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Historical Background

Rehovot-ba-Negev (Rehovot-in-the-Negev, Ruheiba in Arabic, ancient name unknown) was founded by the Nabateans at the end of the 1st cent. B.C. between Haluza and Nitzana[1]. During Nabatean, Roman and Byzantine times it was one of the largest settlements in the Negev, alongside other significant desert cities, including Avdat, Haluza, Mamshit, Nizana, Saadon and Shivta (fig. 1).These were well developed settlements, located along the branches of the Incense Caravan Road that led from the Arabian Peninsula through Petra up to the port of Gaza. Ancient inhabitants built their houses from locally hewn stone, and the roofs were supported by stone beams that were based on arches. Although they lived in the desert, the people of the area had a developed agricultural system: their fields were located in dry river beds that were filled with soil (loess) and were watered by rain and floods. The inhabitants collected rainwater from the roofs and courtyards in rock-cut cisterns in their buildings.

Rehovot-ba-Negev is located in the northern Negev, about 280 m above sea level, north of Nahal Shundra. At its largest extent, the city covered an area of ca. 108 hectares[2]. The number of inhabitants during the Byzantine period is estimated at ca. 5000. Today the city plan of Rehovot-ba-Negev is concealed by heaps of building stones, although a detailed plan was prepared by Joseph Shereshevski in 1991[3]. He recognized three churches south of the southern entrance, as well as a monastery, caravansary (khan), bathhouse and an open reservoir. Of the three churches, only the North one has been excavated, by Yoram Tsafrir in the late 1970s. In 6th cent. A.D., Rehovot-ba-Negev and the surrounding desert cities (Elusa, Subeita, Nessana, Avdat and Mamshit) attest to the expansion of Byzantine society and economy into the desert[4]. Christianity is the only religion represented at these sites during the pre-Islamic period, and classical basilica style churches are present in each town. These churches reveal the wealth of the towns, with imported marble from Anatolia used for wall facings and furniture, and elaborate mosaics; they also used wood imported from the Mediterranean zone for the construction of vaults[5]. Tsafrir et al.[6] suggest that the town declined in the fourth decade of the 7th century A.D. due to the absence of any decorated or glazed Arab pottery from the eighth century onwards. This idea was supported by Shereshevski[7], who believed that Rehovot-ba-Negev was only inhabited until the Early Islamic period. Arieh Issar[8] claims that the burial of the Byzantine towns of Rehovot-ba-Negev and Elusa, beginning ca. 800 A.D., was the result of increased Nile sands on the Levantine littoral, correlated with heavy monsoon rains in East Africa. However Tsafrir et al.[9] point out that some rooms of the church

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1 Tsafrir 1988, 210.
2 Tsafrir 1988, 210.
3 Shereshevski 1991, 350.
4 Rosen 2000, 45–62.
5 Negev 1974.
6 Tsafrir 1988, 210.
7 Shereshevski 1991, 350.
8 Issar 1995.
9 Tsafrir 1988, 210.

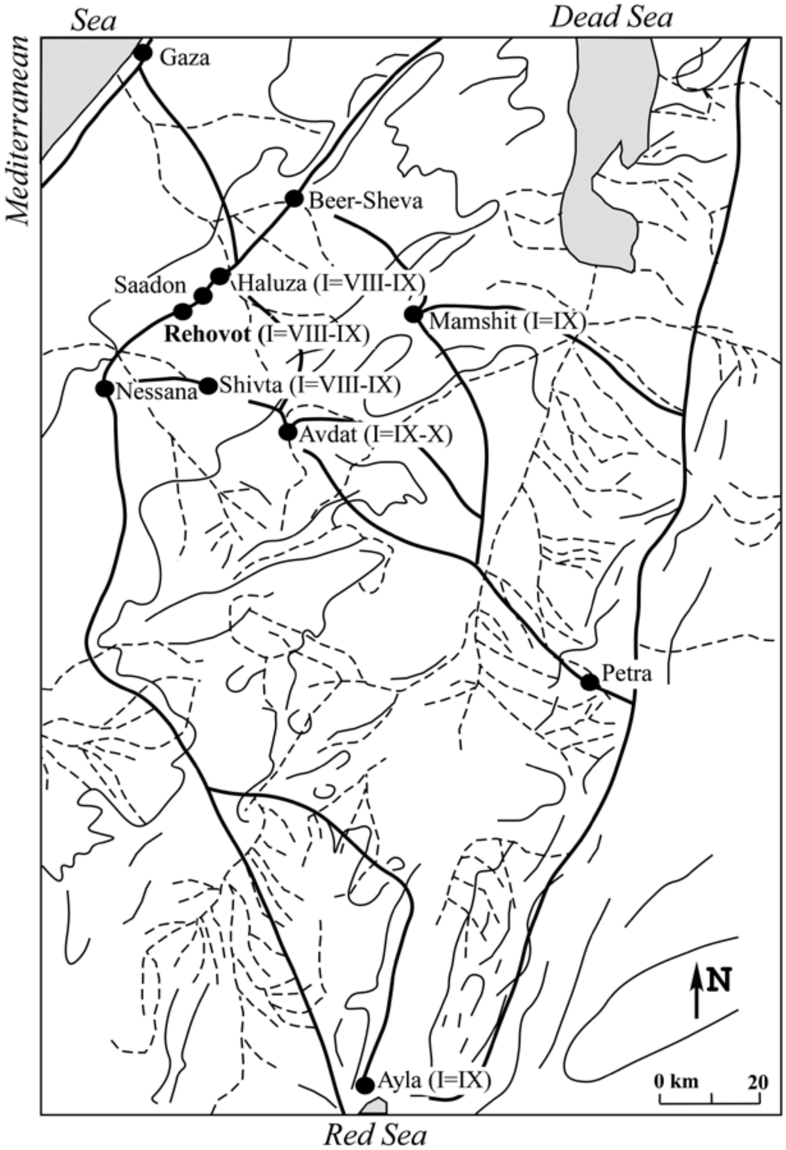

Fig. 1 The ancient caravan routes (thick lines) in the Negev desert, the intensities of the seismic oscillations (according to MSK-64 scale) of past earthquakes in the old cities studied by the authors are shown (scale 1 : 1 500 000)

were also occupied during the Turkish period. For example, they wrote that the cistern at the atrium was cleaned during the last years of the Turkish rule.

Types of Building Deformation – a Key to Recognizing the Seismic Causes of Destruction

Historians and archaeologists usually explain the abandonment of ancient cities by enemy invasions, epidemics, political turmoil and, only rarely, by natural disasters. However, seismic damage is a constant danger that has to be taken into account. Thus, information is needed concerning the nature and magnitude of past earthquakes in the region. The research field of archaeoseismology has been developed to meet this task[10].

The rocky desert of the Negev, in southern Israel, provides an excellent platform for archaeoseismological research. During the Roman and Byzantine periods a number of cities were built in the desert (fig. 1), employing high quality building methods. These cities flourished between the 2nd and 7th cent.,

10 Most important papers published in the field of archaeoseismology during last decade: Hinzen 2005; Korjenkov – Mazor 2005; Galadini et al. 2006; Korjenkov et al. 2006; Similox-Tohon 2006, 322; Similox-Tohon et al. 2006, 371–387; Caputo – Helly 2008; Gomes et al. 2008; Karakhanyan et al. 2008; Korjenkov et al. 2008; Sintubin – Stewart 2008; Korjenkov et al. 2009; Korjenkov – Schmidt 2009; Sohbati – Fattahi 2009; Eppelbaum 2010; Kázmér – Major 2010; Caputo et al. 2011; Karakhanyan – Avagyan 2011; Kázmér et al. 2011; Korjenkov et al. 2011; Korjenkov et al. 2012; Korjenkov – Mazor 2013.

Fig. 2 Izmit (Turkey) earthquake (1999, Mw=7.6), seismic rupture is shown by a white dashed line and the sense of motion (dextral strike-slip movements) by the white arrows; grey arrows indicate collapse direction of the buildings. All destroyed buildings have collapsed left at the upper part of the photograph, as a result of the opposite direction of ground motions during the earthquake. Most of the buildings (80 %) have collapsed right at the lower part of the photograph – also according to the direction of the ground motions at this wing of the fault

and were then abandoned. The ruins of the cities are well preserved, as the terrain was inhabited only by nomads, and the remaining stone walls and ruins were little damaged in the dry climate. Archaeoseismological studies at the ancient building complexes of the Negev reveal the character and dating of the identified destructions caused by earthquakes[11]. Hundreds of seismic deformations have been identified, such as tilts and collapses, shifts and rotations of the elements of ancient buildings, which systematically demonstrate the effect of ground motion directed in sub-longitudinal directions. We based our study on the field epicenter study of the strong recent Suusamyr earthquake (Kyrgyzstan, 1992, Ms=7.3)[12].

An example of a systematic pattern of a recent destruction is given in a photograph (fig. 2) of the epicenter area of the strong Izmit, Turkey, earthquake (1999, Mw=7.6). During the earthquake a seismogenic rupture took place, which reached the surface. It was a dextral strike-slip fault. Most of the buildings collapsed and were totally destroyed. The buildings (with one exclusion) collapsed due to inertia forces, applied on the ground during the seismic event. As is visible in the photograph, two buildings (#1 and #2) located at the eastern wing of the fault collapsed to the left – the opposite direction to the ground motion. At the same time, four buildings (# 3. 5–7) collapsed right, as this wing of the fault moved left. Only one building in this area (#4) collapsed left. Not all the buildings, or building constructions, collapsed, tilted or shifted in the opposite direction to the ground motion, but most of them did[13]. There were several reasons for this, including peculiarities of the building construction, local ground conditions, special interference of the seismic waves, etc. Note also that the seismic impact typically includes two stages of similar

11 Korjenkov – Mazor 1999a; Korjenkov – Mazor 1999b; Korzhenkov – Mazor 1999; Mazor – Korjenkov 2001, 123–153; Korjenkov – Mazor 2003, 51–82; Korjenkov – Mazor 2005; Korjenkov – Mazor 2013.

12 Korzhenkov – Mazor 1999; Korjenkov – Mazor 2005.

13 Korjenkov – Mazor 1999a; Korjenkov – Mazor 1999b; Korzhenkov – Mazor 1999.

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Rehovot-ba-Negev

Fig. 3 Plan of the Northern Church

Fig. 4 A tilt southward of the southern wall at the SE premises of the Northern Church (field station 3). The degree of the tilting is increasing with the distance from the abutted perpendicular wall. This phenomenon is the result of maximum freedom of oscillation at the central part of the wall

strength, in opposite directions. The first one is concerned with acceleration, and the second one with the slowdown of a movement impulse; the building can collapse in the first stage or, if it survives it, during the second stage.

Earthquake Damage Patterns at Rehovot-ba-Negev

The few excavated buildings at Rehovot-ba-Negev offer numerous examples of seismogenic destruction. Most of our observations are from the excavated Northern Church (fig. 3).

Tilted Walls

Tilt and the subsequent collapse of walls are typical features of destruction during modern and ancient earthquakes. While tilting and the collapse of walls could also be caused by military activity or ageing of the buildings with time, only seismic activity produces systematic wall tilts and collapses in a particular direction[14].

At Rehovot-ba-Negev, the southern wall of the SE premises of the North Church (field station 3 in fig. 3) tilted southwards (fig. 4). The wall trend is 108°; declination azimuth is 198°; and the angle is up to 75°. Another example can be seen at the same premises (field station 3) where one can observe the same damage pattern in the western wall: the wall trend is 13°, tilted to 81° and collapsed westward – toward azimuth 283°. Only a few fragments are preserved of the western wall, and only one stone high. The wall continues northward. Here it has a tilt and a westward collapse analogous to the SW corner of the western yard in the North Church (field station 4 in fig. 3). The trend of the azimuth of the wall is 18°; it is tilted at an angle up to 72°; and the declination azimuth is 287°; this is also the direction of the wall collapse (fig. 5). The wall continues northward until it meets the opposite wall of the northern premises (field station 5 in fig. 3). It is tilted WNW at a maximum angle of 21° (fig. 6); the trend of the wall is 31°, and the declination azimuth is 301°.

14 Korjenkov – Mazor 1999a; Korjenkov – Mazor 1999b; Korzhenkov – Mazor 1999.

Rehovot-ba-Negev, Northern Church

Fig. 5 An 18º-tilt and a collapse of the western wall westward at the SW corner of the western yard (field station 4). Opening between two perpendicular walls is shown by a double arrow, and a through-going fissure (joint) cuts three adjacent stones in succession (shown by three white arrows)

Fig. 6 Tilt of the western wall toward WNW at field station 5. There is an opening between the tilted wall and the perpendicular one

Fig. 7 A northward tilt of the original southern wall (field station 10). Note the open space between the mentioned wall and the perpendicular adjacent wall of a small room and the shifting of the upper part of the preserved revetment wall, also northward

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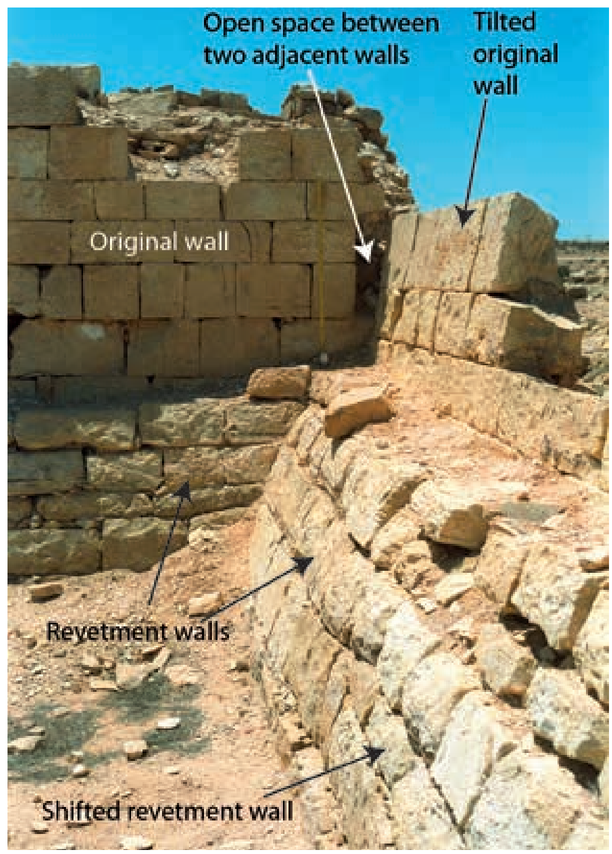

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The southern wall of the North Church (field station 10 in fig. 3) is tilted northward (fig. 7). The trend of the wall is 202º, and the maximum tilt angle is 77º. Because of this tilt one can observe an open space between the southern wall and the adjacent perpendicular one. The existence of revetment walls, supporting the southern wall of the Church from the south, indicates that the

8 a

8 b

southern wall's tilt occurred during the first of the Late Roman earthquakes. It seems that the southern wall began to tilt northward inside the building during the Early Arab earthquakes; additional evidence for this is the shift northwards of the upper part of the revetment wall. Stones of the perpendicular eastern wall are cracked in the small room marked on the plan. Nevertheless, this wall is better preserved (it is much higher) than the main southern wall of the North Church. This indicates that the seismic shocks during both earthquakes acted perpendicular to the main Church wall: it had freedom of oscillation and was significantly destroyed. The small eastern wall, oriented parallel to the effect of the seismic movements, withstood the seismic oscillations better, although many of its stones were significantly damaged. The whole northern wall of the Church (field station 12 in fig. 3) has a significant tilt to the south (figs. 8 a. b).

9

Rehovot-ba-Negev

Fig. 8 A southward tilt of the whole wall of the Northern Church, a: view toward east; b: view towards ESE from above. The angle of tilt is increasing up along the wall (a ›skyscraper‹ effect)

Fig. 9 Tilt and collapse of one of the walls at an unexcavated quarter

Collapsed Walls

At Rehovot-ba-Negev several measurements reveal the systematic failure of the walls in unexcavated quarters in certain directions: walls trending ~ 140° have fallen about 50°, and walls trending ~ 50° have collapsed ~ 140° (fig. 9). The well-house, which was built during the British Mandate, is significantly destroyed (fig. 10). This could be the effect of 20th century earthquakes, which caused building deformations all over Palestine and modern Israel.

Deformed Arches and Roofs

As mentioned above, the walls were not completely destroyed during the first shock that occurred in Late Roman times. The arches and roofs probably withstood the shock too, though many of them were significantly damaged (fig. 11). This is probably the reason why ancient people filled some of the rooms with earth[15] in order to protect them from complete collapse.

15 Tsafrir 1988, 210.

Rehovot-ba-Negev

Fig. 10 Destroyed well-house, built under the British Mandate, above the ruins of the Byzantine bath house

Fig. 11 Collapse of the arch in room L. 207, which has been filled with earth before its complete collapse

Shifted Wall Fragments

Above we wrote that the southern wall of the North Church (field station 10 in fig. 3) tilts northward (fig. 7); however, there is also shifting (10–15 cm) of the upper row of the stones in the same direction (fig. 12). Another example of the same phenomenon is a 15 cm shift eastward of two stones in the upper part of an arch column (fig. 13) in one of the excavated quarters of the ancient city. The arch above collapsed during the Byzantine shocks.

Walls Deformed as a Result of Pushing by an Adjacent Perpendicular Wall

The pushing of walls by a connected perpendicular wall has been identified as one of the seismic damage patterns at Mamshit – one of the ancient towns of the Negev desert, east of Rehovot-ba-Negev[16]. At Rehovot-ba-Negev we

16 Korjenkov – Mazor 2003.

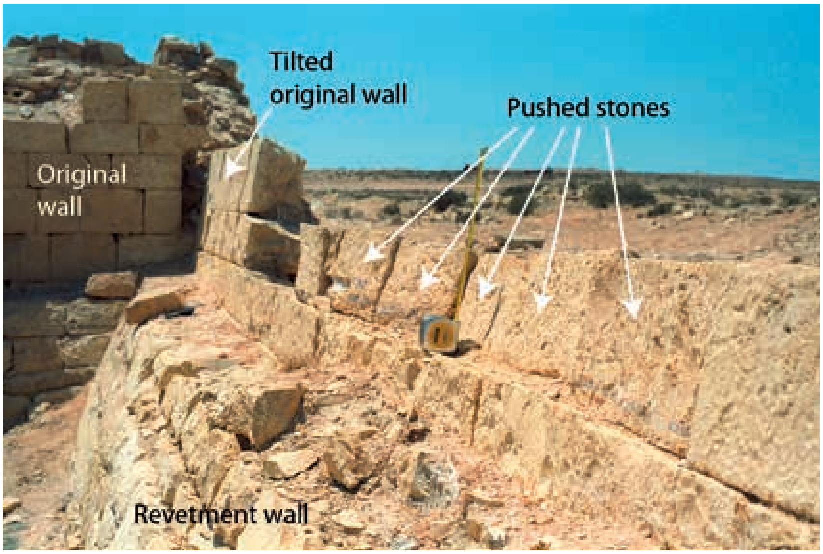

Fig. 12 Rehovot-ba-Negev, northward tilting and shifting of the southern wall of the Northern Church

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Rehovot-ba-Negev

Fig. 13 A horizontal 15 cm shift eastward of the upper part of an arch column in one of the excavated quarters

Fig. 14 Deformation of two perpendicular walls at the Caravansary, the ›feeding‹ wall pushed the perpendicular one. The later wall is significantly tilted. The ›Feeding‹ wall is also deformed: there are some openings in its upper part and joints (shown by arrows) crossing two stones are in the wall's lower part

find such an example at the SW corner of the large premises of the North Church (field station 2 in fig. 3), where three stones at the upper part of the wall have been moved, probably due to the push of an adjacent perpendicular wall. The trend of the deformed wall is 110º. The stones were shifted SSW (200º) at a distance of 12 cm. The perpendicular pushing wall has a trend of 24º. Another example can be observed at the SE premises of the North Church (field station 3 in fig. 3). There the northern wall (trend 115º) pushed the perpendicular western wall (trend 13º) westward. A similar picture can be observed at the stables of the Caravansary (fig. 14). Here the ›feeding‹ wall pushed a perpendicular one. Both walls are significantly deformed, tilted (declination angle 22º) and crossed by joints.

Opening between Adjacent Perpendicular Walls

The pushing of a wall by an adjacent perpendicular one is quite common. The pushed wall is usually tilted or/and collapsed. Between this tilted wall and the perpendicular one (the pusher) an open space is often formed. This could also be due to the especial vulnerability of corners to large seismic shocks, because

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Rehovot-ba-Negev, Northern Church

Fig. 15 Opening between two adjacent perpendicular walls at the SE premises (field station 3)

Fig. 16 Clockwise rotation of a stone in an eastern wall (field station 9)

wave-parallel and wave-orthogonal walls oscillate at different amplitudes and frequencies. Ordinary old buildings often lack coupling elements between adjacent walls, and long-lasting strong seismic oscillation often causes gaps (or long open cracks) which may lead to the failure of corners[17].

Such a phenomenon can be seen (fig. 15) at the SE premises of the North Church (field station 3 in fig. 3), where one can observe an opening of 20 cm between the northern wall (trend 115º) and the western one (trend 13º). Another example of such an opening can be observed at the SW corner of the large yard of the North Church (field station 4 in fig. 3). Here there is a gap between the southern wall (trend 115º) and the perpendicular western wall, tilted westward (fig. 5). The same pattern can be observed in the same wall, continuing northward (field station 5 in fig. 3). Here the western wall of the church tilted westward and there is a gap between it and the perpendicular wall (fig. 6).

Rotations of Wall Fragments

The rotation of wall fragments around a vertical axis is a common phenomenon during strong earthquakes[18]. Foundation stones are pulled out and rotated, indicating dynamic beating in the process of sharp horizontal oscillations of the whole wall (and not only its upper part). A seismic ground motion is the only mechanism that can cause rotation of building elements. A large number of observed rotations, and the obvious directional systematics, support this conclusion[19]. An example of rotation (fig. 16) can be observed outside the eastern wall of the North Church (field station 9 in fig. 3). Here one stone in the upper preserved row was rotated clockwise. The general trend of the wall is 24º; and the trend of the rotated block is 26º.

Wall Crossing Fissures (Joints)

Many researchers mentioned that deformation of through-the-wall fissures at archaeological sites were caused by ancient earthquakes. Indeed, fissures

17 Korjenkov et al. 2009.
18 Korjenkov – Mazor 2013.
19 Korjenkov – Mazor 1999a; Korjenkov – Mazor 1999b; Korzhenkov – Mazor 1999.

crossing adjacent stones are the strongest evidence of the seismic origin of these deformations. Such throughgoing fissures are only formed as a result of high intensity earthquakes, as high energy is necessary to overcome the stress shadow of free surfaces at the stone margins, i. e., the free space between adjacent stones[20].

At Rehovot-ba-Negev, the wall standing to the right of the southern entrance into the North Church (field station 1 in fig. 3) is crossed by numerous joints (fig. 17). One of them crosses through three stones. The trend of the deformed wall is 20°, and the length of the joint is 83 cm. Another throughgoing joint can be observed at the western corner of the large yard of the North Church (field station 4 in fig. 3). Here there is a joint cutting three stones in a wall trending of 114° (fig. 5). The length of the throughgoing fissure is 48 cm.

Fig. 17 Rehovot-ba-Negev, joints at the wall at the southern entrance into the Northern Church (field station 1) cut through three stones

A Crack Crossing through the Wall at the Water Reservoir

A through-the-wall crack was observed at the Rehovot-ba-Negev water reservoir. The whole wall is cut by this rupture (fig. 18), resembling a ›pure‹ seismic rupture with a horizontal displacement (left-lateral shift) on the first ten centimeters. However, this rupture does not continue in either the adjacent ancient building constructions, or in the relief features. Additional study, and palaeoseismological trenching of the rupture is necessary. The described rupture could be the reason for the disappearance of the water resource in the town, and its subsequent abandonment.

Revetment Walls

Sloping support walls have been found in the North and South Churches[21] and in private buildings. The core of the revetment is a combination of small rough stones and earth, with a layer of larger roughly-dressed stones on the outside. The revetment is cemented by grey mortar, consisting of chalk and ashes. The revetment wall is laid on the virgin loess. The wall reaches 1.80 m in height and is 90 cm wide at the base. The whole northern wall of the big courtyard (field station 6 in fig. 3) of the North Church is surrounded by the revetment wall (fig. 19), its half was demolished at present time. The revetment wall continues around the northern room (field station 7 in fig. 3) of the main premises of the North Church (fig. 20). At the NE corner of the North Church, one can observe the continuation of an encircling revetment wall (field station 8 in fig. 3). At this corner the wall is destroyed (fig. 21), with the stones collapsing northwards on an original wall. The encircling revetment wall is of good quality. The destruction event (an earthquake), which deformed the original wall, occurred before the decline of the Byzantine Empire. There was then another seismic event which led to the destruction of the revetment wall itself. The last event was probably an end of ›civilized‹ life here.

The outside part of the eastern wall is also surrounded by the revetment wall (field station 9 in fig. 3), which is now almost entirely destroyed. The same pattern can be observed at the central southern jamb of the North Church (field station 10). All the three walls composing the jamb are surrounded by revetment walls that are also partly destroyed. The revetment walls at Rehovot-ba-Negev were built during the Byzantine period[22]. Such walls are very common at the Negev cities, e. g. ancient Avdat, Mamshit and Shivta[23].

20 Korjenkov – Mazor 1999a; Korjenkov – Mazor 1999b.
21 Tsafrir 1988, 210.
22 Tsafrir 1988, 210.
23 Korjenkov – Mazor 1999a; Korjenkov – Mazor 1999b; Korzhenkov – Mazor 1999; Korjenkov – Mazor 2003.

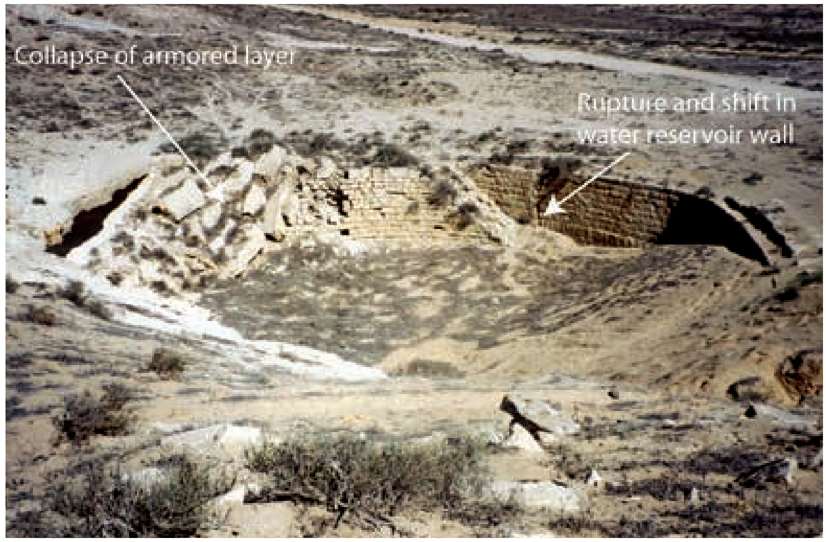


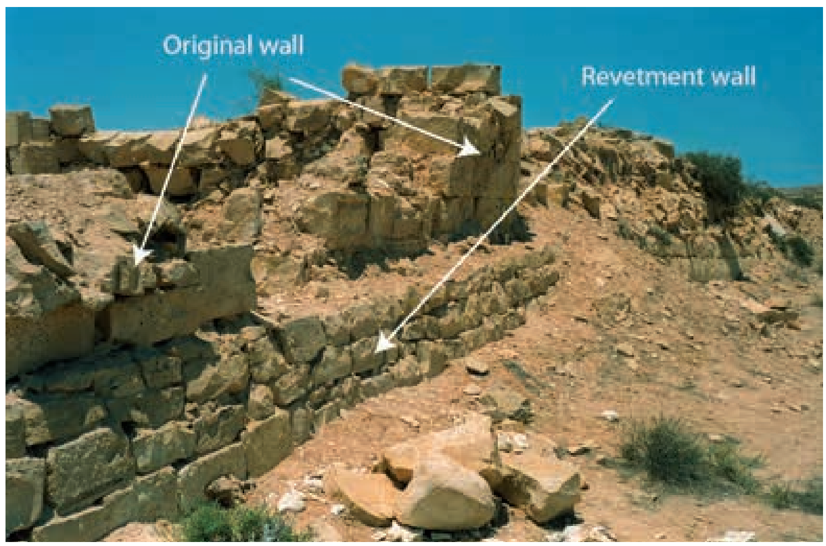
Fig. 18 Rehovot-ba-Negev, seismogenic (?) rupture at the SE wall of the water reservoir. The reservoir was partly cut out of the bedrock and is partly brick-built. Also note the collapse of a significant part of the armored layer which partly covered the reservoir from SW

Rehovot-ba-Negev, North Church

Fig. 19 A deformed northern wall is supported by a revetment wall (field station 6). A strong deformation of the original wall is seen by wide openings between stones and a tilted block at the central part of the Figure

Fig. 20 Continuation of the revetment wall (field station 7)

Fig. 21 Revetment wall at the NE corner



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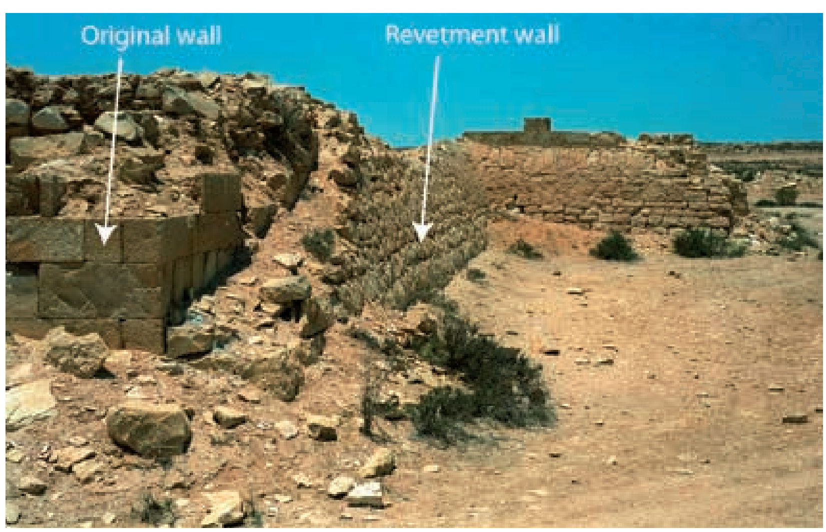

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Fig. 22 Rehovot-ba-Negev, Northern Church. An ancient column within a wall that was built in order to protect it from possible future destruction

Columns Supported by Walls

Columns at ancient and modern buildings cause the redistribution of the static load of the whole building construction, and serve as art decoration of the internal and external parts of the building. When a researcher finds a column supported by a later wall, he can be sure that the column was severely deformed, making the supporting wall necessary. Such an example can be found in the North Church (fig. 22).

Features of Later Repair and Rebuilding

Tsafrir et al.[24] wrote that when the revetment wall was built around the church it closed the entrance to one room. A new threshold was installed which was about 60 cm above the former floor level. No remains of steps inside the room were found. This means that after the first earthquake the floor was covered by debris, which was not cleaned, but leveled, requiring a new threshold.

Another example of the later adjustment of a damaged building was noted at the Staircase Tower. At its NE corner there was a large (75 cm × 80 cm) window, which was later adopted as a secondary entrance from the atrium: long blocks used as steps were found from both sides of the window. Apparently the ›normal‹ entrance was damaged during the first earthquake and went out of use, so the people started to use the better preserved window as an entrance. Sherds, fragments of glass, and metal weights, found in the Staircase Tower, are additional evidence of earthquake damage.

Secondary Use of Stones from Destroyed Walls

Secondary use of stones from damaged and destroyed walls is a common feature at the cities that experienced strong earthquakes. For example, a large fragment of a water basin was found in an Early Arab secondary wall at the east end of the porch (Room L 522[25]). Another secondary wall was discovered at the eastern porch of the atrium behind the stylobate and preserved it at a height of two-three rows, which blocked the atrium from the west.

24 Tsafrir 1988, 210.
25 Tsafrir 1988, 210.

Some screen fragments of imported marble of the common Early Byzantine type were also used to replace broken pavement slabs in rooms L 512 and 521 of the Northe Church's chapel[26], probably by Arab squatters who dwelled in the chapel after the church was abandoned. The blocking of the door of the narthex and Arabic inscriptions written on plaster support this conclusion.

Summary

The damage patterns at Rehovot-ba-Negev lead us to the conclusion that most were produced by seismic oscillations. Later repairs and the numerous support walls indicate several seismic events which left their traces in the city.

One of the earthquakes occurred at the end of the Roman Empire, as indicated by the following features:

- tilted and shifted walls, surrounded by revetment walls (figs. 7. 8. 12. 19–21)
- columns supported by walls (fig. 22)
- deformation of arches and roofs (fig. 10)
- rooms filled with earth in order to prevent the collapse of roofs (fig. 10).
- features of later repair and rebuilding
- secondary use of building elements

The construction of the North Church at Rehovot-ba-Negev was dated by a funerary inscription of 460 to 470 A.D.[27]. Tsafrir has distinguished two phases of construction: an initial phase, whereby the church complex was rebuilt with minor modifications, and a second phase that involved the creation of the revetment walls[28]. Avraham Negev[29] believed that these support walls were features of the renovation of the North Church after it was destroyed by a strong earthquake that occurred before 505 A.D. He mentioned severe earthquakes that took place in the region at 447, 498, and 502 A.D.[30]. The 5th century earthquakes led to the repair of various structures.

Another earthquake occurred at the end of Byzantine sovereignty, which could be the earthquake that destroyed Avdat in the 7th century A.D.[31]. The last caused the abandonment of Rehovot-ba-Negev. Subsequently only Arab-Bedouin nomad families temporarily occupied the houses that survived the seismic shocks.

The features indicating Byzantine shocks are:

- tilted and shifted walls (figs. 4–7. 13)
- stone rotations (fig. 16)
- pushing of a wall by an adjacent perpendicular wall (fig. 14)
- opening between two adjacent perpendicular walls (figs. 5. 6. 15)
- throughgoing joints (figs. 5. 14. 17)
- a crack cutting the water reservoir (fig. 18)
- collapse of the strong layer that covered the water reservoir (fig. 18)

The abundant pottery found by Tsafrir et al.[32] in one of the rooms of the residential buildings in the Southern Quarter (Area B) is typical Byzantine ware that remained in use in the Negev into the first decades following the Arab conquest. They concluded that the roofs likely collapsed in the early 8th century, at the latest, as the finds did not include characteristic forms of the 8th century. The same authors[33] noted that the excavated rooms in the crypt of the North Church and the staircases were completely filled by debris of earth and stones, which had fallen when the vault of the crypt collapsed. They

26 Tsafrir 1988, 210.
27 Tsafrir 1988, 210.
28 Tsafrir 1988, 210.
29 Negev 1989.
30 Amiran et al. 1994.
31 Fabian 1998; Korjenkov – Mazor 1999a.
32 Tsafrir 1988, 210.
33 Tsafrir 1988, 210.

believe that the concentration of drams, capitals and other building elements, which were found in the crypt, cannot be considered as accumulation due to natural processes of decay. For example, five capitals were found in the lower part of debris, above the floor. Such damage patterns suggest two main phases of destruction: the first when the church columns collapsed and the church was severely destroyed[34], the second when the vault of the crypt collapsed and the staircases were filled with debris.

Two phases of destruction can also be identified in room L 509, as described by Tsafrir et al.[35]. They wrote that the room was full of debris, which included stones from the walls and roof slabs. Additionally the authors mentioned slabs and a column dram located close to the floor level (first seismic event). However, most roof slabs were found in the upper part of the debris, at a height of about 3 m, suggesting they collapsed during the second event. Interestingly, hundreds of small fragments of multicolored fresco and inscriptions were found within the lower meter of debris above the floor. Here, Tsafrir et al.[36] discovered large fragments of Late Byzantine pottery, marble, glass and fixtures. Thus, the Church was likely destroyed in Late Byzantine times, while the upper slabs testify to a second (Early Arab?) earthquake. The observed damage probably belongs to a seismic event that occurred after the abandonment of the town in the 7th century A.D.[37]. Although Rehovot-ba-Negev was seriously damaged and destroyed during that earthquake, some walls did withstand the shocks. The following earthquake occurred in the 9th century A.D.[38] and it destroyed these walls.

Features testifying to earthquakes during the Turkish-British time are:

- wall tilting and collapse (figs. 9. 10)

The earthquake of the 9th century was not the last to affect the Negev Desert. There were several strong events which shocked the region; however the absence of buildings of the medieval age means we cannot trace the medieval earthquake features. Thus the preserved parts of ancient buildings and Turkish-British constructions can only be used as ›fossil seismoscopes‹[39] for the 19–20th centuries.

An example of the seismic destruction of constructions built during the Turkish and British Empires is a later rebuilt Byzantine bath house located near a well. The bath house was destroyed during the Turkish time[40]. Most probably there was a natural reason for its destruction. The authors of this paper have traced the impact of an earthquake at Turkish-British constructions in the adjacent Bedouin village of Khalsa, built on ruins of ancient Haluza[41], where the deformations cover a large area. The earthquake which affected the Khalsa village would have also left traces in buildings of the same age at Rehovot-ba-Negev. Interestingly, the well-house, which was built during the British Mandate, was also significantly destroyed (fig. 10). This could be the affect of the Jericho 1927 and/or the Aqaba 1995 earthquakes, which caused deformations all over Palestine and modern Israel.

There are few measurements of tilted and fallen walls, small remnants of which are still projected above the surface (fig. 9). Generally these walls tilted or collapsed toward ESE (fig. 23).

The degree of destruction at all the studied cities of the Negev desert (Avdat, Haluza, Mamshit, Rehovot-ba-Negev and Shivta) is similar (fig. 1). In order to produce such deformations, the local seismic intensity would have had to be I > VIII. In our previous papers[42] we came to the conclusion that most of these deformations were caused by the local faults which dissect the Negev, and not the Dead Sea Transform. If it would be the case of the Dead

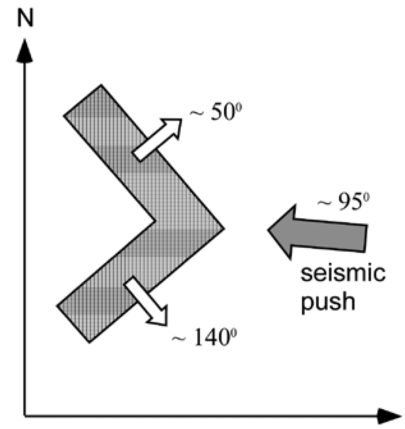

Fig. 23 The scheme shows directions of tilts and collapses in Rehovot-ba-Negev at unexcavated quarters. SE-oriented walls are tilted and collapsed toward NE, while NE-oriented walls are tilted and collapsed toward SW. In order to produce such damage patterns it was necessary to involve seismic shocks coming from the east

34 Christians could nevertheless remove the reliquary and precious decorations when they abandoned the church. Tsafrir 1988, 210.
35 Tsafrir 1988, 210.
36 Tsafrir 1988, 210.
37 Fabian 1998; Korjenkov – Mazor 1999a.
38 Korjenkov – Mazor 1999b.
39 Korzhenkov – Mazor 1999.
40 Tsafrir 1988, 210.
41 Korjenkov – Mazor 2013.
42 Korjenkov – Mazor 1999a; Korjenkov – Mazor 1999b; Mazor – Korjenkov 2001; Korjenkov – Mazor 2003; Korjenkov – Mazor 2005.

Sea Transform, the degree of deformations would decreased from Mamshit in the east (maximum) to Rehovot-ba-Negev in the west. However, the degree of seismic deformation is not damping westward.

Recent geological research has revealed the existence of a strike-slip fault, the ›Saadon fault‹ next to the site of Saadon, and close to Rehovot-ba-Negev. A dry river Nahal Saadon follows the strike of the fault and is incised into the chalk layers of the uplifted geological block. The fault strikes N65 degrees W, dipping steeply to the northeast, and is between 0.5–1.0 km of long, with a vertical displacement of 2–3 m[43]. This fault, as well as other adjacent faults (Sde-Boker, Nafha, Ramon, Paran faults), could be the source of the seismic oscillations which destroyed Rehovot-ba-Negev as well as other adjacent ancient desert cities.

Thus our archaeoseismological study of the ruins at ancient Rehovot-ba-Negev has revealed numerous features of seismic destructions, which testify to at least four earthquakes that affected the ancient town. The seismic intensities of these ancient seismic events were in the range of I=VIII–IX. This data confirms similar results in the adjacent ancient cities of the Negev desert – Avdat, Haluza, Mamshit and Shivta. This region, west of the Dead Sea Transform, is seismically unquiet, and strong earthquakes have occur here every few hundred years. This fact has to be taken into account in the future development of the building code in southern Israel.

43 Greenbaum – Ben-David 2001, 123.

Abstract

Andrey M. Korzhenkov – Emanuel Mazor, Archaeoseismological Damage Patterns at the Ancient Ruins at Rehovot-ba-Negev, Israel

An archaeoseismological study of ruins at ancient Rehovot-ba-Negev (Rehovot in the Negev) has revealed numerous features of seismic destruction, such as tilted and collapsed walls and arches, shifting and rotations of wall fragments, deformation of walls due to pushing by an adjacent perpendicular wall, opening between adjacent perpendicular walls, wall fissures (joints), and wall cracks at a water reservoir. Supporting walls and columns, which indicate post-earthquake repair, are also deformed and destroyed. These seismic damage features testify to at least four earthquakes that struck the ancient town: the first one during the 5th cent. A.D., the second earthquake in the 7th cent., the third seismic event occurred at the Early Arab period (9th cent.) and the fourth earthquake in the 20th cent. Local seismic intensities of ancient seismic events were in the range of I=VIII–IX. These data confirm our previous similar results at adjacent ancient cities of the Negev desert – Avdat, Haluza, Mamshit and Shivta. This region, west of the Dead Sea transform, is seismically unstable. Strong earthquakes occur here once in a few hundred years.

Keywords
Archeoseismology • ancient earthquakes • ancient cities • Negev desert • Israel

Sources of illustrations
Fig. 1: Modified version of a map at Korjenkov – Mazor 2005 • Fig. 2: Background photograph E. Altunel • Fig. 3: Modified after Shereshevski 1991, fig. 12 • Figs. 4–7. 9. 11–13. 15–17. 19–22: A. M. Korzhenkov • Figs. 8. 10. 14. 18: E. Mazor • Fig. 23: A. M. Korzhenkov – E. Mazor

Abbreviations

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