Archaeoseismology in a Bronze aged settlement: La Tira del Lienzo (Totana, Spain)

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Abstract: We present an archaeoseismological study in La Tira del Lienzo (Totana, Spain). The settlement belongs to the Argar archaeological group (2200-1550 BC, Bronze Age) and is being excavated by a team from the Departament de Prehistòria at the Universitat Autònoma de Barcelona (Spain). The site is located on the Alhama de Murcia fault zone (AMF), responsible for the 11/05/2011 Lorca earthquake, and the walls are made up of irregular natural blocks. We: 1) classify the existing EAEs in the site and suggest new ones according to the constructive typology; 2) carry out a structural analysis of all the identified fractures and of the AMF segment beneath the site; 3) suggest a potential earthquake occurred between the start of the second phase of occupation (1900 BC) and the present, and 4) obtain an slip rate of c. 0.03 mm/yr for the AMF based on the observed displacements in the archaeological remains.

Key words: Archaeoseismology, Earthquake Archaeological Effects (EAEs), Bronze Age, Alhama de Murcia fault.

INTRODUCTION

The oldest worldwide archaeoseismological evidence is located in northern Iraq (Middle Palaeolithic, c. 50,000 years old), but normally archaeo-seismological studies go back as much as to the Bronze Age (c. 1700 BC; Nur & Burgess, 2008). The oldest studied archaeological site in the Iberian Peninsula is from the 1st Century AD (Tolmo de Minateda; Rodríguez-Pascua et al., 2011). The site subject of this study will record the oldest archaeoseismological record in Spain, if further evidences support it.

The type of construction used in the studied site (irregular stone blocks) is not considered in the classification of Earthquake Archaeological Effects (EAEs) proposed by Rodríguez-Pascua et al. (2011), but we have used it as a guide to describe those recorded in the site. In addition, we describe new types of EAEs. We located the EAE on a detailed microtopographic map provided by La Bastida archaeological research group (UAB).

LA TIRA DEL LIENZO GEOLOGICAL SETTING

La Tira del Lienzo is a Bronze Age small settlement, belonging to the archaeological group of the Argar. This society was developed between 2200 and 1550 cal BC in the Iberian Peninsula (figure 1; Lull 1983; Lull et al., 2011a). The first human presence in the site is dated 2050 cal BC. The final abandonment of the village took place around 1600/1550 cal BC. Two main phases of occupation are present in the site, but we focus on the second phase (1900-1550 cal BC), in which the archeoseismological evidence are preserved. The architectural features consist of rectangular rooms with walls made up of irregular stones blocks of decimetric size (Figs. 2B; 2C; Lull et al., 2011b). La Tira del Lienzo is located in the town of Totana (Murcia, Spain) just on the trace of the Alhama de Murcia fault (AMF). The fault zone in this area affects Miocene marls, gypsum (mylonitic) and hanged Quaternary alluvial fans (figure 2D).

The AMF is a N45°-65°E sinistral strike-slip fault with a reverse component, coherent with the NW-SE convergence between the Eurasian and the African plates (Silva, 1994; Martínez-Díaz, 1998). Several historical earthquakes of intensity ≥ VII occurred in the zone probably generatet by the AMF (1743 and 1746 in Alcantarilla, 1907 in Totana and in 1579, 1674, 1818 in Lorca; IGN, 2012). The stronger instrumentally recorded event occurred in Lorca on
11th May 2011 has a moment magnitude of 5.2 and VII EMS intensity (López-Comino et al., 2012). Palaeoseismic studies on this fault have characterized its activity, reporting maximum magnitude values between Mw 6.1-7.0 (Silva et al. 1997; Martínez Díaz et al., 2001, Masana et al. 2004; Ortúñ o et al., 2012). These studies record a minimum of 6 palaeoseismic events during the last 274-174 ka. The estimated lateral slip-rates are of 0.21 mm/yr for the last 130 ka (Martinez-Díaz et al., 2003). Recent geodetic studies reveal that the slip-rate is 1.4-1.8 mm/yr (Echeverría et al., 2012).

ARCHAEOSEISMOLOGY OF THE SITE

The results presented here are: 1) the inventory of EAEs recorded in the site, 2) the structural analysis of both the observed fractures and the AMF fault zonet, and 3) the estimation of AMF slip-rate based on the most relevant reported EAE.

Two of the EAEs types proposed by Rodríguez-Pascua et al. (2011) are recorded in the site: a) seismic uplift and b) displaced walls (Fig. 2B; C). In addition, we identified two new types of deformation effects not considered by Rodríguez-Pascua et al. (2011), but mainly due to the type of building material used in the studied site is not considered by these authors. These new EAEs are: c) fractures on the rocky floor, and d) fractured blocks in the walls (Fig. 3; Ferrater 2013). These two new proposed EAEs have their equivalent in the classification of Rodríguez-Pascua et al. (2011), but affecting other constructional materials. Floor fractures correspond to fractures and folds in pavements, and fractured blocks in the walls would be equivalent to penetrative the fractures in masonry blocks and conjugate fractures in stucco or brick walls.

Structural analysis performed in all the fractures affecting the rocky floor of the site and the walls reveals that there are two main dominant orientations of fracturing (NE-SW and NW-SE; fig. 3). The main orientation (NE-SW) coincides with the direction of the AMF trace just located under the archaeological remains. In this sense, one of the floor fractures goes through the...
archaeological site in NE-SE direction separating the building in two and laterally offset its walls (Fig. 2A). On the contrary, the fractured blocks in the walls alone cannot be considered a robust evidence of coseismic deformation, but their orientations generally match with the direction of the AMF (Fig. 3). For a true coseismic origin it will be necessary the occurrence of several fractured blocks assembled in the same vertical plane. Except for those cases where the position of the fractured blocks coincides with the occurrence of fractures on the floor and ground uplift (Fig. 2A), other natural causes cannot be rejected (e.g. gravitational collapse of the hill or thermic contrast).

PALEOSEISMIC ANALYSIS

Based on the lateral displacement recorded by the offset wall (Fig. 2A, B, C) it is possible to estimate the slip-rate for AMF in the site. The wall, built between 1900-1550 cal BC (Lull, Mico, Rihuete, Risch, pers. comm. 2013), is 12 cm anticlockwise laterally dislocated. Considering the wall is 3912 years old (1900 plus 2012), the minimum lateral displacement is 0.031 mm/yr. The striae pitch in the fault (10°-45°, fig. 3) make possible to estimate net slip-rates between 0.031 and 0.043 mm/yr, smaller than those reported in previous works. This could be because the fault trace affecting the site is not the main fault trace of the AMF. In fact the small hill on which is located the studied remains is a pressure ridge (Silva, 1994) and the deformation is distributed over a larger area.

In any case, at least one earthquake occurred after the construction of the second phase (< 1900 BC). This event might occur before the abandonment (causing it) or after the abandonment of the site (< 1550 BC). An event within this time gap will be consistent with two events dated by fault trenching in the central segment of the AMF: 1760-830 BC and >1650 AD (Masana et al., 2004).

CONCLUSIONS

The Bronze Age settlement studied here is located on the AMF fault zone and affected by one of its fault branches. Four Earthquake Archaeological Effects (EAEs) have been identified suggesting the occurrence of at least one earthquake after 1900 BC. The structural analysis indicates two main directions of fracturing. The main fracture direction (NE-SW) coincides with AMF direction in the zone. The main fracture produces a left lateral displacement (c. 12 cm) on the walls remains indicating a mean slip-rate of 0.03 mm/yr for the AMF.

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References

Figure 3: Fractures on the floor and fractured blocks in the walls photographs and structural analysis. Structural analysis includes stereographic projections and rose diagrams. In the Alhama de Murcia fault structural analysis fault planes and striae are shown.