Crusader castle torn apart by earthquake at dawn, 20 May 1202

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ABSTRACT

The Crusader castle of Vadum Jacob, an outpost overlooking the Jordan River, was deformed during a destructive earthquake triggered by motion along the Dead Sea Transform. The M >7 earthquake occurred at dawn, 20 May 1202, and offset the castle walls by 1.6 m. This exceptional precision in dating and estimating displacement was achieved by combining accounts from primary historical sources, by excavating the Dead Sea Transform where it bisects the castle, and by dating faulted archaeological strata. The earthquakes of October 1759 and/or January 1837 may account for the remaining 0.5 m out of a total 2.1 m of offset. Our study exploits the potential embodied in interdisciplinary historical-archaeological-geological research and illustrates how detailed histories of seismogenic faults can be reconstructed.

INTRODUCTION

The amount and timing of slip in historical earthquakes can be reconstructed with exceptional precision by combining evidence from archaeological observations and historical accounts. Excavation of ruins located along active fault traces (e.g., Noller et al., 1994) can also serve to address key questions in earthquake mechanics and aid in assessment of local seismic hazard. Archaeology, however, has had a different agenda, and harnessing this labor-intensive discipline for seismic studies requires a special effort. Guidoboni (1996, p. 7) states, for example, "It is only very rarely that the archaeological identification of traces of earthquakes has gone beyond conjecture, even on those occasions where admittedly a geophysicist has been called in." Our effort, focused on archaeological remains along the Dead Sea Transform (Fig. 1), has yielded the first direct evidence of surface rupture accompanying the earthquake of 20 May 1202. This earthquake, widely reported by contemporary historical sources (Mayer, 1972), was felt in a region extending for more than 3000 km, between Iraq in the east and Sicily in the west. On the basis of eyewitness accounts, Ambraseys and Melville (1988) assigned a magnitude of 7.6 to the earthquake.

The systematic offset of pre-Miocene geologic features across the Dead Sea Transform reveals that motion takes place primarily by left-lateral shear. Many large-magnitude earthquakes have occurred in the region throughout recorded

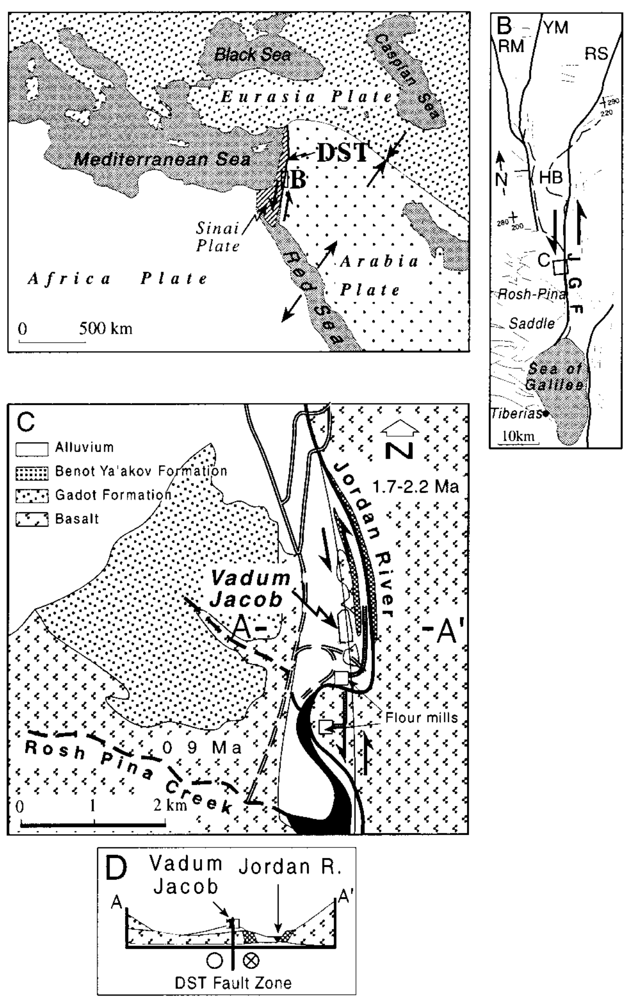

Figure 1. Location maps: A. Tectonic plates of Middle East. Dead Sea Transform (DST) is boundary between Sinai and Arabia plates. B. Dead Sea Transform zone showing main faults (solid lines) and secondary, mostly normal, faults (slim lines). JGF—Jordan Gorge Fault, RM—Roum Fault, YM—Yammuneh Fault, RS—Rashaya Fault, HB—Hula Basin (after Bartov, 1990). C. Geologic map of Vadum Jacob area showing Pliocene to Pleistocene basalt flows with K-Ar ages (Goren-Inbar and Belitzky, 1989; Heimann and Ron, 1993), Quaternary lacustrine sediments of Gadot and Benot Ya'akov Formations, and Holocene alluvium (partly after Belitzky, 1987). D. East-west section across Vadum Jacob showing a fault through fortress. Circles indicate out-of-plane motion: empty circle—toward, crossed circle—away.

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history (Amiran et al., 1994). The destructiveness of these earthquakes is manifested in various archaeologic sites, where human-built structures show extensive earthquake-induced damage, but deformation of a human habitat by transform-related shear has not been previously documented. Here, we report for the first time on a measurable offset of a Crusader castle wall associated with the earthquake of 1202.

The castle of Vadum Jacob (Jacob's Ford) was strategically established on a hill overlooking a ford on the Jordan River (Fig. 1B). It was one of the largest castles in the Latin Kingdom of Jerusalem, spanning about 150 m by 50 m (Fig. 2A). Detailed historical records allow the history of Vadum Jacob to be dated with unusual precision: According to independent Latin sources (e.g., Ernoul, 1871; William-of-Tyre), Muslim chroniclers (Abu-Shama; Ibn-al-Athir; 'Imad al-Din; al-Isfahani), and others (Lyons and Jackson, 1982, p. 140–141), the foundation stone of the castle was laid in October 1178; the partially constructed castle was besieged and destroyed 11 months later, on 30 August 1179. The castle is surrounded by a 4-m-thick wall composed of a parallel pair of meticulously laid ashlar supports, enclosing an ~3 m fill of cemented basaltic cobbles. These walls, built by highly skilled Crusader masons, were erected with great precision along smooth, straight lines. Thus, they serve as excellent strain gauges for deformation after 1179.

GEOLOGIC SETTING AND CURRENT FAULT ACTIVITY

The Dead Sea Transform accommodates sinistral motion between the Arabia and Sinai tectonic plates, transferring extension in the Red Sea to the Arabia-Eurasia collision zone (Fig. 1A). South of the Sea of Galilee, the Dead Sea Transform offsets a variety of pre-Miocene geologic features by 105 km (Freund et al., 1968; Garfunkel, 1981; Quennell, 1956). Between the Sea of Galilee and the Hula pull-apart basin to the north is the Rosh-Pina Saddle, a structural and topographic high. North of the Hula, the displacement is distributed among the Roum, Rashaya, and Yammuneh faults (Fig. 1B); the latter links the Dead Sea Transform to the collision zone. Where the Jordan River crosses the Rosh-Pina Saddle it forms a narrow gorge. Exposures of fault planes of the main trace of the Dead Sea Transform along the Jordan Gorge have not been reported, but the termination of rock units and the different geometry of secondary faults on both sides, along with morphologic indicators, suggest that the main transform fault here follows the gorge (Garfunkel et al., 1981; Harash and Bar, 1988; Heimann and Ron, 1993). A seismic reflection survey showed that the fault zone has a flower structure with the main active fault coinciding with the Jordan Gorge (Rotstein and Bartov, 1989).

Recent activity along the transform near the study area is manifested by historical and current seismicity, and by strong deformation of Pleistocene sediments and basalts (Garfunkel et al., 1981). Microseismicity along the Jordan Gorge is subdued relative to that in the adjacent Sea of Galilee and Hula basins. A focal plane solution of the strongest event recorded instrumentally in the Hula Valley (M_L 4.3) shows mainly sinistral motion and a minor normal component (van Eck and Hofstetter, 1990). A geodetic survey of the area has not detected any creep along the fault since the establishment of the benchmarks in 1988 (Karcz, 1995).

OFFSET ARCHAEOLOGICAL STRUCTURES

We discovered offset archaeological remains at four excavated locations within the castle (Fig. 2). Three of these locations are Crusader structures and the fourth is a late medieval–early modern Muslim structure. The offset, fully expressed in the southern and northern defense walls, reaches 2.1 m in sinistral displacement with <5 cm of vertical slip (Marco et al., 1997). The 50-m-long walls crossing the hill are ideal baselines, having meticulously laid masonry and a fault-perpendicular (east-west) orientation. The displacement measured on the walls records the cumulative slip on the fault since 1179, the year the castle was conquered by Saladin. Displacement is distributed over about a 10-m-wide zone, and the deformation is accommodated primarily by small offsets and rotations of the carved limestone blocks. All the displacements on the southern wall are purely horizontal (all the blocks retain their original level), and all the rotations are about vertical axes. A minor vertical component of slip, up to 10 cm, is observed in the northern wall. North of the southern main gate, the fault trace bends westward and a Crusader floor is torn, forming a 2-m-wide graben (Fig. 2A). The geometry of the graben is compatible with a small left bend in the trace of the fault.

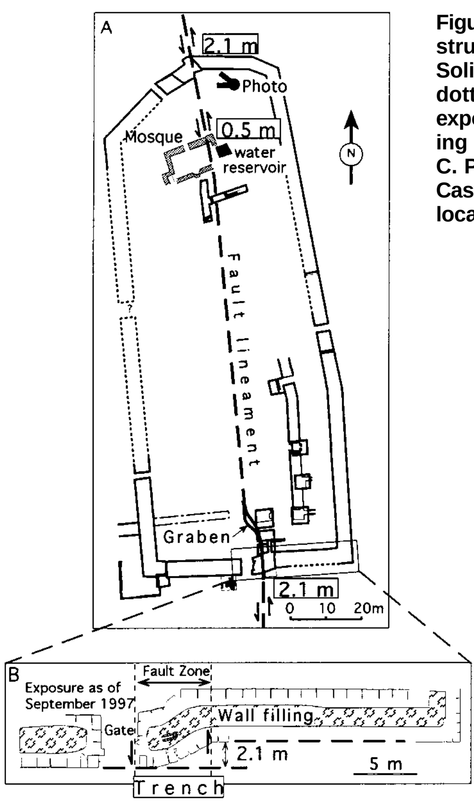

Figure 2. Location of offset human-made linear structures. A. Plan of Vadum Jacob fortress. Solid lines mark well-exposed parts of walls; dotted lines denote unexposed or partly exposed walls. B. Map of southern wall showing displacements and rotations of masonry. C. Photo of deformation in northern wall of Castle of Vadum Jacob. Line marks prefaulting location of wall.

C

In the northern part of the castle, we also unearthed a Muslim mosque whose northern wall is displaced sinistrally by 0.5 m. A mikhrab (the Muslim praying apse) is well preserved in the southern wall. According to the study of the pottery, the mosque was built, destroyed, and rebuilt at least twice: the initial structure was built in the Muslim period (12th century) and later rebuilt once or twice during the Turkish Ottoman period (1517–1917). The 0.5 m displacement is observed in the northern wall of the latest building phase. The repetitive building of this site might be due to earthquakes.

DATING OF EARTHQUAKE-RELATED DISPLACEMENTS

Four post–A.D. 1179 major earthquakes are recorded by historical sources in northern Israel. These are the earthquakes of A.D. 1202, 1546, 1759, and 1837 (Amiran et al., 1994).

The estimated zone of damage to buildings (meisoseismal zone) of the 20 May 1202 earthquake extends from 100 km south to 150 km north of Vadum Jacob. It was felt in the entire eastern Mediterranean region and throughout the Levant. Ambraseys and Melville (1988) estimated the magnitude at 7.6, with maximum displacement of about 2.5 m.

Damage from the 14 January 1546 event extended from 75 km to 150 km south of Vadum Jacob (Amiran et al., 1994). Ambraseys and Karcz (1992) argued for a moderate magnitude (M_S~6.0) for this event and inferred that the epicenter was located in Judea, ~100 km south-southwest of Vadum Jacob. Thus this event is unlikely to have ruptured the Jordan Gorge segment of the Dead Sea Transform.

Two close events occurred on 30 October and 25 November 1759. Sieberg (1932) located the maximum damage zone of the October earthquake between the Sea of Galilee and the Hula Valley, and that of the November event some 150 km farther north in northeast Lebanon. Ambraseys and Barazangi (1989), quote a letter dated 1760 in which the French ambassador to Beiruth reported surface ruptures along 100 km of the Yammuneh segment of the Dead Sea Transform and attributed them to the November 1759 earthquake. Ambraseys and Barazangi (1989) estimated the magnitude of the 25 November 1759 earthquake at ~7.4. The October 1759 M ~6.6 foreshock, determined on the basis of isoseismals that center at the Jordan Gorge (Ambraseys and Barazangi, 1989; Sieberg, 1932), could be related to faulting at Vadum Jacob.

The most recent destructive earthquake to strike the study area was the M ~6.3 1 January 1837 Safed earthquake. The center of the highest damage zone, IX–X Mercalli intensity, coincides with Vadum Jacob (Vered and Striem, 1977).

In order to date the slip events at Vadum Jacob, we excavated a trench adjacent to the offset southern wall of the fortress (Fig. 2). Sediments exposed in the trench provide constraints on the history of surface ruptures, as recorded in the castle construction debris and overlying colluvium.

The trench was excavated into an artificial slope. Sections were made into the slope at several locations, and the pottery was studied and dated. The sediments exposed in the trench compose four primary stratigraphic units (Fig. 3). The lowest, unit 1, is composed of the sediments that were dumped by the builders at the time of castle construction; these bury the first six stone layers of the wall. At two distinct horizons the fill was leveled out and covered with a layer of lime. These limy layers are continuous at the same level around the perimeter of the wall. Unit 2 is the upper limy layer. We found building tools, mason stone blocks, arrowheads, and other remains of the siege immediately on top of the layer indicating that unit 2 was the surface level as of August 1179 and serves as an accurate time marker.

One of the Muslim chroniclers of the siege (Abu-Shama) stated that Saladin, the conqueror of the castle, "tore away the stones of the castle, by his own hands, destroying it like one effaced letters of a parchment." The conquest of the castle and the massacre of its defenders brought about a plague that started within a few days of its capture, causing the evacuation of the site (Lyons and Jackson, 1982). We therefore conclude that the massive destruction and dismantling of the wall started and terminated within a very short period of the conquest and that the two ashlars on the top of unit 2 fell or tumbled there from the wall immediately after the castle was captured by the Muslims, or possibly during the siege.

Overlying unit 2 is a wedge of colluvium, unit 3, that was shed off the wall infill after the exterior wall face was removed. Presumably, the colluvial unit 3 piled up as the weakly cemented interior wall deteriorated and decomposed over the ensuing centuries. Thus unit 3 started to accumulate after the Muslim conquest, and it ranges in age from about the end of A.D. 1179 to the present. Unit 4 is the modern bioturbated A-soil horizon.

The trench (Fig. 3) exposed a system of faults and cracks that are coincident with the displacement of the Crusader wall. The faults extend to two different stratigraphic levels: One group of faults displaces the alluvium of unit 1 and the limy level of unit 2, but extends only a few centimeters into post-1179 unit 3; the second group of faults breaks much higher into the colluvial wedge, up to the base of the modern soil horizon, and possibly to the surface. These observations suggest that at least two earthquakes produced the 2.1 m offset of the southern wall that is now observed. One event occurred soon after the outer ashlar wall was removed, i.e., very soon after 1179. The second post-1179 earthquake also produced rupture at Vadum Jacob, but well after removal of the wall and the accumulation of the colluvium, probably much closer to the present.

The A.D. 1202 earthquake occurred fewer than 23 years after the capture of the castle and is almost certainly the source of the first set of interpreted ruptures breaking the lowermost part of unit 3. The later rupture(s) may be associated with the 1759 and/or the 1837 earthquakes. We adopt Ambraseys and Karcz's (1992) view that

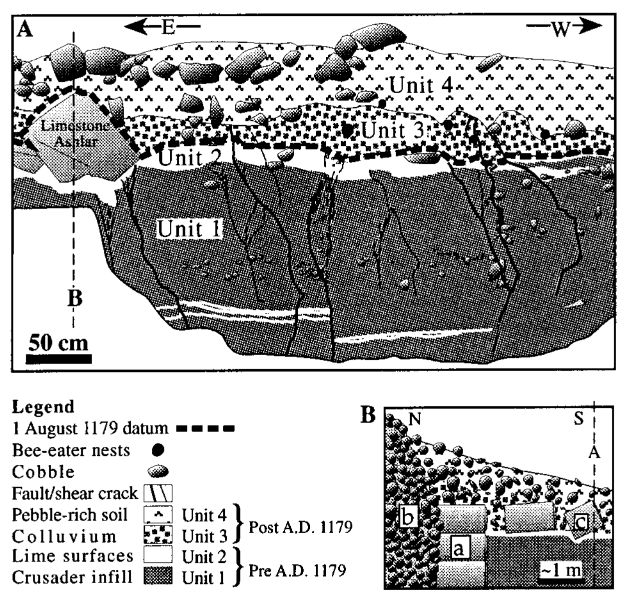

Figure 3. A. Log of a trench wall, parallel southern face of castle. Unit 1, composed of pressed alluvium, and unit 2, a lime pavement, were laid by Crusader masons as wall was built and were used as ramp for hauling heavy building blocks. Unit 2 was at surface on day of Muslim conquest and provides a horizon precisely dated as 30 August 1179 (bold dashed line). Unit 3 started to accumulate after conquest of castle. Degradation of wall infill is apparent in abundance of basaltic cobbles. Masoned limestone ashlars on left were fallen or tumbled there by Muslims who destroyed castle in 1179. Unit 4 is cobble-rich A-soil in which pedogenic processes are intense. Two sets of faults (thick lines) and shear cracks (thin lines) are evident: One terminates at top of unit 2 or lowermost few centimeters of unit 3; second crosses unit 3 entirely. Active bioturbation in unit 4 hinders preservation of cracks. B. Schematic north-south section in southern wall of castle: (a) exterior wall support; (b) wall infill of cemented, mainly basaltic, cobbles; (c) masoned limestone blocks that fell from exterior wall.

the 1546 earthquake was considerably farther south, closer to Judea, and its magnitude was too small to produce surface rupture at Vadum Jacob.

CONCLUSIONS

Our findings support the historical records of large and destructive earthquakes in the Dead Sea region and demonstrate that the Dead Sea Transform poses substantial seismic hazard. The low seismicity in recent years and the absence of significant creep along the fault, evident from repeated geodetic surveys, suggest that the fault is currently locked. Projecting the destructive force of past earthquakes to likely future events warns for the potential of widespread damage in large population centers of Jordan, Syria, and Israel. Future excavation of additional archaeological and prehistoric sites along the Dead Sea Transform should help to characterize the long-term behavior of rupture segments along the fault.

The abundant historical and archaeological data available from the Dead Sea Transform fault region provides an opportunity for detailed studies of destructive earthquakes. This study illustrates the use of geoarchaeology to assess history of faulting in active tectonic zones. On-fault archaeoseismology offers the potential for identifying and accurately dating past earthquakes over several earthquake cycles, thus providing fundamental information on earthquake recurrence patterns and mechanisms.

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