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Shamil-Siahou Earthquake "North-East of Bandar-Abbas" of 21st March, 1977

M. Sobouti, I. Eshghi, and M.M. Mostaanpour

Institute of Geophysics, Tehran University, Tehran 14, Iran

Abstract. In this paper an attempt has been made to reveal the properties of forementioned earthquake from the field observations. The data has been obtained from the Iranian Seismological Stations, the International Seismological Center etc.

This report concerns different kind of data, preliminary studies on the regional seismicity, ground movements isoseismal maps, specifications of the major shocks, the subsequent aftershocks and some descriptions about the nature of the damaged buildings.

Key words: Iran – Earthquake – Regional seismicity – Destruction.

Introduction

In the recorded history of this region we repeatedly notice the occurrence of a series of destructive and devastating earthquakes in the various regions of the country. In the last few decades, some of the major shocks registered throughout the world have had their epicenters in the Plateau of Iran, approximately numbering 50.

Prior to the Shamil-Siahou earthquake, north-east of Bandar-Abbas, 4 earthquakes of $M > 6$ and 24 earthquakes of $6 > M > 5$ occurred around the epicentral zone of this earthquake and were registered in the seismological stations of the world.

Prior to the description of the Shamil-Siahou earthquake of the 21st March 1977, it seems necessary to discuss the geographical situation, the geological condition of the epicentral area and also the seismicity of the Bandar-Abbas region.

This discussion can help us the analysis of the results as obtained from the macro and micro-seismic studies. Consequently this report concerns:

1. A brief geological and geographical aspects connected to the region.
2. The seismicity of the Bandar-Abbas area.

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3. Macro and micro-seismic data and their analysis.
4. Description and nature of the damaged buildings.

1. Geological and Geographical Aspects of the Earthquake Area

The region affected by the Shamil-Siahou earthquake of 21st March, 1977 accommodating 12,000 inhabitants, lies to the south of an elevation having a maximum height of 2,645 m (Pousht-Kuh). The western part (Khur-Kuh) has a maximum height of 1,471 m. This region is believed to have been on the extreme southern border of the Zagross mountains. This is the region where the general orientation of the mountain redge is E–W (Fig. 3). This region is irrigated by the tributaries of three rivers, Shoor, Djalabi and Hassan-Langui. The springs feeding these rivers are mostly associated with some salt contents.

The area is part of the southeastern Zagross tectonic belt. The tectonic frame work consists of parallel east-west trending anticlines and synclines. Three salt plugs are shown in the map (Fig. 1). These salt plugs seem to have been active since the Jurrasic and Cretaceous times. The major Zagross thrust fault zone lies to the north of the area. Apart from a major thrust fault on the southern flank of Pousht-Kuh few other minor faults are also present within the area. (Geological map of Bandar-Abbas area, N10 (1963.) The present structural setting of the area is the result of the Zagross orogeny which started in late Miocene time. Evidence of some tilting of sub-recent conglomerates indicates that this tectonic phase is still active to a certain degree. Apart from the Zagross movements, the area seems to be the site of a predominantly continuous deposition of limestone and shale, exept for a few stratigraphic levels where minor disconformities are indicated.

The oldest exposures of the area consists of the Jurassic limestone outcropping at the eroded core of Pousht-Kuh. The Cretaceous and the lower Tertiary rocks are also exposed at the same places. The younger Tertiary rocks from the Asmarie and Fars group outcrop over the whole area. The Bakhtiary conglomerates from the youngest formation of the area overlies the older with an angular uncomformity. The total known thickness of the sediment from Bakhtiary formation down to the lowest exposures of the Silurian rocks is approximately 8,300 m.

Silurian, Permo-Carboniferous and Triassic rocks are exposed at Kuh-e-Faraghun about 20 km to the north of the area. Below Silurian the thickness of the remaining sediments is not known. But the salt rocks of the salt plug are thought to be of the Pre-Cambrain age.

The maximum intensity of the earthquake was found in the area between Sharu and Dimshahr villages. Field observations could not prove any relationships between the earthquake and the present structural features of the area.

2. Seismicity of the Bandar-Abbas Area

The region which lies between the latitudes 26° to 29° N and longitudes 54° to 58° E, having an area of 125,000 square km, has been known from immemorial

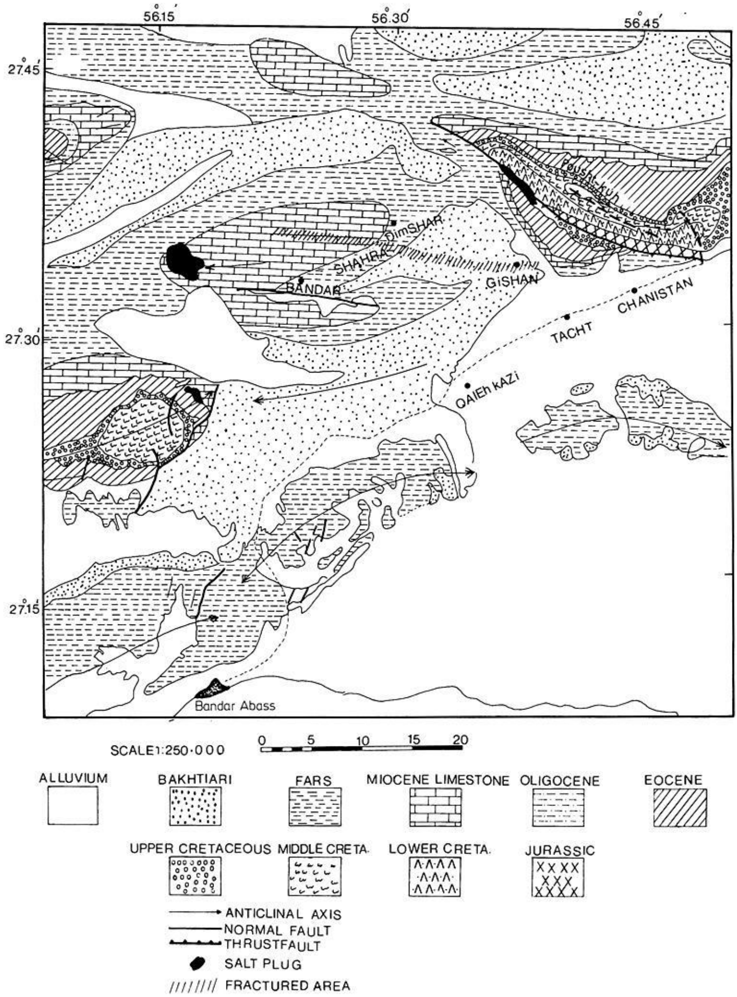


Fig. 1. Geological Map of the Region

times for its seismicity. Legends and history indicate severe and strong earthquakes causing heavy damages in this area.

Reference to the national and private libraries and the publications belonging to the various centers and various authors, has enabled us to discuss the seismic activities of the region. The region described above has had 263 destructive earthquakes that have taken place from 1900 up to the present time. In the case of early earthquakes before 1900, the vague accounts as given by ancient earthquakes for which a determination of epicentral coordinates is not easy to ascertain.

In order to give a picture of the seismic activities of the region, a map has been compiled (after Berberian, 1976). A large number of earthquakes prior to 1960 have remained unknown to us due to the lack of proper recording stations. The compilation of this map is based on the following sources:

1. Individual papers concerning the early earthquakes (see the list of references).
2. Seismicity of the Earth, by B. Gutenberg and C.F. Richter, 1954; and Rothé, 1969.
3. The Bulletins of the International Seismological Summary (ISS).
4. The Bulletins of the Bureau of the International Seismological Centers, Strasburg (BCIS).
5. Preliminary determination of epicenters by USCGS.
6. The Bulletins and Publications of The Seismological Service of the Institute of Geophysics, Tehran University.

Figure 2 represents the distribution of the epicenters and the magnitudes of 263 shocks. Sixty-five of these shocks have occurred prior to 1960 and are recorded by the neighbouring and the European seismological stations. The remaining shocks were recorded by the Iranian Seismological Stations which have been functioning since 1960.

3. *Macro and Micro-Seismic Data and Their Analysis*

3.1. Macro-Seismic Data

A. Epicentral Zone of the Earthquake. The region affected by the principal shock has an approximate surface area of 4,500 square km (Fig. 3). The damaged villages are grouped within the two districts, Shamil and Siahou and are situated in agricultural plains lying between rocky elevations and sometimes at the foot of the mountains of Pousht-Kuh and Khour-Huh. The villages lying in these districts and their agricultural plains are as mentioned, irrigated by the affluents of the three rivers. These tributaries, in different parts of the region, are known with varying names as, Khoor-Joul, Viakan, Ab-Galamoun, Jamash etc. Numerous hot-water springs are located at the foot of the Pousht-Kuh and Khour-Kuh mountains. The water of some of these springs are sulphurious.

B. Visible Effects. The main shock has seriously destroyed the houses and the buildings of about 52 villages. The number of casualties, so far, out of a population of 12,000 people has reached to 168.

Minor cracks and undulations of the ground were seen in the area where the houses and buildings were seriously damaged (like Dimshahr, Jeghan, Guishan, Shahrou, etc. in Fig. 3).

The result of the observations reveal that the crust was fractured in a direction of N 75 ± 5 W. This direction is detected by means of shattering and falling of rocks and overturning of the walls, etc. The water level and even the location of several hot-water springs located at the foot of the mountains has been considerably changed during the earthquake.

C. Intensity Distribution. An attempt was made to visit all the damaged region, but owing to the natural difficulties of the area such as the rocky elevations and lack of roads, only 70% of the villages in the damaged area were visited by the team. A great deal of information was obtained by local investigations from the

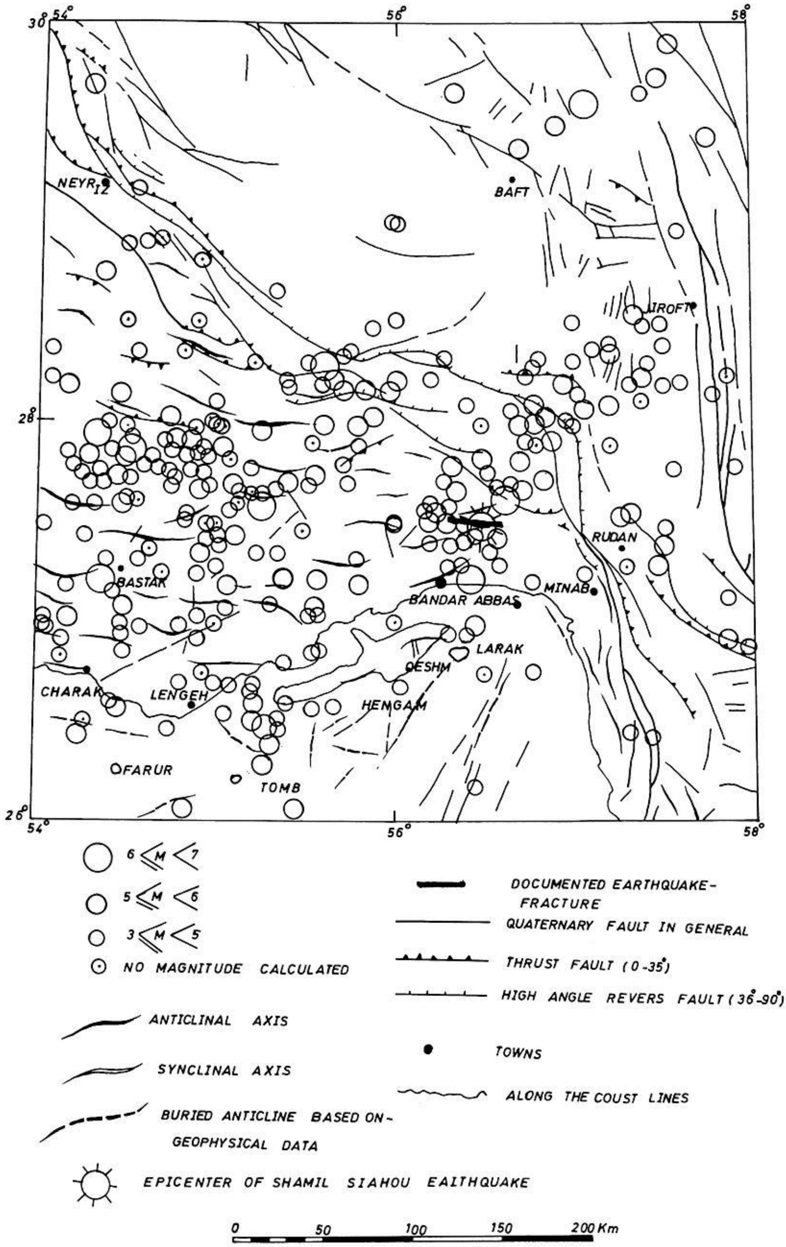


Fig. 2. Seismicity Map of Bandar Abbas. (After Berberian, 1976)

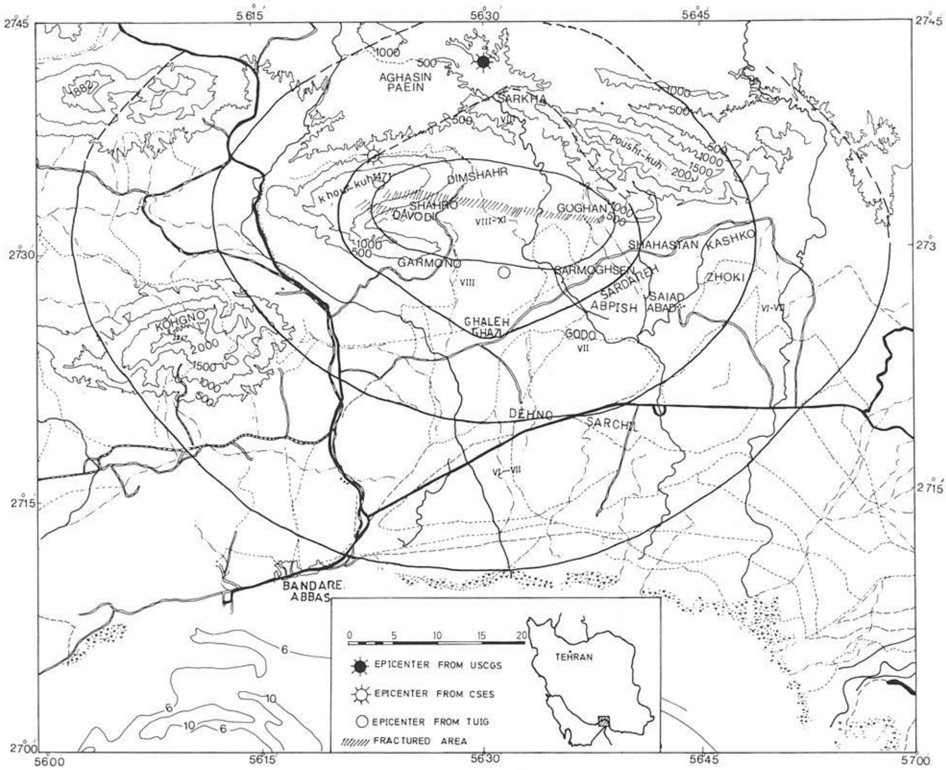


Fig. 3. IS0-Seismic Map of Earthquake

neighbouring villages and from the list of statistics as prepared by the governmental agencies of the Province of Hormozgan.

Accordings to the results of these investigations, the maximum intensity of the earthquake in the damaged area is estimated VIII–IX on the Modified Mercalli scale. Lack of sufficient data and information has made the compilation of the isoseismal lines (Fig. 3) extremely difficult. Whenever the data was complete the isoseismal contour line is indicated by heavy lines and whenever the data has been insufficient or meager, the contour lines are represented by dotted lines.

D. Depth of Focus and Magnitude of the Earthquake as Computed From the Observation Data. In order to calculate the depth of focus, an empirical formula relating the depth of focus with r and I_m is used (Gutenberg's formula):

$$\frac{I_m - 6.5}{3} = \log\left[\left(\frac{r}{h}\right)^2 + 1\right]$$

where

r = Radius of the isoseismal contour line having an intensity of VI–VII,

I_m = Maximum intensity on the ground surface.

h = Depth of focus.

In the case of the earthquake under descussion we have I_m=VIII–IX. For the radius of the isoseismal contour line, the mean of the minimum and the maximum radii are taken:

$$r=\frac{d1/2+d2/2}{2}$$

consequently

$$r=43.75\,\text{km}$$

and $h=23$ m.

As for the magnitude of the earthquake a formula is required relating the magnitude with the depth of focus and maximum intensity at the MM scale:

$$M=0.7\,I_m+2.3\log h-2.0.$$

In the case of this earthquake we have:

$I_m=$ 8.5 (the maximum intensity on the field),
$h=23$ (as determined in para. D).

consequently $M=7.0$.

3.2. Microseismic Data

A. Characteristics of the Main Shock. The geographical coordinates of the epicenter, origin time, depth of focus and magnitude as given by USCGS and CSES are the following:

Epic-coordinates			Origin time	Depth	Magnitude
(USCGS)	27.7°N,	56.5°E	21:18:54:6	33N	7.0
(CSES)	27.63°N,	56.36°E	21:18:54	–	6.75

The geographical coordinates of the epicenter and origin time of the main shock using the registered *P*-Travel times in Iranian seismological stations are given as follows:

Epicenter Coordinates			Origin Time
(UTIG) (Tehran)	27.5°N	56.5°E	21:18:55

The magnitude of this earthquake is calculated at the Tehran Seismological Station from the maximum amplitude (A) of *S* wave recorded by the short-period ($T=0.8$ s) Stuttgart-Hiller seismograph, using the formula:

$$M=\log\frac{A}{T}+3.39\ \text{Log}\,\Delta-4.49.$$

The result is:

$$M = 6.9.$$

In order to evaluate the energy released in this earthquake, use is made of the Both's formula:

$$\log E = 12.24 + 1.44\,M.$$

Using the value as calculated at the Tehran station we have:

$$E = 1.5 \times 10^{22}\ \text{ergs}.$$

B. Aftershocks. As usual after the main shock a series of some hundreds of aftershocks took place in the epicentral area. The majority of these shocks were only felt, without causing material damage. Aftershocks with higher intensity are those that have been registered at the Shiraz station ($\Delta = 420 \pm 20$ km).

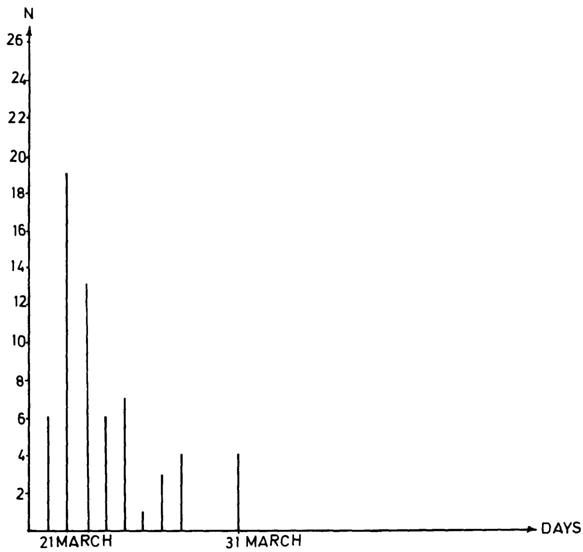


Fig. 4. Aftershocks recorded at shiraz station. From 21st to 31th March $\Delta \simeq 420 \pm 20$ km. $3.5 > m > 6.5$

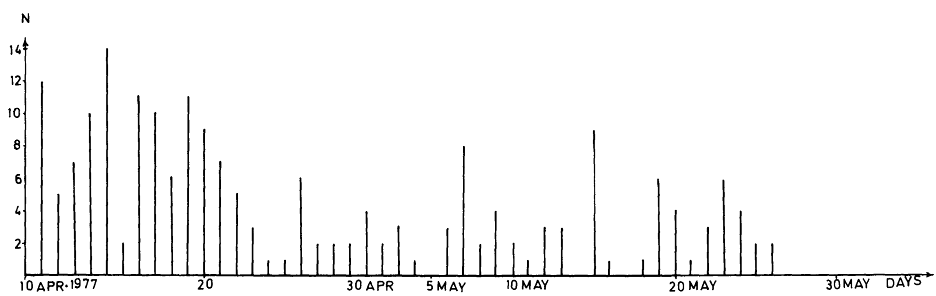
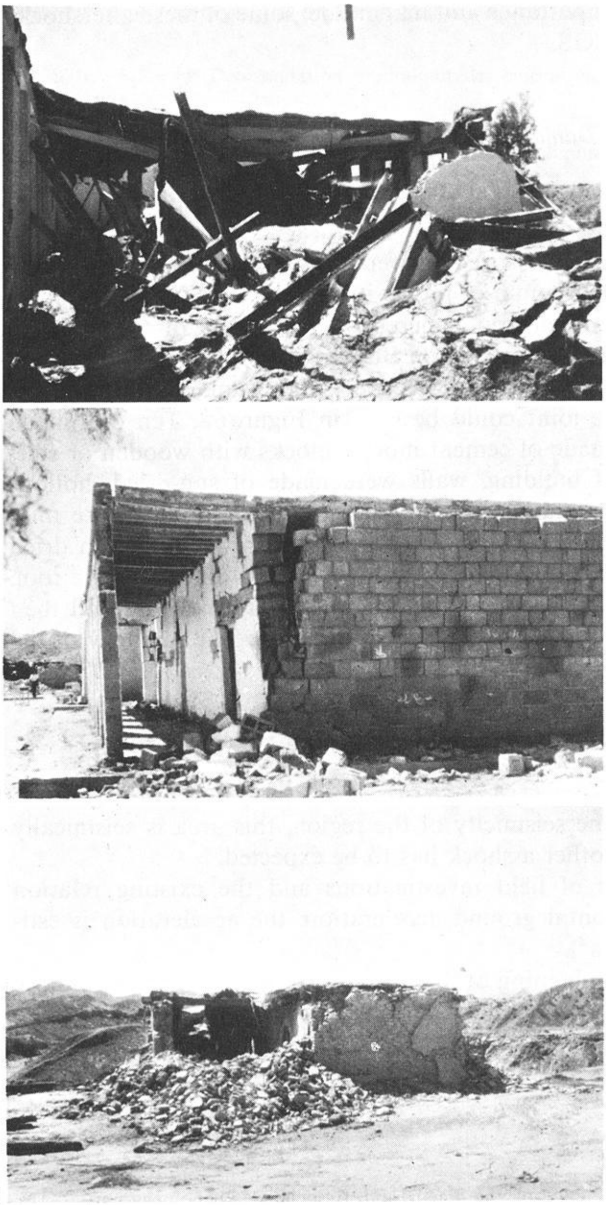


Fig. 5. Aftershocks recorded at Bandar Abbas. From 10th April to 27th May. $\Delta \simeq 80 \pm 20$ km



a

b

c

Fig. 6a–c. Damage to houses of different construction (see text)

These aftershocks caused the already damaged buildings and constructions to collapse further and thus causing more and more destructions.

Figure 4 describes graphically the aftershock actively from 21st March to 31st March 1977.

Figure 5 describes graphically the aftershocks recorded at Bandar-Abbas, by a portable Sprengnether seismograph during 48 days from 10th April to 27th

May, 1977. Owing to their importance and magnitude, some of these aftershocks had been delineated by USCGS.

4. Description and Nature of Damaged Buildings

The damage caused by the main shock was mainly due to the poor quality of the materials used and also to the construction of rural houses in this area.

About 10% of the houses in this region were made of bricks and the joint material was center mortar, pure mud or mud with lime. The roof is made up to steel beams resting on the reinforced concrete. An example of this kind of building was the newly built "Sharou School Building".

In this kind of building, the connection between the beams and the walls is unperfect. The details of the joint could be seen in Figure 6a. Ten or Fifteen percent of the houses were made of cement mortar blocks with wooden or steel roof beams. In this class of building, walls were made of sun-dried, hollow, cement mortar blocks. The material of joint was cement mortar or pure mud (Fig. 6b). Seventy-five or Eighty percent of the houses were made of sun dried bricks, with mud mortar, sometimes with a small amount of lime. For the roof, wooden beams are used which are then covered with a layer of mat and then with a 15 to 20 cm, layer of mud-straw (Kahguel) (Fig. 6c). The majority of the house in the epicentral region were of only one story.

Conclusion

From the point of view of the seismicity of the region, this area is seismically active and at one time or another a shock has to be expected.

According to the results of field investigations and the existing relation between intensity and horizontal ground acceleration, the acceleration is estimated to be ($\gamma = 150 \pm 50\,\mathrm{cm/s^2}$).

In the reconstructing and planning of the urban or rural developement, those results must be taken into the design consideration.

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