DISASTER ASSISTANCE

Earthquake Hazard Reduction

N.9

SECOURS EN CAS DE DESASTRES NATURELS

Tremblements de terre

Vol. 2

EXPERIENCE GAINED FROM RECENT EARTHQUAKES IN TURKEY

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INTRODUCTION

During the past five years, Turkey has experienced a number of destructive earthquakes. Each of these earthquakes were faced with an ever increasing interest and effort, both by governmental and technical authorities. Each one occurred in different regions of Turkey, with different climate, different socio-economic conditions, different materials and building types. The analysis of the events caused by those earthquakes, reveals interesting facts of the country, from the point of view of earthquake engineering.

After a comparative study of the mentioned successive earthquakes, one can say that the performance of post-earthquake activities is more and more efficient, than the previous ones. This is explained in the other paper, titled "General Information on Organization and Activities for Earthquake Disaster Response in Turkey".

Although it is possible to learn some facts through literature, the efficiency and certainty, provided by actual experience, can not be substituted. Many of the lessons, taught by those earthquakes, are of value to engineers, professionals and administrative people, though some of them may be repetitions of known facts.

The earthquakes considered are as follows:

Locality	Date	Loss of Life	Dwellings Destroyed
Varto	19.8.1966	2,500	20,000
Adapazari	22.7.1967	86	7,100
Bartin	3.9.1968	26	260
Alasehir	28.3.1969	41	2,500
Gediz	28.3.1970	1,086	15,000

It is not intended to give full information on each earthquake. Only a rough outline will be given, from points of view of settlement and building materials; then general conclusion will be given, following the indication of distinguished features of each earthquake.

VARTO EARTHQUAKE (19.8.1966)

(M = 7, epicentral intensity I_o = IX (MM), epicentral co-ordinates:
$39^o.2$ N - $41^o.7$ E (U.S.C.G.S.)
$39^o.2$ N - $41^o.6$ E (B.C.I.S.))

The main shock caused a death toll of 2,500. Although the population density is low (24 per sq.km or 62 per sq. mile), most of the local types of buildings were not earthquake-resistant. The isoseismal map is shown in Figure 1(1). The dominant building material is round stone and adobe. Mud is popular as material for mortar, and generally no cement is used. The buildings have heavy ceilings. Most of the damage was focussed on Varto and Mus. The Regional School, which was of reinforced concrete construction, suffered heavy damage. The existing settlements were preferred and new houses were built generally on the same location. Relief and reconstruction activities were considerably larger in size, comparing the previous activities.

ADAPAZARI EARTHQUAKE (21.7.1967)

(M = 7, epicentral intensity I_o = IX (MM), epicentral co-ordinates:
$40^o.7$ N - $30^o.8$ E (B.C.I.S.)
$40^o.7$ N - $30^o.8$ E (U.S.C.G.S.))

The earthquake was accompanied by the activation of a segment of 100 kilometers (60 miles), on the North Anatolian Fault Zone. It lent itself for a clear mapping. The right-handed strike ship and moving down of Northern side, exhibited the known characteristics of the North Anatolian Fault Zone, and once more pointed to the need for systematic study on it.

Adapazari region is in process of development and it is known as one of the richest portions of the country, with agricultural and industrial resources and a suitable climate. Although the ground motion was intensive and the population density was quite high (about 90 per sq.km or 230 per sq. mile), the death toll was only 86, thanks to the type of local construction. The popular construction type is timber frame with brick-fill or timber lath siding. The roof is usually light and of timber construction with tiles.

Lots of landslides were observed. It was noted that the rate of damage was not necessarily too high in the vicinity of the fault zone.

BARTIN EARTHQUAKE (3.9.1968)

(M = 6.5, epicentral intensity I_o = VIII (MM), epicentral co-ordinates:
41°.8 N - 32°.3 E (U.S.C.G.S.)
41°.38 N - 32°.20 E (I.T.U.))

Bartin earthquake caused interest, from the point of view of earthquake zoning. No earthquakes were recorded in the past, and it was considered in the danger-free zone. However, a field study revealed that there were complicated crack systems, pointing out that the region must have experienced earthquakes in the past.

Loss of life was 26, due to local character of the earthquake, (the population density is 75 per sq.km or 195 per sq. mile).

It was observed that a 4 km (2.5 miles) portion of the shore line was uplifted by 40 cm (1' 1/3 approximately) in the middle, gradually decreasing to the ends. The terraces at several heights by the sea, show that there have been continuous uplifting on the Black Sea coast.

Masonry is dominant in the region, but it is not good from earthquake engineering view.

ALASEHIR EARTHQUAKE (28.3.1969)

(M = 5.5, epicentral intensity I_o = VII (MM), epicentral co-ordinates:
38°.3 N - 28°.6 E (macro))

The earthquake was associated with vertical movements. The area is well known from the point of agriculture (grape, fig, tobacco, cotton etc.). The area of damage is within a valley in east-west direction. Soil conditions are very poor in the central part. The town Alasehir exhibits different characters of soil, from the lower part of the valley, towards the higher slopes.

The dominant building type is masonry. Generally stone and adobe is used with mud mortar. Ceiling is covered with raw timber, and earth is put on the top, to provide insulation. As it is heavy, it is not good from earthquake engineering point. Though 41 lives were lost in the earthquake. The population density in the area is 55 per sq.km (or 145 per sq. mile).

Minor relocations were decided, and prefabricated housing is extensively applied after Bartin and Alasehir earthquakes.

GEDIZ EARTHQUAKE (28.3.1970)

($M = 7$, epicentral intensity I_0= IX (MM), epicentral co-ordinates:
$39^\circ.1$ N - $29^\circ.4$ E (macro)
$39^\circ.0$ N - $29^\circ.3$ E (U.S.C.G.S.)
$39^\circ.1$ N - $29^\circ.6$ E (B.C.I.S.))

Much of the effect was felt in Gediz and surroundings. The town rests on a portion of Gediz River Valley. Loss of life is 1,086. The population density is about 35 per sq. km (or 91 per sq. mile). Great fires in Akcaalan and in some districts of Gediz, increased the death toll and loss of property. As may be understood, timber framed buildings are popular. Masonry and reinforced concrete buildings are also met in comparably small numbers.

The location of Gediz town was changed, and microzoning studies were conducted in the new settlement. Reconstruction was completed within four months.

Relation of damage and soil conditions were studied by Earthquake Research Institute of the Ministry of Reconstruction and Resettlement.

One of the distinguished features of Gediz earthquake, is the high interest of governmental and educational institutions.

GENERAL CONCLUSIONS

The experience from the mentioned 5 earthquakes, as representative of the general earthquake picture of Turkey, provide conclusions applicable to the whole country. The most important conclusions are as follows:

- Earthquake resistance of local building types
- Effect of soil on damage,
- Effect of earthquake on reinforced concrete structures
- General

EARTHQUAKE RESISTANCE OF LOCAL BUILDING TYPES

Local buildings can roughly be divided into two groups, with sub-divisions as follows:

(a) Timber frame buildings (brick-fill type; wood lath siding type; massive wood type).

(b) Masonry type (field stone type, hewn stone type, brick, adobe and concrete block types).

TIMBER FRAME AND WOOD-LATH SIDING TYPE BUILDINGS

In the affected areas (e.g. in Akçaalan at Gediz area, and lots of examples from Adapazari area), numerous standing or at most slightly damaged buildings make the observers surprised, who see many destroyed ones around. These are two or three storeyed timber framed and wood lath siding type buildings. The load bearing system is composed of timber columns, beams and diagonals. They are connected together by nails, and wooden laths are nailed to form both inner and outer wall surfaces. The space between the sidings, is sometimes filled with loose material for insulation, or left empty. The sidings are covered by plaster. Use of nailed connections in great extent, increases the ductility. It is well known that ductility is a greatly desired quality in earthquake engineering to absorb energy, transferred to the building. In addition, wood laths prevent the filling material from falling down. This decreases loss of life and keeps the form of walls even under great displacements. In some cases, ground floor of masonry type collapsed, but the upper floor of this type came down without much deformation and damage in itself.

The common defect in this type of building is the connections, where inadequate details are used, and number of nails are less than required.

TIMBER FRAME AND BRICK-FILL TYPE BUILDINGS

Although it has the merits of the former type, falling of filling blocks can cause loss of life and extensive deformation. Ductility is less than that of the former type. Wire mesh prevents falling of the filling blocks to some extent. This type is opposed by some engineers, stating that two building materials (timber and masonry) with quite different dynamical characteristics, are brought together. In case of a serious movement, the plaster cracks are formed on the joints between timber and masonry block.

FIELD STONE TYPE BUILDING

These types of buildings are in great number in Varto. Mud mortar or nothing is used to joint the stones. Usually the ceiling is heavy, a thick layer of earth for insulation, is carried by raw timber beams. Evidently there is no resistance against earthquakes. The loss of life is heavy.

HEWN STONE, BRICK AND CONCRETE BLOCK TYPE BUILDINGS

Though slightly better than the former type, the ductility and resistance is not sufficient. A reinforced concrete slab of adequate thickness and reinforcement, provides connection between walls, resulting in greater strength. As this type is well known in other countries, only the earthquake aspects will be discussed. Although there are some measures to increase the earthquake resistance of masonry buildings (e.g. providing close tie beams, to provide solid wall blocks of adequate dimensions between window or door openings, utilization of high cement mortar, etc.) the past experience shows that this type of building can be easily damaged in serious earthquakes. In Japan, for example, this type is completely forbidden. As the material behaves in the brittle way, not much resistance is expected.

The following factors increase the vulnerability of this type of building:

1. Utilization of mud or lime mortar, instead of cement mortar.

2. Brickwork, without wetting the bricks. In this case the dry brick absorbs the water of the mortar and the hydratation of the cement is not complete. Consequently the sheer resistance of the wall is rather low.

3. Poor connections of the tie beams in the corners.

4. Poor design of roof, allowing the members transferring horizontal forces to walls, resulted from vertical loads.

ADOBE BUILDINGS

Adobe is locally made by mixing clayey mud and hay. Though it has not much strength as concrete block etc., it is light, easily and cheaply produced, and heat insulation is excellent. It can be used in load bearing walls, and in brick filling of the timber frames. Mud mortar is used. Mud alone or mixed with lime is used as plaster material. It requires repairment after heavy rains. Earthquake resistant code of Turkey has provisions on adobe buildings. As this type has already been accepted for centuries, it can be said that this type will still be in use for many years.

EFFECT OF SOIL ON DAMAGE

Wallace, in his report on Varto (1966) earthquake, notes three types of geologic controls:

(a) Degree of saturation of the alluvium;

(b) Proximity to landslides;

(c) Relation to surface faulting;

The following is quoted from his report:

"Within the city of Varto geologic conditions appear to have controlled the damage to the complex of 26 buildings belonging to the Regional School and Agricultural Service. Varto is built on the alluvial plains of a river tributary to the Murat River and on benches rising 50 meters or more above the plains. An old river channel having two branches crosses the higher bench and passes directly under part of the school and agricultural service complex. The old channel is bordered by low subsidiary benches from 3 to 5 meters high. The water table was very near or at the surface in this old channel at the time this study was made, and many springs are present along its course. In the few exposures found, the channel appears to be underlain by poorly sorted alluvial material. In the bench on the northeast, alluvial fan deposits exist, of poorly sorted gravels containing clasts up to cobble size.

Of 14 relatively new buildings of reinforced concrete situated on the old river channel, 12 collapsed and one other was seriously damaged. In contrast, all 12 buildings of similar construction situated on the bench to the northeast remained standing - some were essentially undamaged and others were only slightly damaged. Many chimneys were not even thrown down. Inasmuch as most of the buildings on the old channel were two storeys high, a comparison should be made between the one storey buildings on the two sites. A small one-storey building, on the western side of the complex near the middle of the channel was damaged beyond repair and near collapse. On the other hand, some similar one-storey buildings on the highest part of the bench were almost unharmed. The conclusion seems to be that there was a decided difference in the shaking of the two sites, but whether the difference was in amplitude, spectrum or duration could not be determined."

It is a known fact that high underground water table increases the intensity, as shown by Medvedev in his formula.

Coming to Adapazari (1967) earthquake, a great part of the affected settlement was on the deposits of Sakarya river. The soil is alluvium, and the underground water table is about 1.00 meter (3 feet) from the surface. The collapse of five storied reinforced concrete buildings, may partly because of the predominant ground period, which is probably about the order of the natural period of the structures.

In the area, affected by Bartin (1968) earthquake, it can be observed that the single-storey local type buildings have experienced less damage towards the higher parts of the land, the thickness of the alluvium decreasing.

In Alasehir area (1969), almost all of the vineyard houses collapsed, being on the axis of the alluvial valley, while the town Alasehir had experienced comparably less damage, being on firmer ground.

In old Gediz town, microregioning studies were conducted by A. Tabban, from Earthquake Research Institute. The results confirm that damage is higher to flexible buildings such as reinforced concrete, and timber frame buildings in the lower part of the alluvium (thicker). The damage to the rigid masonry buildings on this type of soil, is not so severe.

After the new settlement was selected for Gediz, microregionalization technics were applied to guide town planners in assuring the optimum use of land.

EFFECT OF EARTHQUAKES ON REINFORCED CONCRETE STRUCTURES

No destruction nor major damage has been observed in well designed and built reinforced concrete buildings.

The major factors, decreasing the strength, can be listed as follows:

1. Unusually short and improper anchor bars for columns.
2. Improper composition of concrete (very coarse aggregate, inadequate amount of cement etc.).
3. Inadequate pouring and compaction of concrete (lack of vibration).
4. Inadequate curing of concrete (lack of wetting, after pouring, for hydration of cement).
5. Inadequate length of lapped splice in connections and corners.
6. Modification of dimension and location of members, from the original design.

Reinforced concrete buildings in general, proved to have enough ductility and strength, when they are properly designed and built, according to well known rules.

It is understood that the conformity to the rules, can only be assured by close inspection of construction activities in all of its three phases:

1. Design of building.
2. Employing material in conformity with the design assumptions.

3. Implementing the design, properly and employing workmanship in conformity with the design assumptions.

Lack of technical personnel in local organizations, is the main cause of inadequate inspection.

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3. Tabban A. Microzoning of Old Gediz Town, From Building Damage (in Turkish) Earthquake Research Institute, Ministry of Reconstruction and Resettlement, Turkey.

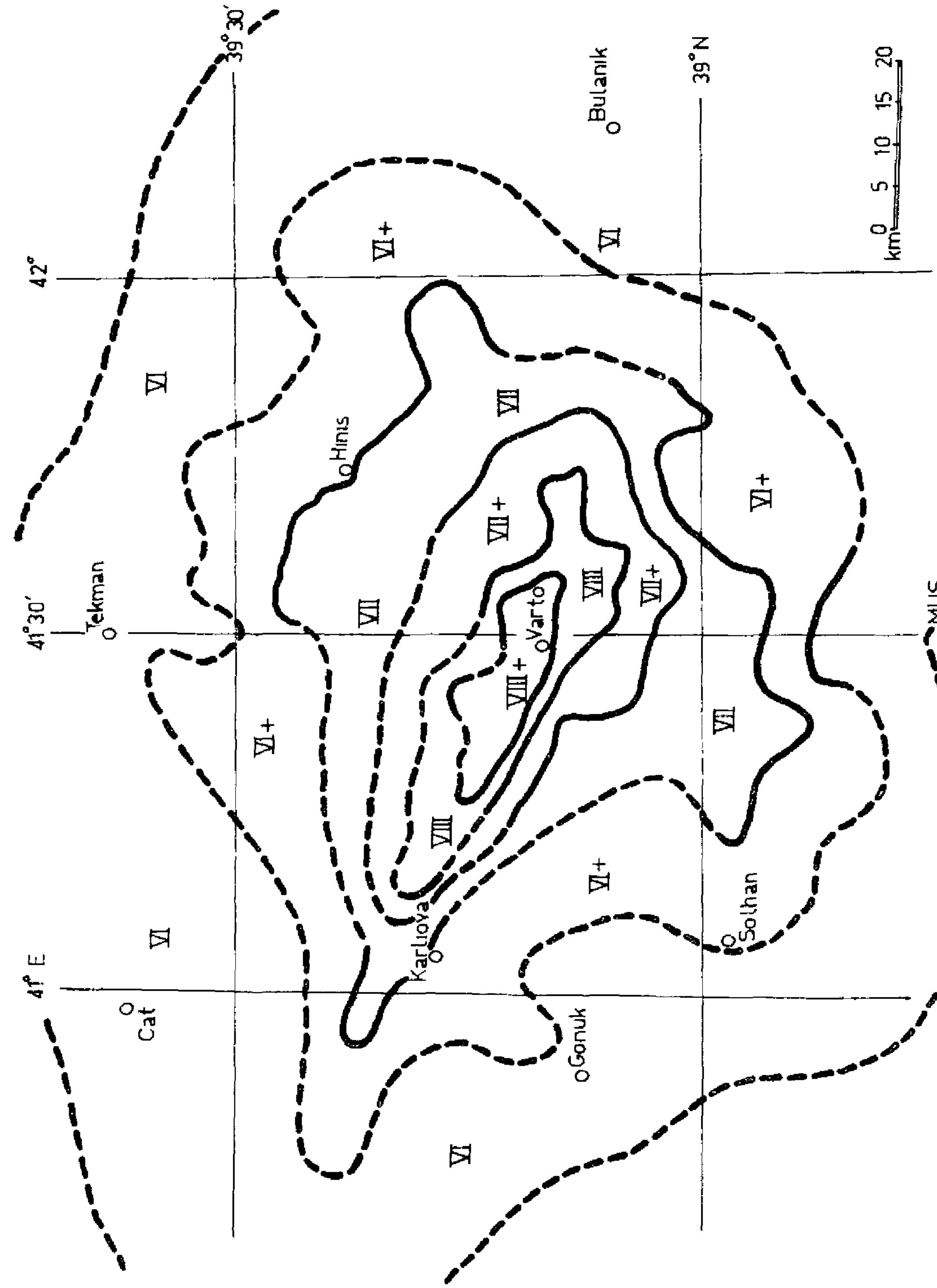

FIGURE 1

ISOSEISMAL MAP OF VARTO EARTHQUAKE
(19 8. 1966)
by N.N Ambraseys and A. Zatopek

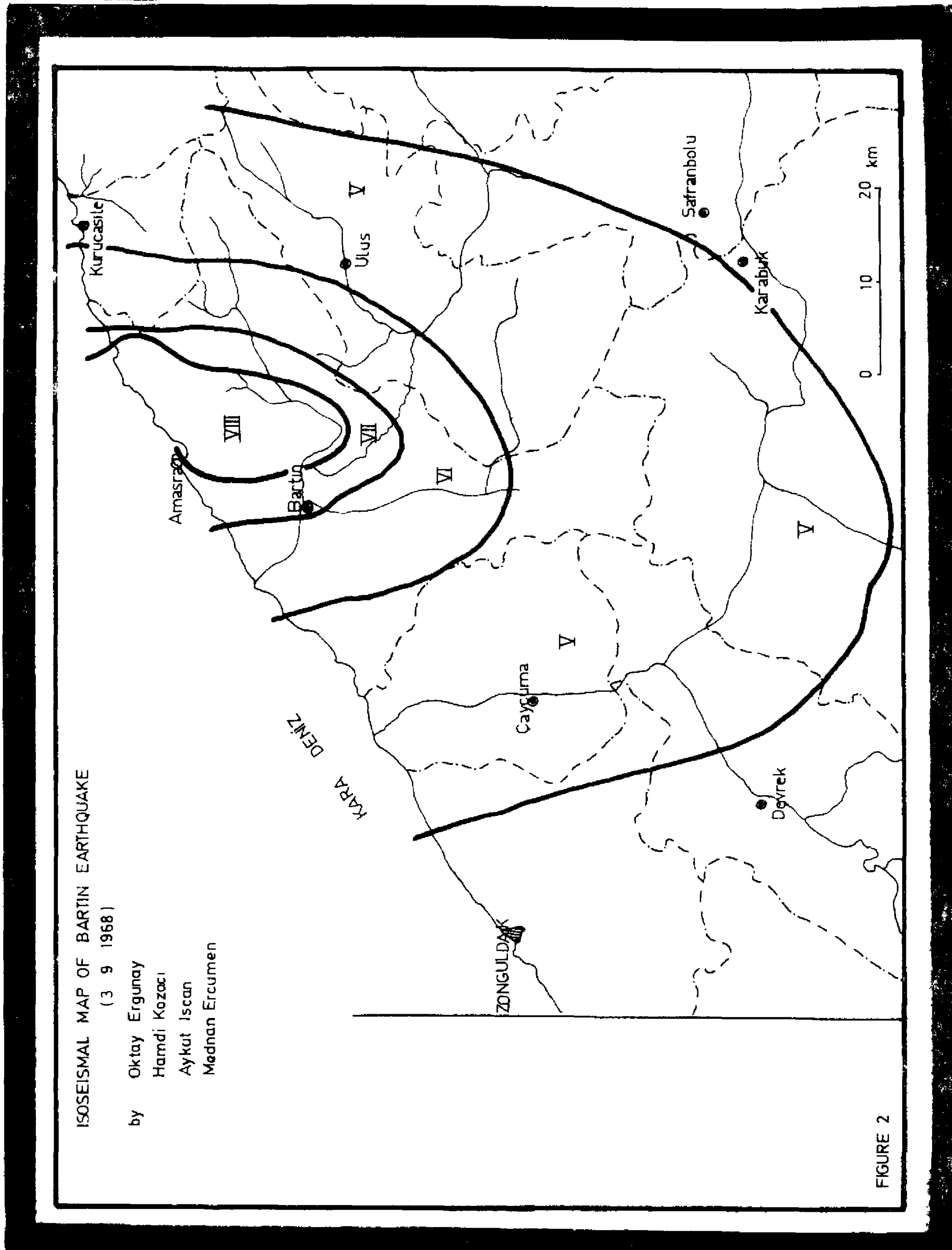
ISOSEISMAL MAP OF BARTIN EARTHQUAKE
(3 9 1968)
by Oktay Ergunay
Hamdi Kozacı
Aykut Iscan
Mednan Ercumen
Kurucasile
Ulus
Safranbolu
Karabuk
Amasra
Bartin
Caycuma
Devrek
ZONGULDAK
KARA DENİZ
V
VI
VII
VIII
0
10
20 km

FIGURE 2

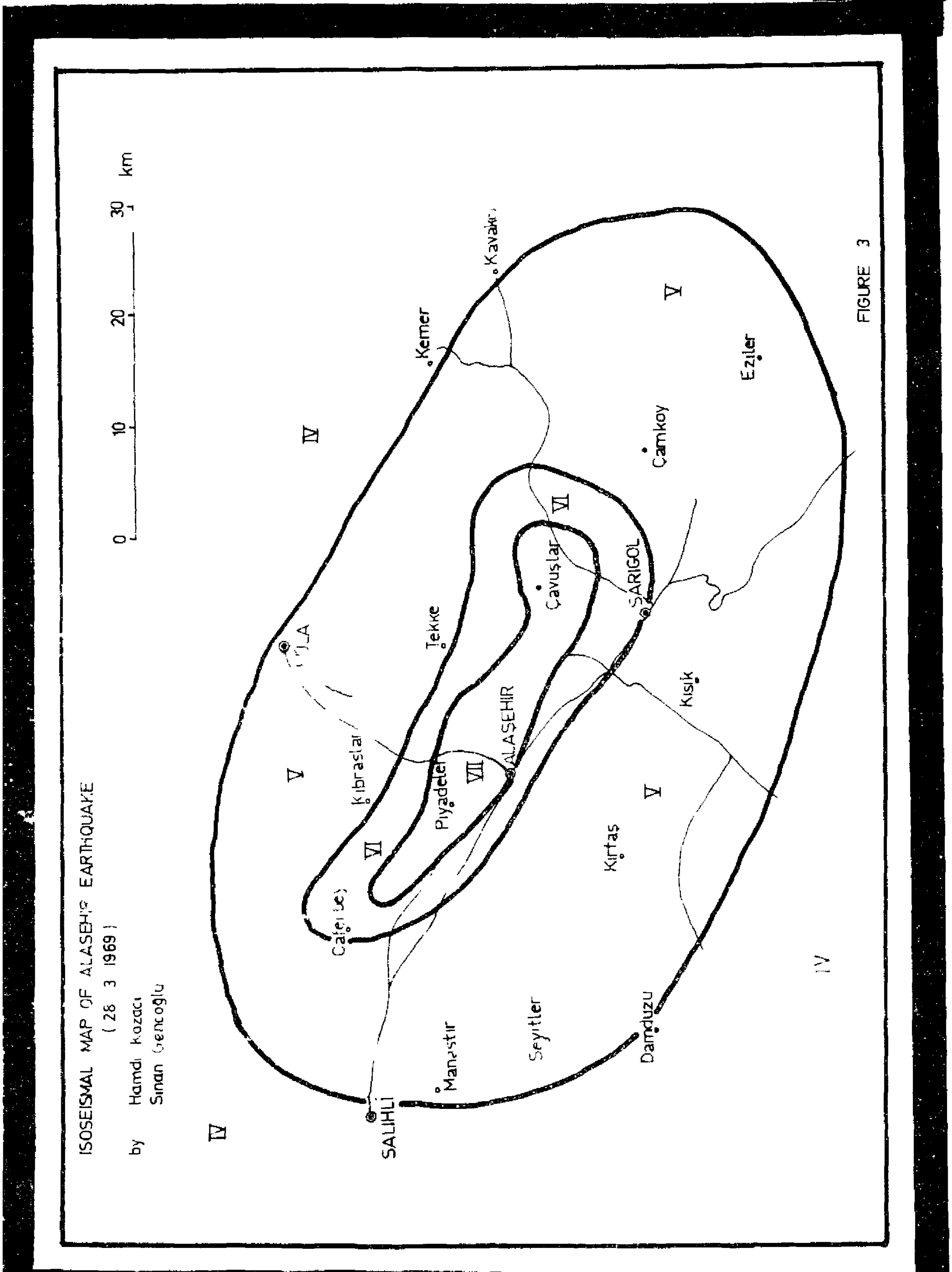
ISOSEISMAL MAP OF ALASEHIR EARTHQUAKE
(28 3 1969)
by Hamdi Kozacı
Sinan Gencoglu
0
10
20
30 km
IV
V
VI
VII
SALIHLI
Manastır
Seyitler
Damduzu
Cafer bey
Piyadeler
Kıbraslar
ALAŞEHIR
Tekke
Kirtas
Kısık
Çavuşlar
SARIGOL
Camkoy
Eziler
Kemer
Kavaklı

FIGURE 3