1. Introduction
This paper presents the latest research concerning hand-driven rotary querns (handmills) and their quarries in the south of Spain from the Iron Age to Contemporary times. Iron Age quern makers show a proclivity for naturally abrasive porous limestone hewn from surface blocks and, possibly, quarries. After the Roman conquest, querns were produced and distributed on a large scale from extractive quarries producing a standardised product. Roman production districts have been identified in this study in the Volcanic Province of southeastern Spain (Cabo de Gata and Murcia) and the Calatrava Volcanic Province (Ciudad Real) in central Spain. By contrast, bioclastic calcarenite querns are dominant in the coastal settlements of the Gulf of Cádiz where at least two coastal quarries have been identified. Granite quern production in the Ossa-Morena and neighbouring zones, although one of the dominant rock types in southwestern Spain, is poorly documented and no quarries are known. Quern production in the long period encompassing Late Antiquity and the Middle Ages has not been studied in depth but there are indications of change in both quern typology and rock choice, with a preference for sedimentary materials (conglomerates, sandstones and coarse limestones). In Contemporary times, larger rotary querns were used for grinding animal fodder. This last quern production shows a distinct preference for compact white and pink limestones, rocks that require complex dressing patterns to grind properly.

Keywords: quern, millstone, quarry, volcanic rock, typology, production, distribution, lamproite, granite, Spain
Furthermore, handmills are also known in Roman metal-working contexts (García 2002:620–621, Gutiérrez & Corpas 2011:25–26). The hand-powered mechanisms, up to about 50 cm in diameter, are not to be confused with other, larger mills driven by man, beast, water or wind. Although Iron Age and Roman querns share typological attributes with their larger counterparts, they differ in that they could be driven by a single person from a stationary position, probably sitting on the floor, with one leg outstretched and the other bent, as attested ethnographically. The larger ring-mills, usually well over 50 cm in diameter, like their cousin the Pompeian “donkey” mill, were driven or pushed from a standing position and thus were most often perched on podiums requiring a peripheral ambulatory space.

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de la Plata (Seville), Rota (Cadiz), Montessa (Valencia) and Puerto Cadena (Murcia) are indicated in hiking or cultural itineraries on the internet. Sisapo and Las Herrerías (Ciudad Real) were spotted during field surveys based on a combination of geological resources and intuition. Personal communications from archaeologists, historians, geologists and amateurs account for the identification of Cerro de Limones and Hoya del Paraíso (Almería), Loja and Motril (Granada) and Trafalgar (Cádiz). Knowledge of Ibi (Alicante) and Sierra de la Cabrera (Albacete) derive from brief mentions in molinological and archaeological reports (Jordan et al. 1984, Marquiegui 2012), whereas Los Molares (Huelva) and Mazarrón (Murcia) were listed in provincial archaeological inventories. Finally, quern production at Moclín (Granada) and Castillo de Locubín (Jaén) was discovered thanks to accounts of 19th century millstone production by the geographer Pascual Madoz (1845–1850).

2. Chronological framework

Nearly all the rotary querns in this study area are surface finds devoid of secure stratigraphical context. Quern quarries themselves are often intensely weathered, and without benefitting from an archaeological excavation, also remain mute as to their age. We therefore, regrettably, can only place the querns and quarries into broad chronological niches.

Iron Age rotary querns referred to in this text correspond roughly to the last centuries before the 2nd century BC. This is followed by the Roman period until about the 4th–5th century AD. The transition
from Late Antiquity to the Early Middle Ages, marked by the Germanic dominion, is hazy and it is possible that some of the querns attributed to the Roman period are in fact more recent. Major social changes taking place with the outset of the Islamic domination dating to 711 is only broadly reflected in quern typology and production. The expulsion of the last Islamic ruler of Granada in 1492 marks the beginning of the Modern Era, which lasts until 1789, with the outbreak of the French Revolution being the outset of the Contemporary period.

3. A sketch of the geology of the southern half of the Iberian Peninsula

The following description of the geology of the southern part of the Iberian Peninsula, originally published in the proceedings of the conference on millstones in Rome (Anderson & Scarrow 2011), is modified and extended from the introductory chapter of La Geología de España (Vera 2004).

The geology of the Iberian Peninsula is dominated by the high central Iberian Massif. After considerable debate, this Massif, which covers most of the western half of the Peninsula, was divided into six main zones (Fig. 2). Broadly from north to south these zones are as follows: Cantabrian, West Asturian-Leonese, Galicia Tras-Os-Montes, Central Iberian, Ossa-Morena and South Portuguese. The central region has an average elevation of 660 m.a.s.l. and is bordered to the north by the basin of the Duero River, to the northeast by the Ebro River and, to the south by the Guadalquivir Valley. Lying beyond these hydrographic confines are the Cantabrian Cordillera in the north, the Pyrenees in the east and the Bétic Range in the south.

This study of millstone quarries basically concerns the region to the south of the River Tagus that flows east to west, cutting the Iberian Massif into two roughly equal parts. Thus, rocks exploited for the millstone production considered here include: the Precambrian to predominantly Palaeozoic granite-gneiss-schist igneous and metamorphic crystalline rocks of the three most southerly zones of the Iberian Massif (Central Iberian, Ossa-Morena, and South Portugal); the Mesozoic-to-Cenozoic limestone-sandstone-conglomerate sedimentary rocks of the southerly basins and the Bétic Range; and the Cenozoic volcanic rocks from recent magmatic activity.

The Central Iberian Zone of the Iberian Massif, encompassing large areas of Extremadura, Castilla-La Mancha and Madrid (Fig. 2 D), comprises Proterozoic and early Palaeozoic metasediments and orthogneissies, extensive Lower Ordovician Armorican quartzites and widespread Carboniferous granitoids. This zone is divided into two domains mainly on the basis of the rocks underlying the quartzite. In the north, the Ollo de Sapo domain has pre-Ordovician rocks, including potash feldspar-augen orthogneissies, high-grade regional metamorphic rocks and Variscan syn-tectonic granites (Fig. 2 D1). In the south, the Greywacke-Schist Complex domain has pre-Ordovician rocks including low-grade schists and metagreywackes, and syn- and post-orogenic granitoids (Fig. 2 D2).

The Ossa-Morena Zone occupying parts of the provinces of Huelva and Seville (Fig. 2 E), is made up of Upper Proterozoic to Carboniferous rocks. Basic igneous rocks crop out at the northern contact with the Central Iberian Zone and the southern contact with the South Portuguese Zone. The main lithologies in this region are low-grade metamorphic rocks and granitoids of varying ages, including Vendian, Cambrian and Carboniferous syn- and post-orogenic intrusions.

The South Portuguese Zone (Fig. 2 F), the southermost division of the Iberian Massif (in the Huelva province), is composed of Devonian to Carboniferous volcanosedimentary, igneous and low-grade metamorphic rocks that, in places, are overlain by Permian sediments. The Bétic range in the south and southeast of the Iberian Peninsula, from Huelva all the way to Alicante, forms the most westerly sector of the Alpine orogen that borders the northern and southern margins of the Mediterranean. The Bétic cordillera is divided into two main zones, which were two separate microplates through the Mesozoic and Cenozoic: the External Zone (South Iberian paleomargin) and the Internal Zone (Alborán Domain fragment of the Mesomediterranean plate). The External Zone, to the north (Fig. 2 G), comprises Triassic to Miocene continental margin sedimentary rocks. This zone is further subdivided into the relatively undeformed, northerly Prebético shallow marine sediments, and the more strongly deformed southerly Subbético lower Jurassic pelagic sediments and submarine volcanic rocks. The Internal Zone, to the south (Fig. 2 H), is made up of a stack of tectonic units, from base to top: the Nevada-Filabride Complex, the Alpujárride Complex, and the Maláguide Complex. In contrast to the External Zone, the pre-Mesozoic basement of this
region was displaced together with the Triassic to lower Miocene cover rocks. The basement part of the two lower units preserves traces of pre-Alpine deformation, magmatism and metamorphism, which, in the Alpujárride Complex, includes continental crust and subcontinental upper mantle. Both the basement and cover of all three units were affected by complex Alpine metamorphism. Throughout the Mesozoic until the mid-Paleogene, turbidites were deposited in a narrow ocean basin that existed between the External Iberian plate and the Internal zone Mesomediterranean plate. These marine sediments are preserved in the Campo de Gibraltar Complex.

Cenozoic volcanic rocks crop out in four regions throughout the Peninsula: Gerona, Gulf of Valencia, Calatrava, and Almeria-Murcia. The last two are of interest in the current work and include the oldest volcanism, Aquitanian, in the Cabo de Gata (Almería) Volcanic Province of southeast Spain, and some of the youngest, Holocene, in the Calatrava Volcanic Province. The Calatrava rocks are basic alkaline and carbonatites. In the Almería-Murcia region, the igneous rocks are more varied, including calc-alkaline to alkaline compositions.

4. Rotary querns and quarries through the ages

4a. Iron Age

Among the hundreds of rotary querns in museum depositories throughout southern Spain, less than half a dozen can be ascribed with a high degree of certainty to the Iberian Culture Iron Age (Fig. 3.1). All are devoid of stratigraphical context and are classified as Pre-Roman by comparison with querns from Iron Age settlements elsewhere, notably in the northeast of the peninsula. Even less is known about quern quarries of this period.

The first quern studied is a fragment of an upper stone from the Iberian settlement of Bastí at Cerro Cepedo, Baza (Granada). It is small, about 37 cm in diameter, bears a hemispherical section, has a concave grinding surface and is asymmetrical (tapering from 12 to 10 cm in thickness), probably due to wear. Its driving cuttings are not preserved. The second and third examples, maybe a pair, are from a private collection in Ventorros de San José. Both stones measure between 30 and 32 cm in diameter. Given that they are cemented into a wall as decoration, their lower surfaces cannot be observed. Nonetheless, the upper stone has a hemispherical profile with a large circular eye and its driving mechanism consists of opposite “inverted keyhole” cuttings for handle fittings. In the museum of Jódar (Jaén), there is an upper stone fragment from Cerro Castillejo with similar handle cuttings. The rock in this case appears to be a conglomerate. A third upper stone (ca. 35 cm diameter) from La Ribera Alta, displayed in the Museum of Alcalá la Real (Jaén), also has an asymmetrical section and is equipped with lateral lugs with vertical slits destined to lodge driving and rynd fittings.

Based on studies of Iron Age querns elsewhere in Spain (Burés et al. 1993:134, Fig. 14, Checa et al. 1999:64–65, Asensio et al. 2001:68, Plate 6, Guérin et al. 2003, Portillo 2006, Alonso et al. 2011), certain typological tendencies emerge. To begin with, pre-Roman querns are significantly smaller than their Roman counterparts. Other unique features include opposite slits and “inverted keyhole” cuttings carved into the upper stone’s edge to lodge the fittings for assembling and driving the mill. This type of cutting, present on the Ventorros de San Juan stone, is frequent among the querns exposed at Numancia (Soria) and is present at the Catalan sites (e.g. Burés et al. 1993:134, Fig. 14, Asensio et al. 2001:68, Plate 6, M-7 and M-17). Similar cuttings are also known on larger, better-dated, Iberian Iron Age push-mills at several sites in southern Spain (e.g. Cerro de la Cruz, Loja, Priego de Córdoba and Alcalá la Real) and on a unique find from the ancient city of Lacipo (Casares, Málaga) stored in the Museum of Málaga (inv. A/CE 2585, Puertas 1982:88, Fig. 50). It is a volcanic biconical upper stone, a variant of the Morgantina type and precursor of the Pompeian mill, clearly an import dating to the 3rd or 2nd century BC (J. Suárez, pers. comm.). What interests us is that one of its original “ribbon” handles (a feature unknown in this region), after breaking, was repaired with “inverted keyhole” cuttings following local Iron Age tradition (Anderson et al. in press). Opposite ear-like lugs (fashioned directly from the rock) are also typical of the Iron Age querns. These features, also bearing cuttings to assemble and drive the mill, however, are not a conclusive criterion for dating because they are present, although not common, on some Roman models.

It is probable that Iberian (and even later Roman) quern makers in the south of Spain collected and fashioned rounded surface boulders. This could be the case of the upper stone in the museum of Jódar (Jaén). However, most Iron Age querns in our study area are
Fig. 3. Schematic representation of the major rotary quern types in southern Spain from the Iron Age to Contemporary times. In general, over time, querns progressively increase in diameter while grinding surface angles decrease, eventually becoming horizontal. Handle cuttings change from a lateral slot to a single circular hole on the upper surface and rynd fittings shift from the top to the bottom. Drawing: Timothy J. Anderson.
hewn from a highly porous, naturally abrasive, cream-coloured rock, which we loosely call travertine (*toba calcarea*), known throughout the Bétic Cordillera (Baena & Díaz 1995). There are, for example, units to the south and the west of Ventorros de San José (Lupiani & Soria 1985: Geological map, IGME, 1008), possibly the source of the Ventorros querns. The source of the La Ribera Alta quern is probably local because the reputed Iberian Culture settlement site sits on or beside a unit of limestone tufa or travertine (Geological map IGME, 991). It could also, like the series of larger 2nd century BC Iberian ring-mills at the settlement of Cerro de la Cruz (Córdoba, Quesada et al. 2010), come from an outcrop on the outskirts of Almedinilla (Geological map IGME, 889) about 15 km away. The source of the Baza stone is also uncertain. It may come from a large outcrop about 10 km to the north of Baza near the Baños de Zujar (Geological map IGME, 972).

The propensity of Iberian mill makers for the relatively soft travertine type rocks makes it likely that some come from true extractive quarries. These early mill makers certainly had the technical mastery to carve directly from bedrock, as seen not only through the sculptures of goddesses, warriors, horsemen and mythological beasts, but also through the use of rectangular building blocks for sanctuaries, funerary and other monumental constructions. Hence, we cannot disregard the possibility that some Iron Age querns were scored from bedrock, leaving behind quarries with circular extraction hollows. Nevertheless, if these quarries existed, they were certainly more modest than their Roman counterparts and had not yet manufactured a standardised product or developed a sophisticated network of quern trade.

**4b. Roman period**

From the standpoint of rotary querns and quarries, the Roman period is by far the best documented in southern Spain (Fig. 3.2). The number of querns attributed to this period greatly outweighs that of all other periods together. The higher proportion of Roman querns can be attributed, in part, to the focus of archaeological fieldwork on this period, and, in comparison to the preceding Iberian Culture, is also certainly related to an ever-burgeoning population.

Rotary querns are typical finds at excavations of rural settlements. In towns and cities they are found in conjunction with other more complex, industrial milling equipment, such as the ring-mill destined, it seems, for both grains and oil production. Pompeian donkey mills and watermills do not appear to have been widely adopted in Spain (Anderson et al. 2011, Anderson et al. in press). Although most often associated with domestic activities, querns are also well known to have formed part of the equipment of armies on the move in Roman times. However, no examples incised with military inscriptions are known in our study area.

The most frequent type of *catillus* (runner) in southern Spain is a cylindrical upper stone bordered by a rim and combining radial slots, with a large circular eye and receptacles for grains (Fig. 3.2 A). For the assemblage and driving, one of the slots or cuttings extends from the eye to the inner edge of the rim, whereas the other extends from the eye to the outer edge of the quern. These slots are meant to lodge an iron crosspiece (never preserved) about 45–50 cm long and about 3 cm wide that projects to one side beyond the outer edges to serve as a base for a vertical handle. Two querns in our study area show that molten lead was poured around the crosspiece to bond it with the stone (Palomo & Fernández 2007:357, Fig. 8, Linares museum, inv. no. CE02430) (Fig. 4). The central hole in the crosspiece lodges the spindle of the lower stone and assures the fit of the two mill halves. To each side of the slots, in a mirror effect, are two semi-circular shallow hollows that, from above, resemble the wings of a bat. These receptacles are like hoppers for the grains. On account of their slight inclination toward the centre, and through vibration and gravity, the grains progressively fed into the eye to be ground.

Other upper stone types are less frequent. A second type is driven by means of one (or rarely two) lateral lugs bearing a vertical socket to lodge the handle (Fig. 3.2 B). The lug, usually rounded, is carved directly from the rock. This handle system is independent from the rynd crosspiece, probably of iron, lodged in two small cuttings to each side of the eye on the upper surface.

A third type, even less frequent, is characterised by a horizontal handle socket or hole cut into the side of the upper stone for a piece of wood that was the base of a vertical handle (Fig. 3.2 C). The handle socket is most often circular but is also known to be rectangular and can be independent of the opposite rynd cuttings on the upper surface. This is probably the most common type of handle fitting elsewhere in Europe in Roman times but apparently was not adopted in southern Spain.

A fourth type, also not widespread, has a vertical handle socket cut into the upper surface. This is the most simple of handle fittings and dates, presumably, to the transition from Late Antiquity to the Early medieval period (Fig. 3.2 D). It is unclear whether the
rynd slots are on the top or the bottom of the upper stone. In any case, the placement of the handle hole on the upper surface became widespread in the medieval period and has endured until recent times.

Lower stones, in general, show few typological features and hence are more difficult to date when devoid of context. The upper stone cited above with the radial handle and rynd cuttings is associated with two types of lower stones (metae). The first consists of the “normal” conical lower stones with or without a small lip around the eye (resulting from wear), a type that is known all over the Roman world. A second type presents a unique feature, a prominent collar around the eye (Fig. 5). This collar is a premeditated feature carved at the quarry and not a result of wear. It is found in abundance at Cerro de Limones (Anderson et al. 2011) where dozens of abandoned blanks and fragments resemble “sombreros”. This type is also present at a second quarry in the Cabo de Gata area, Hoya de Paraíso, a rhyodacite exploitation, and also further north, in the Mazarrón (Murcia) area. Although analogous collars are known on upper stones elsewhere in Europe, notably in the rhyolite productions of the Esterel in southern France (to facilitate feeding the grains), this morphological feature seems to be unique to lower stones in southeastern Spain and for this reason is labelled the “sombrero” type.

Roman rotary quern quarries in the volcanic province of southeast Spain

a) Cerro de Limones dacite quarry: The reddish, vesicular dacite exploitation on top of the Cerro de Limones (Cabo de Gata, Almería), with its hundreds of abandoned half-made and broken querns, is, to date, the most significant Roman quern quarry found in southern Spain. The site was recently published with petrographical analyses (Anderson et al. 2011) and will not be dealt with in detail here.

b) Hoya del Paraíso rhyodacite quarry: Since the Cerro de Limones publication, this second quern quarry has been identified at Hoya del Paraíso, 4 km to the southeast of the first, between the Caldera of the Majada Redonda, one of the more visible volcanic craters of the district, and the Isleta del Moro, a small fishing village on the Mediterranean coast. In contrast to the mountaintop Cerro de Limones, this site is not centralised in a single area, but instead spreads over a vast surface, comprising both the valley floor and the slope of the hill to the east leading to the Majada Redonda Caldera. It also contrasts with the Cerro de Limones in that there is no evidence of extraction pits. The querns appear to have simply been knapped from material collected on the surface among the talus or possibly pried from columnar jointing further up the hill to the east. Although there are abandoned querns

![Fig. 4. Examples of upper stones of the Roman period with radial handle-rynd slots and receptacles. Top) handmill with reconstructed crosspiece fastened with molten lead (surface find, Cástulo, Museo Arqueológico de Linares, inv. no. CE02430, photo by museum). Bottom) upper stone (unknown context, Museo Histórico Municipal de Priego de Córdoba). Rock types: volcanic. Photo: Timothy J. Anderson.](image)

![Fig. 5. Examples of unfinished Roman lower stones (“sombrero” type). Top) rhyolite roughout at the quarry of Hoya del Paraíso (Almería). Bottom) broken lamproite roughout (Los Ceniceros, Mazarrón, Museo Arqueológico de Murcia). Photo: Timothy J. Anderson.](image)
along the slope, most are at the valley bottom or now recycled in retaining walls for agricultural fields (Fig. 6). This valley bottom area was probably a large workshop where blocks were assembled for knapping. Like Cerro de Limones, the site has been picked over by collectors who have removed the better preserved querns. So the appearance of the site today is certainly very different than that 2000 years back. Querns produced here are identical to those of Cerro de Limones with their “sombrero” lower stone. There is no evidence of the manufacture of any other type of mill (ring-mills for example). In terms of quantity, production was probably in the upper hundreds, possibly more. The valley, however, is very large and has not been systematically explored. Further fieldwork will certainly bring to light more data about extraction techniques and the organisation of the quarry. Although not yet the object of formal analyses, the rock appears to be rhyodacite.

c) Lamproite quarries: The lamproite exploitations in the northern sector of the southeast Volcanic Province are the latest additions to the inventory of Roman volcanic quern quarries in Spain. This district is not recognised by fieldwork, but by petrographic study of thin sections from a series of discarded and broken quern roughouts stored in the Archaeological Museum of Murcia, which are surface finds from a Roman settlement near the Port of Mazarrón (Murcia) (Fig. 7).

Although the external aspect and typology of these lamproite roughouts from Mazarrón are similar to the Cabo de Gata production (100 km to the south), lamproites do not crop out at Cabo de Gata and therefore the querns must hail from one or more of the dozen lamproite outcrops extending from Vera, in the north of Almería, through Murcia (e.g. Mazarrón, Barqueros, Zeneta and Fortuna) and into the neighbouring Province of Albacete (Castilla La Mancha) near Jumilla (Cambeses 2011, Cambeses & Scarrow 2012, Cambeses & Scarrow in press). Also worth noting, based on a variety of mill types in the Murcia museum collection, is that lamproite was exploited not only for rotary querns, but also for the larger animal- or man-driven ring-mills. These querns are both reddish and grey-black. In the case of upper stones, we also find both radial slot cuttings and handle lugs, while lower stones have either high collars or no collars. This typological variation, as well as the different external colours, suggests more than one outcrop was quarried.

One such probable site is the Cabezo de Oliva near Mazarrón, an outcrop 3 km to the north of the Roman settlement where the half-made and broken querns were discovered. Unfortunately, according to S. Agüera, the author of the find, reforestation work at the Cabezo de Oliva has probably destroyed any remnants of the ancient quarry. A second potential lamproite quern quarry is Cancarix, a volcanic dome in the Sierra de las Cabras (Albacete), 12 km to the southeast of Hellín (near the Murcia border). In a study of the
Roman occupation of the nearby Minatda-Agramón Valley (Jordan et al. 1984:222–223, 227) state that the rotary querns (unfortunately neither described nor illustrated) from two of the regional Roman villae (La Horca, Tolmo) were extracted at the Cancarix outcrop. Although there is no direct published evidence of quern production (aborted roughouts, knapping debris), it is perfectly plausible that querns were scored from either the prominent polygonal columnar jointing or hewn from naturally detached blocks collected at the base of the columns.

**Roman rotary quern quarries in the Calatrava Volcanic Province (central Spain)**

*a) Sisapo olivine melilitite quarry:* The site of Castillejo de la Bienvenida, 500 m from the Roman city of Sisapo, like that of Cerro de Limones, was published recently (Anderson et al. 2011). The site comprises three small contiguous volcanic cones located in the vast plain between the mountain ranges of the Sierra de la Solana de Alcudia and the Sierra de la Umbría de la Alcudia. These domes represent the southwestern-most eruptive manifestation of the vast Calatrava Volcanic Province (approximately 5000 km², Ciudad Real, Castilla La Mancha). It is worth noting that the Sisapo quarry is a true extractive exploitation with circular hollows carved directly into the grey-black, vesicular rock. There is no evidence of working the rock masses formed by columnar jointing. Both querns, larger millstones (ring-mills) and rectangular (ashlar) extractions, are visible. As a result of the absence of roughouts (most certainly pillaged or in a depository), the quern type cannot be determined. While the presence of upper stones with radial cuttings in depositories in the north of Andalusia suggests an upper stone production similar to that of the southeastern volcanic fields of Cabo de Gata and Murcia, there is no evidence of the manufacture of the “sombrero” type of lower stone.

*b) Las Herrerías alkaline volcanic rock quarry:* This site is on the southeastern outskirts of the city of Bolaños de Calatrava and is currently a vast exploitation for construction material. Evidence of millstone and quern production comes from ten black, highly vesicular roughouts set aside by workers of the modern quarry and identified by one of the authors (A. Cambeses) (Fig. 8). Of these ten, only one corresponds, according to its dimensions, to a rotary quern lower stone (the others are ring-mills). Lamentably, since all of these finds are whole or nearly whole, other smaller fragments were probably obliterated by the modern machinery. The loss of context also prevents knowledge of extraction techniques as well as other data related to the spatial organisation of the quarry. According to the geological map, the rock is either an olivine nephelinite or olivine melilitite (Geological map, IGME 785).

*c) Cerro Columba olivine basalt quarry:* The collection of dark basalt rotary quern roughouts at the site of Oreto y Zuqueca (Granátula de Calatrava), on the outskirts of the ancient city of Oretum by the Jabalón River, suggests the presence of a nearby quarry. The nearest volcanic edifice is 4 km to the west at Cerro Columbua. A number of these querns could have been hewn from surface material, still scattered about the fields from the volcanic explosion. The northward lava flow that deviated the course of the Jabalón River is considered the source of construction material for neighbouring Roman Oretum (M. Donoso Gómez, pers. comm.) and a potential source of querns (Anderson et al. 2011). This cannot be verified because the potential quarry, along with a nearby Roman bridge (erected with volcanic rock), are now under the waters of the Jabalón dam reservoir (Escobar et al. 2010:106).

**Roman conglomerate and bioclastic calcarenite facies rotary quern quarries (southwestern Spain)**

*a) The Trafalgar shell-rich conglomerate quarry:* This quern and millstone quarry, on the coast of the Bay of Trafalgar, has been reported in recent articles (Anderson 2011:231–232, Anderson & Scarrow 2011:267–268). Rotary quern production is limited to the eastern sector where several hundred querns were extracted directly from the bedrock. As a result of the constant erosion by wind and water, the hollows are extremely weathered and reveal no tool marks. There are also no remains of working debris. The cylinders
extracted from the eastern sector correspond to querns measuring about 40 cm in diameter. The only morphological element we can deduce, from the size of the hollows, is that querns extracted here probably did not include handle lugs.

b) The Rota ostionera facies bioclastic calcarenite quarry: This quern and millstone quarry on the coast of downtown Rota is not concentrated in a single sector, but instead spread out between the “Playa de la Costilla” and the “Playa del Rompidillo”. The construction of the new port between these two beaches probably destroyed part of the quarry. The extractions, only visible at very low tide, are also extremely weathered and the precise typology of the querns cannot be determined (Fig. 9).

In addition to the sites mentioned above, there are a number of other quarries along the Bay of Cádiz that exploited the shell-rich, biocalcarenite for millstones and building material (e.g. Isla de Tarifa and Chipiona). In addition, Punta Camarinal (Tarifa) stands out as the source for much of the construction material in the nearby Roman city of Baelo Claudia, including cylindrical drums for columns – an artefact that shares an identical extraction technique with the rotary querns. Although there is no direct evidence of quern extraction at Punta Camarinal, it is difficult to imagine that it did not produce querns.

Fig. 9. The Roman bioclastic calcarenite quern quarry of Rota (Cádiz). Photo: Prudente Arjona.

**Roman quern quarries in the granitoids of southwestern Spain**

Granitoid rotary quern quarry sites are practically unknown in our study area. This contrasts with the high number of modern granite millstone and oil roller exploitations identified throughout the Central Iberian and Ossa- Morena geological zones in the southwest of the peninsula. These include, among many others, Aroche and Aracena (Huelva), Quintana de Serena, Gerena, Jerez de los Caballeros (Badajoz) Plasencia, Villar de Plasencia, Guijo de Galisteo, Logrosán (Cáceres) and Colmenar Viejo (Madrid). Small extractions are reported at Los Molares (Almonaster la Real, Huelva) in the Andalusian inventory of historical sites (Patrimonio Inmueble de Andalucia, Huelva, Denominación: Molares, Código: 01210040006). The site's name “Los Molares” is the place-name par excellence of millstone quarries and certainly alludes to the modern phase of millstone exploitation. Smaller extractions cited in the inventory remain unconfirmed, however.

From the large number of querns and millstones in the depository of the Museo Nacional de Arte Romano in Mérida it is obvious that granite was the most important local and regional source. In fact, a large part of the stone used to build the Roman city of Mérida was hewn from nearby granite quarries, such as the site by the Proserpina Dam, about 6 km away. A similar situation is that of Gerena (Seville), where granite quarries probably supplied the nearby Roman city of Italica (Seville); despite this, quern extraction at these sites is not confirmed.

To consider the spread of Roman granite querns, we have to refer to the archaeological record. A group of querns is reported at Medillín, to the east of Mérida (Haba 1998:412), two from Quintana la Serena (Badajoz, Léon & Carmona 2006:47) and two from Marmorejo (Jaén; Andalusian Heritage Inventory). There are also granite querns in the Municipal Museums of Gerena (Seville) and the Municipal Museum of Villanueva de Córdoba possesses several biotite granite examples produced, according to its director S. Gutiérrez, from local quarries in the Pedroches district.

The exploitation of granite for rotary querns in Roman times, although at present impossible to quantify, was probably massive due to the widespread availability of the rock in the form of extended outcrops and surface boulders. It is plausible that the larger, more extensive exploitations would have been destroyed by successive extractive work. The secondary, more discrete sites would leave little or no material traces.

**Other possible Roman rotary quern sources**

Rotary querns were also scored from rocks of other lithologies, notably sedimentary rocks in Roman times. This production, however, is only a small proportion of the finds in the collections of southern Spain and little is known about their production.
The tradition of carving cream-coloured porous calcareous limestone (travertine), described above in the Iron Age, persisted into Roman times as seen by several examples in the Museum of Almedinilla (Córdoba). One upper stone is of a type (radial slots, receptacles) identical to the production of the Cabo de Gata. A second, however, is equipped with totally different handle and rynd fittings. In lieu of radial slots on the upper surface, it has a horizontal lateral handle socket with a rectangular section and two small rynd cuttings on the upper surface along the eye. The first is certainly a local copy of an imported volcanic quern, whereas the second clearly reflects a different, possibly regional, typological tradition.

A second sedimentary rock-type exploited in the area, similar in colour and texture to travertine but much older (Triassic), is a very hard limestone (carniola) exploited in medieval times to produce projectiles for catapults (R. Carmona, pers. comm.). One carniola upper stone quern in the Museum of Priego de Córdoba is identical to the travertine model with the rectangular lateral slot. It is unique in that both its iron rynd, lodged in two small slots around the eye, as well as a small iron fitting for a lateral edge handle, is still attached to the quern by means of poured lead. The source of the carniola querns, as well as larger ring-mills, is probably either local or regional.

This list of “other rocks” includes isolated examples, such as a fragment of an upper stone made from a yellow calcareous sandstone recently brought to light at the Roman villa of El Tesorillo (Illora) (excavation by I. González). The rock is identical to an outcrop outside the town of Zuajara (Granada) exploited since Late Prehistory for saddle querns and in modern times for construction of the local church (Anderson 2011:231).

The inventory of quern quarries in “other rocks” is completed with two white limestone or dolomite exploitations, at Moçlin (Granada) and Ibi (Alicante), that produced querns about 40 cm in diameter. In the case of Moçlin, the few small hollows surrounded by larger extractions are possibly the last remnants of an earlier Roman phase. The dozens of extractions on a steep slope above the Molinos Valley to the north of Ibi could also, from their diameter and depth (40–50 x 20 cm), date to Roman times (A. Marquiegui and J. Lajar, pers. comm). The chronology of these last two sites is, however, far from certain.

The final example is a Roman (or possibly older) lower stone of garnet schist from Baza (Granada), a metamorphic rock common to the region.

4c. Medieval rotary querns and quarries
If headway has been made on the subject of querns and quarries of the Roman period, research on medieval querns and quarries is still in a nascent stage. The number of querns in museum depositories is extremely limited and few are described or illustrated in the literature (Gutiérrez 1996:205–207, Joncheray & Sénac 1995:30–32). Needless to say, the typology of medieval querns is poorly defined and their dating is sketchy.

In spite of their paltry number, medieval querns (Fig. 3.3) differ from Roman querns. The first difference
is their size. Although some are still about 40 cm, the average diameter increases to between 40 and 50 cm. A second major difference is that their general shape becomes discoidal with horizontal grinding faces. Upper stones also are devoid of rims and grain receptacles, and a simple vertical handle hole cut toward the edge of the stone replaces the Roman radial handle cuttings. The diameter of their eye also decreases and rynd cuttings appear to relocate from the top to the base of upper stones.

The progression from the steep grinding surfaces of Roman models to essentially horizontal grinding surfaces suggests that the driving and centring fittings were sufficiently efficient to assure that the grains (or other product) were transported from the centre to the edge of the mill unassisted by gravity. The systematic change of the handle hole from the side to the top might indicate that, to increase torque, the mill was driven with a long vertical rod connected, for example, to the ceiling of the house or with horizontal connecting rods (Comet 1997:80, Fig. 2–3, Jodry 2011:26, Fig. 17). These theoretical fittings, however, do not leave any material trace.

The main characteristic used to identify the half dozen medieval quern quarries identified throughout

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Fig. 11. The medieval quern and millstone quarry of Puerto de la Cadena (Murcia). Large millstones extractions are side by side with small quern extractions. Rock type: conglomerate. Photo: Timothy J. Anderson.

Fig. 12. The medieval quern quarry of Almadén de la Plata (Seville). Rock type: conglomerate. Photo: Timothy J. Anderson.
the study area (Fig. 10) is that of the size of the extraction hollows (diameter and depth). In contrast to most Roman quarries, no aborted querns or roughouts remain on these sites, complicating both chronological and typological studies.

**Medieval conglomerate quarries**
Conglomerate rocks with large rounded clasts appear to take on an important role in the production of medieval rotary querns, a tendency that has also been noted for the larger water millstones (Anderson & Scarrow 2011). Quarries producing small conglomerate rotary querns (ca. 40 cm in diameter) are known from Rambla Honda, Albox (Almería) (Martínez et al. 2011), at Puerto Cadena (Murcia) (Fig. 11), and at Calahonda (Granada). A quern of this rock type is found at Cabezo del Moro (Albanilla, Murcia) and published by Gutiérrez (1996:205–206, Fig. 88.2), whereas a second is in the museum in Almuñécar (Granada), not far from Calahonda.

The recently discovered exploitation at Almadén de la Plata (Seville), in a finer-grained conglomerate, produced a larger quern between 45 and 50 cm in diameter (Fig. 12). Straight chisel marks at the base of cylinders recall the extraction technique identified in a series of Menorca quarries dating to the Islamic domination (9th–13th centuries, Sánchez 2011:201–202). Examples of larger querns from quarries of similar rock type are in depositories of Baza and Almuñécar (Granada) and Vélez Rubio (Almería).

**Medieval coarse sandstone and limestone quarries**
In the Late Roman and Early medieval phases of Baelo Claudia and Iulia Traducta, along the Bay of Cádiz there are reports of the use of *ostionera* querns. The use of this rock in this transitional chronological phase is reinforced by the fact that it endured until modern times, as evidenced by modern quarries for windmills and watermills at Chipiona and Rota (Anderson & Scarrow 2011:268).

Away from the coastal area, coarse sandstone and limestone quarries of medieval aspect are present in the lapidarium of the Alcazaba of Mérida (Extremadura), in the depository of the museum in Murcia, and on display in the museum of the medieval settlement of Siyāsā (Murcia) (Fig. 13). Two quarries in this rock type are known near each other on the border between the municipalities of Loja and Zagra (Granada). The first, at La Merced (Loja), is set in the bed of a ravine and comprises only three hollows corresponding to querns about 50 cm in diameter. We do not know why this coarse bioclastic calcareous limestone (Lupiani & Soria 1985, Geological map, IGME, 1008) extraction site was abandoned; it is particularly curious given that the same stratum 60 m downhill was exploited for several dozen larger millstones in a small subterranean quarry. It appears that the former is an exploitation, the only one identified to date in southern Spain, that can technically fall into the category of a “prospecting” site to test the quality of the stone (Grenne et al. 2008:51).

Less than a kilometre to the west of the La Merced site is the quern quarry at Atalayuela, Zagra (Granada), with hundreds of quern hollows organised on three different bedding planes (Fig. 14). The site produced querns 50 cm in diameter. They were cut out probably by pick and then split by chisels, as seen by thin horizontal marks identical to those of the site of Almadén de la Plata (Seville). The chronological relationship of this quarry with an adjacent rock-cut tomb cemetery is not clear. It is difficult to conceive, nonetheless, that the cemetery, with its consecrated ground, and the quarry, representing a mundane craft, were contemporary and shared the same locality. There is no visible contact between the tomb cuttings and the quern extractions, so a relative chronology cannot be established. The study of the morphology of the funerary chambers suggests a 6th–7th century (Visigothic) date whereas the pottery collected on the surface (no proper excavation has been undertaken) falls in the 10th–11th centuries (Jiménez 2002:226). In the case of the quarry, the size of the extraction hollows suggests a date during the period of Islamic domination.
Another quarry attributed to medieval times is the coarse sandstone exploitation at Montesa (Valencia). A tubular quarry face several metres high is visible on the scarp at the base of the walls of the medieval castle, which is perched on the hill above the present town. One sector of the quarry shows extractions at the foot of the castle, a structure dating to the 14th century. It is reasonable to assume, for reasons of stability of the castle, that the extractions preceded its construction. If this is correct, the quarry would fall in the medieval period.

A final, poorly dated quern blank was found at the Canteras quarry of Castillo Locubin (Jaén). This coarse yellow sandstone quern, measuring 50 cm in diameter, is possibly a remnant of an earlier work at the quarry, where there are numerous large cylindrical extractions for watermills dating from the 19th century.

**Medieval volcanic rock quarries**

One of our main observations concerning medieval querns is the decline and practical disappearance of volcanic rock, a trend also seen in watermills. It is conceivable that some volcanic production around Murcia lasted into Early medieval times, as indicated by a few examples of larger querns in the depositories of Murcia and Baza. If this is the case, these quarries were probably of limited size and extent.

**Medieval granite quarries**

The Museum of Villanueva de Córdoba shelters several granite querns that correspond typologically to medieval querns. Although these artefacts suggest that granite was still exploited for querns beyond Roman times, no quarry site has yet been identified.

**4d. Modern and Contemporary rotary querns and quarries**

To date we have not identified any quern or quarry that can be dated to the short three century span from the fall of the Islamic rule in 1492, to the outset of the Contemporary period, corresponding roughly with the French Revolution. During this period watermills are ubiquitous throughout the landscape and the number of windmills, in areas devoid of running water, was growing. We do not imagine that hand querns played an important role in grinding foodstuffs for...
human consumption. They did, at least in the last two centuries, remain throughout the rural landscape on cortijos in the form of animal fodder mills (molino de cebo) (Fig. 3.4). In Priego de Córdoba, M. Campos has collected a dozen complete examples (both upper and lower stones) for a future ethnographical museum (Fig. 15).

These Contemporary querns are distinguished from their older counterparts by their size (often surpassing 50 cm in diameter). Their driving fittings are standardised with a vertical handle socket carved into the upper surface near the edge, and rynd cuttings on the lower surface that vary from simple opposite rectangular slots to more complex cruciform slots. Lower stones are always totally perforated and are equipped with an iron spindle plugged with wood or plaster. A characteristic they share is the complex dressing patterns (radial or harp-shaped furrows) on the grinding surfaces of both upper and lower stones. These querns differ from crankshaft mills with no handle holes that are driven from below by means of a metal crank and known elsewhere in Spain (e.g. Pascual et al. 2010).

The mills in the Córdoba area were fashioned from hard cream or greyish limestones or dolomites or pink fossiliferous limestones (ammonitico rosso). These rocks have been exploited since Roman times in the area of Cabra and Carcabuey (Córdoba). In recent times a vast millstone ammonitico rosso quarry supplied larger millstones to watermills as far away as the capital of Córdoba (Montero 2008). There is no evidence, however, that this quarry produced the smaller animal fodder querns, the quarries for which must be found elsewhere, possibly around Alcaudete and Luque (Córdoba) (R. Carmona and M. Campos, pers. comm.). The lack of knowledge about these sites might be explained by the possibility that the querns were fashioned from previously detached angular blocks that do not leave circular extraction hollows along the quarry faces.

5. Discussion

Iron Age: Despite of the small number of pre-Roman rotary querns there is a notable preference among Iberian quern makers for porous calcareous rocks, the same type of rock used for the larger push-mills as seen in situ at the site of Cerro de la Cruz, Almedinilla (Córdoba). It is not known whether these querns were hewn from surface boulders or whether there are rock outcrops that mill makers frequented on a regular basis to extract querns. Based on the Iberian Culture’s knowledge of rock sculpting and monumental construction, we would expect that true extractive quarries existed. There is no evidence, however, of a vast and organised Iron Age network of quern production and distribution like that which appeared after the Roman conquest.

Roman Period: Quern production and distribution in southern Spain reached its peak in the Roman period in spite of the introduction of more sophisticated milling mechanisms, in particular the larger versions of the Iberian ring-mill. Other mills, specifically the hydraulic mill and the “donkey” Pompeian mill (Anderson et al. in press), do not appear to make a significant impact in Spain’s milling tradition. From the initial spread of rotary querns throughout southern Spain, it is evident that volcanic rocks dominated a large sector of the market, particularly in the southeast of our study area (Fig. 16). This is not surprising since volcanic rocks are known to have been traded over long distances throughout the Roman world.

The quarries of the Volcanic Province of southeast Spain, such as those in Cabo de Gata (Cerro de Limones and Hoya del Paraiso), obviously supplied the local and regional settlements in the area and would have, on account of their proximity to the coast, benefitted from maritime trade routes, opening up markets up and down (and possibly beyond) the Mediterranean coastline. The lamproite sources near the coast, like Mazarrón (Murcia), would have benefitted not only from sea transport, but, as noted in a brief geological study of millstones from Baza (Molina & Cultrone 2012:39), also from land transport through the Almanzora Valley.
a long-established trade route connecting the coast with the interior from Cartagena (Murcia) through the ancient centres of Guadix and Baza (Granada). If other volcanic outcrops to the northwest of Murcia, such as Cancarix (Albacete), produced querns these would also have benefitted from the long-standing network of inland trade routes.

The quarries of the Calatrava Volcanic Province, in the heart of the Iberian Massif and far from the coast, traded their querns and millstones by means of the routes crisscrossing the centre of the Iberian peninsula. Sisapo and Las Herrerías near Bolaños (Ciudad Real) and possibly the Cerro Columba by Oretum are along or near major ancient thoroughfares. These routes explain the distribution of volcanic querns throughout the Province of Córdoba and as far west as the Roman city of Mérida (Extremadura), where they might have been floated on barges down the Guadiano River. From Roman Corduba, querns and mills could have been ferried along the Guadalquivir River through Seville down to the Atlantic coast at Cádiz. Although this could explain the lava upper stones with the typical radial cuttings and grain receptacles at Carmona (Seville) and Baelo Claudia (Cádiz), we cannot exclude the possibility that these rocks reached these destinations from the Volcanic Province of southeast Spain by other routes. Other volcanic districts in the Mediterranean, notably in North Africa or even that of Olot-Garrotxa in Gerona, Catalonia, are unlikely sources because they are not known to have produced upper stones with radial cuttings like those of Cabo de Gata. Nevertheless, they cannot be completely ruled out as possible sources.

As seen on the distribution map (Fig. 16, volcanic rocks), there is a potential overlap of volcanic querns in the Province of Jaén at Ubéda and Castulo-Linares, situated about halfway between the Calatrava and the southeast Volcanic provinces. Petrographical analyses could certainly clarify whether the querns come from the Calatrava or southeastern volcanic fields.

It is interesting to note that the sphere of distribution of volcanic querns stops abruptly in western Andalusia and Extremadura, and no volcanic rocks are cited in the catalogue (55 mills) of Conimbriga (Portugal) (Borges 1978). Based on the present state of research, the main material exploited for querns both in northwest Andalusia and Extremadura is granite (Fig. 16, granitoids). This is not surprising because granitoid surface blocks and outcrops are ubiquitous in this area. We infer the presence of local or regional granite quarries from the many querns in the depository of the museum in Mérida. We also suspect granite exploitations in the Pedroches district around Villanueva de Córdoba, Gerena (Seville) and at Los Molares (Huelva), the last being the site of a modern millstone quarry. There were almost certainly other granite quern quarries in southwestern Spain that have left scant or no evidence. Future research will probably confirm granite to have been the dominant regional rock for grinding stones following the tradition, for example, of the Early Iron Age granite saddle querns on display at the site of Cancho Roano (Badajoz).

In the southernmost area of the Iberian Peninsula, mill makers in the Spanish coastal sites on both sides of Gibraltar, even as far as Manilva (Málaga), appear to have remained faithful to their local and regional shell-rich ostionera rock (Fig. 16, bioclastic calcarenite), based on the rarity of volcanic imports. The presence of only one volcanic upper stone (with radial cuttings) among the many ostionera querns from settlements with direct access to the open sea, indicates that volcanic querns did not make inroads into this area. The reason remains obscure. The local ostionera querns were possibly better suited for grinding local fish-derived products.

Finally, the few Roman porous limestone (travertine) and carniola querns in the centre of our study area, as well as querns made from a variety of other sedimentary rocks that are spread throughout southern Spain (Fig. 16, other sedimentary rocks) reveal that there were always local and regional alternatives to imports. The preeminence of sedimentary rock in Conimbriga (Borges 1978) suggests the existence of local or regional sedimentary rock quarries of acceptable quality. This dominance, as it has been previously noted (Anderson et al. 2011:151–152), also diminishes the potential of the Lisbon Volcanic Province, about 200 km to the south, as a quern producer.

**Medieval period:** Production and distribution of querns in medieval times is poorly charted. The first problem is that there are only a few excavated settlements from this period and quern assemblages are not published. From the few examples we can identify, as in the case of watermills, there is a move away from volcanic rocks in favour of sandstones and conglomerates. This cannot be related, as in the case of watermills, to the speed of rotation and the “burning” of the flour, because handmills do not maintain a high speed of rotation over long periods. The change in stone type might be related to a change in the nature of the products being ground. This period could also be witness to changes in extraction techniques. This
Fig. 16. Distribution maps for querns and quern quarries. Top) Roman rotary querns and quarries by rock-type. Bottom) major inland trade routes and centres of Spain. Published querns: **Albacete:** 1) Hellín (Jordan et al. 1984, Jordan & Matilla 1995); **Cádiz**/**Gades:** 2) Iulia Traducta (García & Bernal 2009, Vargas & Bernal 2009), 3) Carteia; **Ciudad Real:** 4) Terrínches (Benítez et al. 2011); Córdoba: 5) Villanueva del Duque (García 2002), 6) Villanueva de Córdoba (Palomo & Fernández 2007); **Extremadura:** 7) Medillín (Haba 1998), 8) Quintana de Serena (Léon & Carmona 2006); Jaén: 9) El Centenillo (Gutiérrez & Corpus 2011); **Málaga:** 10) Málaga (Soto 1977), **Valencia:** 11) Villar del Arzobispo (Pérez 2006), Museums, depositories and private collections (unpublished): **Almería:** 12) Isla del Moro, 13) Vélez Rubio; **Cádiz:** 14) Baelo Claudia; **Ciudad Real:** 15) Bolaños de Calatrava, 16) Oretam; Córdoba: 17) Córdoba, 18) Almendinilla, 19) Priego de Córdoba, 20) Villanueva de Córdoba; **Extremadura:** 21) Mérida; **Granada:** 22) Almuñecar, 23) Guadix, 24) Baza, 25) Galera; Jaén: 26) Linares, 27) Ubéa; **Málaga:** 28) Manilva; **Murcia:** 29) Cartagena, 30) Murcia, 31) Siyás; **Seville:** 32) Carmona. Drawing: Timothy J. Anderson.
question is, however, difficult to evaluate due to the absence of archaeological excavations of quarry sites, the only proper means to observe and interpret tool marks.

**Contemporary period:** Animal fodder mills are incidental to this study. They are, nonetheless, interesting for gathering information about this recent, forgotten industry. This is not only from the standpoint of rock type and exploitation, but also because, in recent troubled times, this mill is said to have ground foodstuff for human consumption. The complex dressing patterns present on both upper and lower stones are features that were necessary to assure grinding with rocks that are not naturally abrasive, and serves as a reference for the study of ancient dressing patterns.

To conclude, as we have noted in previous articles, there is still much work to be done: on the question of rotary quern typology in museum depositories; on characterising production centres, notably volcanic, by means of petrographical analyses; on identifying quarries by means of field surveys; and on excavating a quern or millstone quarry by means of a controlled modern excavation, a task that has yet to be undertaken in our study area.

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