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SEDIMENTOLOGICAL, GEOARCHAEOLOGICAL AND HISTORICAL EVIDENCES OF THE 881 AD EARTHQUAKE AND TSUNAMI IN THE WESTERN MEDITERRANEAN SEA (ESTEPONA, MÁLAGA)

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ABSTRACT

A spectacular earthquake struck the southern margin of the Iberian Peninsula and part of the western fringe of North Africa in 881 AD. Historical sources suggest it was followed by a tsunami. However, the origin and characteristics of this event are yet to be determined. We present evidence, both historical and geo-archaeological, of a tsunami and outline the characteristics for the catastrophe. The presence of a sedimentary layer rich in marine and continental materials, appears to be of a tsunami *backwash artifact*, and in addition to archaeological remains, provides compelling data supporting our present study.

Keywords *Iberian Peninsula • Tsunami • AD 881 • Geo-archaeology • Backwash*

1. INTRODUCTION

Studies related to tsunamis in the Mediterranean Sea and of their historic impact are very extensive (Papadopoulos et al., 2005; Pararas-Carayannis & Mader, 2010; Pararas-Carayannis, 2011; Papadopoulos et al., 2014; Pararas-Carayannis, 2021). Without a doubt, one of the most prominent and oldest is the catastrophic event caused by the Santorini volcano around the 16th -17th century BC. (Pararas-Carayannis, 1992; Goodman-Tchernov et al., 2009), with important implications for the Minoan culture and civilization. Obviously, most of these Mediterranean catastrophes have a greater incidence due to their location between tectonic plates, particularly those located in the easternmost sector of the Mediterranean, which account being more than 75% of 400 catalogued tsunamis (Maramai et al., 2014). However, the westernmost sector of the Mediterranean coast that surrounds a good part of the Iberian Peninsula, is not exempt from specific tsunamis, as is the case presented in this present study. Indeed, a spectacular earthquake struck the southern margin of the Iberian Peninsula and part of the western fringe of North Africa in 881 AD. Historical sources suggest that it generated a significant tsunami; however, the characteristics of this event are yet to be better determined. The objective of the present study is to present an analysis of the evidence of this particular tsunami event, as it was registered in a sedimentary deposit of Estepona City (Málaga, Western Mediterranean), as well as an analysis and an outline of the origin and characteristics for this catastrophic event.

2. METHODOLOGY

2.1 Study Area

2.1A Geological Context

Estepona City is located on the southern coast of Andalusia (Spain, Western Mediterranean), halfway between the Strait of Gibraltar and Malaga City (Fig. 1). The historic centre of the city is located about 40 m. above the Mediterranean Sea, on a Pleistocene glacis deposit consisting of marls, sands and clays. At the base of this deposit are friable materials such as calcarenites, with varied sandy-clay materials from the Pliocene and Miocene and with traces of Quaternary alluvial sediments (IGME, 1978).

The most outstanding nearby relief close Estepona City is Sierra Bermeja (1,443 m. in height), which is part of the Baetic Mountain Ranges. It consists of an amalgamation of materials of Palaeozoic origin that had elevated in the last Alpine Orogeny. The rocks that make up this sector are predominantly metamorphic peridotites (IGME, 1978) (Fig. 1).

The thickest materials of Estepona City of Sierra Bermeja are a set of peridotites but also Precambrian-Palaeozoic rocks belonging to the "Alpujarride Unit", such as gneiss, marbles and micaschists. However, the extreme complexity of the unit between the "Alpujarride Unit" and the "Malaguide Unit" located in turn in the Betic Cordilleras and in transition to the Tertiary deposits, define the "Campo de Gibraltar” (IGME, 1978; Guerra-Merchán et al., 1996).

2.1B Background

Archaeological prospecting was carried out by the Arqueotectura S.L. Company between April and May 2017 in 98 Real Street, which is located at the southern base of a hill, dominating a stretch of the Rada anchorage between the Calancha stream to the east, and the Monterroso River to the west. Two other streams drain further north, supplying sediments to the beaches of Estepona: the creek of La Cala and the Padrón river (Fig. 1).

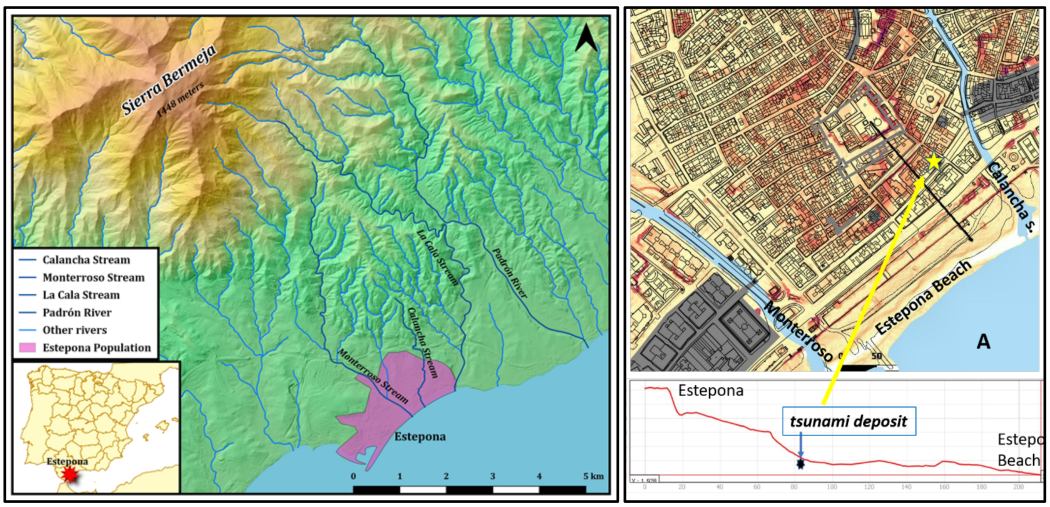

Fig. 1. Location of Estepona City (A) and the prospecting site in the historic centre of the city (B), in the base of a small hill (C).

Archaeological interventions carried out in the environment indicate that in late Roman times it was a dune area but without any instance of its anthropic use until our evidence from the 9th century. Between the 10th and 15th centuries the area was part of the periphery of the Andalusian population, occupied by commercial and artisan facilities. After the Castilian conquest, and until the end of the 18th century, it was prohibited to populate the area for military reasons, in order to create a clear space in front of the artillery fortification of the Castillo de San Luis. Finally, from the middle of the 18th century, the area between the castle and the beach has been urbanized through the layout of a series of streets (Real, Santa Ana, Castillo and Viento) that constitute the basis of current urban planning (Suárez et al., 2017).

2.1C Sedimentological Analyses

The upper strata of the trench were discarded as they contained deep anthropic alterations. In this context, samples of the trench from levels A36, A37, A39 and A42 were taken. Level A-36 occurs in the middle of the profile, more than 1.5 m below the current surface and over 2.5 meters above mean sea level.

Sands from the different beaches that border the municipality of Estepona were also sampled: Estepona Beach, Padrón Beach, Casasola Beach and Saladillo Beach. At the same time, sediments samples were taken from the Monterroso stream, La Cala stream and El Padrón and Guadalmina rivers, to rule out not only storm surge deposits, but also fluvial flood levels. Lastly, sediment samples from relict dunes close to Saladillo and Mateas Verdes beaches were analyzed. In total, 22 samples were taken to compare the site's current and past dynamics.

The 22 samples were subjected to textural and morphoscopic analysis. Once the samples were sifted and treated, statistical grain size parameters were obtained in order to determine the nature and classification of the sediments. These analyses were carried out following classic sedimentology criteria set out by Trask and Wu (1932), Cailleux and Tricart (1963), Folk and Ward (1957) and Soil Survey Division Staff (1993). When the presence of silt and clay was noted, Bouyoucos' criteria were applied (Bouyoucos, 1936; Day, 1965). The studies were carried out in the Physical Geography Laboratory of the Autonomous University of Madrid.

The Trask index (S0) is a statistical variable obtained from the particle accumulation curves designed by Tricart and Cailleux (Trask and Wu, 1932) using the 25% (Q25) and 75% (Q75) quartiles: $S_0 = \sqrt{(Q75/Q25)}$. This statistical index (**S0**), despite its antiquity and simplicity, was the choice due to its effectiveness in recognizing the sediments worked by the different geodynamic agents. In most cases, it is important to consider that this variable usually ranges between S0=1, and 3 when natural modelling agents (rivers, dunes, beaches, etc.) are present. On the other hand, slopes and colluvium material often produce higher Trask values (> 4) (Trask and Wu, 1932). Therefore, it is very useful showing in palaeo-tsunami deposits that the sediment is selected, but within the stratigraphy it is usually the least selective of the different overlapping strata, as we have seen in other deposits on the coast of Andalusia (Arteaga, 2004; Arteaga et al., 2015).

In addition, thin-section micro morphology analyses were applied to obtain a more detailed understanding of the characteristics for the soil block of level A-36. The sample was prepared for thin section analysis at the McBurney Laboratory of the Department of Archaeology, University of Cambridge (UK), according to Murphy (1986) and Courty et al. (1989). Soil micro-morphology is a well-established geoarchaeological method and a very powerful tool for understanding landscape changes and other geo-morphological phenomena (French, 2015), particularly because of its ability to investigate and interpret environmental and cultural signatures that are typically concealed within the landscape itself (French, 2003). Geoarchaeological field research, therefore, is aimed primarily at understanding human-landscape relations (Goldberg and Macphail, 2006).

Finally, a large number of spines, ichthyofauna tissues, and plant remain and bio-clasts with clear marine morphometry were identified and separated for the subsequent identification in the Physical Geography Laboratory of the Autonomous University of Madrid. Mollusc fragments were classified according to Lindner (2008).

2.1D Archaeological Analyses

The archaeological excavation was developed according to a stratigraphic process (Harris, 1991; Roskam, 2002; Carandini, 2007; Ruiz, 2013), manually excavating to clear the stratigraphic units that, once identified and described, were raised in the opposite direction to that of their deposition. The information obtained goes with graphic documentation, such as profile drawings, photographic and topographic documentation. For the dating of the sequence, a techno-typological classification of the artifacts, mostly composed of ceramic fragments within their contextual levels, were taken into consideration.

2.1E Analysis of Historical Documents

For a critical review of historical documents citing the AD 881 earthquake, two Islamic historical texts were considered: i) *Kitāb al-bayān al-muġrib fī ājbār mulūk al-āndalus wa-l-maġrib* – better known as *Al-bayān al-muġrib*, attributed to Ibn Idari – and ii) *Kitāb al-ānīs al-muṭrib bi-rawḍ al-qirṭās fī ājbār mulūk al-maġrab wa tārīj madīnah Fās* – better known as *Rawd al-Qirtās*, attributed to Ibn Abi Zar. Among all the transcripts of these documents that have been consulted for this study, we have chosen several to be reproduced in Spanish, due to some ones being longer, and therefore, greatly enriching the case study.

3. RESULTS

3.1 Sedimentological Features

3.1A Stratigraphic Units and Textural Description

The investigated trench presents an alternation of strata of different thickness and origin, alternating mostly anthropic levels with others that still have natural connotations. The trench was divided in a total of 44 stratigraphic units (Fig. 2).

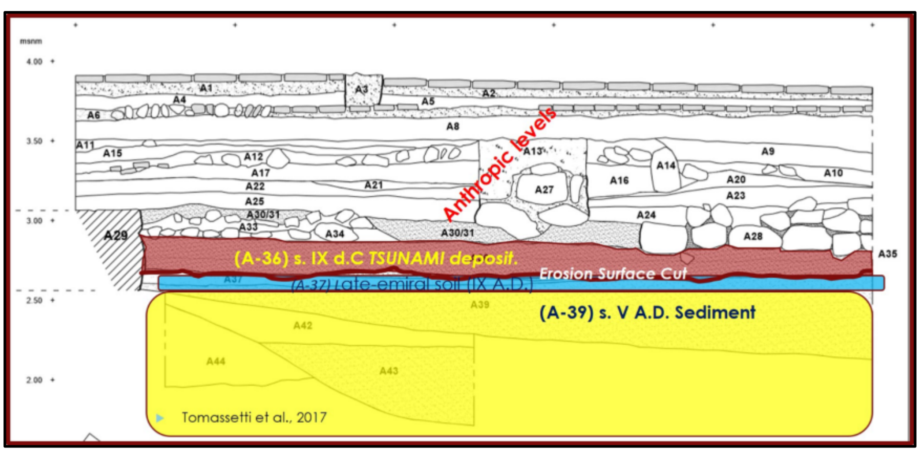

Fig. 2 North section of the trench. Numbers indicate stratigraphic units.

Phase II of the trench presents a clear stratigraphic unconformity with Phase I, i.e., an erosive contact. It includes levels A37, which corresponds to a narrow sandy deposit, and A-36, which is composed by a mixture of sands, gravels, marine fauna and archaeological settlement debris.

Just over a meter from the current surface, the A-36 level is located with a thickness of 25-30 cm. This horizon is greyish-brown (10YR5/2) and is composed of edges and tapes of centimetric to decimetric size (45% to 68%), broken by a high percentage and separated by a matrix of sand and silt that increases towards the lower zone (32% to 55%). The sedimentary deposition (A-36) has a *clast-supported* structure at the top and *matrix supported* at the bottom (Miall, 2016) (Fig. 2). Strata are arranged with some overlap towards the sea and in turn rest on a sandy layer with morphologies of ripples of centimetric thickness that culminate in erosive contact with the underlying level. The level has lateral continuity until it is interrupted by ashlars of later chronology. Throughout the stratum, broken molluscs are visible. The coarse sediments of the deposit (A-36) (Fig. 3) are mainly composed of peridotite gravels and, secondarily, gneiss and phyllites. These rocks are imbricated towards the sea, flattened (71 %) and broken in a relatively high percentage (34,6 %), example, of high-energy transport and deposition. The matrix of A-36 also contained fragments of mudstones, whose origin can be diverse: vestiges of a riverbed or marsh plucked by high energy (Table 1).

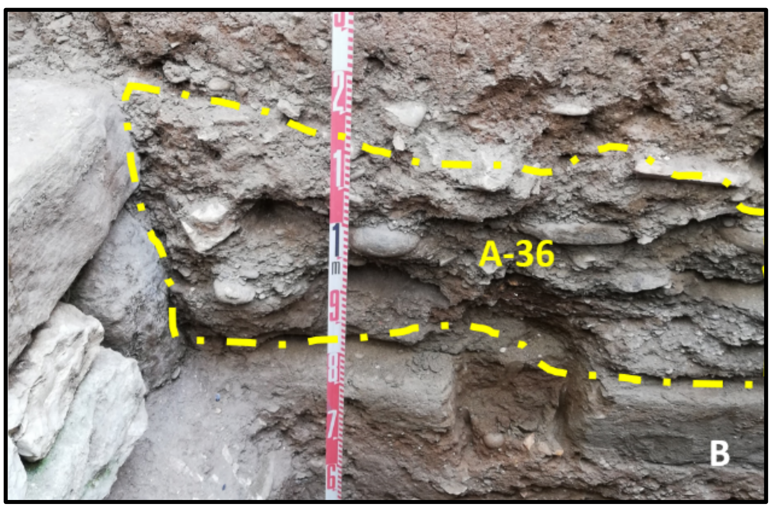

Fig. 3. Photograph of level A-36.

On other hand, the sand is moderately well sorted and is upwardly fining. The average grain size of the A-36 sediment is 330 microns (0,33 mm). Then, it is finer sand than the other of samples taken from the nearby beach and the nearest streams. The coarser sediments are from the river systems; on the beaches of Estepona, medium to coarse sands make up the majority, but grain size increases towards the mouth of the main rivers, where the materials are mixed (i.e., 0.6 mm in Guadalmansa River and 0.71 mm in Guadalmina River). The dune sediments are the finest and the best classified (Table 1).

Table 1 Granulometric and morphoscopic indexes obtained according to their nature of samples from the trench (levels A-36, A-39) and the present surrounding environments.

Samples	**Mean size (mm)**	**Trask Sorting Index (S0)**	**Textural classification**	**Morphoscopy - rounded quartz-**	Morphoscopy **matte rounded**
Streams-Rivers	0,59-1,7	1,42-1,84	Sand-Sandy loam /grabel	15-20%	< 3%
Beaches	0,27-0,7	1,20-1,33	Sand (coarse – fine sands)	24-32%	11-16%
Dunes	0,24-0,32	1,18-1,20	medium to fine sands	>50%	> 30%
A-39 (ancient dune)	0,35	1,26	Medium sand	36%	8%
A-36 (high energy event-possible "tsunami "deposit?)	**0,33**	**1,64**	**Medium sand**	**16%**	**8,6%**

The Trask sorting index (S0) ranges between 1.4 and 1.85 for rivers and streams, and from 1.18 to 1.33 for beaches and dunes, in the study area. However, in the trench, level A-36 has a S0 value of 1.64, and mean grain size corresponds to medium sand (0.3 mm); it is also standing out as being the sample with the highest percentage of silt-clay (> 11%).

The lower levels present an alternation of different sedimentary environments. A-37 is a level of medium-fine sands around 0.25 mm, and A-39 represents a build-up of deposits of marine origin, with the presence of bioclasts and a Trask index of 1.26 (possible beach) and more than 54% of sub-rounded-rounded grains. The base of the profile culminates with stratum A-42, with an average grain size of coarse sand (0.5 mm) and S0 close to 1.4, also typical of a marine nature. Morphoscopic analysis shows that fluvial systems of the Estepona environment rarely reach the roundness of the quartz in their flow beyond 15%. It must be taken into account that they are rivers and streams with a very short route. Once on the beaches, the action of the waves works and well-rounded grains up to 32% and, as a result of the dune dismantling due to coastal erosion, you can see rounded quartz matt up to 16%. In contrast, A-36 has 16% rounded quartz, very similar to that of river systems, but contains rounded quartz by wind action (above 8%).

3.1B Micro-morphological Description of the A-36 Thin Section

Thin section of level A-36 is porous (30-40%) and *apedal*, but it has a complex microstructure, a dominant single grain and vughy microstructure superimposed onto a bridged grain microstructure. Voids are dominantly compound packing voids, vughs and a few chambers. The groundmass shows a dominant concave *gefuric* and a coarse *monic* related distribution pattern. It has a *c/f* 50µm ratio of 2/1. The coarse fraction has a strongly expressed banded basic distribution pattern. The coarse material is dominantly (>90%) moderately sorted, rounded and sub-rounded fine and medium sand (150-275µm). There are also larger rounded limestone (<5%) gravels (5-50mm). The remainder consists of fine and medium sand sized (500-2500µm).

There are places where the groundmass becomes predominantly extremely thin, with dominant large gravels (<10cm) forming 5% of the horizon and these are sub-rounded and sub angular. The organic components are marine shell (500-1250µm) and other marine fauna (10-30µm) and tissue and cell fragments within the groundmass located in compound packing voids. There are a relatively large amount of tile, brick, plaster and charcoal fragments derived from an archaeological context. The micro mass is humic brown speckled clay exhibiting a weakly calcitic crystallitic b-fabric. The dominant pedofeatures are typical clay and silt coatings on sand grains. Pedofeatures are characterised by those that show the movement and accumulation of calcium carbonate. Many rock fragments have compound juxtaposed calcite and clay pendants (<750µm). Most of the sands and coarser clasts have been bridged and coated by calcite. In addition, there are coatings of needle-fibre calcite on the walls of voids (25-100µm). Throughout the groundmass moderately impregnated Fe-hydroxide typical orthic nodules are observed (25-75µm).

This thin section clearly shows the sedimentation of well sorted medium and fine sand, horizontally bedded between finer clays, silts, comminute organic matter and marine diatoms, some of them broken, and the sand generally tend to fine upwards. The sand has been deposited unconformably in thin, horizontally orientated lenses as a result of tsunami processes. Thicker bands containing larger limestone gravels, stones and bioclasts among other materials; brick and plaster fragments have been deposited generally separating the larger clasts first. The coarser material and archaeological is clearly evident from the close vicinity of the deposit. Within the matrix is well-sorted sand, almost certainly from a coastal context (Govorushko, 2012).

Within this aggrading sedimentary system, vegetation evidence of organic material comes from charcoal fragments within the groundmass. These fragments clearly have a cultural origin and are almost certainly derived from one of the many medieval buildings that are thought to occupy the surrounding landscape. Humified and Fe-replaced root tissue can be observed in various states of preservation. Abundant comminuted plant tissue and cell fragments are evidence for the breakdown and cycling of organic matter. The humic brown speckled clay is primarily the end member of these processes.

3.1C Results from Faunal Remains

Throughout the stratum A-36, contained within the sandy matrix is a mixed assemblage of fragments of seashells, coal, vertebrate and fish bones that will be the subject of subsequent analysis.

In the 600 grams of sample A-36, around 2.5% suppose remains of molluscs, ichthyofauna and remains of plant tissues. Centimeter-sized mollusc fragments correspond to *Acanthocardia tuberculata* (32%) and *Venus verrucosa* (68%).

The habitat of both species is below 5 m deep, although it should not be ruled out that it was a material taken from the beach. More specifically, the first usually lives between 5 and 100 m deep, while the second barely reaches 20 m (ICTIO.TERM, 2018).

One of the main factors that reveal the violence of the event, is the presence of the ichthyofauna trapped in the sediment included crushed fish scales, spines and vertebrae, among the matrix of gravel and sand (Fig. 4). It has been possible to identify the tuna (*Thunnus thynnus*) as the majority species by the spines, which correspond to young specimens.

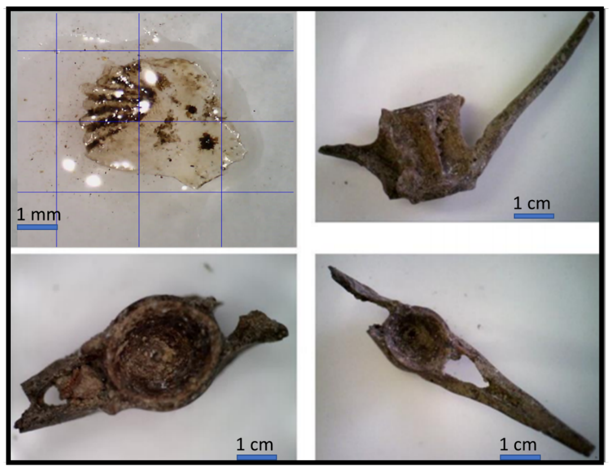

Fig. 4 Fish scale (upper left image) and tuna spines found in the sedimentary deposit. The wave had to have high energy to be able to catch and crush several fish between the gravel and sand.

It is truly anomalous to find ichthyofauna remains in storm surge or river flood deposits, and less in the volume of the sediment analyzed. Although the spines do not correspond with adult specimens, more heavier, it is difficult for a wave to carry them in its bosom if it does not carry with it a great transport capacity. The presence of this species also perfectly corroborates the proposed date of the tsunami, since in historical times the passage of tuna between spring and June is recognized (Florido y Menanteau, 2006).

Together with molluscs and ichthyofauna of a clearly marine character, continental plant remains typical of wetlands, marsh environments or riverbanks were also found. This is the case of the presence of *Carex sp.* pertaining to the family of the sedges. In fact, in Estepona there are up to three taxa of this genus: *Carex halleriana, Carex hispidia y Carex pendula*. Although several fragments were found, their state of preservation prevents further identification.

3.1D Ceramic Debris

The ceramic acquires a great value, since it helps the dating of the strata. For the Phase II it can be classified as a horizon corresponding to a room with the following elements: in level A37 the space is conditioned for use in the open air by inserting several post holes (A40 and A41) and the installation of a fireplace (A38).

The ceramic materials found in levels A36, A37 and A38 form a set of 224 fragments and an almost complete piece. For their analysis we divided them into two large series: glazed ceramics and unglazed ceramics. Only six fragments represent the glazes: three of ataifores (deep plate representative of Andalusian tableware), one of cup and two closed forms. The glazes are represented by only six fragments (three of ataifores, one of cup and two closed forms). As will be seen later, this type of glazed pottery is representative of the 9th Century Acién et al., 2003; Acién et al., 2009; Martínez Enamorado, 2003; Melero et al., 2015).

The set of unglazed ceramics constitutes the largest (Fig. 5), with an almost complete piece and 217 fragments. The most represented type is the little jug, with highly flown handles on the edge. Some specimens are slipped in black, sometimes with strokes of white paint. In a more minority, there are black or red brush decorations. Another type that is highly represented in the sample is the slow lathe *alcadafe,* with three different models: the small one, with vertical walls and projecting edge, the one with sloping walls and, finally, the large one with vertical walls and fingered cords in the body.

Fig. 5 Selection of unglazed ceramics from phase II. 1. Slow lathe edge of alcadafe (UE-36). 2. Rim of the jar on a slow lathe with finger cord (UE-36). 3. Jar handle with white paint stroke (UE-36). 4. Edge of *alcadafe* with slow lathe (UE-36). 5. Slow lathe chuck edge (UE-36). 6. Arranged fragments of glass cup (UE-38). 7. Background fragment of glazed ataifor (UE-36). Photo by J. .M Tomassetti (Arqueotectura S. L.).

Other minority slow-lathe types have also been studied, such as jugs, jars, pots and pans. The only almost complete piece is a kettle made on a lathe, with a slightly convex bottom, a spherical body and a recessed frustoconical neck, with vertical mamelons on the shoulder. It appeared overturned on the ground near the hearth and contained an ocher-colored matter. Although the dating of unglazed ceramics is, as a general rule, more imprecise than that of glazed ceramics given the durability of some types, the set fits perfectly with those dated to the second half of the 9th century (Acien et al. 2003).

The ceramics of phase III (units A32 / 33, A34 and A35) are, on the whole, similar to those of the previous phase, also with the presence of glazed and unglazed fragments. Among the former, a roasted *ataifor* on both sides and interior decoration with manganese lines, as well as some roosters and a flask handle with "green and manganese" decoration, can be dated as corresponding to the second quarter of the 10th century (Acién et al., 2003; Acién et al., 2009; Martínez Enamorado, 2003; Melero et al., 2015). Unglazed productions confirm the survival of those made on a slow lathe (jars with finger cord, pots, casseroles) and some simple-rimmed jugs. Therefore, it is a material set similar to that of the previous phase, but it includes clear guide examples, such as green and manganese ceramics, which determine its chronologies as directly related to the Caliphate of Córdoba. If the beginning of the production of these glazed ceramics must be dated towards the middle of the 9th century, level A37 corresponds to the 9th century too, dated from the ceramic evidences and coinciding with the high-energy episode documented by Galbis (1932). The stratigraphic sequence of the trench continues until the 20th century, with alternating periods of occupation and abandonment that do not affect the subject of this study.

3.1C Identification of the AD 881 Earthquake and Tsunami in Historical Documents.

The first text that we are going to take into consideration is the most well known. It appears in the quoted work of Ibn Abi Zar, which was translated by Ambrosio Huici Miranda (1964) and José Antonio Conde (1820). While Conde has transmitted this text to us through his studies, it must be said that, in his work, he mixes and transcribes various Islamic sources to create a complete history of Muslims in the Iberian Peninsula, often making it difficult to recognize his original sources.

When comparing Conde's translation with other translations of the same text, it can be seen that Conde's is broader. This leads us to think that he is translating texts that we don't know or that have been lost over time. Conde's work was highly reviled in the mid-nineteenth century, but for a few years it has been recovering and re-giving the importance it deserves, proving its historical and linguistic value in various studies (among them Calvo Capilla, 2016, Calvo Pérez, 2003, Domínguez Prats, 2006, Haro Cortés, 2012, Hitchcock, 1986, Manzanares de Cirre, 1968 can be cited).

Both texts describe the same seismic phenomenon according to Souto (1995, p. 230 and citation 131), who has demonstrated this by comparing the two texts. Having established this, the facts can be laid out, providing us a wealth of information regarding the seismic episode that occurred in Al-Ándalus and other neighbouring areas in 881. From the texts we can ascertain the following (view appendices):

The Date: The various catalogues ascribe a differing date to the AD 881 earthquake. The *Catálogo de Tsunamis en las Costas Españolas* compiled by the Instituto Geográfico National, records that the tsunami of the 881 earthquake occurred on the 10^{th} of June.

The IGN extracts this information from one of Galbis's catalogues, which derives its information from Juan García Lomas, without giving further references (1940, p. 12). In that same work, Galbis quotes Roux (1934) and reproduces a fragment of one of the texts discussed here, but he transcribes it incorrectly and with erratum, changing the date. Another possible option is May 26th, 881, according to the catalogue of Martínez Solares and Mezcua Rodríguez (2002). No one has questioned why several dates are not given, nor has any effort been made to correct it – researchers adopt one or the other depending on their choice.

After verifying the documentary sources and resorting to the most reliable translations of the *Rawd al-Qirtās*, the earthquake can be date to the 22nd day of the moon of Xarwâl (Shawwal) in the year 267 of the Hegira, according to the established formulas for converting AH to AD, a date of May 26th, AD 881 is derived.

The Hour: The text by Ibn Idari provides the most relevant information as to the approximate time of the earthquake. According to the two translations that have been provided from *Al-bayān al-muġrib*, the earthquake occurred *at the hour of the azallah of sunset* or, *when the prayer of al-Magrib*. In both translations they refer to the same moment: the Magrib prayer. *Azallah* or *salat* is the sunset prayer, the fourth daily *salat* of Islam. It takes place just a few minutes after sunset. For May 26th this would correspond to a time close to 21:30.

3.1D Historical and Geographical Context.

At this time this part of the Iberian Peninsula was part of the Emirate of Córdoba, under Emir Muhammad I (852-886). The Christians had not yet crossed the Duero River in their conquest; their king was Alfonso III of Asturias.

Geographically two different realities are embodied in the texts, two testimonies from two different places where the earthquake was felt. The first place is Córdoba, the then capital of the emirate, where the court resides. In a place of such political importance like Córdoba, they collected all the relevant events that occurred, and for this reason the text of Ibn Idari has been preserved. The second place comes from the text of Ibn Abi Zar. In the year 267 of the Hegira a population uprising took place from the towers (*husûn*) of the territorial divisions (*kūrah* or *coras*) of *Rayya*, *Tākurunnā* and in the Algeciras area, which had to go to solve Muhammad I or his son Al-Mùndir. This event was the one that made the earthquake witness from another geographical perspective that is the one that *Rawd al-Qirtās* provides us and that we present in the following map.

Places Affected by the Earthquake: According to the different copies of Ibn Abi Zar and Ibn Idari that have been consulted (Huici Miranda, 1964; Fernández González, 1860; Roux, 1934, Souto, 1995), the earthquake was felt particularly strongly in *El Adoua* or *Al-Magrib* (possibly in the vicinity of Fez, Morocco), Tlemcen (Algeria), Tangier (Morocco) and throughout Al-Andalus. Likewise, they say that the earthquake had its affected from the Mediterranean Sea or *Al-Sham* Sea – the Syrian Sea, one of the names that Muslims used for the Mediterranean in the Middle Ages – to the northernmost part or *al-Magrib al -Aqsa* – a term for the westernmost region of Morocco. They also report that the earthquake was felt even “in the last part of the land of Christendom” or, as Muslims sometimes prefer to call Christians, “even the most remote polytheistic land” (Lapida Gutiérrez, 1997). The earthquake was felt in Christian lands and could be recorded, because the Muslims were fighting against them at this time, as reflected in Conde's text (1860). In other words, it was felt across the entire Iberian Peninsula (Fig. 6). For his part, Ibn Idari mentions that the earthquake was felt with great force in Córdoba and, for his own, Ibn Abi Zar affirms that there was a tsunami, confirmed in this study for Estepona.

Fig. 6 Map showing the places where there was an earthquake in 881 and the places where it was felt.

Singular Phenomena: Earthquake Lights: Among the information that can be extracted from these texts, a singular fact stands out. They refer a singular phenomenon reported in the city of Córdoba, related to so-called "earthquake lights" (Derr et al., 2011). The text narrates how several people were in the mosque preparing for the *Magrib* prayer and how electricity produced by the earthquake affected them. The first thing they relate is the appearance of a lightning-bearing cloud, which killed two people by electrocution. Although death associated with these phenomena is not common, the description is very similar to so-called "earthquake lights". Several studies report the appearance of this type of cloud in the moments leading up to an earthquake or at the exact moment of its occurrence (Derr et al., 2011; Thériault et al., 2014).

Could this not just have been a thunderbolt? This is unlikely because firstly the phenomenon occurred alongside the earthquake, and second because the text reports that no damage was done to the fabric of the building. Considering that the text says that these six people were knocked down on their backs, it is very likely that there was an explosion resulting from the thunder (St-Laurent, 2000). Two people died and showed burns on their faces. Four others felt "a fire like a heavy wave". It has been mentioned that after this incidence the environment had a burning smell resulting from the burnt human flesh.

According to the studies already mentioned, these luminaires can occur up to 150 kilometres from the epicenter, with even greater distances being reported in some cases. This phenomenon provides us with a better idea of the magnitude of the earthquake since, among the earthquakes studied by Derr (2011) or Thériault (2014), all exceeded M5 on the Richter scale. The number of earthquake lights and their power increase proportionally with the strength of the earthquake. This released energy can take various forms: tongues of light, bright flashes from the ground, spheres and lightning. This electricity moves through an environment and is only a problem if it meets someone, just as reported in Córdoba.

4. DISCUSION

4.1 Sedimentary identification of a Tsunami deposits

Identification of "tsunamites" from sedimentology should be as accurate as possible. For this reason, it is sometimes convenient not only to take samples from the deposit creditor of said event, but also to compare all the sedimentary material deposited by the different natural agents of the geographical framework in which it is circumscribed, including beaches, dunes, rivers and streams. Especially if there is a risk of incorrect identification with storm deposits, it will have different implications altogether. Extreme tsunami events imply the presence of continental and marine material (especially of different depths), erosive scars, gravels imbricated towards the sea, anthropic and natural materials mixed in a chaotic and fragmented manner, and decimetric thickness of the stratum (Nott, 2004; Morton et al., 2007; Kench et al., 2008; Komatsubara et al., 2008; Goto et al., 2010; Lario et al., 2010a; Papadopoulos et al., 2014; Shinozaki et al., 2015; Mottershead et al., 2015; Usani et al., 2017).

The excavation of Trench A offered a complex sequence. It begins in late Roman times (phase I, centuries IV and V), with alternation of continental and marine events in a dune environment. In the nearby-inhabited area there are levels of abandonment during the 5th century, both in residential areas and in artisanal facilities (sinks for fish processing, amphora furnaces for marketing, etc). This confirmed abandonment was perhaps due to the passing of the vandals in 429, which left its reflection in the stratigraphy (Bernal, 2018, p. 107). In line with this, the intervention of C / Real, 98 shows a first occupational hiatus between phases I (5th century) and II (9th century), which must be interpreted as an absence of population for more than 450 years in the excavated area.

The analysed trench has made it possible to establish a historical sequence between the 4th and 20th centuries.

Within the stratigraphic unit A36, anomalous sediments appeared along with archaeological remains dated to the 9th century. The presence of some elements of apparent marine origin at about 2.6 m above sea level and 150 m from the seashore, suggested the possibility of a past high-energy event. S0 values (Trask index) close to 1 are generally related to sediment well selected by a dynamic agent (i.e. dunes and beaches; Trask an Wu, 1932), coinciding with a grain size of medium to fine sand. However, level A-36 has a S0 value of 1.64, relatively high if we consider its mean sizes corresponds to medium sand (0.3 mm), and it also standing out as being the sample with the highest percentage of silt-clay (> 11%).

The presence of eolian rounded quartz in level A-36, together with the high Trask index, its composition of medium sands, the presence of silts and clays, peridotites with fluvial morphologies, tuna bones, numerous fragments of fish scales, various mollusk bioclast and the existence of mudstones positioned chaotically in the level, leads us to think that the sandy matrix presents both continental and marine sediments.

In fact, in micro morphological analysis we can observe containment of abundant small red tile or ceramic, which appear to be of the medieval period date. These are generally sub-rounded due to various weathering processes, not least those associated with the mass movement of sediment within a high energy wave environment associated with a possible tsunami.

The diatoms observed, have been embedded within the sandy matrix containing geological and anthropogenic material because the tsunami has inundated the coastal margin and inland areas, eroding, mixing, transporting, and redepositing a variety of components. Some of the diatoms have been observed broken due to their relatively fragile valve constructions; perhaps suggesting that the preservation is related to the speed and violence of transportation and burial (Smol 2010). Consequently, from the micro morphological analysis it can be deduced that the horizon became emplaced very quickly because of a catastrophic sequence of high-energy related waves. Therefore, A-37, with medium-fine sands, representing the soil of the 9th century (dated after the chronological identification of the ceramic remains) that would have been eroded by the tsunami. On the other hand, A-39 represents a build-up of deposits of marine origin, with the presence of bioclasts and a Trask index of 1.26 (possible beach) and whose morphoscopy also indicates this origin with more than 54% of the sub-rounded-rounded grains. The base of the profile culminates with stratum A-42, with an average grain size of coarse sand (0.5 mm) and with an S0 close to 1.4, also typical of a marine nature.

During the archaeological excavation, it was possible to verify how the stratigraphic elements of phase II were destroyed by a high-energy event that the joint relative chronology of the sequencing and the ceramic typology places in the second half of the 9th century. The contrast of this data with the records of historical earthquakes yielded from the beginning a single coincidence (Suárez et al., 2017): that of the earthquake of the year 881 that the late medieval Islamic sources have transmitted to us. This catastrophe caused the abandonment of, at least, this sector of the settlement, giving rise to a phase III that dates back to the first third of the 10th century, some 50 years later. This discontinuity can be explained by referring to the repercussion in the entire Malaga region of the rebellion of Ibn Hafsun, which began a little before the tsunami of 881 (Manzano, 2006, p. 276-287; Martínez, 2003, p. 534).

In principle, the sedimentological characteristics of A36 fit with a sedimentary deposit of extreme wave events (EWE) (Lario et al., 2010a). If we add to this the absence of multiple interior lamination, its clear contact with the underlying layers and its thickness of no more than 25 cm, it seems to fit a tsunami deposit, according to Lario et al. (2010b). In short, the alternation of both marine and inland materials seems to correspond at first with a backwash phenomenon.

4.2 Archaeological dating of the Phase II

In relation to the fragments of glazed pottery, similar assemblages have been published in Malaga sites, both coastal (Cortijo Félix, Cerro Luis, Marbella, Málaga or Bezmiliana), and inland (Vélez-Málaga, Valsequillo, Belda), as well as in numerous other Andalusian locations in the provinces of Granada (El Castillón), Almería (Pechina), Córdoba (the same capital, Priego), Jaén, Murcia, etc. In general terms, in most of these sites the dating of these first glazed ceramics is very extensive and they are classified as "emiral pottery", "emiral-caliphal pottery", "andalusian pottery", etc., proposing *as terminus ante quem* for its dating the appearance of green and manganese ceramics in the 10th century, and on the other hand, the beginning of the production of these glazed ceramics must be dated towards the middle of the 9th century. (Acién et al., 2003; Acién et al., 2009; Martínez Enamorado, 2003; Melero et al., 2015).

In summary, the set of glazed materials from the levels of our phase II is consistent with those that, roughly, are considered to belong to the second half of the 9th century. These glasses most likely come from pottery located in the city of Malaga, if we stick, for example, to the similarity of the cup specimen (honey on all its surfaces, decorated with manganese lines) with the Malacite parallels (Acien et al. 2003, p. 420). In general, dating of unglazed ceramics is more imprecise than that of glazed ceramics. Nevertheless, given the durability of some types, the set fits perfectly with those dated to the second half of the 9th century (Acien et al., 2003).

Therefore, the historical context to which we can refer to phase II as a whole places us around the reign of Emir Muhammad I (852-886). In the middle of the 9th century, we found a varied population, where it is not possible to know the percentage of Mozarabs, Muladis and Berbers that were in the area. This led to the existence of different types of settlements, such as inland villages and/or in height, as well as towns along the coastline, as is the case of Estepona, which made it a well-connected anchorage and in which commercial and artisan activities would be promoted. An indication in favor of this interpretation would be the appearance in the intervention of C / Real, 98, of glazed ceramics produced in Malaga, a city that currently knows an authentic re-foundation based on trade and pottery production (Gutiérrez, 2011; Melero, 2015, p. 272).

Other examples of this type of population are the settlements on the Malaga coast, Marbella and Bezmiliana, for which it has been proposed that at the time of their foundation, the second half of the 9th century, they would not have an urban character, being classified as farmhouses (Martínez, 2009, p. 100; Acién y Salado, 2009, p. 145).

In summary, the set of glazed materials from the levels of our phase II is consistent with those that, roughly, are considered to belong to the second half of the 9th century (Fig. 7). On the other hand, these glasses most likely come from pottery located in the city of Malaga, if we stick, for example, to the similarity of the cup specimen (honey on all its surfaces, decorated with manganese lines) with the Malacite parallels (Acien et al., 2003, p. 420).

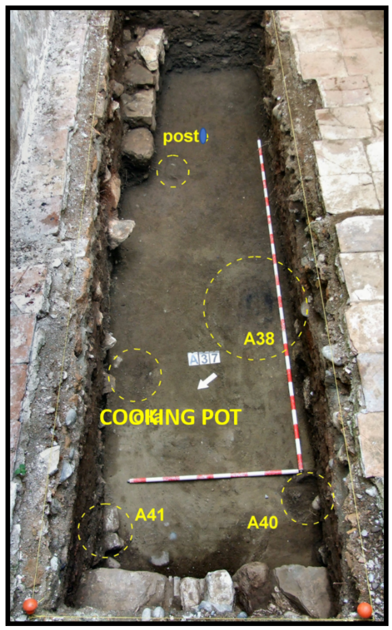

Fig. 7 Plan of the habitation horizon of Phase II of ditch A from the West. Numbers indicate stratigraphic units. The A36 tsunami tank mounts on the units shown. A38 is home. A40 and A41 are post holes

In the top, Phase III has been dated as corresponding to the Caliphate of Córdoba by the ceramic analyses. In our opinion, the revolt caused by Ibn Hafsun and the destructive effects of the tsunami reflected in the A36 level, led to the abandonment of the place for several decades. It was not until the rule of Abderramán III (924 A D), in which the Cordovan troops conquered the nearby castle of Nicio (Navarro et al., 1998; Salado and Navarro, 2001). This historical event again implied Cordovan dominion over the Strait region. On a local scale, it presents a very different aspect to the previous scenario, since the first constructions with stone walls (A28 and A29) are verified, evidence of the reoccupation of a previously abandoned space.

4.2 Analysis of Historical Sources

Analysis of historical sources in both the Eastern Atlantic and the Central and Eastern Mediterranean, indicate that past earthquakes and coastal landslides have generated damaging or destructive tsunamis along the coasts of Southern Spain. For example, the 1755 Lisbon earthquake caused considerable damage not only in Portugal but also in southwestern Spain. The tsunami generated by this event, caused damage to Cadiz and Huelva, and its waves penetrated the Guadalquivir River, reaching Seville (Pararas-Carayannis, 2021).

Also, destructive earthquakes and tsunamis in the Eastern Mediterranean region have had significant impacts on the ancient world and even changed the course of history. One of the most destructive earthquakes which occurred on July 21, 365 AD along the western coast of the Island of Crete generated a mega-tsunami, which mainly devastated the southern and eastern coasts of the Mediterranean Sea, but numerical modeling studies indicate that it must have also impacted to some extent its eastern coastlines as far as Spain (Pararas-Carayannis & Mader, 2010). According to historic records, this 365 AD earthquake was felt throughout the Eastern and Western Mediterranean and as far away as the eastern coast of Spain, particularly in the area where present Malaga is located (Pararas-Carayannis, 2011).

The first stage of the present study includes a historiographical review of events. It is clear from the reviewed documentation that a series of conflicts exist that has the potential to inhibit efforts to gain a clear understanding of the AD 881 earthquake. Realizing a state of the question that covers only the AD 881 earthquake, serious deficiencies have been found in the usual lines of investigation. The main problem is that: in the investigation of historical earthquakes, the catalogues published from the end of the 18th century to the present day are often used, and all of these require substantial revision. In these widely known catalogues, for example the Galbis Catalogue (1932), the information provided is not always evaluated one by one, but we will say that practically all of them have been collected in more recent works such as by Martínez Solares, by Mezcua Rodríguez (2002) and by Udías (2015, 2017).

The historical texts compiled in the catalogues have not always been contrasted with the original documentary sources, and often the authors have been copying the texts among themselves. In this way information can be mixed, losing its origin, meaning and context. For this reason, it is necessary to update and critically review the existing documentation concerning the AD 881 earthquake, so as not to show doubt on a historical event that undoubtedly occurred and shook the Andalusian world.

With regards to the Islamic historical sources, the first thing to keep in mind is that any such texts that address the 881 earthquake and that have survived to this day, have been repeatedly recopied throughout the Middle Ages. Islamic chroniclers, historians, and geographers copied each other's texts to create their own. This is why we have different translations of the same text, and also why we have chosen to resort to the closest translations to the originals.

Both Islamic historic texts considered, *Kitāb al-bayān al-muġrib fī ājbār mulūk al-āndalus wa-l-maġrib* – better known as *Al-bayān al-muġrib*, attributed to Ibn Idari – and ii) *Kitāb al-ānīs al-muṭrib bi-rawḍ al-qirṭās fī ājbār mulūk al-maġrab wa tārīj madīnah Fās* – better known as *Rawd al-Qirtās*, attributed to Ibn Abi Zar, date from the beginning fourteenth century, although ascertaining the original their composition is problematic. Most probably, both *Al-bayān al-muġrib* and *Rawd al-Qirtās* come from other chronicles of an Islamic leader previous to the 14th century (Fernández Fonfría, 2010; Souto, 1992, 1995). This is very common and has been studied in various works, some as important as the *Kitāb al-muqtabis fī aḫbār al-Andalus*, better known as *Al-Muqtabis*, one of the great works of Ibn Hayyan Al-Qurtubi and which also references and intersects our sources (Molina, 2005; Penelas and Molina, 2011).

4.3 Possible Origin of the Earthquake

The precise origin of the earthquake that caused the tsunami is not yet fully understood, although there are at least two plausible possibilities. The first is that it originated from a tectonic event in the Betic Cordillera, which, directly or indirectly, triggered an underwater landslide leading to a tsunami. The other option is an underwater earthquake caused by one of the nearby Mediterranean faults, halfway between Africa and the Iberian Peninsula.

The Estepona coast is part of the imposing and long geological framework of the Alpine-origin Cordilleras de las Béticas that run through southern Spain. It is located in a convergence zone, from 4 to 6 mm/year (Argus et al., 1986; DeMets et al., 2010), between Africa and Eurasia, two much larger plates (Argus et al., 1986). The Azores-Gibraltar fracture zone represents the western boundary between these two plates approximately from the Lower Miocene, at which point the Iberian Plate became part of Eurasia (Srivastava et al., 1990). Finally, during the Cenozoic, its paleogeographic and tectonic evolution is linked to the closure of the Tethys ocean and the Alpine Orogeny (Jabaloy et al., 2002). All this makes this sector of the Iberian Peninsula the most active in terms of seismicity.

Although earthquakes and tsunamis in the Iberian Peninsula do not match the frequency and intensity of other coasts, they have occurred approximately every 99 years in the last 2000 years (IGN catalog, 2020). The most intense, depending on the definition, occur between 450 years (Carreño, 2005) and 1.200-1.500 years over the course of the Holocene (Lario et al., 2011).

The most devastating tsunamis originate on the Atlantic coast from the Bank of Goringe, the Gloria Fault and the Arc of Gibraltar (Carreño, 2005; Lario et al., 2011; Alonso et al., 2011; Pararas-Carayannis George, 2021.), west of the Gulf of Cádiz, but the Mediterranean world is also no stranger to this natural phenomenon. Numerous catalogues, updated by researchers, have reported such catastrophes for centuries, although their effects appear to be of a lesser degree. The last tsunami that hit the Spanish coast in 2003 affected the Balearic Islands. In the analysis of the historical texts identified in this work, two important facts have been confirmed. The first is that the earthquake was sizeable in magnitude and intensity, close to 8 (Mw). Its incidence radius is significant, since the seismic shock reached a large part of

North Africa and the Iberian Peninsula. Locating the epicentre is difficult, but it is likely to have been located between the Betic Cordilleras and the Mediterranean Sea. When its destructiveness and reach are described in the texts, it is said that it "feels" in North Africa and even "in the last part of the Land of Christianity" and damage to the same mosque in Córdoba. But the destruction, and the greater ruin in buildings with the fall of "magnificent buildings and fortresses" that were "very broken" with the disappearance of towns, is mentioned as a geographical framework on the coast to the Baeticas. An earthquake in this zone is not bound to produce a tsunami, but a few cases are documented such as the earthquakes that occurred between the 15th and 19th centuries on the Andalusian Mediterranean coast. The most powerful occurred in 1884, with a magnitude of 6.7Mw (Sánchez, 2011), and had disastrous consequences for local populations, but did not cause tsunamis. Only those that occurred in 1522, associated with the aforementioned Carboneras Fault (Reicherter and Becker-Heidmann, 2009), and 1680, with a possible epicenter in the vicinity of the city of Malaga, were associated with tsunamis. According to chronicles, the sea rose to about 5 m in the port and claimed several dozen victims (El Mrabet, 1991; Macías et al., 2013).

Both Ibn Abi Zar and Ibn Idari explain the effects of the earthquake, which allows us to get an idea of its destructive level. The first thing they mention is the loud sound they heard when they said the earth shook with a dreadful noise and shudder. It had to be a significant earthquake as Ibn Abi Zar reports that men had never seen or heard such an even, and were forced to seek truces in their various battlefields – the most educated Muslims understood that earthquakes were part of nature, but a large part of the population saw it as divine punishment for their actions.

In Córdoba great destruction is not reported. Fortresses and mountains shuddered or moved, but the fall of buildings was not described. However, the text of Ibn Abi Zar, closer to the Malaga coast, reports that many fortress and magnificent buildings fell, others were ruined, mountains sank, crags opened, and the earth sank and swallowed towns and heights, just as many towns on the southern and western coast of Spain were ruined. Clearly the intensity of the earthquake was higher closer to the coast, further exacerbated by a tsunami. The text says that the sea retreated and separated from the coasts, and islands and reefs in the sea disappeared. Thanks to the location in which it is known that they were fighting with other Muslims, and to the archaeological remains found in Estepona, we believe it possible that a tsunami affected, at least, a sector of the eastern coast of Andalusia.

Returning to the sedimentary record of Estepona from the year 881 AD, few works make any kind of allusion about its existence beyond documentary sources (Gracia et al., 2010; Reicherter et al., 2010; Ruiz et al., 2013), and none provides clear evidence in this regard. It is currently assumed that the epicenter of the earthquake/tsunami was located in the Gulf of Cádiz (IGN, 2020), but this possibility can be ruled out. Firstly, this location is surprising because this was never mentioned in documentary sources. Secondly, taking the Lisbon Earthquake of 1755, the largest comparable European catastrophe (Baptista et al., 1998), as an example, the tsunami waves resulting from this event were barely able to flank the Strait of Gibraltar, and caused only very slight disturbances on the Malaga coast (Martínez Solares, 2017; Macias et al., 2013). The same is true of other Atlantic tsunamis.

Another option is that the epicenter was situated the coasts of North Africa. The waves generated from this sector after an earthquake, especially from the Algerian margin and according to recent simulations (Lorito et al., 2008; Álvarez-Gómez et al., 2011), have the capacity to reach the Spanish coast, but on its easternmost side: the coasts of Almería, Alicante, and especially the Balearic Islands, but without incident on the coast of Malaga or Estepona. In any case, slight alterations are recorded from centimetric to decimetric (Macías et al., 2013). Historical data confirms this. If we turn to the memory of earthquakes of some importance that have affected the northwest of the African continent (Hamdache et al., 2010; Soloviev et al., 2013; Maramai et al., 2014), no tsunamis reached the Estepona coast.

For this reason, we point to a third option, to an origin in the faults closest to the Malaga coast and in the spine of the Alboran Sea. In this sector, there are several possible failures that may be related to the paleo-tsunami found in Estepona (González et al., 2010; Álvarez Gómez et al., 2011). One of these is the so-called Al-Idrisi Fault, located just over 100 km from Estepona (Álvarez Gomez et al., 2016). However, other may be a possibility: the Alboran Ridge Southern Fault East, Alboran Ridge Southern Fault West, and the Tofiño Bank Fault (Álvarez Gomez et al., 2011). On the other hand a tsunami caused by an underwater landslide triggered by the earthquake cannot be ruled out, feasible in the deep incision that occurs in the Alborán Ridge, also called Al-Borani Canyon (Macías et al., 2013).

The height of the wave from AD 881, according to the geomorphologic position (>2 m) and its proximity to less than 100 m from the sea implies it must have reached the Estepona coast with a height between 1-2 m. Although simulations do not usually show waves exceeding 1.7 m, the 1680 episode seems to suggest this (El-Mrabet, 1991; Santonja, 1998). Once it reached the continent, and taking into account its geographical and topographic location, and the nature of the sediments found, the wave must have penetrated the "Arroyo de la Calancha" and with the retreat to the sea, the hill being an obstacle, eroded its surface and subsequently deposited the marine-fluvial-continental sediment load.

5. CONCLUSIONS

It has been determined that the deposit named A-36 more than 2 m above sea level found in a small deposit in the city of Estepona (Málaga), corresponds very likely to the tsunami documented in historical sources in the year 881 AD. The lack of recognition is presumably due to its superficial nature and the poor understanding of this type of sediment in coastal of Spain.

The archaeological foundations that support the identification of our archaeological level A36 with a tsunami are developed in different aspects. On the one hand, A36 overlaps in a clear stratification sequence; its analysis reveals that stratigraphic actions occurred as an effect, first, of its deposition, which implied the devastation of an immediately previous housing horizon (phase II) and, second (after a hiatus with exclusively interfacial physical representation), as an effect of the reduction of its volume by the foundation of two buildings and the formation on its roof of a new level of use (phase III).

On the other hand, it has been determined that the ceramic materials present in the units that make up phase II (in their horizons of use and destruction) are techno-typologically located in the second half of the 9th century, while those corresponding to phase III belong and to the repertoires of the first half of the 10th century.

The adjustment of the archaeological chronologies relative to the dating of related historical events (tsunami in 881, caliphal subjugation in 924) suggests that the abandonment subsequent to the tsunami may be estimated at several decades in duration. It should be taken into account that our analysis deals with a specific sampling (6 m^2) and that until now it cannot be contrasted with other local or regional stratigraphies, being the excavation in c/Real 98 in Estepona the first and, until now, the only one in providing contextualized archaeological information on these historical events on the western Costa del Sol and its hinterland. Finally, it has been determined that the archaeological deposit A36, corresponds to the tsunami of the year 881 documented in the historical sources. Thus, it becomes the first witness of its existence.

Several strands of evidence confirm the deposits as the result of a tsunami and not of a storm surge. Two stand out: the presence of sedimentary material with marine elements (bioclasts, ichthyofauna and other organisms) and continental (soft ridges, fluvial ridges and sands, riverside vegetation) intermingled, and the presence of tuna remains indicating high-energy events.

Analysis of the historical texts confirms not only the approximate date of the catastrophe (May 26), but also its possible location in one of the faults or canyons in the Alboran Sea.

The micro morphological study confirms that A-36 samples share characteristics consistent with emplacement through the action of an historic tsunami during the medieval period. The section exhibited distinct facies, mainly distinguished by the degree of sorting and the range in particle size. Medium and coarse sands dominated the sediments; however, there were facies with a greater abundance of heterogeneity in the form of gravels and boulders. This can be interpreted as a consequence of each wave associated with the tsunami event forming a distinct sedimentary unit. Distinct upper and lower sub-units representing run-up and backwash are probably represented although there is considerable uncertainty about when most deposition occurred. There appeared to be cross bedding within the sedimentary units and perhaps these correspond with landward and backwash seaward currents associated with the individual tsunami waves. Certainly the imbrications of shells and the rounding and sorting of archaeological material can be included in these processes. The association of building debris, archaeological residues and beach sediments and marine fauna are perhaps compelling evidence of a geoarchaeological tsunami signature.

However, considering the height of the wave, the subsequent continuity of the human presence in the vicinity of the site and the exceptional nature of these events in this part of the Mediterranean, it seems that the tsunami had a limited capacity for destruction and did not result in the discontinuity of Estepona as a local focus of the population.

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APPENDICES

The text that we reproduce below is the translation made by Conde (1820, p. 310-311):

> *In the year two hundred and sixty-seven, Thursday, twenty-two of the moon of Xawâl, the earth shook with such terrible noise and trembling, that many fortresses and magnificent buildings fell, and others were very broken, mountains sank, rocks were opened, and the earth sank and swallowed up towns and heights, the sea retreated and moved away from the coasts, and islands and reefs disappeared in the sea. The people left the towns and fled to the fields, the birds left their nests and the frightened beasts left their caves and burrows in general embarrassment and upset: men never saw or heard such a thing: many towns on the southern and western coast of Spain were ruined. All these things so influenced the moods of men, and especially the ignorant multitude, that Almondhir couldn't persuade them that these were natural things, although infrequent, that these hadn't influence or relation with the behaves of men or with their endeavour, but because of their ignorance and vain fears, that the earth shook the same for Muslims as for Christians, for beasts and for innocent creatures. In agreement with King Muhammad, Almondhir arranged truces with the King of the Christians, who sent his messengers to Córdoba, accompanied by Muslim knights.*

The second text comes from Ibn Idari's quill. There are two similar translations that provide information to help us understand the event (Fernández González, 1860, p. 205-206; Souto, 1995, p. 230).

And of the admirable things that happened that year (Hegira 267), which shook the earth with a horrible shudder at the hour of the azala of sunset, and it raised a cloud full of darkness, and it thundered and flashed and six men were struck by the thunderbolt and fell on their backs, dying two and the people prostrated themselves in adoration, minus the imam that remained standing, although it was the two who died, those of the people who were closest to the imam and the hair of one of them was

Among the wonders of this year (Hegira 267) is what Ar-Rāzī and others tell. They say: The earth shook in Córdoba by a strong earthquake and the wind rose when the prayer of al-Magrib, unleashing a cloud carrying darkness, thunder and lightning. Six people were struck down and thrown on their backs. Two of them died. All the people fell prostrate except the Imam, who remained standing. The two men who died were from the people closest to the imam. The hair of one of them was *burned and his face and his left side blackened, and the other appeared with his right side black, and the four passed out remained motionless until the imam was filled with unease, and they were asked about what they had felt and said: "We have felt fire like a heavy sea wave." And the people of the mosque were found dying of fire and no trace of lightning was found on the ceiling (or acicafe) or on the wall and the fortresses and mountains were shaken, and the people of the fortresses fled to the fields, humiliating themselves before God, exalted be his name, and the earthquake was general from the Ax-Xemí sea to the extreme Guf and the last of the land of Christendom, that there has been no one who has a different opinion about it.*

burned and his face and left side blackened, while the other showed black his right side. The four taken down remained that way until the imam was unoccupied. They were asked about what they felt, and they answered: "We feel a fire like a heavy wave." The people of the mosque smelled the fire, but no trace of the spark was found on roofs or walls. As a result of this earthquake, the fortresses and mountains shook, and the people fled to the open fields, supplicating God, the Almighty. [The intensity of] this earthquake ranged from the Mediterranean Sea to the northernmost and even the farthest polytheistic land, without experiencing any variation.

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