TECHNICAL COMMUNICATION:
THE LICE, TURKEY, EARTHQUAKE OF SEPTEMBER 6, 1975
(RECONNAISANCE REPORT)

by

Peter I. Yanev

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URS/Blume

URS/John A. Blume & Associates, Engineers

130 Jessie Street (at New Montgomery)
San Francisco, California 94105 (415) 397-2525

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ACKNOWLEDGMENTS

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INTRODUCTION

On September 6, 1975, a destructive earthquake occurred near the town of Lice (pronounced Lee' juh), about 75 kilometers north northeast of Diarbakir, eastern Anatolia, Turkey (Figure 1). Initial newspaper reports indicated a magnitude of about 6.8 on the Richter scale and fatalities exceeding 1,000. At that time I was in London, en route to represent URS/John A. Blume & Associates, Engineers (URS/Blume), at the Fifth European Conference on Earthquake Engineering (5ECEE), held September 22 through 25 in Istanbul, Turkey. Although news reports in London were very sketchy, they were sufficient to indicate that the structural engineering lessons of the shock would be limited but of interest.

Upon arrival in Istanbul, Mr. Behram Gonen (of URS/Blume) introduced me to several officials and engineers in the Ministry of Reconstruction and Resettlement (MRR) and its Earthquake Research Institute (ERI). The MRR and ERI arranged a special trip to the earthquake disaster area and described the current efforts of the government of Turkey in earthquake engineering and public education concerning earthquakes and the various remedial measures for construction.

On September 30, 1975, about three and one-half weeks after the earthquake, our party of four -- Mr. Nejat Buyülke, of the ERI; Ms. Inger Norell, representing the government of Sweden; Mr. Juhani Lindfors, an engineer with the Puutalo Sales Association of Helsinki, Finland; and myself -- visited the stricken area. After a two-hour drive north of Diarbakir, we reached the towns of Lice and Hani and surveyed most of the structural damage there. Lack of time prevented us from investigating any of the ground effects, except the many rockfalls and landslides that dotted the countryside and that had caused many casualties. Roads in the area were good; most were paved and others were improved and well graded, although roads to the many affected villages are apparently less suitable for automobiles.

FIGURE 1 MAP OF TURKEY SHOWING LICE, HANI, AND DIARBAKIR.

THE REGION

The epicentral region and most of the damaged area, which experienced Modified Mercalli intensities of V or greater, are in the province of Diarbakir, eastern Anatolia. The city of Diarbakir has a population of over 160,000 and is located on the river Tigris, on one of the historically important trade routes between Europe, the Middle East, and Asia.

The epicenter of the September 6, 1975, earthquake has tentatively been located near Lice (see Figure 2), which, with a population of 8,200 (1970 census), is the largest town strongly affected by the earthquake. Lice and Hani, a smaller nearby town, are located on the edge of the Diarbakir Plateau (elevation 660 meters), at the foot of the Taurus Mountains, which form a picturesque backdrop.

The Lice/Hani area is agricultural, with no visible industries. The topography and vegetation of the region strongly resemble Southern Ca ifornia near the Tehachapi Mountains and the White Wolf fault.

Both Lice and Hani are divided into two sections, old and new. The older sections of the towns are located on the steep slopes of the mountains; the newer sections and most of the larger buildings are located in the lower, flatter parts of the towns.

FIGURE 2 VIEW OF LICE LOOKING NORTH TOWARD THE THRUST FAULT SYSTEM AND THE TAURUS MOUNTAINS.

EARTHQUAKE HISTORY

Turkey has a very long history of destructive earthquakes. The five largest and most recent earthquakes that have affected the area are shown in Table 1.

TABLE 1

LARGEST RECENT EARTHQUAKES*

Date	Epicenter	Richter Magnitude	Modified Mercalli Intensity
November 12, 1934	39.0°N - 41.0°E	6.0	VII
March 28, 1954	39.1°N - 41.0°E	7.0	IX
July 7, 1957	39.0°N - 40.5°E	6.5	VIII
August 19, 1966	39.2°N - 41.5°E	6.8	IX
May 22, 1971	38.8°N - 40.5°E	7.0	IX

* This information was presented at the Fifth European Conference on Earthquake Engineering, Istanbul, Turkey, September 22 through 25, 1975; it is also found in Dewey (1975).

(ed. note) See additional listing on following page.

The May 22, 1971, event occurred at the extreme eastern end of the Anatolian fault system (Figure 3), near the town of Bingöl, 50 kilometers north of Lice and not far from the town of Varto, where a Richter magnitude 7.0 shock in 1966 resulted in 2,529 deaths. The earthquake killed 812 people, injured about 2,000, and destroyed thousands of structures (U.S. Geological Survey, 1971).

Between 1909 and 1971, 32 earthquakes of Richter magnitude 6.0 or greater have occurred along the Anatolian fault zone, with at least one earthquake of Richter magnitude 8.0 (U.S. Geological Survey, 1972). Figure 3 illustrates much of this activity.

DATE	LOCALITY	RICHTER MAGNITUDE	DEATHS	BLDGS. DESTROYED OR BADLY DAMAGED
Dec. 26, 1939[1]	Erzincan	8.0	23,000	30,000
Dec. 20, 1942	Erbaa	7.3	1,000	5,000
Nov. 26, 1943[2]	Amasya	7.6	2,900	
Feb. 1, 1944[2]	Bolu, Gerede	7.6	2,381	
May 31, 1946	Varto	6.0	1,300	2,000
Aug. 17, 1949	Erzurum	6.7	320	
Aug. 13, 1951	Kursunlu	6.7	50	3,400
Mar. 18, 1953	Yenice, Gonen	7.2	1,200	8,000
Apr. 25, 1957[3]	Fethiye	7.1	15	
May 26, 1957	Bolu Province	7.1	66	
Oct. 6, 1964	Western Turkey	6.7	36	4,000
Aug. 19, 1966	Varto	7.0	2,529	19,000
July 22, 1967	Mudurnu Valley	7.2	100	1,500
Sept. 3, 1968	Bartin	6.6	24	2,000
Mar. 28, 1969	Alasehir	6.4	11	4,000
Mar. 28, 1970	Gediz	7.5	1,000+	10,000+

[1] Greenwich date (G.M.T.); local time, next date.
[2] Total fatalities resulting from Feb. 1 shock and aftershocks through Feb. 8.
[3] Epicenter off south coast of Turkey.

Reprinted from "Earthquake Information Bulletin," May-June 1970

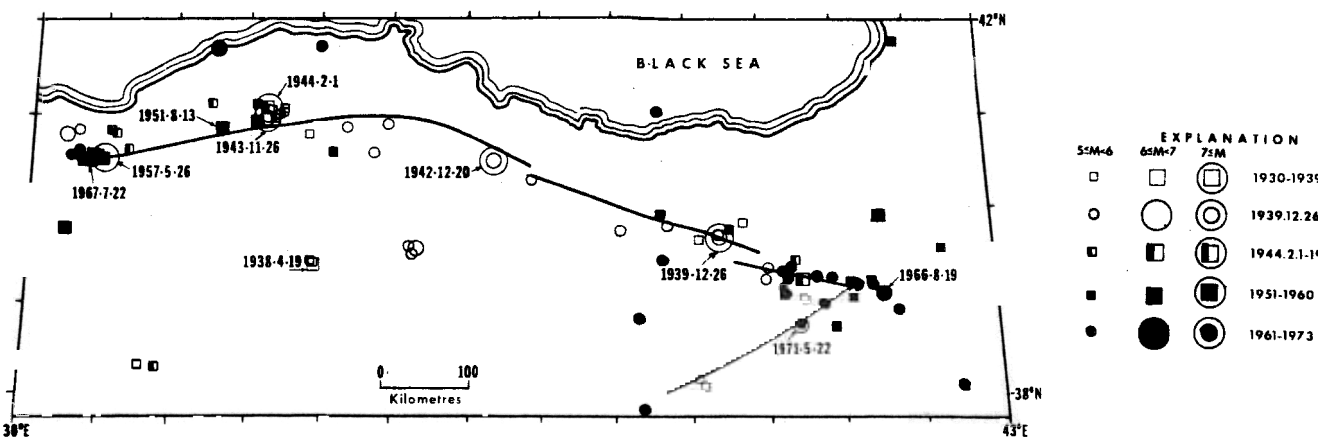


FIGURE 3 SEISMICITY OF THE NORTH ANATOLIAN FAULT AND VICINITY. THESE INSTRUMENT-DETERMINED EPICENTERS REPRESENT THE POINT ON THE FAULT AT WHICH THE EARTHQUAKE ORIGINATED. FOR LARGE EARTHQUAKES, THE FAULT SLIP MAY EXTEND FOR HUNDREDS OF KILOMETERS. EPICENTERS OF ALL EARTHQUAKES ARE ACCURATE TO WITHIN 30 KILOMETERS; EPICENTERS OF EARTHQUAKES SINCE 1961 ARE GENERALLY ACCURATE TO WITHIN 10 KILOMETERS. EPICENTERS WITH DATES SHOWN WERE ACCOMPANIED BY SURFACE FAULTING. (FIGURE REPRINTED FROM DEWEY, 1974.)

SEISMOLOGICAL DATA

Figure 4 shows the isoseismal map of the September 6, 1975, earthquake, as presented at the 5ECEE in Istanbul. The highest Modified Mercalli intensities noted by the author in the vicinity of Lice were IX, as evidenced by the almost total destruction of masonry D, heavy destruction of masonry C, many rockfalls, and massive destruction of the rock formations along the ridge overlooking Lice. The following information was also presented at the 5ECEE:

Time of shock:	09:22:27 GMT; 12:22:27 local time
Epicenter location:	38.5°N - 40.7°E
Depth of hypocenter:	16 kilometers
Richter magnitude:	7.4 ATH (LV) 6.8 UPP 6.9 (average)
Acceleration:	350 gal (0.35g); source unknown
Energy:	5.63×10^{21} erg
Felt area:	210,000 kilometers^2
Aftershocks:	Numerous, continuing as of September 15, 1975

The National Earthquake Information Service in Colorado had the following information as of October 13, 1975 (obtained in a telephone conversation with Mr. Waverly Person):

Time of occurrence:	09:20:12.0 GMT
Epicenter location:	Latitude 38.57°N - Longitude 40.82°E
Depth of hypocenter:	33 kilometers or shallower (poor information); maybe 10 or 12 kilometers
Richter magnitude:	6.7 (preliminary)

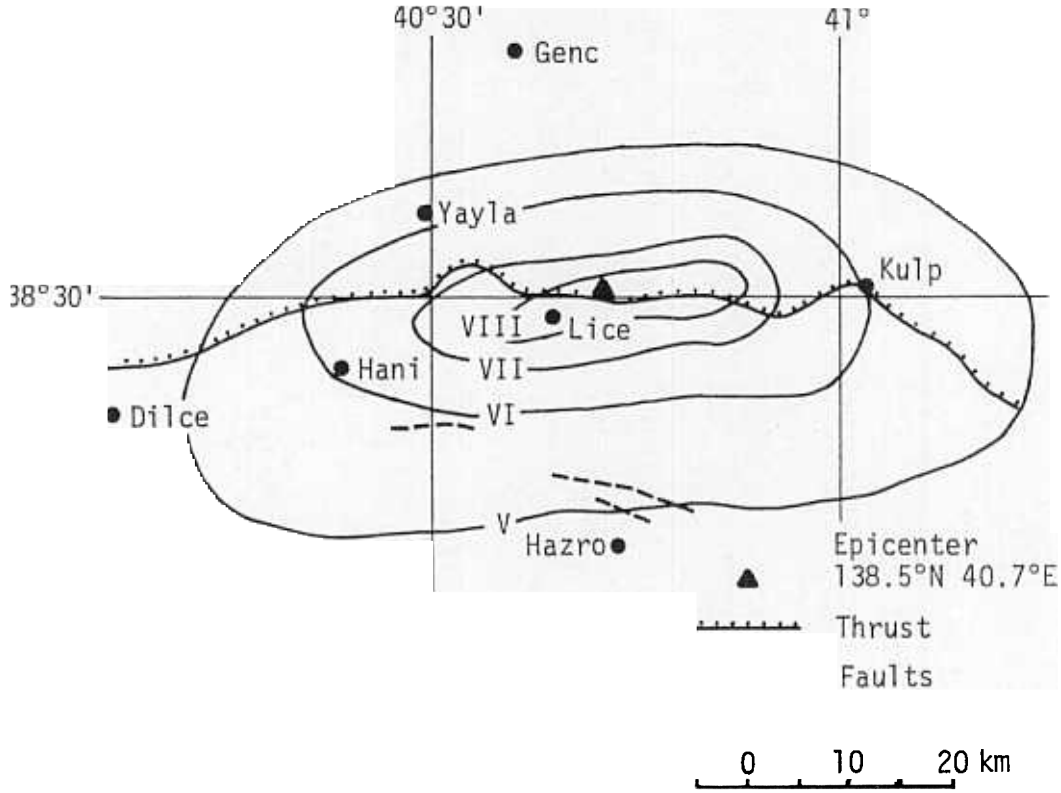


FIGURE 4 ISOSEISMAL MAP OF THE SEPTEMBER 6, 1975, EARTHQUAKE

GROUND EFFECTS

Minor possible surface displacements were reported in the vicinity of the thrust fault between the towns of Lice and Hani. The apparent surface breaks were in the northeast direction parallel to the thrust in the area. The following was reported at the 5ECEE in Istanbul:

> Earth Movements: horizontal displacement of about 10 centimeters observed in the thrust, on the north of Lice. Pieces of Miocene limestone (in the west-east direction), 1 to 4 tons, observed to be broken.

The author was unable to visit the areas of possible faulting; the preceding statement is presented as very preliminary information. Rockfalls were, however, abundant along the slopes of the mountains paralleling the roads between Lice and Hani. Very large rockfalls and landslides were observed just to the east and west of Lice. Large areas of whiter, less weathered limestone were abundant along the rocky ridge tops. In Lice, broken rocks had showered the older section of the town, causing many fatalities and spectacular damage. Figures 5 through 11 illustrate these ground effects.

No other ground effects -- ground cracking, lurching, flow sliding, or liquefaction -- were observed during the brief investigation. The area is generally very dry, and, if such effects did occur, they were probably not abundant.

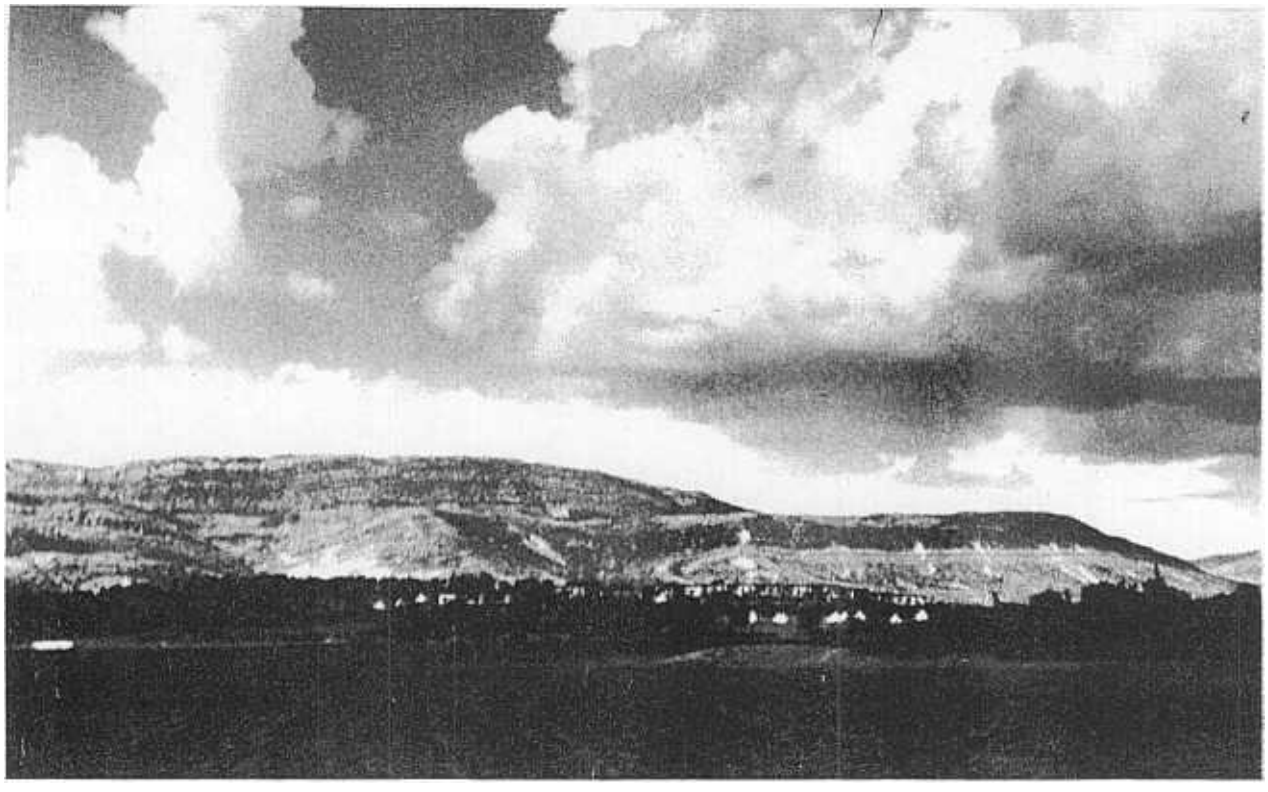


FIGURE 5 VIEW ALONG THE ROAD BETWEEN LICE AND HANI (WEST OF LICE) SHOWING MANY LANDSLIDES AND A HEAVILY DAMAGED VILLAGE IN THE FOREGROUND.

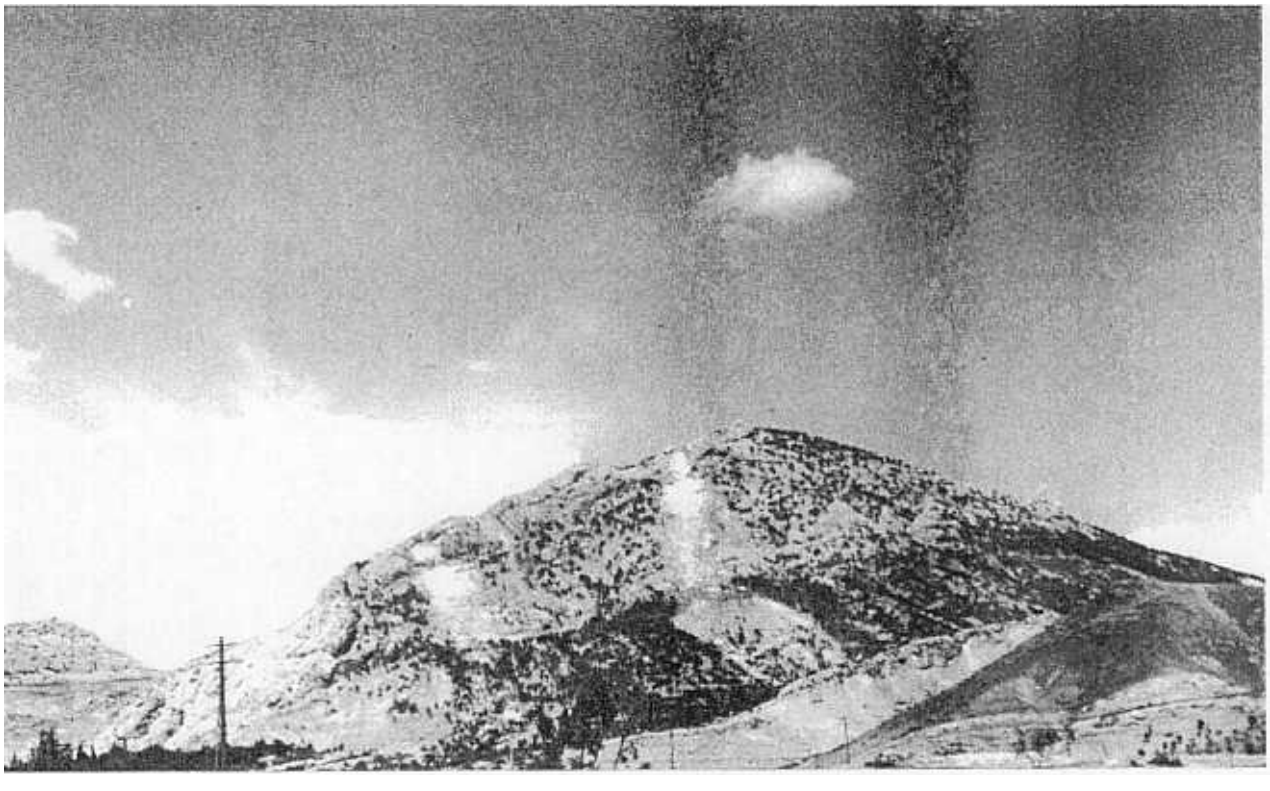


FIGURE 6 A MASSIVE SLIDE, TWO OR THREE KILOMETERS DIRECTLY WEST OF LICE.

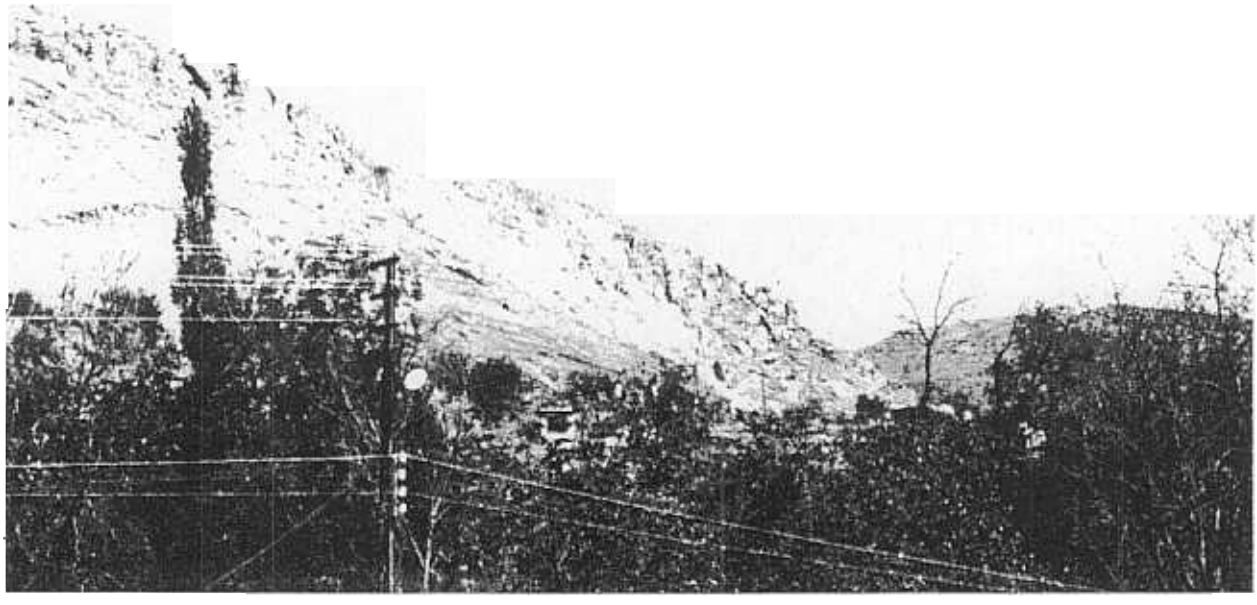


FIGURE 7 MASSIVE SLIDES ABOVE THE EAST END OF LICE. THE WHITER AREA IS RECENTLY EXPOSED LIMESTONE.

FIGURE 8 THE FACE OF RECENTLY EXPOSED LIMESTONE DIRECTLY ABOVE THE CENTRAL SECTION OF THE OLD PART OF LICE, NEAR THE OLD CEMETERY.

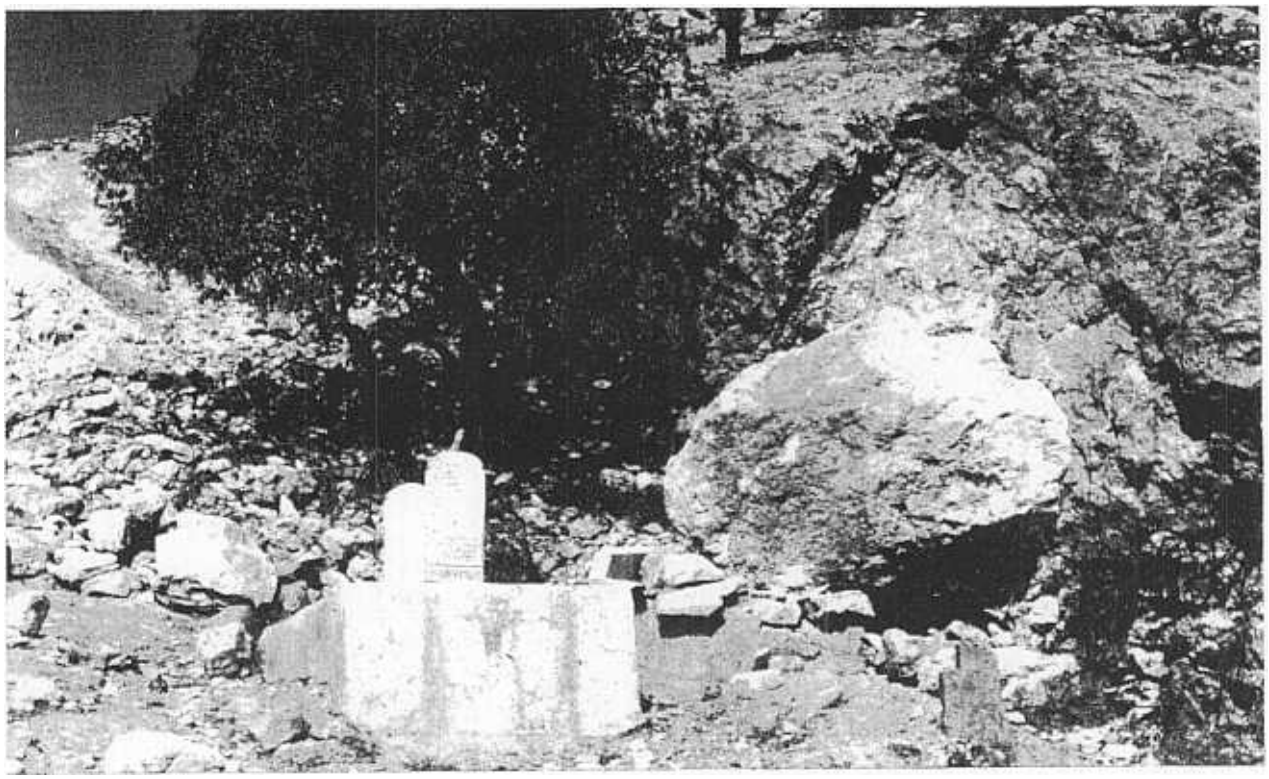


FIGURE DAMAGE THE CEMETERY CAUSED ROCKFALI THE AREA JUST ABOVE TOWN WAS TTERED ROCKS THIS SIZE AND SMALL

FIGURE 10 GENERAL VIEW OF ONE OF THE RIDGETOPS OVERLOOKING LICE. FRESHLY EXPOSED LIMESTONE IS EVIDENT, ESPECIALLY AT THE LEFT (WEST) END.

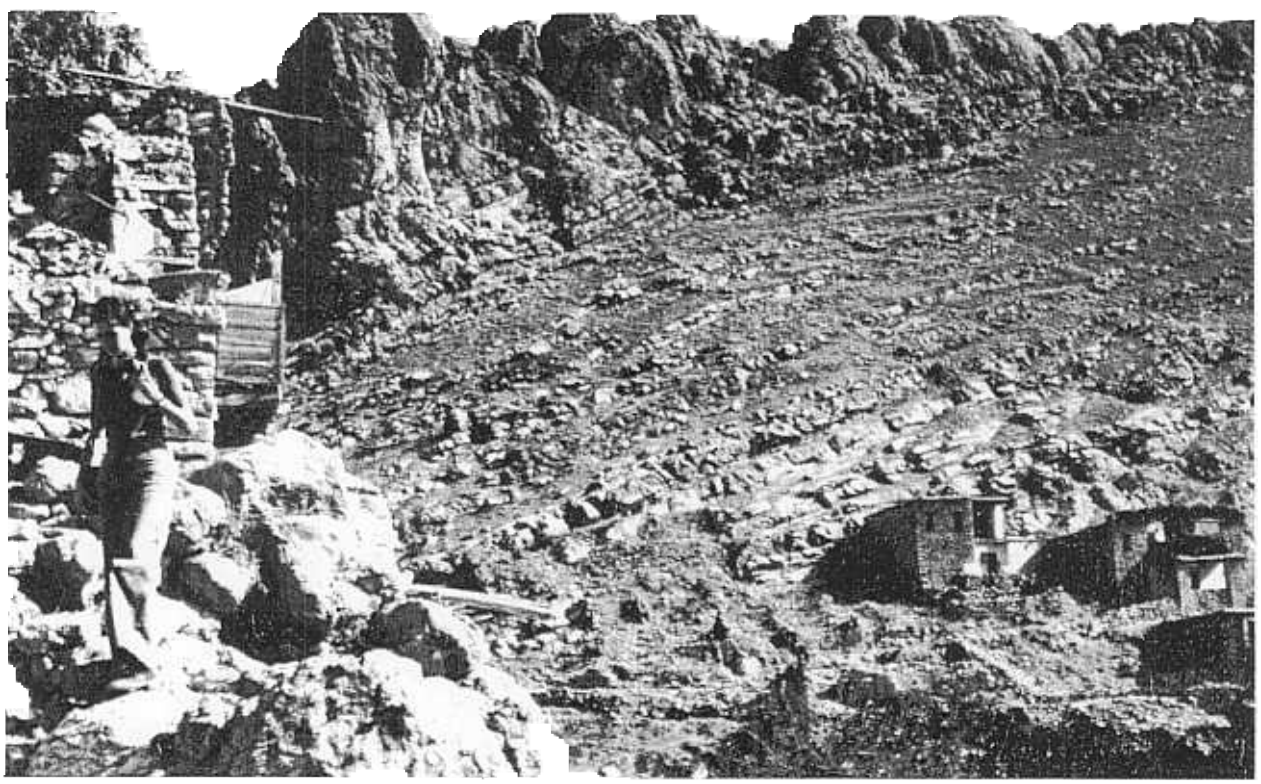


FIGURE 11 GENERAL VIEW OF THE RIDGETOPS SHOWN IN FIGURE 10

CASUALTIES AND BUILDING DAMAGE

The following losses were reported at the 5ECEE, as of September 15, 1975:

People killed	2,386
People injured	4,500
Demolished houses	5,275
Damaged houses	6,850
Property loss	7 million dollars, U.S

Table 2 summarizes in more detail the data available from ERI as of September 30, 1975, for the three largest towns in the damaged areas and their surrounding villages (each town is also a county seat). The data make it obvious that Lice was the most severely affected area. Approximately 5,000 of the existing 6,800 houses collapsed or were heavily damaged -- a 75% loss. Lice also suffered more than 1,200 fatalities out of a population of about 8,200. The shock struck a little after noon, local time, when many of the inhabitants were at home, but the casualties would have been much higher had the earthquake occurred at night.

TABLE 2

PRELIMINARY DATA, AS OF SEPTEMBER 30, 1975

Area	Number of Fatalities	Number of Houses	Number of Collapsed or Heavily Damaged Houses	Number of Houses with Medium Damage	Number of Houses with Slight Damage
Lice, villages	742	4,522	2,886	800	462
Lice, town	570	2,238	2,096	19	21
Hazro, villages	1	1,942	220	120	396
Hazro, town	0	741	21	118	261
Hani, villages	1	1,935	220	120	396
Hani, town	111	1,200*	75*	300*	unknown
Totals for above areas	1,425	12,578	5,518	1,477	1,536

* Approximate

STRUCTURAL DAMAGE

The towns of Lice and Hani have a few 2- and 3-story reinforced concrete buildings, several dozen 2- and 3-story unreinforced brick buildings with reinforced concrete slabs, about 200 earthquake-resistant single-family dwellings constructed by the MRR following the nearby Bingöl earthquake of 1971, and several thousand single-family homes constructed of stone or other masonry and held together with mud or cement mortar.

The typical stone dwellings, which make up about 92% of all dwellings in the area, generally suffered almost total damage in the areas with Modified Mercalli intensities of VIII or higher. Almost all such houses in Lice were destroyed. The more substantial unreinforced brick buildings in Lice were generally damaged severely, while the few reinforced concrete buildings suffered moderate damage to the frames and moderate to severe damage to the infill walls. The newer earthquake-resistant homes suffered light damage in Lice, mostly to the tile roofs, and no noticeable damage in Hani, where about 400 typical masonry houses suffered moderate to severe damage.

The tallest structures were the minarets of the mosques. At least two of these collapsed, one lost a few feet of its top, and one, in Hani, appeared to be undamaged. The many steel or wood street utility poles exhibited no obvious damage. No bridges, industrial buildings, or other less common types of structures were observed. A small diesel generator house in Hani appeared to be undamaged and had no obvious equipment displacements.

REINFORCED CONCRETE BUILDINGS

Two reinforced concrete buildings were examined in Lice. The buildings and some of their damage are illustrated in Figures 12 through 15. Keightley (1975) and Uzsoy and Ersoy (1969) describe in some detail the construction practices for this type of building in Anatolia and rural Turkey. My findings closely agreed with these two sources. Generally, the concrete frames were damaged near the top and/or bottom of columns, where an infill masonry wall had failed in shear. Some of the damage, as shown in Figure 14, was concentrated in areas of extremely poor workmanship; for the column shown in Figure 14, it appears that some stones were dry-packed in place to fill in voids. The very obvious gradation of the aggregate (note the roof/floor slab in Figure 15) indicated that the concrete may have been hand mixed and hand placed. Overall damage to the frames was light, indicating moderate shaking intensities of VII to VIII in the area.

FIGURE 12 THE NEW REINFORCED CONCRETE MUNICIPAL BUILDING, ONE OF THE FEW ENGINEERED BUILDINGS IN THE AREA. IT SUFFERED MODERATE DAMAGE TO THE FRAME AND SIGNIFICANT DAMAGE TO ITS INFILL WALLS

FIGURE 13 INTERIOR OF THE ENTRANCE HALL OF THE MUNICIPAL BUILDING SHOWING DAMAGE TO THE FRAME AND THE INFILL WALLS.

FIGURE 14 DETAIL OF A DAMAGED COLUMN IN THE MUNICIPAL BUILDING SHOWING DAMAGE IN AN AREA OF APPARENTLY POOR CONCRETE PLACEMENT.

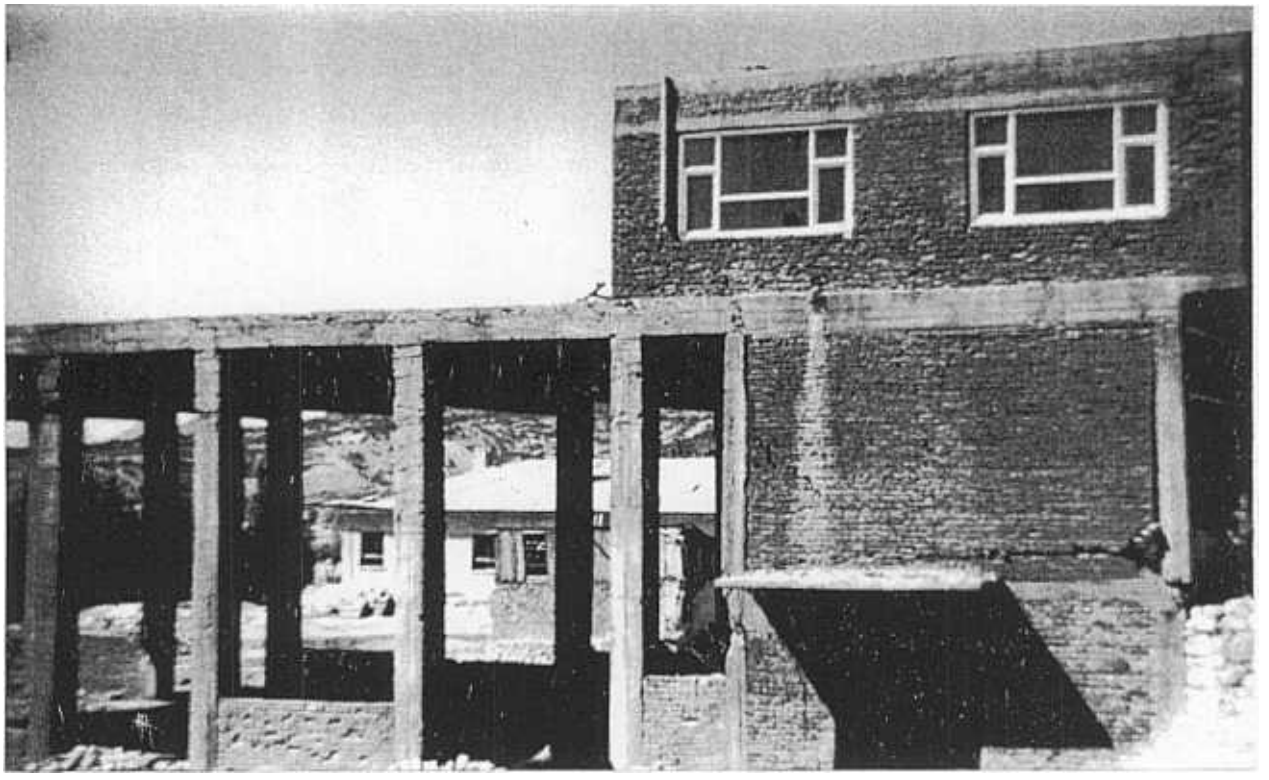


FIGURE 15 A REINFORCED CONCRETE BUILDING IN LICE THAT SUFFERED SOME COLUMN SHEAR FAILURES (LOWER RIGHT CORNER). A NUMBER OF THE BRICK INFILL WALLS HAD FALLEN OUT, MOSTLY ON THE OPPOSITE SIDE.

LARGER MASONRY BUILDINGS

All of the larger masonry buildings appeared to be of unreinforced brick or cut stone, with reinforced concrete floor slabs and generally with tile roofs. Except the hospital building, most of the larger brick buildings in Lice were located in the newer section of town, which is flat and at the bottom of the hills.

In Lice, almost all of these buildings suffered severe damage; several buildings partially collapsed. Figure 16 shows one such partial collapse of a government building built of cut stone and held together with weak cement/lime mortar. This failure was unusual because the most severe damage generally occurred in the lower floor. Figure 17 shows a collapsed masonry store. A number of these buildings had collapsed, leaving the concrete floor slabs intact.

Three of the largest buildings in Lice, the police station (Figures 18 through 22) and two high school buildings (Figures 23 through 34), suffered the most spectacular damage. All three are of unreinforced brick, with weak mortar that has a high lime content. All three buildings were very severely damaged and were unsafe to enter, as aftershocks were continuing to occur. It can only be assumed that the buildings were held up by the interior walls because the outside bearing walls were generally totally damaged. The few interior walls that could be seen were also of unreinforced brick, were probably bearing walls, and had also suffered shear failures. Diagonal cracks were visible everywhere. Torsion had also caused some of the damage; in several cases, the concrete slabs had pushed out parts of the corner walls of the buildings. The entrances to all three of the buildings were littered with masonry debris and pieces of plaster. Most of the brick chimneys were broken off, and several had fallen through the wood and tile roofs. The buildings do not appear to be repairable.

All of the school and government buildings in Lice were destroyed by the earthquake. The current rebuilding effort seems to be aimed primarily toward building enough residences to house the homeless population before the severe Anatolian winter.

One of the most interesting examples of earthquake damage in Lice is shown in Figure 34. The vertical accelerations of motion appeared to have had significant amplification in the middle of the roof spans between the roof trusses, because the roofing tiles were dislodged only in those areas and this damage was not caused by falling chimneys.

The 2- and 3-story Lice hospital (Figure 35) is located to the west of the main section of Lice, in the foothills of the mountains. It was the only major unreinforced brick building in Lice to escape serious, spectacular damage. This was probably due to lower intensities on the upslope of the hills rather than to superior construction. The brick walls suffered many shear cracks, but these were generally minor, causing some spalling of plaster. The building was nevertheless evacuated and remained unused at the time of the visit, over three and one-half weeks after the event. A variety of interior damage was present, most of it to loose, unanchored minor support equipment. Some interior walls lost a few bricks. The major mechanical equipment in the basement appeared to have survived undamaged, but it was not running during the inspection. The piping had been supported only with light pipe hangers, and many of these were torn loose. The boilers and other pieces of major equipment were bolted down and did not appear to have moved from their supports.

FIGURE 16 A PARTIALLY COLLAPSED MASONRY GOVERNMENT BUILDING IN LICE

FIGURE 17 A COLLAPSED MASONRY STORE IN THE CENTER OF LICE.

FIGURE 18 THE POLICE BUILDING IN LICE. THE LOWER STORY IS VERY SEVERELY DAMAGED, WHILE THE SECOND STORY IS LESS DAMAGED.

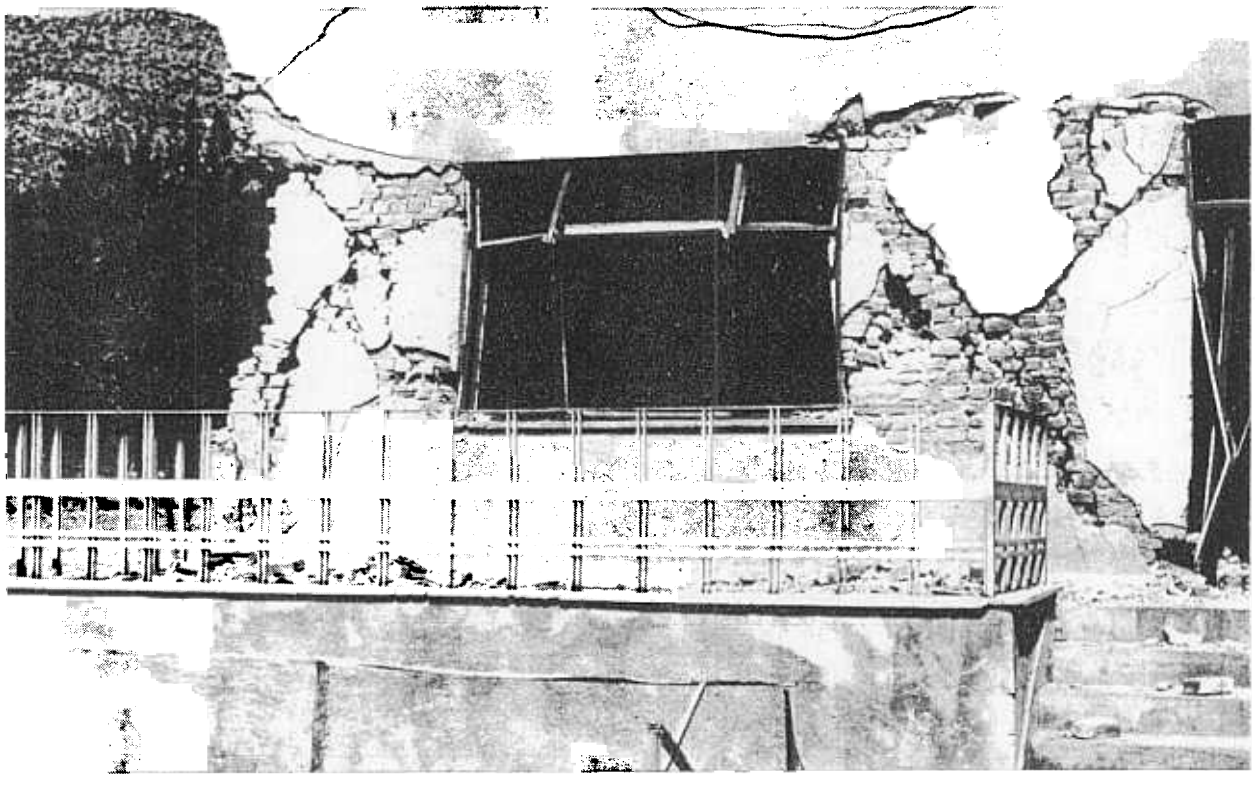


FIGURE 19 SHEAR FAILURE OF THE PIERS OF THE POLICE BUILDING. THE FIRST STORY HAS COMPRESSED A COUPLE OF INCHES, AS SHOWN BY THE BUCKLING OF THE WINDOW AND DOOR FRAMES.

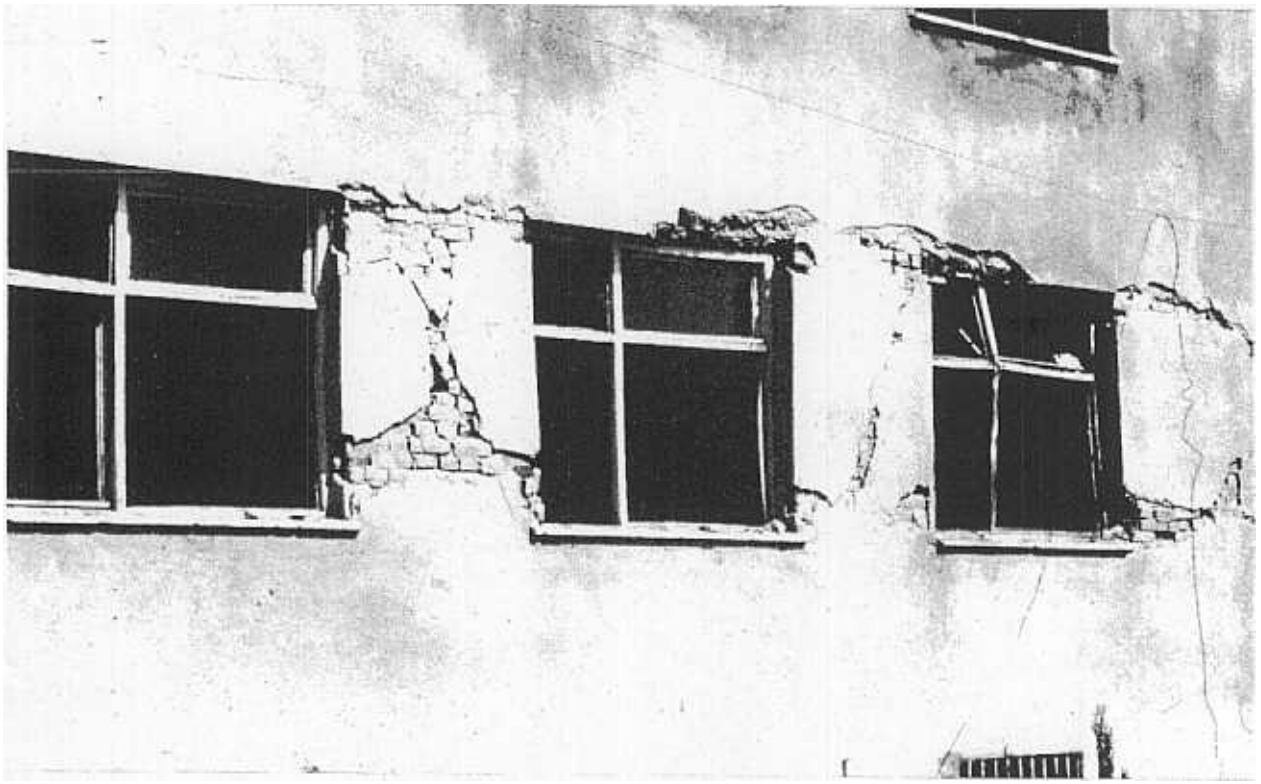


FIGURE 20 DETAIL OF THE POLICE BUILDING.

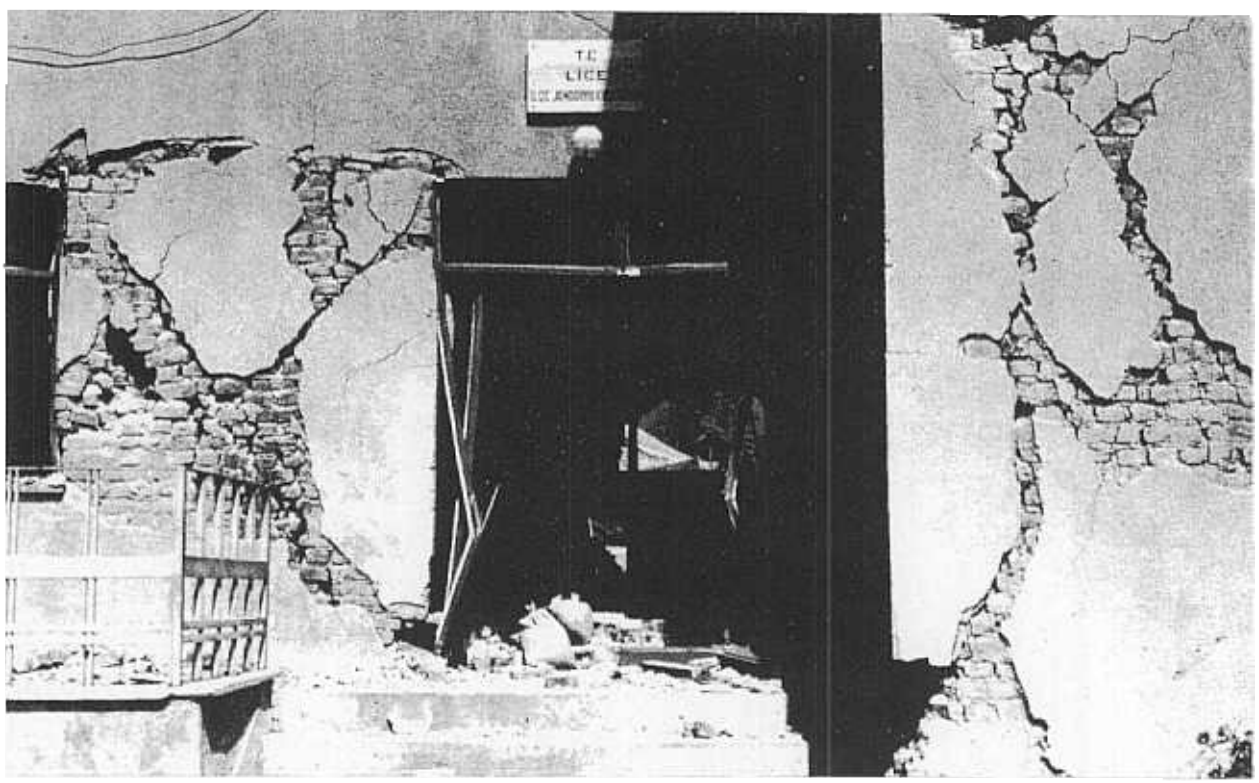
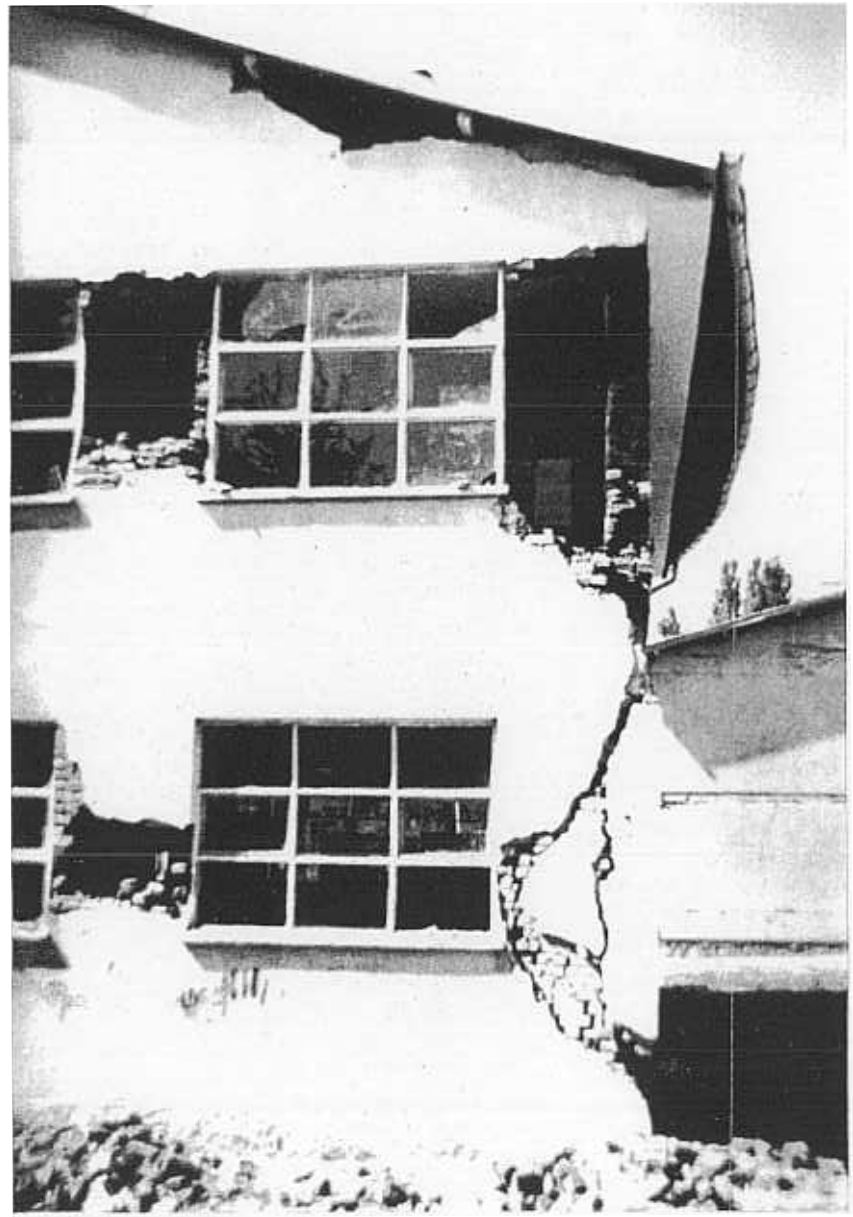


FIGURE 21 DETAIL OF DAMAGE AROUND THE ENTRANCE TO THE POLICE BUILDING.

FIGURE ONE THE FIRST· OOR CORNERS THE POLICE BUILDING SHOWING WHAT SEEMS DAMAGE DUE TORSION AND POUNDING TWEEN THE FLOOR SLABS AND THE WALLS



FIGURES 23 AND 24 THE EAST END WALL OF ONE OF THE HIGH SCHOOL BUILDINGS. ALL LATERAL RESISTING ELEMENTS OF THE WALL ON BOTH FLOORS WERE SHATTERED.