This is a pre-print of an article published in Journal of Archaeological Method and Theory. The final authenticated, peer-reviewed version is available online at: https://doi.org/10.1007/s10816-019-09429-7

Title: Understanding pit sites: storage, surplus and social complexity in Prehistoric Western Europe.

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Abstract

The importance of pits for archaeological inference can hardly be overstated, given their virtual omnipresence in the archaeological record. In Prehistoric Europe pits occasionally form large concentrations known as ‘pit sites’, where they are the most visible, sometimes the sole, remnants of past human activity. If we follow the generally accepted view of pits as grain storage containers, how can we interpret the social role played by places comprising hundreds or even thousands of pits? This paper is an attempt to shed light on this topic by summarising and critically analysing much of the current knowledge on storage of grain in non-industrial societies. We will start by gathering relevant and up-to-date experimental, ethnographic and historical data about the challenges that the storage of grain poses and how pits may have helped Prehistoric communities to overcome them. This will be followed by a discussion of their advantages and disadvantages relative to other methods: why would anybody use airtight pits instead of, for instance, weather-proofed raised granaries? Next, we will undertake an examination of the social and economic contexts in which storage pits are an effective solution as opposed to those in which their performance is far from optimal. The conclusions drawn will serve as a background against which to evaluate current interpretations concerning three selected case studies in Prehistoric Western Europe.

Keywords.

Archaeology, Prehistory, storage of grain, pit site, surplus, social complexity.

Acknowledgements.

The authors would like to thank Imma Ollich, Penny Cunningham, Alfonso Vigil-Escalera, Adam Gašpar and François Gentili for helping us find obscure bibliographic references or for answering our insistent questions. Thanks go also to Ildefonso Navarro, for providing us with images from Loma de la Alberica. Of course, the opinions expressed here remain the sole responsibility of the authors.

Introduction

Pits constitute one of the most pervasive archaeological features of Prehistoric sites both in the Old and the New World. They may appear in settlements, in the proximity of vital resources, in sacred places and around funerary contexts. Their importance for archaeological inference can hardly be overstated. Whatever functions, meanings or social roles pits played, they must have been associated with widespread and recurrent practices. What were they used for? What purposes did they serve? In European archaeology, they are most commonly interpreted as airtight receptacles for the storage of grain. Of course, Prehistoric pits exist in many sizes and shapes, and they may have been involved in a broad range of activities depending on the context. For example, it has been pointed out in several occasions that Iron Age pits were rather different from their Neolithic and Bronze Age counterparts (Garcia 1997, p. 89), and in fact for some the characteristics of the latter would not generally support the grain storage pit hypothesis (Marshall 2011, p. 80; Thomas 1999). Similar concerns have been raised for Neolithic to Bronze Age pits in Iberia (e.g. Cámara Serrano and Lizcano Prestel 1996, p. 315; Márquez-Romero 2001; Márquez-Romero and Fernández Ruiz 2002) and France (Beeching et al. 2010, p. 165). However, in this paper we will focus solely on the grain storage pit hypothesis and on everything that it entails, and will not consider the relative merits and demerits of alternative interpretations of the functions of pits.

Given the reliance of many agrarian societies on cereal cultivation, the grain storage pit hypothesis has significant interpretative ramifications: "*the status of an individual site, the interpretation of a whole economy and the computed population of the country can depend on a view of whether (or which) pits held corn*" (Bowen and Wood 1967, p. 1). Crucially, in Prehistoric Europe pits occasionally form large concentrations known as 'pit sites', where they are the most visible, sometimes the sole, remnants of past human activity (Fig. 1). If we follow the generally accepted view of pits as repositories of grain, how can we interpret the social role played by places comprising hundreds or even thousands of pits? Many answers have been given to this question. Most have established direct links between pit sites and the centralised storage of surplus production (e.g. Burch and Sagrera 2009; Cruz-Auñón and Arteaga 1999, p.; Cunliffe 1984, pp. 556–559; Czebreszuk and Müller 2004; Gracia Alonso 2009; van der Veen 2007). Since surplus has such a prominent role in the appearance of redistributive systems (Earle 2011), pit sites are key in our understanding of local and regional economic systems and the emergence of social complexity in the areas of Europe where they are present.

These debates are a perfect opportunity to explore broader issues concerning storage systems in Prehistory. This paper is an attempt to shed light on this topic by summarising and critically analysing much of the current knowledge on storage of grain in non-industrial societies. We will start by gathering relevant and up-to-date experimental, ethnographic and historical data about the challenges that the storage of grain poses and how pits may have helped Prehistoric communities to overcome them. This will be followed by a discussion of their advantages and disadvantages relative to other methods: why would anybody use airtight pits instead of, for instance, weather-proofed raised granaries? Next, we will undertake an examination of the social and economic contexts in which storage pits are an effective solution as opposed to those in which their performance is far from optimal. The conclusions drawn will serve as a background against which to evaluate current interpretations concerning three selected case studies in Prehistoric Western Europe.

Grain storage methods.

Fundamentals of grain storage.

Agriculture can produce huge amounts of food. However, in seasonal environments it is a delayed-return activity. This means that work on the fields begins months before crops are harvested. It also means that food is available for a short time only. Cereals are a prime example of this. As a result, farmers in these types of environments, such as temperate climates, have to find ways to preserve agricultural produce until the next harvest. This is what Winterhalder et al. have termed 'intra-annual storage' (2015, p. 338). Agriculture is closely linked to weather conditions, as well. Temperature, humidity, rainfall and other factors fluctuate from one year to the next, and so does production. Inter-annual variation in crop yields has been a problem for farmers worldwide since the beginning of agriculture. For instance, in environments of the Mediterranean area, towards the middle of the 19th century, a bad harvest in a given year could amount for as little as 10-15% of the production of the previous year (Miret i Mestre 2009: 2.1). Near complete crop failure occurred on average every five years or so in some regions (Forbes and Foxhall 1995, p. 72). To complicate things further, drought years often came in clusters. It is very likely that Prehistoric economies, with a simpler technology at their disposal, suffered from recurrent and unpredictable drops in crop yields leading to cycles of scarcity and even famine. Low yields may be caused also by disease, pests, war and a multitude of other factors. Storage is a risk mitigation strategy, one of several 'buffering mechanisms' that small communities, especially farmers, put in practice to cope with scarcity (Halstead and O'Shea 1989a). When stored foodstuffs outlast the harvest cycle we can categorise it as 'inter-annual storage' (Winterhalder et al. 2015, p. 338). Because of the characteristics of Prehistoric pits, our chief concern in this paper is with inter-annual storage in immovable containers.

The processes whereby grain can be preserved long term and the types of structures suitable for this have been extensively studied, both ethnographically and through experimentation (Adrian et al. 1979; Asensio et al. 2011; Bowen and Wood 1967; Cardona et al. 2013; Currid and Navon 1989; Dunkel 1992; Hill et al. 1983; Jayas et al. 1995; Kunz 2004; Marshall 2011; Miret i Mestre 2009; Reynolds 1974, 1979, 1988, 1998, 1999; Shejbal 1980; Sigaut 1978, 1979). Storage of grain usually has three main objectives: 1) to maintain grain dormancy and avoid premature germination; 2) to slow down microbial decay; 3) to protect grain from pests and animals. They are inter-related: active, non-dormant grain breathes, and thus it contributes to increasing temperature and humidity in the storage area, therefore creating ideal conditions for the activity of microorganisms. Microorganisms, insects and animal themselves also breathe. By contrast, dormant grain can remain in good condition, even viable as seed, for several years. To effectively maintain grain dormancy ideally the temperature of the room must remain low, grain must be kept away from light as much as possible, and moisture content of the grain must be limited. The latter is probably the most important condition of all. Variations in environmental humidity associated with local climatic conditions can decisively affect moisture levels of the grain, but they are not the only factor to take into account: the place of harvest time within the seasonal cycle, the maturity of the grain when harvested, and the form under which it is to be stored may have an influence as well (Sigaut 1988, pp. 7–8). Sometimes it is necessary to dry the grain before storage, either by exposing it to direct sunlight — e.g. drying on the stem in the fields — or by storing it provisionally in a ventilated area — e.g. the threshing floors, or a granary — (Kunz 1981, p. 121; Sigaut 1979, p. 16). However, this greatly increases the risk of insect infestation in environments prone to it (Kadim 2014, p. 201). Sometimes grain is washed in bulk before storage, but only where the climate is hot enough to dry up the grain quickly (Halstead 2014, p. 154). In dry and hot climates, grain which has been stored for a long time may be taken out to dry and ventilate, and then stored again (Doyère 1862, p. 84).

Microbes are already present on the grain in the fields. In order to keep their activity under control, moisture and temperature levels must remain low. Low-oxygen atmospheres contribute to slow down microbial decay as well, but some microorganisms can continue their activity under these circumstances. Protection from vermin requires ways to prevent the access of animals and insects to the interior, and it can involve insecticides and even charms and magical artefacts (Levinson and Levinson 1998; Luca 1981; Panagiotakopulu et al. 1995; Holtz, in Sigaut 1978, p. 118). Low-oxygen atmospheres and low temperatures can kill most insects.

Inter-annual storage methods.

Essentially, there are two ways to achieve grain preservation in the long-term: anaerobic and aerobic (Table 1). Anaerobic methods entail the creation of airtight conditions to generate low-oxygen inner atmospheres. This is done by preventing the exchange of gasses between the inside and the outside of the storage area. Once the container is hermetically sealed, oxygen is slowly replaced by carbon dioxide, as a result of the breathing process of microorganisms, insects and the grain itself. Eventually, CO_2 dominates the entire inter-granular atmosphere and the breathing cycle stops. Insects and animals die, grain becomes dormant and most microbes are unable to decompose the grain. Some cereal is inevitably lost in the process, since part of the grain has to rot for oxygen depletion to occur — it is actually the sacrifice of a portion what prevents the breakdown of the rest —, but often the loss is acceptable. Grain is usually stored in bulk or in the ear.

The application of anaerobic methods requires sealed containers. For the purposes of this article, we will highlight four different types:

A) *'Simple' pits*, the main focus of this paper (Fig. 2, a). They are pits simply dug in the ground, circular or subcircular in plan, variable in size but typically 1-3 m in diameter and depth. The need to create anaerobic micro-environments favours the adoption of forms with overhanging sides and constricted openings, such as bell, beehive or bottle-like (Bersu 1940) — although cylindrical pits are not rare (Miret i Mestre 2009, p. 68) and other forms are possible (e.g. Abdalla et al. 2002, p. 171; Kamel 1980, p. 30). Pits can be sealed up with different materials: stone slabs, mud, dung, etc. Most pits used by many small-scale communities today and presumably those employed by Prehistoric societies in Europe are simple pits.

B) *'Elaborate' or 'expensive' pits* (Fig. 2, b). 'Expensive' here refers to the energy expenditure involved in their construction, including overall working hours, materials procurement and preparation, and the need for specialised personnel and tools. More work is the price to pay for more structurally sound pits, with extended durability. Elaborate or expensive pits are normally large in size, have been dug in hard rocks (e.g. Dandria 2010; Fletcher and Ghosh 1921, pp. 730–731; Sunano 2016) and/or may include strong supporting features — e.g. stone-based linings — and substantial sealing systems — e.g. necks and lids made of hard materials— (Gast 1979, fig. 6; Jourdain 1819). Examples of elaborate pits are the huge hermetic pits employed for centuries as repositories for grain reserves by Early Modern states across the Mediterranean: Malta, Dubrovnik, Valencia, etc. (Kunz 2004; Valls et al. 2015). The distinction between simple and elaborate pits is not clear cut; rather, they seem to sit along a continuum. However, when examples from opposite ends of the spectrum are compared, the differences are immediately obvious, and have significant implications: unlike simple pits, elaborate pits can be reused almost indefinitely, and can sustain the physical stress associated with periods of intense use much better. Thus, the rate of pit reuse and replacement is considerably lower. This may be reflected in a smaller number of pits in the archaeological record, and hence it may have a meaningful impact in calculations of overall surplus grain or production.

C) *Underground silo complexes* (Fig. 2, c). Sophisticated complexes comprising many hermetic subterranean storerooms, highly compartmentalised, and with a relatively easy access to the grain from above. Examples of this are the massive complexes recently recorded in Anatolia (Dörfler et al. 2011) and Crete (Privitera 2014), and dated to the Bronze Age.

D) *Aboveground silos* (Fig. 2, d). Free-standing hermetic containers built using diverse materials. They come in a variety of sizes and shapes. Their use by small farmers and archaic states has been documented ethnographically and archaeologically (e.g. Currid 1985; Garfınkel et al. 2009).

Aerobic methods, on the other hand, are based on the premise that aeration prevents the accumulation of water by renovating the inter-granular atmosphere. Grain must enter the storage area as dry as possible, and must be kept dry and cool all along. Continuous ventilation of the grain through techniques such as exposure to air and shovelling is common, especially in humid climates. Animals, such as rodents, and pests, like the wheat weevil (*Sitophilus granarius*), are further threats to successful storage. Leaving aside movable containers made of basketry of pottery, aerobic methods require structures which are both weather-proofed and aerated. Two basic types can be distinguished:

E) *Unsealed pits* (Fig. 2, e). Pits, sometimes lined using stone or bricks, that remain open albeit protected by a weather-proofed cover. Grain is constantly exposed to outside air and readily accessible. Small unsealed pits may have been in use in Iron Age Britain (Marshall 2011).

F) *Granaries* (Fig. 2, f). They may vary in size, shape, materials — timber, stone —, building techniques — ground-based, raised — and even the kind of content they hold — grain in bulk, spikelets, smaller containers such as vessels or baskets, etc. —. Archaeological, ethnographic and historical examples of granaries abound (e.g. Bray 1984, pp. 402–414; Gardiner 2013; papers in Manzanilla and Rothman 2016; Rickman 1971; Strasser 1997).

Simple airtight pits vs granaries: a comparison.

As stated in the previous section, grain can be stored in various types of containers. In this section, we will examine their strengths and weaknesses. A particular attention will be given to simple airtight pits and granaries. The former, because they are the main concern of this paper, as most Prehistoric pit sites were primarily composed of simple pits; the latter, because in many respects they sit at the opposite end of the spectrum of storage practices.

Advantages of simple airtight pits for grain storage.

Simple sealed pits are quite effective at preserving grain in good condition for years, especially in dry climates where grain is naturally dry and rainfall is not abundant. This is so because temperatures are kept constant: the interior of a pit tends to adopt the temperature of the bigger mass (the surrounding soil or rock), and thus it stays relatively cool in warmer climates and/or seasons. There is little exposition to light and heat. The damage caused by animals is limited, mainly because they have no easy access to the grain. The same thing applies to insects, some of which may be harmful to humans as well. In fact, it has been noted that preventing insect infestation is the main motivation behind the employment of airtight methods across the southern Aegean (Halstead 2014, p. 160).

Simple airtight pits are also exceptional at concealing their contents, or even their presence. When sealed, they are hard to find (Gronenborn 1997, p. 436; Reynolds 1974, p. 123). Some ethnographic reports indicate that in certain contexts pits are dug mostly in the fields, on ploughed land, for camouflaging purposes (Vignet Zunz 1979, p. 215). Whereas granaries may be fairly vulnerable, underground storage tends to slow down major theft activities. In southern Tunisia, for example, where both airtight subterranean pits and aboveground basketry containers are kept in large storage areas and guarded by a designated person, the custody of the former is cheaper than that of the latter, because it entails less risk of theft (Louis 1979, p. 206). In fact, concealment and security reasons are a prime motivator for underground storage across cultures (Abdalla et al. 2002, p. 174; Kunz 1981, p. 120, 2004; Sigaut 1978, pp. 115, 116, 119, 1979, p. 15; Stafford 1955; Vignet Zunz 1979, p. 217). Threats to communal or private grain reserves that hidden pits may be effective against may come from within the community, from rival groups, or even from superior authorities, in the form of taxes (Anderson 2014, p. 211; DeBoer 1988; Halstead 2014, pp. 160–161; Mauny 1979, p. 50; Triantafyllidou-Baladie 1979, p. 152). Sealed pits also drastically reduce losses caused by accidental fire (Abdalla et al. 2002, p. 174; Bersu 1940, p. 61; Kunz 2004; Ward 1985, p. 99).

A major and often overlooked advantage of simple airtight pits over other methods is that, generally speaking, they represent a smaller investment of energy, especially in areas of scarce or low-quality timber and stone (Abdalla et al. 2002, p. 170; Adejumo and Raji 2007, p. 10; Fletcher and Ghosh 1921, p. 730; Kunz 2004; Mauny 1979, p. 50; Sigaut 1979, pp. 30–31). Raw materials are readily available, and do not have to be procured, sought after, traded for or transported from afar (Sigaut 1979, p. 17). Depending on the characteristics of the pit and the local geology, digging a pit may take time, effort and expertise (Alonso Martínez et al. 2017, p. 45; Doyère 1862, p. 84; Kunz 2004; Reynolds 1974, p. 121; Whittle 1984, p. 130). Nonetheless, for the simplest pits the techniques required are easier and less specialised than those needed for building the simplest granary, and normally no sophisticated tools are necessary (Gronenborn 1997, p. 435). Moreover, for the reasons listed above, keeping grain in good condition takes less work: once sealed, owners do not have to worry about maintenance, rodents or security until the airtight pit is broached and the grain removed. Unlike sealed pits, long term preservation in granaries requires frequent shovelling for improved ventilation, periodic inspection and continuous monitoring to prevent infestation or weather-related damage. Finally, underground storage takes very little space on the surface, which can be rather valuable in certain contexts, like crowded settlements or where arable land is limited. All this makes it possible even for small-scale communities to establish pit-based, large, dedicated communal storage areas. Not surprisingly, poor farmers living in marginal areas all around the world often resort to simple storage pits as their chief storage method.

Disadvantages of simple airtight pits for grain storage.

Simple hermetic pits are in no way immune to problems of spoilage and loss. The longer the storage period, the bigger the risk of substantial spoilage. After one year, grain stored in airtight pits usually begins to suffer from a number of problems, namely vermin and mould, mostly due to increasing levels of moisture (Halstead 2014, p. 163; Marshall 2011, pp. 118–119): grain breathes CO2, but also water, which is retained by the pit walls and the lack of ventilation. This issue can become a major problem if the grain was not dry enough before storage, or if isolation from external sources of moisture fails. The latter is difficult to avoid, and rather unpredictable. For instance, with heavy rainfall, the water table can rise up to pit level. When this occurs, the grain can only be recovered if removed as soon as possible and dried, and only if the pit is still flooded. Flooding for a short time may spoil much of the grain (Reynolds 1974, p. 128). This is obviously less of a problem in arid geographies (Louis 1979, p. 205).

Farmers are well aware of these threats and normally try to minimise them. The geologies were airtight storage pits are dug in are often non-permeable quaternary formations, or non-layered hard rocks. A proportion of 40 to 60% clay is ideal — pure clay may produce leaks when dry and hence is not optimal (Miret i Mestre 2009, pp. 55–56; Sigaut 1979, p. 32). However, experiments have proved that permeable rocks are also viable substrates under favourable circumstances, because they allow water to move vertically through their mass (Reynolds 1988, p. 134). As it would be expected, sealed storage pits are usually placed on dry, well drained and elevated places (Kadim 2014, p. 202; Kunz 2004; Miret i Mestre 2009), namely slightly sloped or inclined surfaces, sites where the water table is low, hilltops and, in general, any dry space where rain water does not accumulate, thus decreasing the risk of leaks. Small mounds over their mouths can be built to keep surface water away from their openings and mark their location (Doyère 1862, p. 78; Peña-Chocarro et al. 2013, p. 215; Holtz, cited in Sigaut 1978, p. 118). Pits dug within houses tend to work better (Reynolds 1974, p. 128). It has been reported that pits dug anew may be more humid than those which have been used several times (Jourdain 1819, p. 356), although this surely depends on climatic and geological factors.

Simple pits can be lined or not. Lining can increase isolation from external sources of moisture. Lining materials in simple pits include soft or non-permanent solutions such as clay, basketry, straw mixed with clay or even dung — if harder, more permanent materials such as brick, stone or concrete are employed, the pit falls into the ‘expensive’ pit category —. In the Mediterranean area, linings made of straw were common (Miret i Mestre 2009, pp. 56–57), although they have been reported not to work very well in other contexts (Marshall 2011, p. 119). Straw was deposited at the bottom of the pit before the grain was poured, but also covering the walls and on top of the grain. Basket-work linings are fairly effective, but they have to be renewed frequently because basketry promotes the development of microflora (Reynolds 1974, p. 127). Clay-based mortars usually yield good results: they increase the loss rate because of their own humidity, but the risk of leaks is reduced, and some farmers wait for clay linings to dry up properly before storage anyway (Holtz, cited in Sigaut 1978, p. 117). Sometimes a fire is lit within the pit, in order to dry the inner walls or the mortar more quickly, and to disinfect the pit prior to use (Gronenborn 1997, p. 435; Lavigne 1991, p. 571; Peña-Chocarro et al. 2013, p. 215). If fired *in situ*, clay may crack and fall away (Reynolds 1974, p. 128).

Reynolds’ classical experiments (references above) put considerable emphasis on the importance of creating hermetic conditions, the idea being that gas exchange increases oxygen levels, thus leading to renewed bacterial and insect activity. This would make sealed pits unsuitable for the storage of cereals destined for daily consumption, since "*it is virtually impossible to remove a quantity of grain and reseal the pit*" (Reynolds 1998, p. 133). Newer experiments have shifted the focus to humidity, temperature and, to a lesser degree, light, as we have seen (Marshall 2011, pp. 117–120). In fact, it has been shown that re-opening sealed pits, extracting and drying up the grain, and putting it back again with a new seal may have positive effects in the long term because of the removal of accumulated moisture (Doyère 1862, p. 80; Halstead 2014, p. 163), although this takes quite a lot of work. Further, the low-oxygen atmosphere typical of sealed pits inhibits the action of insects and aerobic microorganisms, but not the anaerobic ones, as mentioned earlier.

Having said that, Reynolds was ultimately right when he concluded that routinely exposing the contents of the pits to air from the outside by repeatedly extracting small quantities of grain for consumption or barter is likely to cause substantial losses. As an example, experiments in Ethiopia have determined that opening a sealed pit once a month can increase the loss rate caused by insects from 3% to 38% in fully filled pits, and from 6% to 55% on partially filled pits; these figures do not include damage by microbes (Boxal, cited in Lavigne 1991, p. 577). Ethnographic reports also suggest that, once opened, it is better to empty the pits at once (e.g. Adejumo and Raji 2007, p. 9; Ayoub 1985, p. 159; Gronenborn 1997, p. 436; Kadim 2014, p. 201; Kunz 2004). This is because piecemeal withdrawal, contrary to the drying up of the grain once a year that we have just mentioned, does not usually entail a reduction in moisture content. Moreover, re-sealing may become progressively more difficult each time the pit is broached (Marshall 2011, p. 107), thus enhancing the potential for water penetration. Even if the seal is fully restored, the removal of some grain leaves more space for fresh air from the outside, which restarts insect and microbial activity (Kadim 2014, p. 201; Miret i Mestre 2009, p. 218; Reynolds 1974, p. 124). Pits have to be full of grain at all times to be most effective (Kunz 1981, p. 121), and in fact grain is often trampled to remove as much air as possible before any sealing is put in place (Burch and Sagrera 2009, p. 77; Jourdain 1819, p. 362; Sigaut 1979, p. 15; Vignet Zunz 1979, p. 216).

A further disadvantage of simple sealed pits is the uncertainty they create. No storage method guarantees success, especially in the long term, and the list of potentially destructive agents is long either way. However, for the reasons explained above and others, access to grain, monitoring and maintenance during use are normally much more complicated than in granaries (Abdalla et al. 2002, p. 170; Adejumo and Raji 2007, p. 10). Filling them up and emptying them may be a very time-consuming operation (Jourdain 1819, p. 360). If the farmer is not very careful, the mouth and neck of the pit may rapidly deteriorate with people coming in and out of the pit, as well as the bucket used for adding or withdrawing grain (Kunz 2004). A recently opened storage pit may contain toxic gasses in dangerous concentrations (Dandria 2010, p. 51; Fletcher and Ghosh 1921, p. 732; Kunz 2004; Sunano 2016). Any maintenance may require the participation of children, given the restrictions on bodily movements that the small openings and limited inner spaces impose (Gronenborn 1997, p. 435; Vigil-Escalera Guirado 2013, p. 132). As a result of all this, storage pits are checked out less often, and the chances of detecting a problem and avoiding disaster with a quick and timely intervention are smaller.

Broadly speaking, simple airtight pits are less durable than granaries, as demonstrated by archaeological experiments analysing both side by side (Ollich et al. 2012, pp. 215–216), although this of course depends on the building techniques and materials used for building the granaries. Reynolds' experiments showed that simple pits dug in chalk have a virtually unlimited life-span, that is, they can be reused indefinitely (Reynolds 1999, p. 390). However, when a broader range of archaeological, ethnographic, historical and experimental sources are studied, the resulting picture is more heterogeneous and complicated, with pits that deteriorate rapidly, collapse easily under their own weight, or are simply abandoned while still functional for a multitude of reasons (Alonso Martínez et al. 2017, p. 48; Cunliffe 1992, p. 79; Doyère 1862, p. 78; Gronenborn 1997, p. 436; Jourdain 1819, pp. 356–361; Kunz 2004; Leféburе 1985, p. 223; Peña-Chocarro et al. 2015, p. 383; Rawlings in Sharples 1991, p. 93). Local geologies, environmental conditions and other factors such as the shape of the pit (e.g. pits with inward sloping walls vs cylindrical pits), how intensively they are used or how they sustain periods in between uses have a lot to say in this regard.

Lastly, when open and empty, for example in between uses, simple pits pose certain problems that aboveground granaries do not: potential hindrance or hazard for people or animals, accumulation of water, deterioration (collapse, appearance of leaks), etc. (Bersu 1940, p. 60; Kunz 2004; Peña-Chocarro et al. 2015, p. 383; Villes 1981, p. 211).

Negative consequences of long term grain storage.

We will now turn our attention to further non-desirable effects of grain storage. These have traditionally been deemed disadvantages of airtight pits. Nevertheless, unlike those described in the previous section, the problems we will examine now do not constitute inherent shortcomings or deficiencies of the method. Instead, they appear to have more to do with the storage of grain for a long time. It just happens that hermetic pits tend to be associated with long term storage more often than alternative solutions.

Although it can remain edible for a long time, there is agreement that grain stored for years, especially if exposed to moisture (Burch 2000, p. 328), tends to acquire an easily recognisable colour, a fermented odour or a certain sweet-sour taste, with the corresponding loss of culinary qualities and value in markets (Adejumo and Raji 2007, p. 10; Fletcher and Ghosh 1921, p. 730; Halstead 2014, p. 163; Triantafyllidou-Baladie 1979, p. 153). This odour may be nearly impossible to remove (Doyère 1862, p. 80, 87). Grain stored in sealed pits for too long may even be poisonous (Miret i Mestre 2009, p. 137).

More controversial is the question of whether seeds can or should be stored in sealed pits. Initially, Bersu (1940, pp. 61–62) rejected this possibility while discussing the results of his excavations at the British Iron Age site of Little Woodbury. He believed that storage of cereals in subterranean containers in a damp climate was only viable if the grain was roasted in advance. This would drastically reduce the germinability of the seeds, so the most logical conclusion was that seed corn was isolated from the rest of the harvest and stored aboveground somewhere else. Later, Sigaut (1979, p. 33, 1988, p. 22) pointed out that storage of seed corn in pits was rare outside of arid areas. Based on this, van der Veen & Jones (2006, p. 224) have argued that we should not expect most pits in Prehistoric Europe to have held seed corn. Marshall (2011, p. 85) seems to share this view, but recognises that, in a context of violence, like that supposed for the British Iron Age, seeds, which would be a critically important resource, would be safer if stored underground in capped and well camouflaged small pits. By contrast, other researchers assume, not only that some pits were used for the safe keeping of seed corn, but that most, if not all of them, were used for that purpose (Collis 2000; Cunliffe 1995; Reynolds 1974).

More ethnographic examples of this practice, in a variety of climates, are known today (Alonso Martínez et al. 2017; Burch and Sagrera 2009, p. 76; Halstead 2014, p. 159; Jourdain 1819, p. 355; Kunz 2004; Louis 1979, p. 205,207; Miret i Mestre 2009, p. 63; Holtz in Sigaut 1978, p. 119; Vignet Zunz 1979, p. 217). In Kosovo, a region traditionally famous for the fertility of its lands, all pits were used for seed grain (Kunz 2004). Moreover, Reynolds' experiments proved that seed corn stored in sealed pits for 6 months in the colder and more humid climate of Britain, and for over a year in the Mediterranean area, remained mostly viable (references above). The key question appears to be for how long the seeds are stored, rather than which method is used (Miret i Mestre 2009, p. 8). The more time passes, the greater the risk of the grain losing its germination power (Adejumo and Raji 2007, p. 10; Sigaut 1978, p. 52). In fact, using fresh grain as seed corn was recommended by the classical sources — Columella, Varro, Pliny and others — and Early Modern agronomists like Alonso de Herrera (Bellido Blanco 1995, p. 20).

Exposure to moisture and high temperatures are also relevant factors negatively affecting the viability of the grain (Burch 2000, p. 329; Miret i Mestre 2009, p. 136). Sealed pits help retain humidity, and from that point of view they may not be ideal repositories for seed corn. Nevertheless, some degree of moisture has a positive effect in that it keeps the seeds ready for planting right away, especially in arid climates (Sigaut 1978, p. 42).

Importantly, in traditional societies where there is only one annual harvest, done in the summer, the safe keeping period for seeds would extend for 2-3 months at maximum. Some authors have suggested that it is not worth digging pits for such a short time span. It is only when spring cereals are grown that the need to store seed corn for longer periods arises, in pits or otherwise (Marshall 2011, p. 99; Miret i Mestre 2009, p. 63; van der Veen 2007, p. 118). However, if pits provide an advantage over alternative solutions in some way that is valued by the community, they are likely to be used regardless. For instance, ethnographic studies conducted in the Aegean (Halstead 2014, p. 159) have documented the use of sealed pits for seed corn even though the safe keeping period only encompasses the summer months, the reason being their effectiveness in neutralising pests.

Simple airtight storage pits in context.

Among the strengths of simple sealed storage pits we have highlighted: a) their potential for preserving grain in the very long term (years or even decades); b) their superior security against theft of attack; c) the relatively small investment in time and effort that they require, both for construction and for continued use; d) less dedicated space is needed. Their weaknesses include: a) vulnerability to moisture; b) difficult access to grain for inspection and maintenance, which ultimately leads to uncertainty; c) inferior durability on average; d) hindrance for people or animals when open; e) reduced germinability and loss of culinary properties over time, associated with long term storage. These advantages and disadvantages are known to traditional societies employing sealed storage pits today and in the recent past. We must assume that they would not go unnoticed to Prehistoric peoples either.

When it comes to choosing a storage method, geography and environmental conditions are key (Halstead 2014; Marshall 2011; Miret i Mestre 2009; Reynolds 1974). Simple airtight pits seem particularly suited for arid climates with low rainfall, where grain is naturally dry in the fields and moisture is a manageable problem. High temperatures, sunshine and vermin, common threats in those areas, are taken care of by the pit. In dry-hot summer areas like the Mediterranean, airtight pits tend to work well, too, essentially for the same reasons. Here winters are cooler and wetter, but many insects and animals are active all year round, and moisture content of the grain at the time of harvest is usually not high. The violent episodes of heavy rainfall in short periods of time that typically characterise these climates may be an issue for underground grain storage. In spite of this, pits have often been preferred to built granaries for long term storage in Mediterranean climates. By contrast, in colder and more humid climates, like those of temperate Europe, temperatures are lower, humidity levels in the fields are higher and the activity levels of rodents and insects vary seasonally. All this makes airtight pits less attractive and, at the same time, favours the long term preservation of grain in aerobic conditions. Weather-proofed, ventilated granaries and even unsealed pits can effectively perform the same functions without many of the disadvantages of sealed pits. In fact, the reasons why airtight pits were used at all in northern Europe during the Iron Age remain unclear. According to Marshall (2011, pp. 84–85, 127–128), other factors may be at play: climate deterioration, protection against fire, violence or theft, beliefs, etc.

With all the pros and cons of sealed pits in mind, their ideal use-case appears to be what we will term 'static storage practices', whereas granaries would be better suited for 'dynamic storage practices'.

Simple airtight pits and static storage practices.

By 'static storage practices' we mean all the activities leading to the preservation of grain which do not require regular access and manipulation of it. They are usually associated with inter-annual storage. For small farmers, for example, this would include long term storage of excess food-grain after a good harvest, in anticipation of future bad years. The idea is to accumulate enough household food supplies to cover at least one major disaster (Forbes and Foxhall 1995; Halstead 2014, p. 162; Halstead and O'Shea 1989b). In truth, for poor farmers the ultimate destination and use of the grain is not given from the outset, but it is decided on the go, depending on a multitude of variables (Burch and Sagrera 2009, p. 76, 78). For many farmers today, large pits are a form of saving, a way of getting extra cash through sale in case of need. Stored grain can also be used for barter exchange, gift-giving or solidarity with others. Importantly, because this grain is not immediately needed, seals can be left untouched. In places subject to war or unstable political conditions, the possibility of hiding grain reserves underground greatly increases the appeal of airtight pits. Static storage practices are also typical of seasonally abandoned settlements, especially in contexts were residential mobility is common (DeBoer 1988; Smith, cited in Gronenborn 1997, p. 435; Kunz 2004; Ward 1985), or in seasonally occupied gathering places (similar to those described by Laguens 1993). Another form of static storage concerns the safe keeping of seed corn until the next sowing. As discussed above, hermetic pits can perform this function just fine for weeks or months. Burch (2000, p. 329) has suggested that pits located away from the settlements, in the fields, might be more suited to store seed corn than food. This type of behaviour has been documented ethnographically (Louis 1979, pp. 205, 207).

Farmers are seldom alone. They tend to form groups, and so do their pits. Indeed, community food storage is a classic form of risk management (Johnson and Earle 2000, p. 30). Communally owned and maintained, large, dedicated storage areas composed of pits are widespread in ethnographic and historical sources, especially around the Mediterranean and Northern Africa ((Morales et al. 2014). They are often located in inaccessible places, and may be fortified; they may even acquire a sacred character (Peña-Chocarro et al. 2015, p. 383). This is the case in southern Tunisia, where farmers draw signs with specific motifs near or over their pits to signal ownership of their contents. The guardian is familiar with all these motifs and who they correspond to (Louis 1979, p. 206). Grouping of privately owned storage pits outside villages and towns, with a designated custodian, was a common occurrence in parts of Europe, as well, chiefly because disused pits may be a problem in crowded settlements (Kunz 2004). It is easy to see how, in the archaeological record, these types of arrangements could be mistaken for redistributive facilities owned by states and fully beyond the realm of private or household-level practices.

In complex societies, at the state level, static storage practices would encompass a range of purposes, such as strategic reserves to use in times of famine, supplies for the army in military campaigns or in case of siege and food used to fatten up livestock for feasting. Sealed pits can also serve as receptacles for the long term accumulation of grain for the purposes of trade, or when governments want to ensure that the prices of basic foods remain stable (e.g. Ayoub 1985, p. 159; Doyère 1862; Fletcher and Ghosh 1921, p. 731; Jourdain 1819; Kunz 1981, pp. 121–122; Sigaut 1978, p. 56; Triantafyllidou-Baladie 1979, p. 152; Valls et al. 2015, p. 186). This makes perfect sense in market economies: while the demand for grain usually remains the same through the seasons and from one year to the next, the supply may fluctuate widely depending on a variety of factors (mainly climatic). For governments, storage evens out changes in market supply and stabilise prices by taking produce off the market in surplus years, and releasing it back onto it in times of scarcity. For private merchants and large corporations, and even for small farmers who are not deficit producers and therefore can wait to sell their grain, the rise in prices in lean seasons or years normally covers the cost of storage and provides some profit. In long-distance commodity exchange, goods are sometimes collected together and kept for as long as necessary in centralised facilities before shipping. Elaborate pits and, to a lesser extent, simple pits, are perfectly suited for this sort of speculative purpose. Moreover, because of the humidity of the micro-environments that airtight pits create, grain may increase its weight, and with it its profitability (Fletcher and Ghosh 1921, p. 730; Holtz in Sigaut 1978, p. 120). On the downside, the unpleasant odour and taste which grain may acquire if stored in pits for long in humid conditions may reduce its market value (Adejumo and Raji 2007, p. 2). Nevertheless, the use of pits for short periods before exporting the grain could have had positive effects on its own, e.g. as a temporary measure against insects (Halstead 2014, pp. 159–160).

Simple airtight pits and dynamic storage practices.

‘Dynamic storage practices’, on the other hand, entail frequent access to the grain for monitoring, maintenance, addition or extraction of grain, bookkeeping, etc. They can be associated with both intra-annual and inter-annual storage. Given that simple sealed pits are generally fragile, difficult to re-seal and less efficient if frequently opened (see above), they are a suboptimal solution for activities such as piecemeal consumption or barter. Using pits for dynamic storage activities thus appears to be anti-economic behaviour. Nevertheless, it is not that uncommon, according to ethnographic reports (Abdalla et al. 2002, p. 174; Halstead 2014, p. 159; Kadim 2014, p. 201; Lavigne 1991, p. 577; Miret i Mestre 2009, pp. 61–62; Peña-Chocarro et al. 2015, p. 383; Holtz in Sigaut 1978, p. 119; Vignet Zunz 1979, p. 217). This may make sense in relation to culturally and situationally specific conceptions of what 'acceptable loss' is, with a focus on the short and the middle term as opposed to the long term (Miret i Mestre 2009, pp. 7, 63), or simply with more pressing concerns, such as insects. Periodic extraction of grain will inevitably reduce the effectiveness of the pit as a long-term container, but many of the other advantages of sealed pits will remain. It is worth noting that small pits are less affected by this problem than larger pits, and therefore would be more suited to domestic consumption (Gonzalo et al. 2000, p. 319). In any case, this behaviour seems typical of small farmers in self-subsistence economies or in marginal areas, who have no choice but to admit losses from time to time.

For larger scale, centralised operations, especially at the level of the state, the implications are substantially different. It has long been acknowledged that, in areas where staple production is seasonal, the study of storage structures is one of the most effective ways to identify and characterise redistribution archaeologically, since different exchange systems require distinctive facilities (Earle and D’Altroy 1982, pp. 268–269). Highly complex redistributive systems, such as those of the early states, involved surplus mobilisation through taxation to a remarkable degree. Tribute and taxes were often paid in kind (staple finance). Part of these staple goods were destined to support the structure of power and bureaucracy of the state, and to acquire products and services, for instance, from state-supported craft specialists, or from full-time warriors or priests. The distribution and features of state storage are highly patterned. For instance, in most Ancient states, grain was gathered and stored in centralised locations.

At this point, it may be useful to mention the distinction that Rothman & Fiandra make between ‘storehouses’ and ‘warehouses’ for early Mesopotamian contexts: “*storehouses are the final stage in dispersal while warehouses refer to the main, longer-term storage buildings, more concerned with inputs rather than dispersals*” (Rothman and Fiandra 2016, p. 42). In archaic states, additions and withdrawals of grain from state storehouses were frequent — payments in staple goods, subsistence rations for fully dependent workers, etc. Government officials exerted administrative control over all grain coming into and out of the storehouses. Monitoring, inspection of quality and remaining quantity, record-keeping and maintenance had to be carried out on a regular basis. Easy access to the stores was therefore paramount. We can then safely classify bureaucratic redistribution as a dynamic storage practice. By contrast, warehouses would serve as receptacles for the incoming surplus mobilised via tributes and taxes, probably once a year. Apart from that, the type of storage required would be mostly static. Here convenient access to the grain would be secondary, whereas good long term preservation would be of the utmost importance.

It is difficult to imagine how hermetically sealed simple pits, like those recorded in most parts of Prehistoric Western Europe, would be adequate as storehouses, in the terms we have just described (Garcia 1997, p. 94; Gransar 2000). Proper monitoring and maintenance would face considerable difficulties, and bookkeeping would be a daunting task. At the same time, almost all the advantages of simple airtight pits would be lost: constantly opening and closing the sealed pits would cause unacceptable losses for a state economy, and their use-life would presumably be very short due to wear and tear. Aboveground, ventilated granaries, with proper entryways, on the other hand, would be an excellent fit for this purpose. Any Ancient state would have had no issues investing the necessary resources in building and managing centralised storage systems based on granaries, as the benefits would have been evident.

The idea that pits would not work well as storehouses has been brought forward to explain the transition from belowground — simple sealed pits — to aboveground storage — granaries — that occurred in parts of the Mediterranean after the Roman conquest. Simple pits did not match the requirements of a highly bureaucratic system like that of the Roman Empire (Garcia 1987, p. 93; Salido Domínguez 2009, p. 105; Vigil-Escalera Guirado 2013, pp. 141–142). Salido (2009, pp. 105–107) has suggested that in Roman times the use of simple airtight pits was restricted to private contexts, such as rural *villae*. Similarly, under Roman rule, airtight storage pits were progressively replaced by alternative methods in areas of northern Europe such as Britain (Cunliffe 1992; Gardiner 2013, p. 23; Miret i Mestre 2009, p. 15; Morris 1979). Interestingly, the Late Antiquity and the Early Middle Ages periods saw a return to sealed pits as an important form of storage in some regions, coinciding with the demise of Roman domination and the appearance of more decentralised forms of power (Garcia 1997, p. 90; Vigil-Escalera Guirado 2013, p. 142).

Could simple pits have performed reasonably well as warehouses (in Rothman/Fiandra's classificatory scheme)? In theory, yes, but to our knowledge there are no clear examples of this. Instead, most warehouses associated with archaic states were elaborate pits, massive underground silo complexes, aboveground silos or granaries. In any case, warehouses never were the sole storage container, but a complement to others in a wider system. Hence, we do not see how a Prehistoric pit site with no visible granaries could have performed well as the main storage area of a complex redistributive centre.

Long-distance trade often requires changing transport modes. Bulking and debulking of goods, provisional storage and record-keeping are therefore expected at intermediary locations, such as ports of trade (Earle and D'Altroy 1982, p. 269). Pits can be employed in the context of a market economy to keep large quantities of grain off the market while the prices are low (see above). However, once grain starts moving, storage systems based on sealed pits face similar difficulties to those we have described above for redistributive facilities. It comes as no surprise, then, that the study of ethnographic and historical sources suggests that, when production and consumption of grain are set apart from each other, storage pits are usually located closer to the producer than the consumer (Sigaut 1978, p. 35). In Roman times, for example, when grain was traded on a massive scale all across the Mediterranean, granaries, as opposed to hermetic pits, were prevalent at important ports, such as Ostia, which regularly provided Rome with much needed grain supplies (Rickman 1971, p. 86).

Some conclusions.

It is widely assumed that the individual pits forming Prehistoric pit sites in Europe functioned as simple airtight grain storage repositories. In the spectrum of storage practices, these pits would fall into the hermetic containers category — anaerobic conditions —, and as such they had the potential to preserve grain for years. They are located underground and generally have small openings; this makes them easy to hide if needed. The energy demands of their construction and the adequate preservation of the grain are usually low, and they do not require special technical knowledge or materials.

On the negative side, their sealed character makes the outcome of storage an uncertain one and creates all sorts of difficulties for regular inspection, maintenance and accounting. If routinely opened, losses pile up quickly. As simple pits, often with undercut sides and no structural reinforcements of any kind, they are less likely to be able to sustain long periods of intense and repeated use than other types of containers. Disused pits are a potential hazard for people and animals, particularly in crowded areas, and need to be filled up with whatever material is deemed appropriate. Overall, they seem to be more suited for static rather than for dynamic storage practices.

For all these reasons, they are an excellent choice for small farmers and mobile populations in most environments, but especially for those living in climates with long dry seasons: cheap, easily replaceable, with low maintenance costs and very effective in keeping basic supplies and emergency reserves away from various threats. For larger-scale societies, namely states, hermetic simple pits are one of several options available for static storage, although perhaps not the best. When it comes to dynamic storage practices, however, they are remarkably inefficient and inconvenient, especially if used as storehouses involved in complex redistributive processes.

Prehistoric pit sites in Western Europe: three case studies.

The three study areas.

In Prehistoric Western Europe, pits were ubiquitous. Strictly speaking, pit sites are archaeological sites where the only surviving remains of Prehistoric activity are the pits themselves (Garrow 2015). However, for comparative purposes, in this paper we will follow a somewhat more imprecise definition of pit sites as those where pits are present in high numbers, and represent a very significant part of the archaeological evidence, but not necessarily all of it. Known pit sites as defined here have been dated to the Neolithic and the Chalcolithic (e.g. Andersen 1997; Anderson-

Whymark and Thomas 2011; Beeching et al. 2010; Márquez-Romero and Jiménez-Jáimez 2010; Price 2015, pp. 126–137), the Bronze Age (e.g. Bellido Blanco 1995) and the Iron Age (e.g. Asensio et al. 2002; Buchsenschutz 1981; Collis 2000; Garcia 1987; Gransar 2000; Marshall 2011; Villes 1981). Pits are also a common occurrence in archaeological sites of historical periods in certain regions of Europe, as well (Buttler 1936; e.g. Kunz 2004; papers in Vigil-Escalera Guirado et al. 2013). For the sake of brevity, in the present article we will focus exclusively on three socio-cultural contexts in Prehistoric Western Europe: Iron Age Britain, Late Neolithic/Chalcolithic southern Iberia an Iron Age north-western Mediterranean (Fig. 3, a, b and c, respectively). These areas have been chosen primarily because they are relatively well-known, because they are to an extent representative of the phenomenon as a whole, and because some of the most interesting and original interpretations revolve around them.

The Chalcolithic or Copper Age in Iberia (present-day Spain and Portugal) is a conventionally defined period between the Neolithic and the Bronze Age which roughly encompasses the 3rd millennium BCE. Literature about Iberian Chalcolithic landscapes is dominated by the analysis of various types of monumental structures, funerary or otherwise: on one hand, Megalithic tombs, a Neolithic building tradition that persisted during the Copper Age with certain changes (Boaventura 2011; García Sanjuán 2009); on the other hand, enclosures of vast sizes and striking features. The latter followed two rather different architectural 'styles': a) stone masonry based walled sites, sometimes with so-called 'bastions' and 'towers', often enclosing areas which included circular houses (walled enclosures) (Chapman 2003; Jorge 2003); b) sites, occasionally very large, delimited by U or V-shaped ditches, with roughly circular or oval layouts (ditched enclosures) (Márquez-Romero and Jiménez-Jáimez 2013; Valera 2012).

Much less conspicuous, and less intensively researched, is the practice of pit-digging. Pits dating from different periods have been identified across several Iberian regions, but the practice seems to have flourished in a remarkable way in the south during the Late Neolithic (c. 3500-3000 BCE) and Chalcolithic (c. 3000-2200 BCE). The biggest concentrations are in the Guadiana and Guadalquivir basins. The vast majority of Iberian pits are circular or subcircular in plan, but other than that they are quite variable in form and size. Whereas some have overhanging sides and constricted openings — bell, bottle, flask or beehive-shaped, truncated cones, etc. —, others are roughly cylindrical and have vertical or slightly splayed sides. Bottoms are usually flat or, less frequently, slightly concave. As for their size, they range from less than 1 m to 2-3 m, exceptionally 4-5 m, in diameter, and from a few dozen cm to 2-3 m in depth. Sometimes, their original shape or size is difficult to discern because they are not fully preserved, the upper part being lost at some point, or because all there is publicly available are preliminary excavation reports and grey literature which do not provide detailed data. Their fills usually contain complex assemblages suggestive of a wide range of activities: ceramic sherds, flint tools and knapping waste, quern stones, animal remains — sometimes complete — and human remains, amongst other artefacts and ecofacts. Importantly, elaborate or expensive pits are virtually unknown for this period in the region.

Generally speaking, Iberian pits from this period tend to form large clusters in unenclosed pit sites called in Spanish *campos de hoyos* (literally, 'pit fields'). Examples include sites in the Arroyo Salado estuary (Cádiz), such as Base Naval (Rota) and Cantarranas-La Viña (Puerto de Santa María), El Trobal (Jerez de la Frontera, Cádiz) or Loma de la Alberica (Estepona, Málaga) (Fig. 1), to name just a few (a synthesis and full references in Márquez-Romero and Jiménez-Jáimez 2010, pp. 185–188). Pits are the most salient features at unenclosed pit sites for their sheer number alone. More than that, they often represent the only traces of past activity visible in the archaeological record. Additionally, groups of pits are often found in and around ditched enclosures, sometimes in high densities. Some of the most notable are Valencina de la Concepción (Sevilla), Polideportivo (Martos, Jaén), Marroquíes Bajos (Jaén), Porto Torrão (Ferreira do Alentejo, Beja), Perdigões (Reguengos de Monsaraz, Évora) and La Pijotilla (Badajoz) (fully referenced syntheses in Márquez-Romero and Jiménez-Jáimez 2013; Valera 2012). Overall, although difficult to quantify due to the variable quality of the available data, the number of known pits dated to this period is impressive; they can be counted in the thousands at some sites. Importantly, however, the largest pit sites and ditched enclosures have long and complicated histories, with complex internal sequences and a considerable number of intersecting pits with heterogeneous chronologies. For example, research has shown that the biography of Perdigões stretched for almost 1500 years (Valera 2018).

Thousands of pits and numerous pit sites dating from the Iron Age have been recorded between the rivers Ebro and Rhône, with a especial concentration around the Gulf of Lion, in the north-western Mediterranean. This coincides with coastal parts of present-day Provence-Alpes-Côte d'Azur and Occitanie (France), and Catalonia (Spain) (Asensio et al.

2002; Burch 1996, 2000; Burch and Sagrera 2009; Garcia 1987, 1997). Cultural developments in the NW Mediterranean, as in other parts of southern Europe and Northern Africa during the 1st millennium BCE, were mediated by a complex history of interaction with Ancient civilisations, namely Greeks, Phoenicians and Punics. Although trade with the Phoenician-Punic settlement of Ebusus (Ibiza) appears to have been frequent, it was the Greeks who founded several colonies in this territory or its immediate vicinity from the early 6th century BCE onwards: Rhode, Emporion and Massalia. The earliest Iron Age pit sites appeared in the 7th century BCE, while the heyday of this phenomenon has been dated to the 4th and 3rd centuries BCE. Pit digging remained an important practice through the 2nd century BCE, before its almost complete disappearance in the 1st century BCE, under Roman rule.

The average dimensions and range of shapes of these pits, and even the nature of their fills, do not differ much from the southern Iberian Chalcolithic examples we have just described, including the presence of human remains in some of them. In this area, however, pits appear in a wider variety of contexts, from fortified enclosures forming large clusters and little evidence of occupation beside them, to unenclosed pit sites in the proximity of important proto-urban settlements, to small hamlets in the countryside. They sometimes coexist with substantial houses, outstanding buildings and other constructions. Among the recorded Iron Age pit sites in the NW Mediterranean, Ensérune (Nissan, Hérault), Carsac (Carcasonne, Aude), Sant Julià de Ramis (Girona), Mas Castellar (Pontós, Girona) — a 'specialised site' where c. 2500 pits have been located (Gonzalo et al. 2000, p. 315) (Fig. 4) —, Ullastret (Girona) and Montjuïc (Barcelona) stand out from the rest. Very few elaborate or expensive pits have been recorded (examples in Burch and Sagrera 2009, p. 76).

The period conventionally known as Iron Age began in Britain around 800 BCE, and ended with the Roman conquest of much of the island in the 1st century AD (Haselgrove 1999; Haselgrove and Pope 2007). The period is generally subdivided into an Early (c. 800-350 BCE), a Middle (c. 350-100 BCE) and a Late Iron Age (c. 100 BCE-43/84 AD). Mixed farming seems to have been the basis of all economic activity, although by the Later Iron Age southern Britain was fully integrated into the international trading networks centred upon the Mediterranean states. The settlement evidence for the Iron Age is not equally known for all the regions of Britain, but in southern England it is abundant and very diverse: from individual farmsteads to huge enclosed hilltop settlements. The latter, usually called 'hillforts', are of particular interest to us. Their ditches and banks of monumental size enclosed areas typically 300-600 m in diameter. These places could host hundreds of people, although it remains unclear whether they were occupied on a permanent basis. After c. 300 BCE, settlement patterns in southern England appear to be more nucleated, and the so-called 'developed hillforts' emerged, with immense ramparts and substantial evidence of interior occupation.

Iron Age Britain is one of the most prolific contexts in Prehistoric Western Europe as regards pit-digging (Collis 2000; Marshall 2011; Reynolds 1974, 1979). Pits are distributed geographically across southern, central and eastern England, in nearly all territories south and east of an imaginary line from the Welsh Marches to the estuary of the river Tees (Gent 1983). Interestingly, right at the other side of the Channel, continental NW Europe shows a similar pattern of pit digging practices (Gent 1983; Gransar 2000). British Iron Age pits first appeared shortly after 800 BCE, and all but disappeared towards the end of the period, with a peak of usage from c. 350 BCE to 50 BCE. Pits have been found in all kinds of sites: from small groups of pits at modestly-sized farms and hamlets to striking clusters at the largest hillforts. As in the NW Mediterranean examples, pits must have coexisted with other types of features, such as round houses and the much discussed four- and six-posters: post-built structures the function of which is controversial, with a majority of researchers advocating their interpretation as raised granaries. Iron Age British pits show comparable characteristics to those in our other study areas. Most have either vertical (cylindrical) or inward sloping sides (barrel-shaped, beehive-shaped, etc.), 1-3 m in depth and about 1-2 cubic meters in capacity. Their fills comprise a variety of artefacts and ecofacts, including, once again, human remains and other 'special deposits' (Cunliffe 1992; Hill 1995). Some examples are Maiden Castle (Dorset), Gussage All Saints (Dorset), Little Woodbury (Wiltshire), Gravelly Guy (Oxfordshire), Wyndyke Furlong (Oxfordshire) and Danebury (Hampshire) — a hillfort where 2400 pits have been located and 1700 or so have been excavated (Cunliffe and Poole 1991, pp. 153–162) —. We are not aware of any clear cut example of elaborate or expensive pit in this context: to our knowledge, all pits recorded are simple pits.

An assessment of current interpretations in the study areas.

How can these huge sites, with thousands of pits, be explained? In this section we will evaluate some of the answers given to this question within our study areas. It has been argued that, to fully assess a scientific theory or hypothesis, we need to at least look at 5 characteristics: accuracy, internal and external consistency, scope, simplicity and fruitfulness (Kuhn 1977). For this paper, we cannot examine all these aspects in full, but we can look at their external consistency: "*a theory should be consistent, not only internally or with itself, but also with other currently accepted theories applicable to related aspects of nature*" (Kuhn 1977, p. 322).

The first hypothesis comes from researchers studying the NW Mediterranean evidence (Adroher et al. 1993, pp. 66–69; Asensio et al. 2002; Garcia 1987, pp. 93–98; Gonzalo et al. 2000; Gracia Alonso 2009; Martín i Ortega 1982, pp. 119–120; Ruiz de Arbulo 1992, p. 68). The proposition is as follows. In the context of the far-reaching trade networks that developed in the Mediterranean during the 1st millennium BCE, the Iron Age populations around the Gulf of Lion were capable of producing great amounts of a highly demanded commodity: grain. From the 5th to the 1st centuries BCE, important population centres such as Athens and, later, Rome, were unable to feed themselves, and therefore were in constant need of external supplies of grain. The Greek and Phoenician-Punic settlements established all over the coasts of the Western Mediterranean, and particularly Massalia, Emporion and Rhode, were in a perfect position to act as middlemen for such profitable transactions. In return, the elites of north-east Iberia and Mediterranean France would receive highly valued crafted items and prestige products (wine, garum, oil). Because the market price for grain fluctuated constantly, it was a good idea to store the surplus grain in suitable containers until prices rose and a substantial profit margin was available. This would explain the existence of fortified sites with little evidence of permanent occupation and significant concentrations of pits: from this perspective they would act as places fully specialised in the storage of grain. Mas Castellar, where even a temple possibly dedicated to fertility goddesses was built, would be the best example. The coincidence in time of the peak of pit-digging with that of long-distance exchange seems to support this proposition. A similar albeit different hypothesis has been put forward for Iron Age pit sites in Britain by Reynolds (1979: 74). In support of this idea are the claims made by Strabo (Geographica, book IV, ch. 5), writing at the turn of the era, that the Britons exported grain, and the archaeological confirmation that during the Late Iron Age long-distance trade was an important activity in Britain.

From the perspective of external consistency, these interpretations have some merit. We have shown that it is indeed possible to keep grain off the market for years if necessary by storing them underground in airtight pits, both simple and, especially elaborate. In fact, there are historical and ethnographic examples that prove precisely that. The questions that these hypotheses raise have more to do with accuracy than with consistency. For example, Burch (2000, p. 328; Burch and Sagrera 2009, p. 85) maintains that the number of pits known in the NW Mediterranean is not big enough to support the requirements of large-scale grain trade when the length of time that passed — several centuries — is considered. For the British case, van der Veen & Jones (2006, p. 226) have pointed out that the reactivation of long-distance trade was approximately simultaneous with the progressive disappearance of pits, which would suggest that if grain was indeed exported out of Britain, it was not stored in pits.

An alternative explanation for the formation of large pit sites has been offered on the basis of the Chalcolithic Iberian evidence (Arteaga and Cruz-Auñón 1999; Cruz-Auñón and Arteaga 1999; López Aldana and Pajuelo Pando 2001, 2011; Morán Hernández 2014; Morán Hernández and Parreira 2003; Nocete Calvo 2001, 2014; Nocete Calvo et al. 2008, 2010). There are slightly different versions of this hypothesis, but the main points are surely shared by all researchers involved: the most outstanding Chalcolithic pit sites in southern Iberia constituted redistribution centres in the context of state economies. Simply put, these would be the earliest state societies in Western Europe (3rd millennium BCE). In support of such claims these researchers have argued that Copper Age populations in southern Iberia show many of the features that typically characterised Archaic states (D'Altroy et al. 1985; Feinman and Marcus 1998):

A) Agrarian intensification and demographic growth, leading to surplus production.

B) Surplus mobilisation, via tribute in kind, corvée labour, or both, obtained through coercive measures — physical and/or ideological.

C) Concentration of surplus production (grain) in immense storage facilities — pit sites — controlled by elite groups.

D) Large-scale (bureaucratic?) redistribution, materialised in long-distance trade — grain in exchange for imported raw materials and manufactured products —, a strong social division of labour — part- and full-time specialists such as warriors and craftsmen, who would work with the exotic materials previously imported —, and the realisation of collective and monumental works — such as fortifications and tombs for the elites —.

E) Spatial division of labour, consisting of a marked settlement hierarchisation and specialisation — sites specialised in activities like agrarian production, defence, trade, storage, metallurgical activities, stopgap locations for products and tribute on the move, etc.—.

F) Social stratification, with at least a ruling class, a peasant class and full-time specialists.

Underlying this interpretation is the assumption that the storage needs of large-scale redistributive centres can be fulfilled exclusively by simple pits, serving as both warehouses and storehouses. In other words, that simple sealed pits can deal with dynamic storage activities on a massive scale. This is not consistent with the picture depicted by our broader study on the strengths and weaknesses of simple grain storage pits. Quite the contrary, our literature review shows that granaries and other structures specialised in dynamic storage are required for that type of workload. It is difficult to imagine how the state economy of an archaic state would have tolerated, for centuries, the disadvantages of simple airtight pits for dynamic storage, especially when much better solutions where surely within reach. Iberian pit sites might have stored a significant surplus, but not in the terms suggested by the hypothesis. Other critics have challenged it by questioning the empirical support to some of these claims, i.e. strong social division of labour and class stratification, and by emphasising a variety of aspects of production, consumption, settlement organisation and treatment of the dead in Chalcolithic Iberia which do not match widespread definitions of 'state' (e.g. Chapman 2008; Díaz-del-Río 2004; García Sanjuán and Murillo-Barroso 2013; Gilman 2013; Márquez-Romero and Jiménez-Jáimez 2010; Risch 2017). There has been some discussion about possible redistributive practices taking place at British Iron Age hillforts, but it primarily involves four-post granaries rather than pits, so we will not address this (Cunliffe 1984, pp. 556–559; Gent 1983).

In a series of works describing the extensive excavations carried out at the Iron Age hillfort of Danebury (Hampshire, England) and their results, Cunliffe (1992, 1995, pp. 84–85; Cunliffe and Poole 1991, p. 162) propounded an innovative hypothesis to make sense of the exceedingly large number of pits recorded at the site. The hypothesis postulates that most pits were used to store seed corn in between seasons, rather than surplus grain. After the harvest, farmers would dig pits with the purpose of keeping seeds safe until the next sowing. By doing that, they were handing over the safety of a critical resource to chtonic deities. In exchange for their protection, when sowing time arrived and the pits were broached, the faithful would show their gratitude to the supernatural powers by depositing valuable, sacred or special items in the pits. This way, pits were normally used only once, and the repetition of these rituals year after year, for centuries, would end up generating vast areas with countless disused and abandoned pits.

Empirical support for this proposition comes primarily from the high probability that at least some pits at Danebury were used only once, and from the widespread presence of 'special' deposits within British Iron Age pits, suggestive of recurrent ritualised depositional practices (Hill 1995). Interestingly, the association of pits with specific depositional practices has also been recognised in other periods and regions of Europe (e.g. Baray and Boulestin 2010; Beeching et al. 2010; Delattre 2000; Márquez-Romero 2006; Thomas 1999), and the connections between storage pits and rituals are attested ethnographically (Louis 1979, p. 206; e.g. Holtz, in Sigaut 1978, pp. 117–118).

As regards external consistency, there are ethnographic examples of pits holding seed corn, and many cultural contexts in which grain is associated with sacred places, supernatural powers, magic and propitiatory rituals. That the rate of pit reuse was low in Danebury and perhaps at similar sites in Britain and elsewhere is not at all out of the realm of possibility, considering the limited durability of simple airtight pits dug in friable geologies and the relative lack of incentives for reusing them as opposed to digging new pits. Having said that, most examples known to us of large concentrations of storage pits in ethnographic and historical reports include surplus grain to some degree, with rare exceptions. Assuming that all Iron Age British pits where used for the safe keeping of seeds seems a bit unrealistic, especially in temperate environments, like that of Britain, where insects and other pests and not overly active in the colder months.

The last interpretation selected for evaluation in this paper has been set forth by van der Veen (2007). According to this hypothesis, the remarkable concentrations of pits at British Iron Age hillforts would be the result of the periodic accumulation of surplus for political purposes. Contrary to the Iberian example above, however, this would not necessarily involve highly developed redistributive systems at the state level, but rather more punctuated activities such as feasts. From this perspective, the evolution of pit usage would reflect a slow move from communal feasts to exclusive dining. During the Early Iron Age, the theory goes, the occupation of hillforts in central-southern Britain was probably seasonal. Instead of permanent settlements, they would constitute locations for communal celebratory feasts where everyday, mundane food stored in pits was consumed in large-scale events — both in the amount of food available and in the number of participants. This would enhance social bonds in the context of non-stratified societies. The organisers of the feasts would gain social standing by sharing food with others. The guests consequently would be in debt with the hosts, a debt that would be paid back in the form of either deference or labour. In fact, surplus itself would be produced for this purpose. This can perhaps be put in relation with the suggestion that the construction of the enclosing ditches and banks surrounding the hillforts would have necessitated potlatch-like consumption events in order to mobilise a large enough labour force (Sharples 2007, pp. 179–180).

At a later stage, towards 300 BCE, the elites finally moved into the ('developed') hillforts as residences on a permanent basis. The feasts continued, perhaps as an instrument employed by certain communities or individuals with special status to legitimise growing social inequality. Lastly, in the Late Iron Age (c. 100 BCE), a shift towards more individualised consumption resulted in the disappearance of the communal places and a decline in pit usage. Now surplus grain was exported in exchange for items of elite display, and instead of common staples consumed by the community at large, luxury or exotic foods were consumed in small quantities, and by much fewer people (the elite).

Jones (2007) has found plausible correlations between the number of active pits at a given time and their capacity, on one side, and the calendar of Celtic festivals on the other. And certainly, if all pits stored surplus grain, then their overall capacity, even adjusted for temporality, would clearly exceed the quantities that the inhabitants of the hillforts would require for subsistence.

This interpretation achieves a good degree of external consistency. The punctuated character of these feasts would mean that the storage required was of the static type. Simple sealed pits would have favoured the preservation of grain for months or even years until the next especial occasion. They would have remained hidden and therefore relatively safe from theft or pillage. Stored grain would have needed little care or maintenance, which would have been most convenient if indeed early hillforts were not inhabited on a permanent basis. Once opened, they could have been emptied at once, with no additional losses, and the grain consumed in one massive event. However, Jones himself has questioned this approach by pointing out the relative scarcity of animal bones deposited within Iron Age pits in southern Britain, which would perhaps suggest the regular occurrence of meat-less feasts, something that would not fit the expected character of massive consumption events among Celtic populations.

As we have demonstrated, a careful and exhaustive look at currently available ethnographic, historical and experimental data on storage pits can provide a background of knowledge against which to assess existing interpretations of Prehistoric pit sites in Europe. Many questions remain, such as the alternative functions and meanings that pits may have had, better estimates for their reuse/replacement rate if indeed they were storage pits, how the overall accumulated surplus can be more precisely calculated, etc. Still, the lessons learned here can easily be applied to other contexts and periods where pits have a marked presence in the archaeological record, thus allowing researchers to frame their debates in more realistic terms.

Table 1 Main characteristics of the types of storage structures discussed in the text, for comparative purposes

	Simple sealed pits	Elaborate sealed pits	Underground silo complexes	Aboveground silos	Unsealed pits	Granaries
Method	Anaerobic	Anaerobic	Anaerobic	Anaerobic	Aerobic	Aerobic
Visibility	Low	Low, medium	Low, medium	High	Medium	High
Energy expenditure (construction)	Low	Medium, high	High	Medium, high	Low, medium	Medium, high
Energy expenditure (grain preservation)	Low	Low	Low	Low	Medium	High
Durability	Low	High	High	High?	High?	High
Optimal storage type (time)	Inter-annual	Inter-annual	Inter-annual	Inter-annual	Intra-annual	Intra-annual, inter-annual
Optimal storage type (access)	Static	Static	Static	Static	Dynamic	Dynamic
Optimal storage type (purpose)	Food reserves, seeds, price speculation (trade)?, redistribution?	Food reserves, seeds, price speculation (trade), redistribution	Food reserves, seeds, price speculation (trade), redistribution	Food reserves, seeds, price speculation (trade), redistribution	Daily consumption, seeds	All
Optimal role in redistribution	Warehouses?	Warehouses	Warehouses	Warehouses	---	Storehouses
Most likely context of use	Household, community	Community, state economy	State economy	Household, community, state economy	Household, community	All
Examples	Prehistoric pit sites	Early Modern Mediterranean states	Mediterranean and South-western Asian ancient states	Contemporary small and industrial farmers	Iron Age Britain	Widespread, many different types and architectures

Figure 1

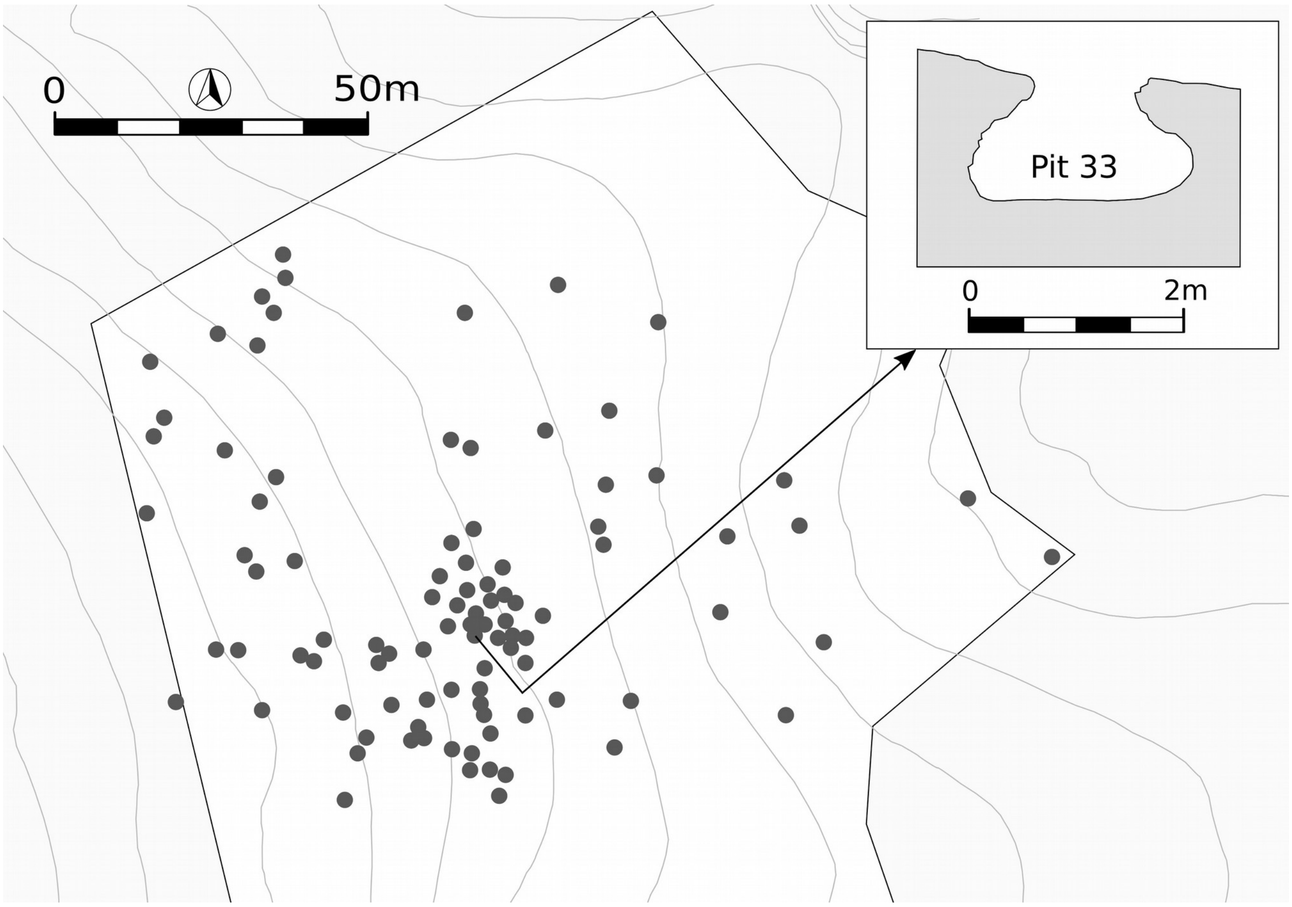

Figure 2

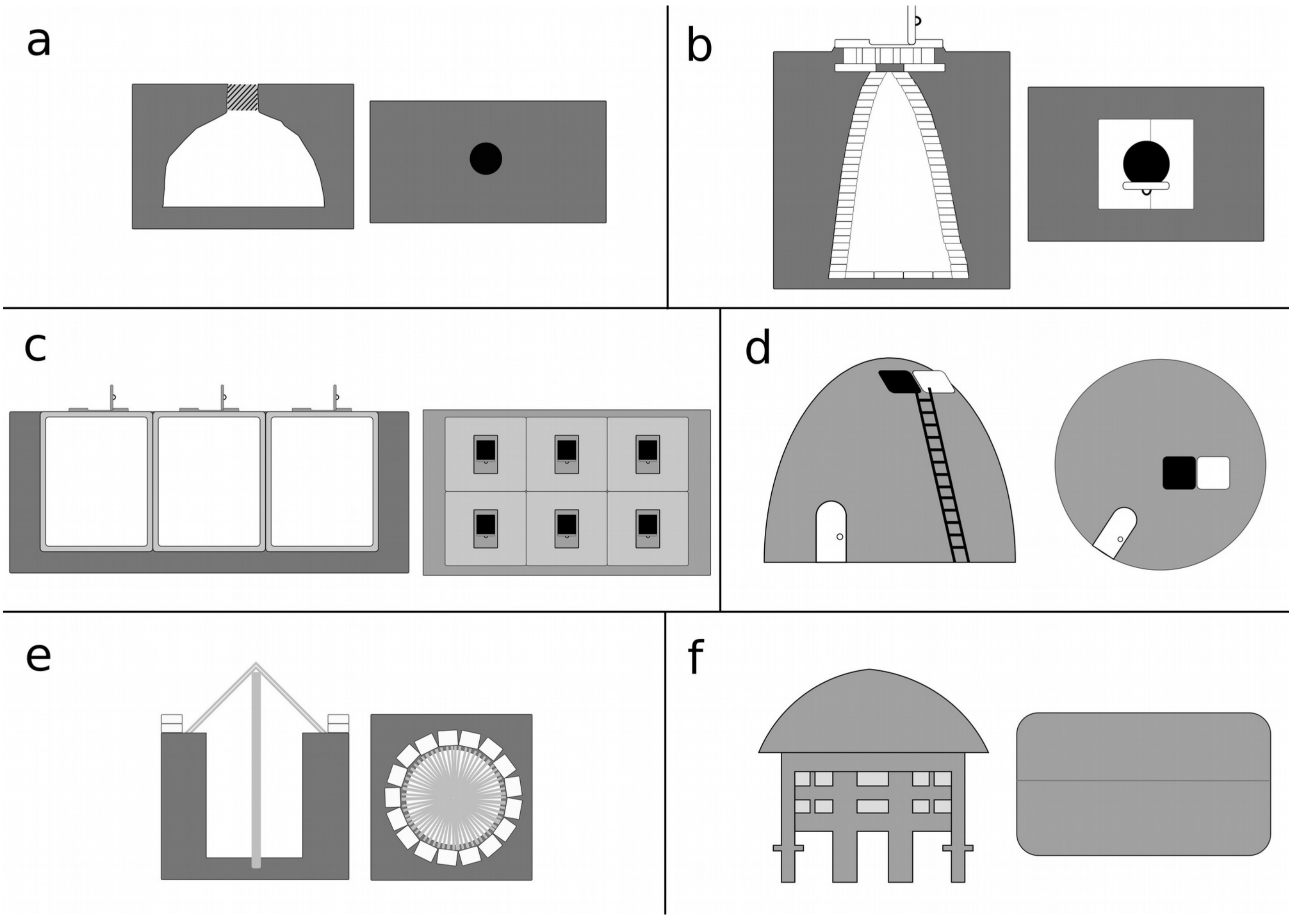

Figure 3.

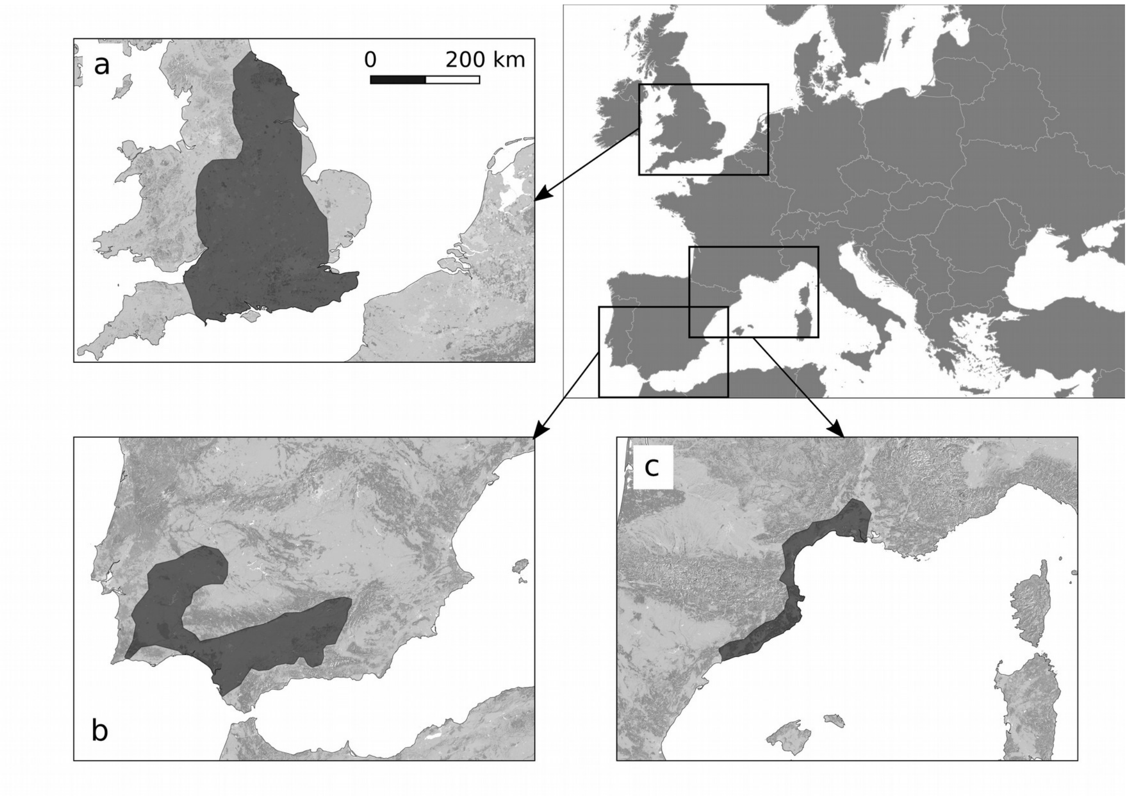

Figure 4.

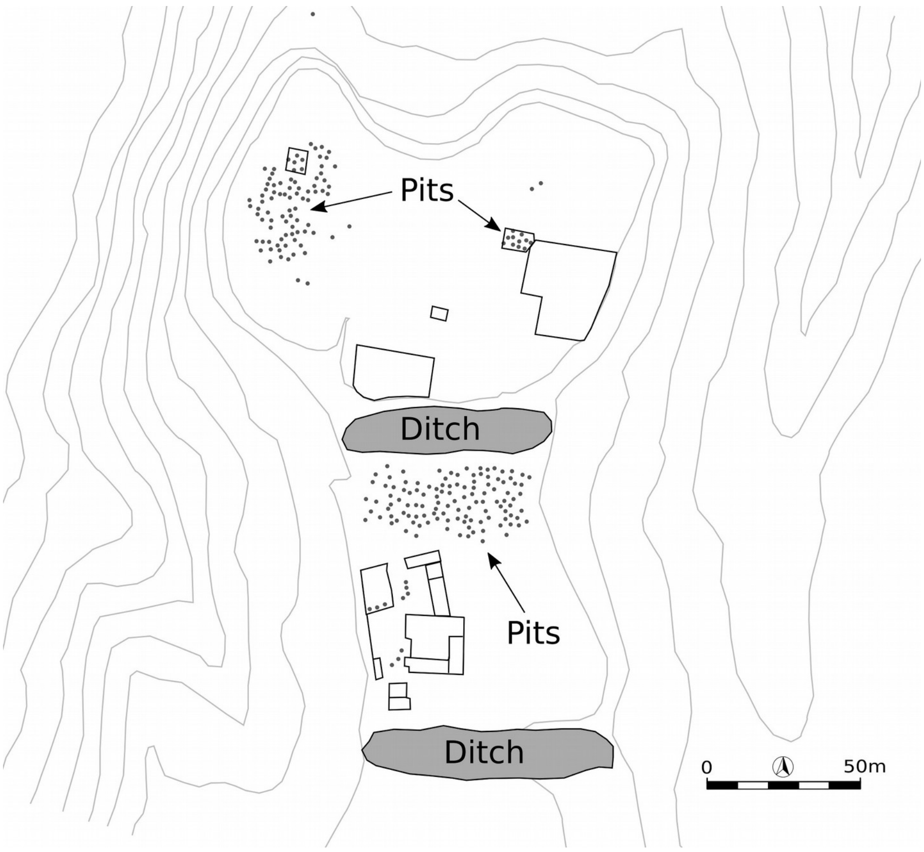

Figure captions

Fig. 1 General plan of Loma de la Alberica (Estepona, Málaga), a Late Neolithic pit site in southern Iberia. Image courtesy of Ildefonso Navarro

Fig. 2 Schematic ideal representation of the types of storage container discussed in the text, both section (left) and view from above (right): a) simple sealed pit; b) elaborate or expensive sealed pit; c) underground silo complex; d) aboveground silo; e) unsealed pit; f) granary

Fig. 3 Map of Europe, with indication of the three study areas discussed in this paper (darker shades): a) Iron Age Britain; b) Late Neolithic/Chalcolithic southern Iberia; c) Iron Age NW Mediterranean. Map tiles by Stamen Design, under CC BY 3.0. Data by OpenStreetMap, under OdbL.

Fig. 4 General plan of Mas Castellar (Pontós, Girona), an Iron Age pit site in north-east Iberia. Modified from (Asensio et al. 2002, fig. 4)

Table captions

Table 1 Main characteristics of the types of storage structures discussed in the text, for comparative p urposes

Funding

The research leading to these results has received funding from the PEOPLE Programme (Marie Curie Actions) of the European Union's Seventh Framework Programme (FP7/2007-2013) under REA grant agreement nº 2012-326129.

Conflict of interest

The authors declare that they have no conflict of interest.

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