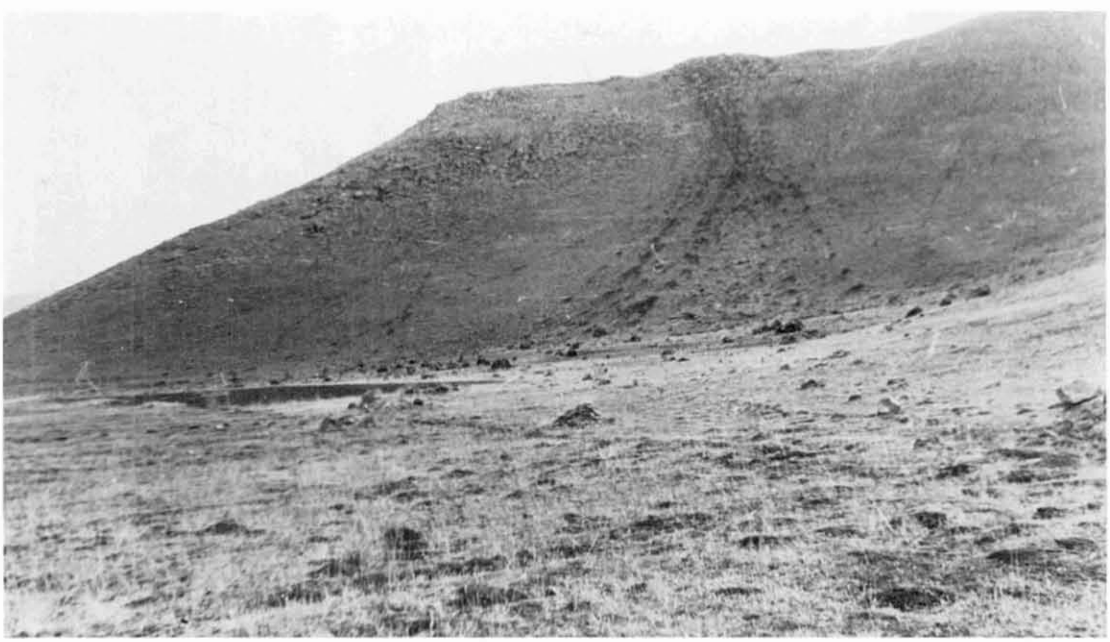
26. Fault Scarp 2 km West of Çaldıran, Looking Southeast

27. Fault Scarp 2.5 km West of Çaldıran, Looking West

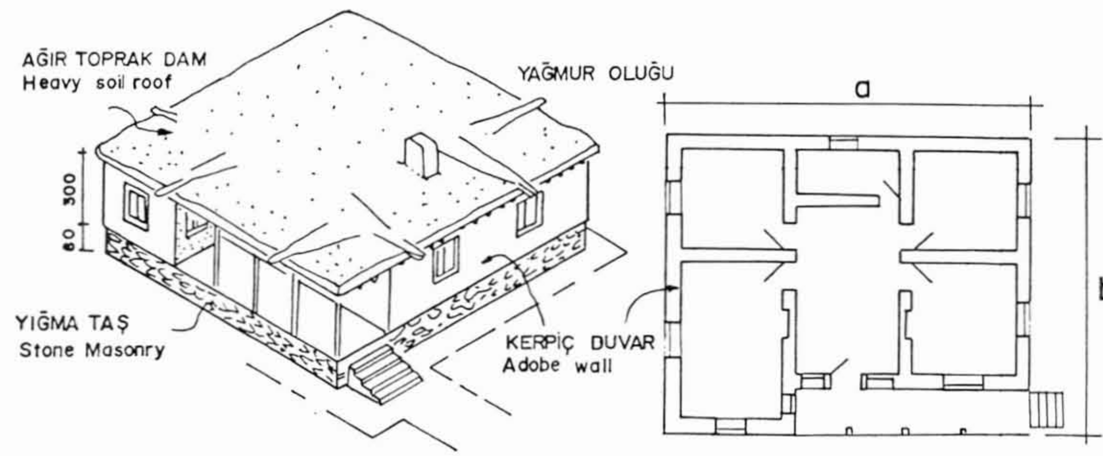
28. Fault Scarp East of Alaçayır, Looking West

29. Fault Scarp 1 km East of Figure 28, Looking South

30. Close-up View of Compression Ridge (Compare with Figure 25)



31. Rockfalls Visible from the Muradiye-Çaldıran Road

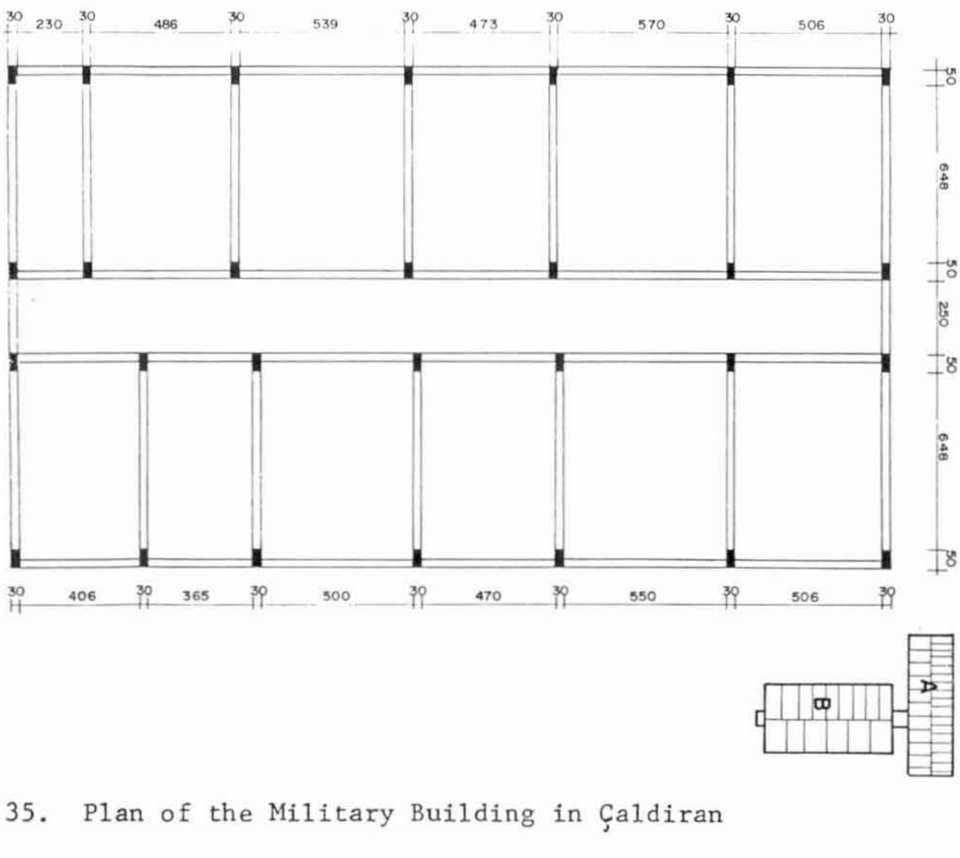


ŞEKİL TİPİK BÖLGESEL YAPI
TYPICAL DWELLING IN THE REGION

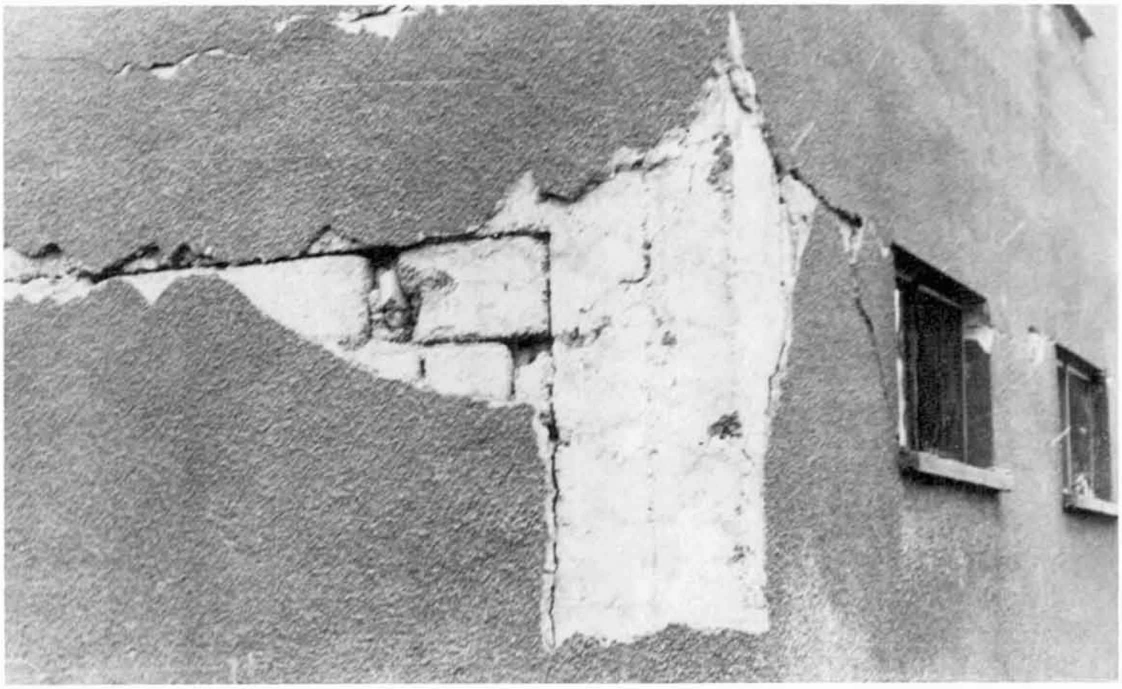
32. Typical Rural Dwelling

33. Caldıran after the Earthquake

34. Collapsed Dwelling, Çaldıran

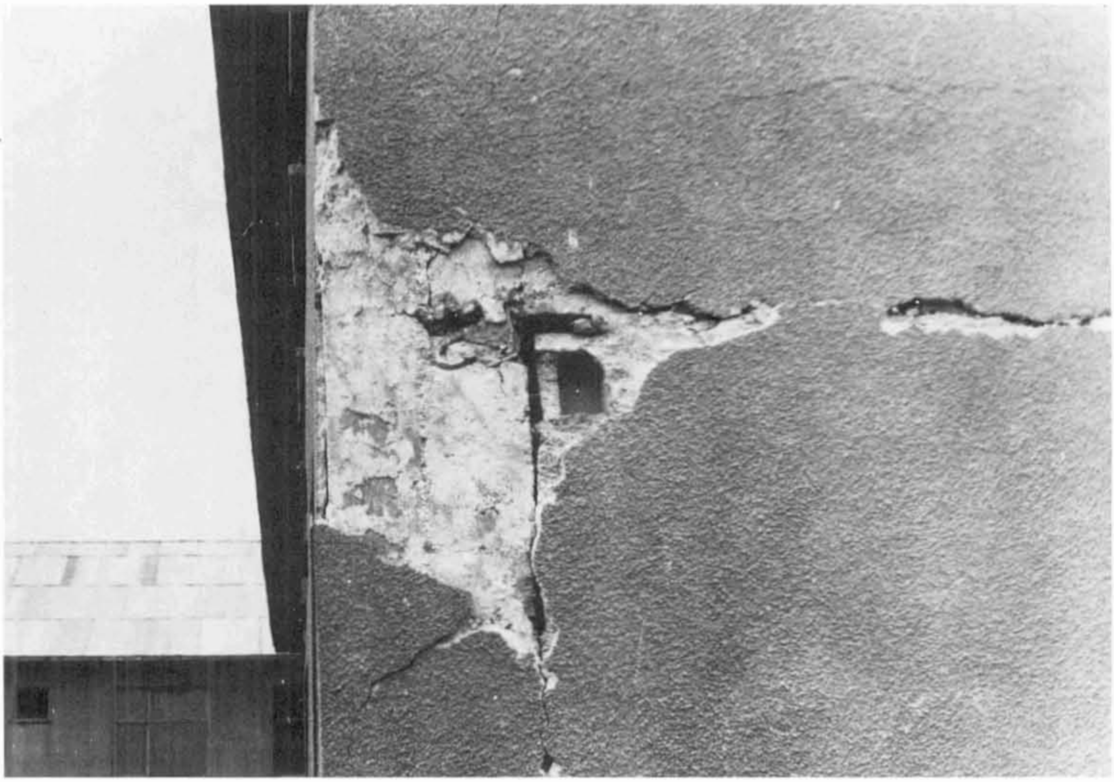


35. Plan of the Military Building in Çaldiran



36. Column Damage in the Military Building

37. Column Damage in the Military Building



38. Column Damage in the Military Building

39. Government Services Building, Muradiye

40. Government Services Building, Muradiye

41. Second-Storey Column, Government Building, Southwest Corner

42. Second-Floor Wall, Government Building, North Face

43. Interior Column, Government Building

44. Gendarmerie Building, Muradiye

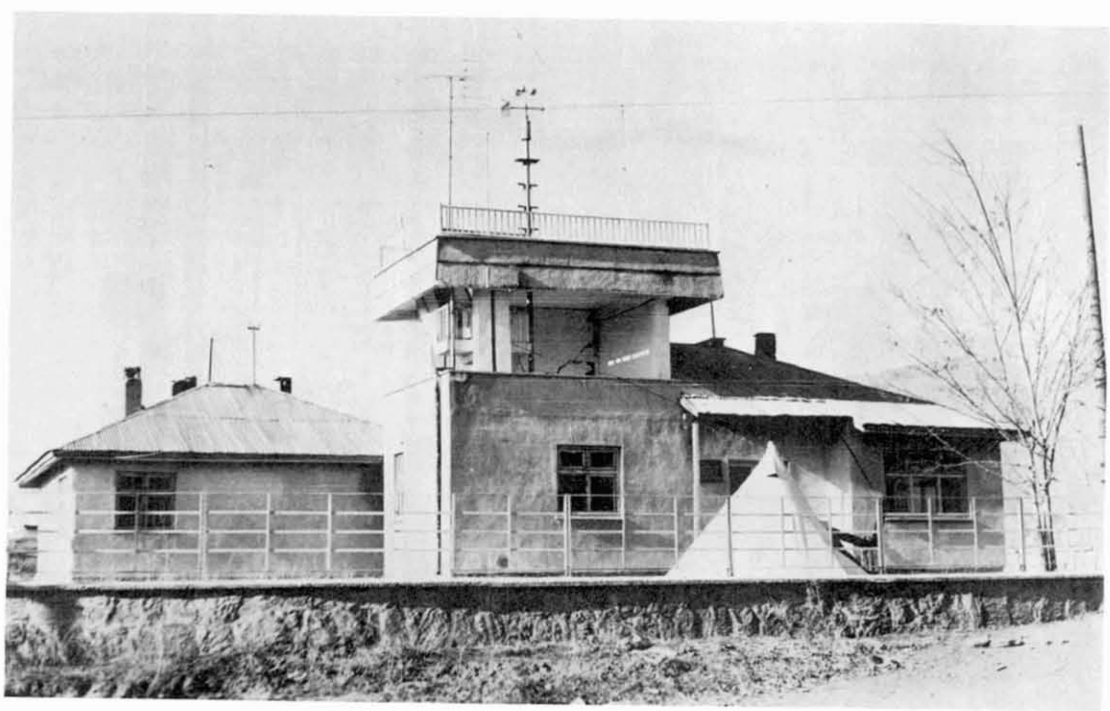
45. Trade Buildings, Muradiye

46. Agriculture Bank, Muradiye

47. Agriculture Bank, Crack in North Face Cantilever

48. Bank Employees' Lodging, Muradiye

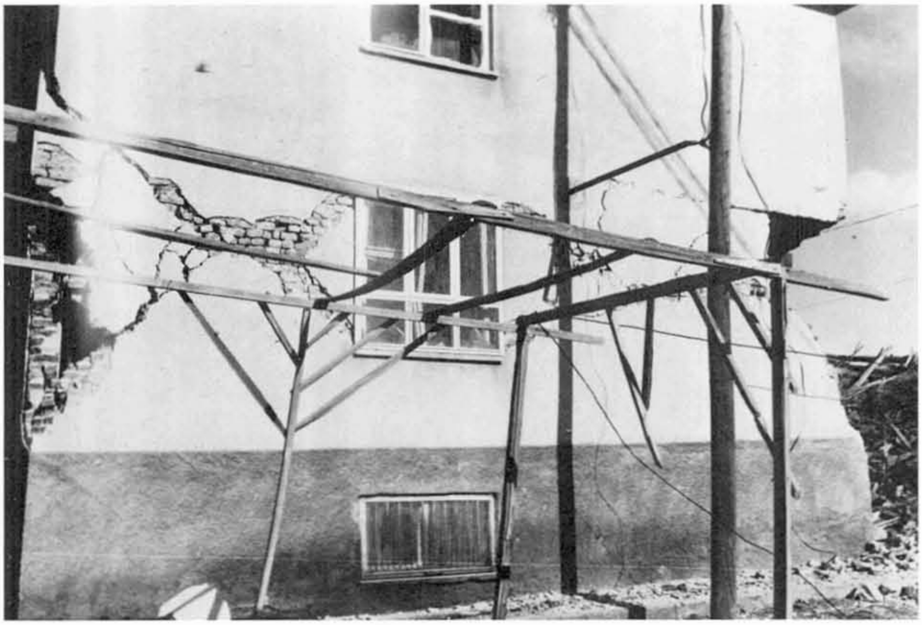
49. Post Office, Muradiye



50. Meteorological Building, Muradiye

51. Officers' Housing, Çaldıran

52. One-Storey Officers' Housing, Çaldıran



53. One-Storey Officers' Housing, Çaldıran

54. Post Office, Çaldıran

55. Wall in Front of Post Office, Çaldıran

56. Health Center, Çaldıran

57. Government Employees' Lodging, Muradiye

58. First-Storey Wall Panels of Employees' Lodging, Muradiye

59. Failed Balcony, Employees' Lodging, Muradiye

60. Single-Storey Employees' Buildings, Muradiye

61. High School, Muradiye

62. Stone Masonry Store Building, Muradiye

63. Settled Bridge Embankment