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Rock art technology, Reflectance Transformation Imaging (RTI) and experimental archaeology: recent research on Iberian Late Bronze Age warrior stelae

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Abstract. This paper proposes a methodological approach for the study of rock art technology that combines the application of digital imaging techniques (in particular Reflectance Transformation Imaging, RTI) with rock art replication experiments. It is argued that this kind of combined bottom-up approach has the potential to offer valuable insights into the communities of practice involved in the creation of rock art. The paper uses Iberian Late Bronze Age warrior stelae as a case study, and presents the results of the recent technological analysis of four stelae from the Guadalquivir river basin, as well as a replication experiment. Added to offering some preliminary new insights into the social dimension of stelae-making, the paper also underlines the significance of tools collected through fieldwork at stelae find-spots as an additional line of evidence.
Keywords: rock art; warrior stelae; Late Bronze Age; engraving techniques; Reflectance Transformation Imaging (RTI); experimental archaeology.

[es] Tecnología del arte rupestre, imágenes por modificación de la reflectancia (RTI) y arqueología experimental: investigación reciente sobre las estelas de guerrero de la Edad del Bronce Final en la Península Ibérica

Resumen. Este artículo propone un enfoque metodológico para el estudio de la tecnología del arte rupestre que combina la aplicación de técnicas de imagen digital (en particular, Reflectance Transformation Imaging, RTI) con experimentos de recreación de arte rupestre. Se argumenta que este tipo de enfoque 'bottom-up', combinando dos líneas de evidencia complementarias, tiene el potencial de ofrecer información valiosa sobre las comunidades de práctica involucradas en la creación de arte rupestre. El artículo utiliza estelas de guerrero de la Edad del Bronce Final en la Península Ibérica como estudio de caso y presenta los resultados del reciente análisis tecnológico de cuatro estelas de la cuenca del Guadalquivir, así como un experimento de recreación. Además de ofrecer nueva información sobre la dimensión social de la creación de estelas, el artículo también subraya la importancia de las herramientas documentadas a través del trabajo de campo en los lugares de hallazgo de las estelas como una línea de evidencia adicional a tener en cuenta.
Palabras Clave: arte rupestre; estelas de guerrero; Edad del Bronce Final; técnicas de grabado; Imágenes por Transformación de la Reflectancia (RTI); arqueología experimental.

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1. Rock art technology

Rock art making has been a rather neglected topic in rock art research. This is surprising since the idea of rock art as a social product is commonplace in rock art research at least since the 1990s. Rock art is conceptualized, either explicitly or implicitly, as the product of individuals or communities, who are commonly granted agentive qualities in rock art production and are believed to have deployed art for a variety of purposes, including information exchange or ritual performance. Attention has been focused on rock art function and meaning, whereas its making, which is key to understand the crafting of its social, cultural and symbolic dimensions, has been largely ignored.

Most rock art research developed from the 1990s has adopted a top-down approach. Focus is usually placed on the formal (i.e. typological, stylistic) analysis of motifs and their combination (iconography), of rock art sites and their spatial settings, as well as on the search for structural patterns which are then interpreted in terms of cosmologies, socioeconomic models, etc. (see, for example, papers in Chippindale and Taçon, 1999; Helskog, 1999; Fredell et al., 2010). The material qualities of rock art panels and their experiential dimension, have only been investigated more recently, and this research is revealing how topography, texture, colour and acoustic properties played key roles in the making of rock art worlds (e.g. Díaz-Andreu et al., 2014; Jones et al., 2011: 10-35; Helskog, 2004, 2014; Pettitt et al., 2014).

These approaches have contributed to advance our understanding of various key aspects related to rock art but there is more we need to do to fully grasp the social – and historical – dimension of rock art. In order to assess the material qualities of rock art panels, their iconographies and spatial settings in social and cultural terms and, more broadly, to relate them to grand theories (i.e. about social organization, lifeways, cosmologies), we need to address the most fundamental parameter of all: practice (i.e. rock art-making). As Bernbeck pointed out some years ago (Bernbeck, 2003: 44), practice (or praxis) is a paradigm that transcends theoretical barriers. It is relevant to processual and post-processual archaeologies, as well as to the so-called 'new materialisms'. Investigating the practices and materials involved in rock art-making has the potential to generate significant knowledge into the ways rock art production was organized (were there communities of practice?) and the social implications of this, the (intentional and unintentional) roles of rock art in the production and reproduction of knowledge (e.g. traditional stories, cosmologies, collective identities) and social relations, including the ways people related to their material worlds (Fahlander, 2012; Jones et al., 2011: 334-35).

Previous research on the making of petroglyphs and painted rock art has paid attention to the identification of techniques and tools – also recipes in the case of paintings – by means of replication experiments, including the analysis of use wear on the stone tools deployed to make petroglyphs. In the case of painted rock art portable technologies are facilitating the broader application of pigment analysis. In relation to petroglyph-making, the most relevant for the purpose of this paper, this kind of research has produced significant insights into the traces and markings left by different tools and the assessment of the production process (Alvarez et al., 2001; Bednarik 1998; Whittaker et al. 2000). But fewer studies have examined the operational sequence (*chaîne opératoire*) and the social dimensions of rock art production (but see, for example, Fahlander, 2012; Fiore, 1996, 2007; Kohring, 2014; Vergara and Troncoso, 2015). Fahlander (2012), for example, explored the complex sets of relations in which rock art motifs are embedded, and their social and ritual significance through a focus on materiality and process. Vergara and Troncoso (2015), conducted a very detailed analysis of the techniques employed to make the petroglyphs within two rock art styles associated with hunter-gatherer and agrarian communities, respectively. The style associated with small mobile hunter-gatherer communities showed greater thematic and technical homogeneity, whereas the style related to larger agrarian communities displayed more heterogeneity. As a result, Vergara and Troncoso suggest that variability in the rules governing rock art-making seems to be directly interrelated with a series of underlying aspects, such as group size, residential patterns, and the degree of interaction between communities.

Iberian Late Bronze Age warrior stelae offer a great potential for carrying out such a study since they constitute, in terms of form and content, a well-defined and rather stand-

ardised rock art tradition that, in addition, adopted a specialized form. Motifs shown on stelae represent a limited range of themes and compositions, and were seemingly made with conventional rock art techniques. Yet, they were carved on a rather original stone canvas: a flat surface of a dressed stela, which was meant to be standing and could be moved.

These monuments have captured the imagination of scholars and the public for more than a century. Nowadays, after the discovery of more than 150 stelae throughout western Iberia and more than a century of research, there are important questions that remain poorly understood. The purpose of this paper is to examine one of these relevant issues: their manufacture. The paper explores the social dimension of stelae-making through the analysis of the carving techniques employed to manufacture warrior stelae by means of Reflectance Transformation Imaging (RTI) and a replication experiment.

2. Iberian Late Bronze Age warrior stelae: from iconography to iconography *and* technology

Iberian warrior stelae are relatively large (c. 0.50/1–1.60 m long) dressed stone slabs that show engraved decoration on one side, usually in its upper and middle portions, and a lower part left blank or unworked, probably because it was meant to be embedded in the soil. The decoration mostly consists of a limited range of carved motifs representing late Middle and Late Bronze Age weaponry (shields, swords, spears), objects of personal care (combs, mirrors), elements of dress (brooches, headdresses), as well as schematic human bodies, small quadrupeds (probably dogs), chariots pulled by horses, sometimes lyres and weighs (some recent overviews can be found in Harrison, 2004; Díaz-Guardamino, 2010: 327-414; Araque, 2018). It is generally agreed that these compositions were created to commemorate deceased elite individuals through the representation of their warrior persona; in some occasions they include secondary human figures composing narrative scenes describing possible funerals.

The contexts of discovery of stelae are poorly known. The slabs were usually found in the landscape, as un-stratified remains, or unearthed through agricultural or construction work. For these we usually have sparse references about the location of the find-spot and the activity that brought them to light. There are some oral accounts providing descriptions about their finding and these sometimes refer to the presence of osteological remains, pottery fragments and, in one occasion, rests of a possible degraded metal artefact (Díaz-Guardamino, 2010: 368-73; 2012: 400-2). Because stelae are durable remains, they can be found reused in more recent contexts (e.g. Iron Age structures, historical rural architecture) (Díaz-Guardamino, 2012: 402-6; García Sanjuán and Díaz-Guardamino, 2015: 189-96). The scarcity of contextual information and their potential movement and reuse led researchers to focus almost exclusively on stelae iconography (e.g. Celestino, 2001). More recently, attention has been placed on stelae biographies and find-spots (e.g. García Sanjuán et al., 2006; Celestino et al., 2011: 144-48; García Sanjuán and Díaz-Guardamino, 2015; Díaz-Guardamino et al., 2019).

The iconography of stelae is a complex field. Its study has much to offer but it requires a bottom-up approach that attends to the idiosyncrasies of these monuments (i.e. durability) as well as the broader social contexts in which they were produced, used, and reused. Traditionally, the analysis of stelae iconography was based on two assumptions: one is that the iconography of each stela was the result of one single intervention and, consequently, it was considered a 'snapshot' of a specific moment in time; the second is the understanding of iconographic variation as the result of a linear evolution in which the simpler develops into more complex forms. Three very similar typologies of Late Bronze Age warrior stelae iconography were produced in the 1970s by Pingel (1974), Gomes and Monteiro (1977, 185-8) and Almagro-Gorbea (1977, 163-74). They defined a series of stelae types (IIA, IIB, IIC and IID, the latter by Gomes and Monteiro) based on the presence/absence of specific motifs (i.e. the basic panoply formed by spear, shield and sword, additional objects, and one or more human figures, these composing scenes). Almagro-Gorbea's study also took into consideration a relevant stylistic trait, that is, the relative position of motifs (e.g. shield and human figure) (Almagro-Gorbea, 1977, 166). His elaborate typology, based on the thirty stelae known to that date, was interpreted as a chronological seriation (Almagro-Gorbea, 1977: 189-91).

Subsequent research and further discoveries (on average more than two new stelae have been published every year since the late 1970s) have reshaped our understanding of stelae iconography. Research by Galán (1993) outlined the need to consider iconography as a social product and to attend to the broader social context in which stelae were produced in order to understand their iconographic variation. He considered stelae as territorial markers and took into account, for the first time, their spatial dimension. In his model iconographic variability is linked to social competition. The former would have increased in areas where stelae-bounded territories met, a hypothesis that only seems to be applicable to one of the many regions where stelae are found. Even though Galán downplayed temporality in his understanding of stelae iconography (he considered the main types as coetaneous), he examined some interesting conventions that seemed to be geographically bounded, like the representation of the sword on the waist of the human figure (Galán, 1993: 47-50). In the early 2000s, Harrison highlighted the fact that some stelae iconographies were clearly the result of more than one intervention (Harrison, 2004: 46-52), a fact that he incorporated in his account of stelae iconography as a historical process, and which has been more extensively illustrated by subsequent research (Díaz-Guardamino, 2012). He interpreted stelae as expressions of a chiefly ideology whose manufacture/modification was controlled by local chiefs (Harrison, 2004: 75-80). In this context stelae are interpreted as media for social competition and more broadly as part of a process for building power whereby stelae iconography changed, a perspective that highlights the need to take into account both dimensions, the spatial and the temporal, to approach iconographic variability.

A review of stelae iconography (Díaz-Guardamino, 2012) draw on radiocarbon dating and the concept of stelae biographies to produce an updated understanding of their temporality. Stelae show representations of objects that are known to have been circulating throughout western Iberia during the Late Bronze Age. Sometimes these representations are faithful to material correlates whose context of discovery has been dated by means of radiocarbon dating. These dates provide provisional maximum dates (*termini post quem*) for the carving of specific motifs on stelae. In combination with other lines of evidence, such as the re-use of some stelae during the Late Bronze Age and the Early Iron Age, these dates seem to confirm some elements of the sequence proposed in the 1970s, that is, that the stelae of type IIA are the first to appear and the ones of type IIC the most recent. Yet, instead of developing in a linear fashion, as it was proposed then, the different types seem to have been largely contemporary and overlap geographically, underlying once again the complexity of the phenomenon (Díaz-Guardamino et al., 2020: 77-83).

As underlined by these contributions, a key topic to understanding stelae is social interaction (connectivity) at different spatial and temporal scales (Galán, 1993; Celestino, 2001; Harrison, 2004; Díaz-Guardamino, 2010: 389-411). Stelae are consistently distributed in transitional areas articulating social interaction between the Iberian hinterland and its coastal periphery in the Northwest, West and Southwest of Iberia at a time when these coastal areas are part of broader interaction networks reaching other regions in the Atlantic and the Mediterranean. In this context the representation on stelae of objects that are in circulation should come as no surprise. There are correlates that haven't been found on Iberian soil until now, like shields, chariots or lyres, possibly because they were made of perishable materials, but are known in other areas of the Mediterranean and the Atlantic with which Iberian communities were in contact (e.g. like the Cloonbrin shield in Ireland).

A recent multivariate analysis of the co-presence/absence of motif-categories on stelae compares well with the main chronological and geographical trends of interregional interaction known to date for the Late Bronze Age in the Iberian Peninsula (Díaz-Guardamino et al., 2020). At the same time, the ways in which motifs that are seemingly carved simultaneously are combined and placed on the stone canvas – representing some of the types distinguished by researchers – follow patterns that also seem to conform to the main trends of interregional interaction. But the range of formal variability in stelae iconography is broad – steadily increasing in tandem with new discoveries – and we are still far from understanding its full complexity. A further layer of variability is that shown by specific conventions found in small groups of stelae, some of which seem to be geographically clustered in specific regions (i.e. sword in waist of human figure),

as highlighted by Galán (1993), while others appear in different, at times distant, regions (i.e. human figures with extended arms with open hands, these primarily along the Guadiana basin).

In short, new discoveries and recent research are revealing that iconographic variability on stelae was the result of various phenomena developing at different temporal and spatial scales/rates. Researchers have addressed the social dimension of stelae iconography but have only been able to provide incomplete accounts due to the predominant adoption of top-down perspectives and the persistent focus on large scale phenomena/patterns (e.g. interaction, ideology) and selected agents (i.e. 'the chief', social elites).

In order to understand rock art iconography (and more specifically warrior stelae) as a social phenomenon, including its crafting as tradition and historical process, we need to adopt a bottom-up approach, focus on materials, their qualities and relations through the practices deployed to shape them, taking into account the many social actors (i.e. beyond elites) that may have been involved in the production, use, and reuse of warrior stelae, that is, the broader social relations in which they were culturally and socially embedded.

In the case of warrior stelae, such an approach requires addressing basic questions such as the knowledge and level of skill needed to make a stela, the provenance of the rock, the sources of iconographic inspiration, that is, the ways in which conventions were crafted and disseminated (since stelae are not easily movable, we need to think of people, mental and material images – on perishable materials –, in motion), the people involved in their making (where these specialists?) and eventual modification. One of the most obvious outcomes of such an approach would be new information on how stelae production was socially organized (e.g. can we speak of communities of practice?), as well as to assess how local communities perceived and reacted to their direct or indirect involvement in long distance social interactions.

A restricted but essential aspect of such an approach is the *technology of stelae-making*. Mainstream research has paid very little attention, if any at all, to this question. Most works briefly describe some of the carving techniques that could be identified (sometimes erroneously) through visual inspection but do not offer further considerations beyond description. The first systematic work, conducted by Enríquez and Fernández (2010), offered a general description of the engraving techniques documented on the stelae held at the Archaeological Museum of Badajoz (Extremadura, Spain). Albeit based on documentation produced with traditional recording methods (i.e. direct tracing and photography with oblique light), they were able to verify that the techniques employed to carve stelae were similar to those used to create rock art in the region (pecking followed by abrasion, not incision as suggested by Celestino for the generality of warrior stelae in 2001: 87), as well as to assess the extent of later modifications in several stelae.

The paper here presented first written and submitted for publication in 2016, took a step further and combined two new lines of evidence in the evaluation of this matter: on the one hand, the results of the surface texture analysis of a series of warrior stelae (i.e. four cases from southern Iberia) conducted through Reflectance Transformation Imaging (RTI) between 2012-2015; on the other, the evidence produced through a replication experiment performed with students in 2013. This strategy aimed to provide insights into the techniques employed and the skill and time required to produce these stelae, the identification of possible technological styles, making inferences about carvers and, ultimately, the social conditions of stelae production.

Since 2016, three key developments have taken place. Firstly, in 2018 a new project *Rock Art, Words and Warriors* (RAW) (2019-22), of which I am part, was funded by the Swedish Research Council (PI. Johan Ling) to produce and disseminate high resolution digital recordings of warrior stelae (at least 100), and compare them (including their manufacture) with Scandinavian rock art. Secondly, between 2019 and 2021 various key papers have been published reporting on the results of new replication experiments exploring the manufacture of warrior stelae from the upper Tagus valley with metallic tools (Gutiérrez et al., 2020), and offering new insights on the manufacture techniques and *chaîne opératoire* of warrior stelae obtained through the application of digital technologies (García-Arilla et al., 2021; Díaz-Guardamino et al., 2019; 2020); other papers explore some of the theoretical implications of those tecnological findings (Díaz-Guardamino, 2020; 2021). Fi-

nally, in 2020 another project was granted to Ralph Araque, *The Iberian stelae of the Final Bronze Age: iconography, technology and the transfer of knowledge between the Atlantic and the Mediterranean* (2021-23), funded by the DFG. As part of this project, with which I collaborate through the RAW project, a series of replication experiments are being conducted to explore how stelae from the Beira Interior (mostly made of granite) were manufactured.

In short, this paper offers a theoretical and methodological framework that complements well these developments, all of which underline the need and importance of generating new empirical evidence on the technology of warrior stelae-making for understanding the social context in which these monuments were created.

3. Digital Imaging and rock art technology: the case of warrior stelae

Nowadays there is a range of digital imaging techniques that provide powerful solutions for recording and analysing cultural heritage artefacts. Because of their portability, non-invasiveness and, more often than not, their low cost, digital imaging techniques are particularly well suited for the documentation and interpretation of painted and engraved rock art. One of these techniques is Reflectance Transformation Imaging (RTI), a robust method for surface data capture and the interactive visualization of the 3D shape of surfaces (Malzbender et al., 2001). RTI is particularly powerful for rendering texture (surface detail). It enables the visualization and examination of very subtle details that may be invisible to the naked eye or that have proven challenging to be recorded by means of other established 3D surface data capture methods such as laser scanning or close-range digital photogrammetry (Díaz-Guardamino and Wheatley, 2013; Horn et al., 2018; Papadopoulos et al. 2019).

The capabilities of RTI make it a very valuable asset for rock art research, and specifically for the analysis and interpretation of engraved rock art (Mudge et al., 2006; 2012; Díaz-Guardamino et al., 2015) – for a detailed description of the method see (Cultural-Heritage-Imaging, 2011, 2013b, 2013a). Importantly, RTI has the ability to go beyond the identification and delineation of petroglyphs since it is capable of rendering a broad variety of marks indicative of different gestures and practices produced in the course of stelae preparation, carving and later modification (Díaz-Guardamino et al., 2015; Horn et al., 2018). The documentation of these marks through digital methods is a necessary step towards the formalized study of rock art carving techniques. Methods such as RTI or close-range photogrammetry produce robust and objective records of carving marks allowing their systematic characterization and comparison between those documented in different warrior stelae.

Until now, RTI has been applied to around half of the warrior stelae known to date in Iberia as part of the activities of the RAW project; most of the results are currently being prepared for publication in 2023. The analysis that follows focuses on four stelae (the first ever recorded with RTI) found in the Guadalquivir river basin in highly connected landscapes, and whose recent review was published (Table 1, Figure 1). Their analysis by means of RTI looked at stelae from a biographical point of view, attending to all marks, ancient and recent, held on their surfaces in order to draw genealogies of practices. The present study, however, only focuses on the marks that inform us about the practices deployed to prepare and engrave these stelae during the Late Bronze Age in order to compare the techniques and operational sequences involved in their manufacture and provide a preliminary overview of Late Bronze Age warrior stelae technology.

These four stelae display comparable iconographies, constituting a coherent dataset (Figure 2). The stelae of Mirasiviene and Setefilla (Lora del Rio, Sevilla) are particularly relevant to the present study because they show similar iconographic compositions and were found barely 3km away from each other, nearby droveways, in an area of transition between the Guadalquivir river plain and the Sierra Morena (Díaz-Guardamino et al., 2019: Figs. 24, 27). Fieldwork conducted at the findspot of the stela of Mirasiviene documented a rich pottery assemblage that included sherds with shapes that chronologically match the Late Bronze Age and Early Iron Age (i.e. they may be considered broadly coetaneous to the manufacture of the stela), as well as a nearby settlement with indication of Bronze Age – if not Late Bronze Age – occupation (Díaz-Guardamino et al., 2019). The stela of Setefilla was found reused as a cover of an Early Iron Age grave at the necropolis of Setefilla, which sits barely 3km to

the West of Mirasiviene. The necropolis, which was persistently used as a sacred site throughout many centuries (i.e. from the Bronze Age to the Roman period), lies around 600 meters to the South of a multi-temporal site that includes a possible Late Bronze Age settlement, a situation that closely corresponds to the one found in Mirasiviene (Bonsor and Thouvenot, 1928; Aubet, 1997; Díaz-Guardamino et al., 2015; 2019).

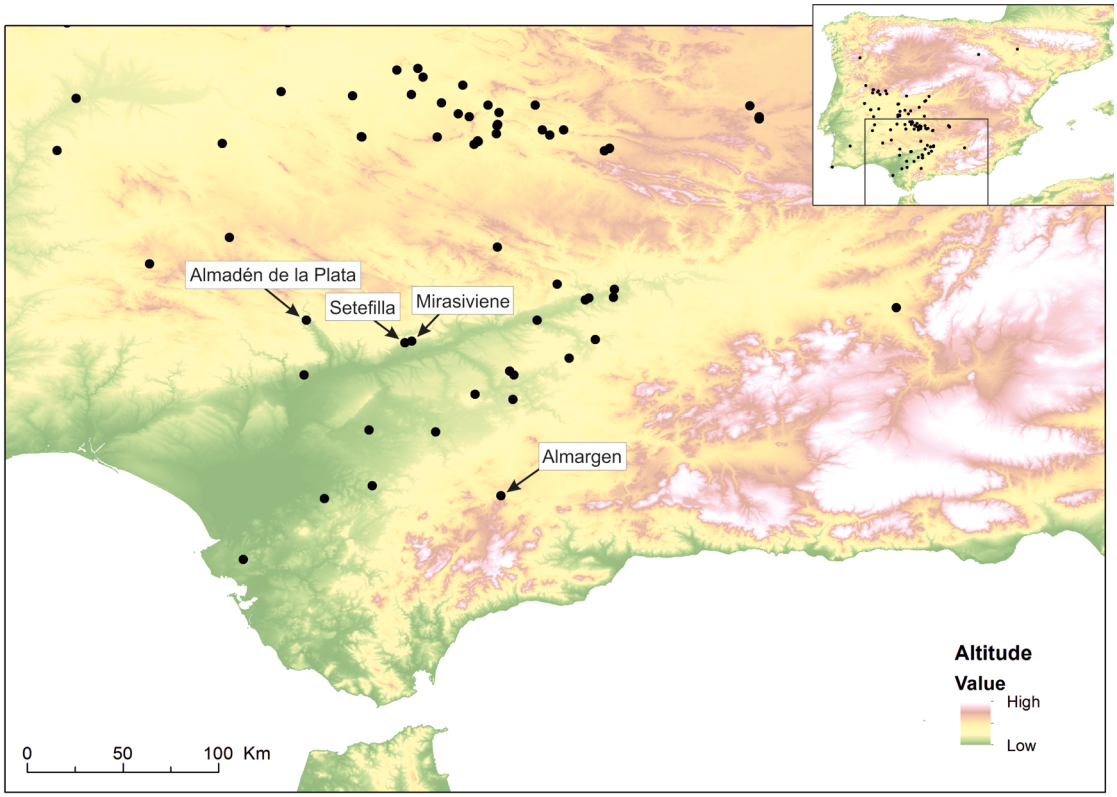

Figure 1. Distribution of Late Bronze Age stelae in southern Iberia and location of the stelae considered in this study.

Table 1. Late Bronze Age stelae considered in this study.

Stela name	Province/Region	Current location	References
Almadén de la Plata 2	Sevilla/SW-S	Museo Arqueológico Provincial de Sevilla	García Sanjuán et al. 2006; Díaz-Guardamino et al. 2015
Setefilla	Sevilla/SW-S	Museo Arqueológico Provincial de Sevilla	Bonsor and Thouvenot, 1928; Aubet, 1997; Díaz-Guardamino et al. 2015; 2019
Mirasiviene	Sevilla/SW-S	Mirasiviene farm	Díaz-Guardamino et al. 2019
Almargen	Málaga/S	Museo Municipal de Almargen	Vilaseca, 1993; Díaz-Guardamino et al., 2020

Two further stelae included in this study, those of Almadén de la Plata 2 and Almargen, were found 42km to the Northwest and 90km to the South of Lora del Río respectively. The stela of Almadén de la Plata 2, jointly with a fragment of another Late Bronze Age stela (Almadén de la Plata 1), was found beside a significant concentration of white quartz stones situated nearby a traditional droveway in a mountain environment (García Sanjuán et al., 2006). The stela of Almargen was also found nearby a significant cultural feature, a large mound yielding Iron Age materials situated in a highly connected landscape, a basin in which a variety of traditional droveways converge (Villaseca, 1993; Díaz-Guardamino et al., 2020).

Whilst the iconographies on these four stelae share a clear air of familiarity, each of them shows

a series of unique formal traits (Figure 2). Their iconographies revolve around two common motif-categories, the human figure and the shield, and three of them include the representation of a sword. Beyond this broad similarity there is a variety of idiosyncratic traits. Firstly, the spatial arrangement of those motif-categories on the stone canvas varies from one stela to another, following patterns seen in the broader group of warrior stelae as shown in Almagro-Gorbea's typological study (1977). Secondly, the same motif-category is represented following distinct stylistic standards on each stela, an aspect that will not be examined in detail in this paper but that will be taken into account when considering variability in stelae-making technology.

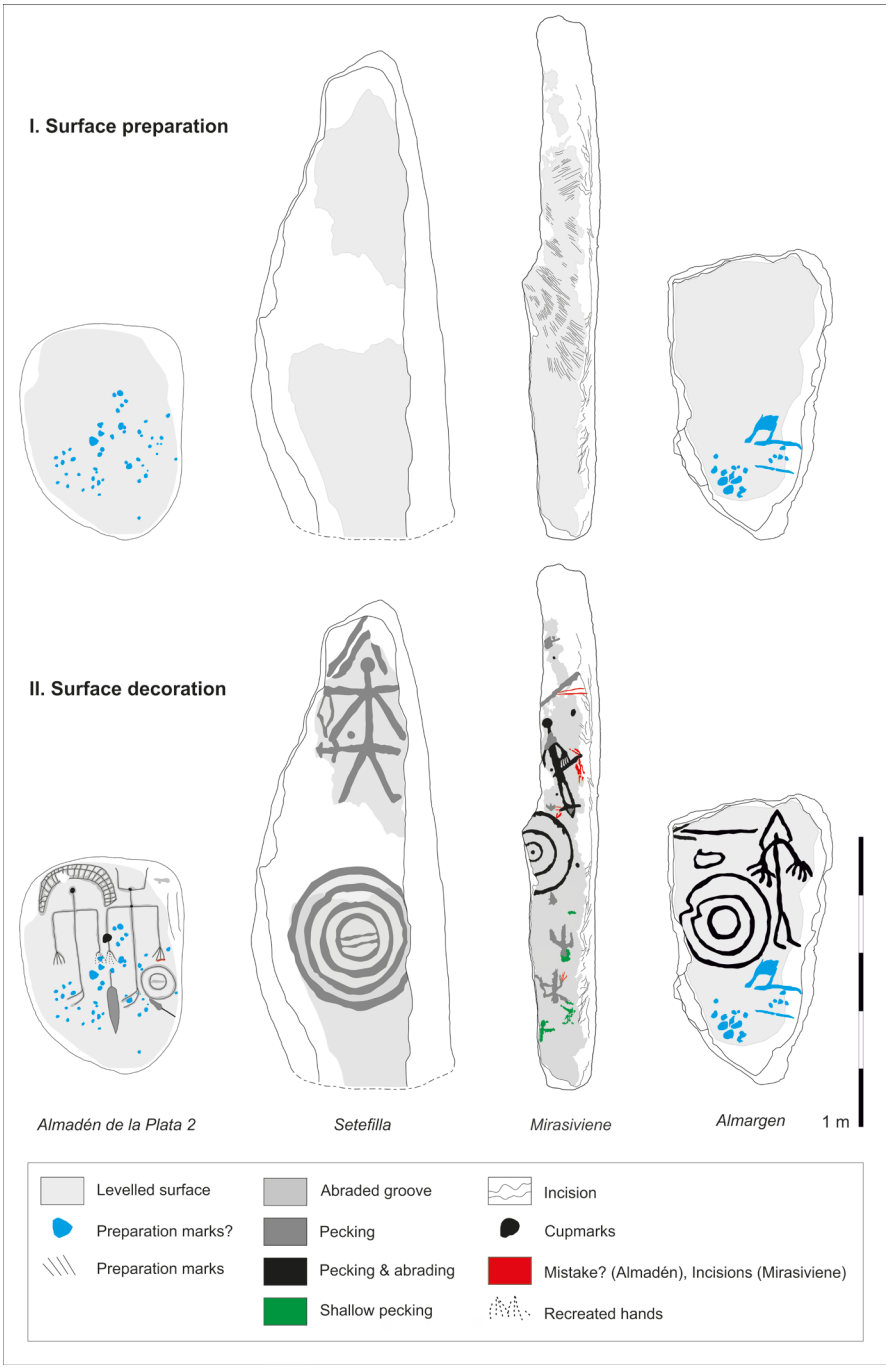

Figure 2. Interpretative syntheses of the Late Bronze Age warrior stelae examined in this paper. The 3D models of Mirasiviene and Almargen are available here https://skfb.ly/orTCN and here https://skfb.ly/onXSI respectively.

In addition, the techniques deployed to prepare the stone's surface and to carve the same motif-categories also vary from one stela to another, adding yet another layer of distinctiveness to each stela (Figure 2, Table 2). The surfaces of these four stelae were prepared by pecking, pecking followed by abrasion, abrasion, or pecking followed by chiselling (Figure 2: I). The decorated surface of the stela of Almadén de la Plata 2 shows a few marks that were probably produced by pecking and countless marks of chiselling (c. 5mm width) evenly distributed throughout the decorated surface (Figure 3: I-A). The decorated surface of the stela of Setefilla was smoothed, most probably through abrasion (Figure 3: I-B). The effects of surface abrasion are well documented on the stela of Mirasiviene, where numerous fine parallel grooves are clearly visualized through RTI (Figure 3: I-C). Finally, some marks of roughhew as well as abrasion can be seen on the stela of Almargen (Figure 3: I-D).

Variable are also the techniques employed to carve motifs on the stelae (Figure 2, Table 2). Different techniques were used to carve distinct motifs on the same stela as well as to carve similar motif-categories on different stelae (Figure 2: II). Both facts are particularly relevant to our study since technological variability may be linked to both the hardness and structure of the stone and the skill of the carver (see below). Finding different degrees of skill in the manufacture of a formally coherent group of stelae could be indicating that, most probably, despite their iconographic homogeneity, there was no prescribed way of making a stela, that is, that in the Guadalquivir valley stelae-making was an activity carried out by non-specialists– local carvers belonging to restricted communities of practice.

The shield, for example, was created by incision and abrasion in Almadén de la Plata 2, pecking, pecking and abrasion in Setefilla and Mirasiviene respectively, and by pecking and abrasion again in Almargen (Figure 3: II A-D). The human figure was also made with a variety of techniques: incision and abrasion in Almadén de la Plata 2, pecking in Setefilla, pecking, abrasion and re-pecking in Mirasiviene, and pecking and abrasion in Almargen (Figure 3: III A-D). This variability is also apparent in the manufacture of the sword: fine incision and shallow pecking detailing the blade in Almadén de la Plata 2, pecking and pecking and abrasion outlining a very simple sword positioned in the belt of the human figures of Setefilla and Mirasiviene respectively.

Each one of these stelae is made of a different type of rock: Almadén de la Plata 2 of tuff, Setefilla presumably of limestone, Mirasiviene of mica-schist, and Almargen of dolomite. Each type of rock affords different possibilities, in terms of hardness and internal structure, for stone working. In addition, each boulder needs to be considered individually: in the beginning it may have been shaped naturally (e.g. as probably the boulder of Almadén de la Plata 2) or quarried (e.g. as was probably the case of Almargen). Freshly quarried stone may behave differently since the surfaces of 'new' stone may be softer, as is the case with mica-schist (i.e. Mirasiviene). Also, the surface texture and the internal structure of each individual boulder may vary greatly within the same type of rock, thus, offering distinct vulnerabilities to be exploited in shaping and carving stelae. Here, the skill of the engraver in identifying and exploiting the stone's qualities are very important.

The relative hardness of each type of rock and the structure and texture of each individual stone had a relevant effect on the way stelae were shaped and carved, but to which extent? The four cases here considered suggest that the skill of the engraver had an important role here. The stelae of Almadén de la Plata 2 and Mirasiviene, which show a more careful preparation and better quality finish, are made of tuff and mica-schist respectively. Both – in the case of mica-schist if freshly quarried – are rocks with medium hardness (4-6 and 4-5 on Moh's hardness scale, respectively) that can be scratched with flint (7 on Moh's scale). In the case of mica-schist, the mica occurs in foliated masses which give the rock a laminated structure. In the case of Mirasiviene, the decorated surface partly coincides with an exfoliation plane of the rock, a fact that probably facilitated its preparation and carving (see below). On the other hand, Setefilla and Almargen were made of softer stones. The first is believed to be a limestone, which can be a fairly soft stone (3-4 Moh's scale). The second is made of dolomite, which rates 3.5-4 on Moh's scale, and could also be easily scratched with flint. Clearly, these two rocks have the potential to produce smooth stone surfaces and carefully finished engravings through the work of less skilled hands than tuff or mica-schist. Still, the stelae of Setefilla and Almargen show less carefully worked surfaces and carvings than those seen in Almadén de la

Table 2. Details of the Late Bronze Age stelae considered in this study: type, techniques deployed to prepare the surface and engrave motifs, and dimensions of stone block.

Stela name	Type (Almagro-Gorbea, 1977)	Stone	Hardness (Moh's scale)	Surface preparation	Shield – techniques	Human figure – techniques	Sword– techniques	Length (cm)
Almadén de la Plata 2	IIC-D	Tuff (local)	4-6	Pecking (?) and fine chiselling (5mm width)	Incision and abrasion	Incision and abrasion	Pecking	76
Setefilla	IIC-C1	Limestone (?)	3-4	Abrasion	Pecking	Pecking	Pecking	170
Mirasiviene	IIC-C1	Mica-schist (local)	4-5	Abrasion marks (fine grooves)	Pecking and abrasion	Pecking and abrasion, re-pecking	Pecking and abrasion	182
Almargen	IIC-B	Dolomite (local)	3.5-4	Rough-hew and abrasion	Pecking and abrasion	Pecking and abrasion	--	100
Tools recovered at Mirasiviene	hammers, grinding stones, ground-edge tools, and smaller precision tools	Flint: 7 Quartzite: 7 Diabase: 5-6						

Plata 2 and Mirasiviene. In short, skill, as much as rock type and the characteristics of the individual boulder, played a role in the crafting of warrior stelae.

But still, the question remains, how much skill was needed to produce a warrior stelae? This was addressed through a replication experiment that is described in the next section.

Figure 3. RTI snapshots revealing marks of manufacture on the stelae examined in this study. I, Surface preparation; II, Shield; III, Human figure and sword. A, Almadén de la Plata 2; B, Setefilla; C, Mirasiviene; D, Almargen. The RTI files of the Mirasiviene stela can be downloaded here: https://doi.org/10.15128/r2tb09j5674, and those of Almargen here: https://doi.org/10.15128/r2dv13zt222 (The RTIs of Almadén and Setefilla will be delivered upon request).

4. Stelae carving replication experiment

A stelae carving replication experiment was conducted at the farm of Mirasiviene in 2013, when fieldwork to study the stela of Mirasiviene and its find-spot were conducted at the site (Díaz-Guardamino et al., 2019). The experiment had the aim to assess the skill and

time needed to produce a warrior stela by making two decorated stelae comparable in shape and decoration to Late Bronze Age examples using boulders and lithic tools made of stones found at the site and flint brought by us. The experiment was conducted by myself and five first-year undergraduate students from the University of Southampton, Connie Baker, Gina Duffy, Tim Hill, Cordelia Howell and Edward Wallis (Figure 4). I coordinated and recorded the experiment with the help of one student, and we guided the remaining four students on how to perform rock carving since they had no previous experience in stone working.

We selected two stone boulders of mica-schist (rated 4-5 on Moh's hardness scale) found at the farm which afforded relatively levelled surfaces. The survey we conducted at the findspot of the Mirasiviene stela had recovered a series of lithic tools that could have been used in the manufacture of the stela: tools made of allochthonous flint, as well as hammers, grinding stones and ground-edge tools of diabase and quartzite (Diaz-Guardamino et al. 2019: Table 5; Figures 15, 16). Thus, for the replication experiment we collected a series of stones from around the farm to be used as tools: quartzite pebbles, mica-schist and diabase blocks. Quartzite is rated 7 on the Moh's hardness scale, while diabase at 5-6, both rated higher on the Moh's scale of hardness than mica-schist (Table 2). Flint (7 on Moh's scale) is not naturally available in the area but our fieldwork recorded evidence of its use. Thus, we also used flint tools to conduct the experiment, in this case made from large flint flakes brought from the lithic tool manufacture workshop of the University of Southampton (Figures 5 and 6).

Figure 4. Process of surface preparation at different stages.

Our current knowledge indicates that the decoration of warrior stelae was usually performed on flat and/or smooth surfaces. These 'canvases' could be naturally provided by the stone boulder selected (e.g. large 'pebbles' from the Guadiana basin such as the stelae of Capilla 6 and 7) but more often they were obtained through careful work of shaping the slab, and levelling and smoothing the surface to be carved (the cases examined here, Figure 2). For the experiment we started by selecting a naturally levelled surface on each boulder to minimize the effort of surface preparation and by performing surface abrasion by rubbing it with a variety of large stones (also aided by water to ease the friction) (Figure 4). On the surface of one boulder a series of fine parallel grooves, similar to those documented

on the stela of Mirasiviene, were created. On the other boulder a very smooth surface was produced. This different result was created by the different structure of each boulder as surfacing mica layers appeared at different angles. Additionally, some levelling by splitting and chiselling was required to complete the smoothing of the surface.

Afterwards, the outlines of the motifs to be engraved were drawn with smooth incisions by using the sharp edges of various tools (Figure 5). The motifs and their positioning on the rock canvas were copied from a very basic design drafted by the author inspired by warrior stelae iconography. The designs were then carved using a variety of techniques known to be common in the manufacture of warrior stelae (see Section 4): indirect and direct percussion, incision and groove abrasion. Larger stones (mainly of dolerite and quartzite) were used as hammers, whereas smaller tools, including of quartzite, were used for pecking and punching, as well as flint for pecking, chiselling and incision. Overall, flint and quartzite were the most effective rocks for carving motifs on mica-schist.

Two of the main challenges encountered in the process of rock carving were surface hardness and, on one of the boulders, uneven surface structure. As mentioned earlier, none of the student-carvers had previous experience in rock carving, so they were all learning by doing. In the process it became clear that knowledge of the surface structure of the specific boulder at hand, in particular the identification and exploitation of its vulnerabilities, was key to be able to carve motifs successfully.

After four hours of work the students were able to produce two semi-complete decorated surfaces (Figure 6) which are comparable to those found on some warrior stelae from the middle Guadiana basin, where numerous simpler – and more roughly made – versions of 'type A' stelae are known (e.g. Orellana or Capilla 4).

This experiment provided many relevant insights on rock art making that are in agreement with what had been revealed previously by some key replication experiments. Prominent among this is the fact that direct pecking does provide equal control and requires less time than indirect pecking (Whittaker et al., 2000: 165-66), inviting us to reconsider the traditional pre-eminence given by researchers to the latter (e.g. Gutiérrez et al., 2020). But, above all, this experiment revealed that petroglyph making does not require a huge effort, neither 'exoteric technical skills, and rarely if ever cost much in terms of either labour or resources' (Whittaker et al., 2000: 166; see also García Sanjuán et al., 2006: 143-44). See also the experimental replication of a warrior stela conducted recently by Gutiérrez Sáez and colleagues (2020). Even if they worked with metallic tools on a slab of slate, which is relatively easy to work (certainly easier than mica-schist) and already offered a flat and smooth surface, saving the levelling work that in our experiment took quite a lot of time, they managed to carve a complete set of seven motifs in 4 hours.

One of the most valuable outcomes of our experiment is that it exposed the social dimension of rock art making in a very clear fashion. Rock carving is a social process in which both people and stones (boulders, tools) are actively involved. Throughout the experiment it became clear that the techniques employed to shape and carve, and the morphology and quality of the resulting decoration were highly dependent on the interaction between the skill of the engraver, the types of rocks being carved and used as tools and, also, the surface properties of the specific boulder. The interaction between these elements, including the choices met by carvers – who were learning through their interaction with the rocks, other carvers, and myself –, produced variable results (Figure 6). Consequently, analysing rock art technology needs to pay special attention, not only to the type of stone and its hardness or the marks produced by carvers in the process of stone working, but also to the broader community of actors involved in the process, such as the surface texture of the stone and the broader community of carving practitioners.

Figure 5. Sketching and carving motifs.

Figure 6. Decoration on two boulders produced through the replication experiment.

5. Making stelae in Late Bronze Age Iberia

The combination of the results of the surface texture analysis of a series of warrior stelae (i.e. four cases from southern Iberia) by means of RTI, with those provided by a stelae carving replication experiment provides interesting insights into the techniques employed to produce these stelae and the social dimension of their manufacture.

The stelae carving replication experiment revealed that the techniques employed to manufacture stelae and the morphology and quality of the outcome were conditioned by the interaction between the skill of the engraver, the types of rocks being carved and used as tools and the properties of the surface of the specific boulder being worked. The interaction between these elements, including the choices met by carvers, who were learning by doing through their interaction with the rocks and other carvers, produced variable results (Figure 6). Even though the students involved in this experiment had no previous experience in rock carving, they were able to produce, in four hours, two partially decorated surfaces that are comparable to those held by some of the simpler warrior stelae known in the middle Guadiana region. In short, the experiment revealed that stelae manufacture did not necessarily require a huge effort, neither specialised technical knowledge.

The results of the replication experiment were supported by the detailed examination of the surface texture of four stelae by means of RTI. Different techniques were used to carve distinct motifs on the same stela as well as to carve similar motif-categories on different stelae. As the replication experiment revealed, the technological – and to a certain extent morphological – variability documented on Late Bronze Age warrior stelae can be linked to the hardness of the stone, the structure of the surface of the specific boulder and the skill of the carver. The warrior stelae examined in this paper share a series of iconographic conventions (motif-categories present, their combination and position on the stone canvas) whose dissemination needs to be related with long distance connectivity (Díaz-Guardamino et al. 2020; another relevant formal convention is the presence of a 'canvas', that is, a flat, smooth surface on which to carve the decoration). However, they were manufactured with different sets of techniques and variable degrees of skill, suggesting that stelae-making was an activity carried out by non-specialists, local, and possibly occasional, carvers belonging to restricted communities of practice (but that were, nonetheless, connected to long distance networks).

The study presented in this paper shows that the combination of digital imaging technologies for the study of manufacture marks on Late Bronze Age stelae with the conduction of replication experiments can be a fruitful strategy to advance our knowledge on the social dimension of warrior stelae. More replication experiments need to be performed, with different types of stones, and more systematic analyses of the surface texture of warrior stelae by means of digital imaging methods need to be carried out to inform those experimental projects. The work published by García-Arilla and colleagues (2021), for example, offers insights about the manufacture of the Luna (or Valpalmas) stela that would be interesting to materialize through a replication experiment. Also, we will publish very soon key results of the RTI analysis conducted within the RAW project, data that will be useful for the design of future replication experiments with other lithologies. Added to digital recording and experimental work, I would like to highlight the importance of fieldwork conducted on stelae find-spots. The insights gained from the lithic tools collected at the site of Mirasiviene were really valuable, as they prompted us to reconsider the role of stone tools in Late Bronze Age sculptural and rock art work, possibly complemented by metallic tools in some regions with other lithologies, such as granite, a topic Araque and his team are exploring. In short, developing such a bottom-up approach combining these three lines of evidence (digital, experimental, fieldwork) with targeted case studies in specific regions has the potential to expose the full complexity of warrior stelae, a multidimensional tradition that materialized the many ways in which Late Bronze Age communities in Western Iberia interacted with each other and with their worlds.

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