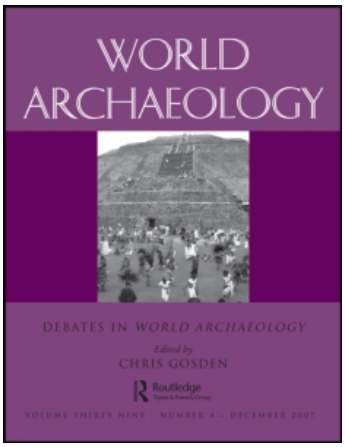


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# Original design, tribal management and modifications in medieval hydraulic systems in the Balearic Islands (Spain)

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# Original design, tribal management and modifications in medieval hydraulic systems in the Balearic Islands (Spain)

Helena Kirchner



**Abstract**

Case studies of hydraulic systems in al-Andalus prove them to be inextricably linked with specific forms of local clan procedure of water allocation. On the basis of the past and ongoing research on the irrigation systems of al-Andalus, especially in the Balearic Islands, amounting to just under 200 cases studied, it can be safely said that they were conceived, created and managed by peasant groups without any significant intervention by the state. Consequently the diffusion of plants from the east and the water technologies associated with their cultivation are best understood as a part of peasant knowledge, a technical transmission that took effect outside the Wittfogelian paradigm. In this paper I will try to show that the size of irrigated areas is important and that its modifications are key aspects of the discussion on the peasant management of the hydraulic systems of al-Andalus.

**Keywords**

Water allocation; medieval hydraulic systems; Balearic Islands; Al-Andalus; irrigation.

The archaeological investigation of the hydraulic systems of al-Andalus[1] initiated by Barceló in the 1980s has led to the development of specific research procedures from which original results have been obtained, mainly for the eastern regions of the Iberian Peninsula and the Balearic Islands (Barceló 1989, 1995; Glick and Kirchner 2002; Kirchner and Navarro 1993).[2] The aim of the archaeological method used has been to reconstruct the original design of the irrigated areas and to distinguish the modifications and extensions which occurred between the feudal conquest of al-Andalus, begun in earnest in the middle of the twelfth century, and the present day. A typology of hydraulic systems has also been established.[3] Glick, in his classic book *Irrigation and Society in Medieval Valencia* (1970), first laid the foundation of modern studies on the question of Andalusian hydraulics. On

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the basis of medieval written sources, toponymic analysis and careful observation of contemporary functioning of the great hydraulic systems of the *huertas* of eastern Spain, he convincingly argued that local control and management were the governing factors of the irrigated areas, and that there was no need for large-scale centralized administration, of the sort postulated by Wittfogel (1964 [1957]).[4]

Glick's argument has been reinforced (see Glick 2007: 104–22) by the research of Barceló and collaborators,[5] showing that the level of cooperation that irrigation schemes required can be adequately reached by the kin-based social organization of Andalusian peasantries. Already Maass (Maass and Anderson 1978: 366) had observed a strong connection between local control of hydraulic systems and the coherence and stability of that local control. Local control also resulted in some measure of growth regulation, and this provided security. Glick remarked that a clan-based society could easily meet the managerial requirements of hydraulic systems. An equitable water allocation, without which no hydraulic system can be efficiently maintained, rendered unnecessary or superfluous any administrative or coercive structure other than the social control procedures of a clan-based society.

The reconstruction of hydraulic designs that extensive archaeological methods, combining field-work with written and toponymic evidence, have made possible has gone a long way towards proving and refining Glick's and Maass's early observations. Case studies of hydraulic systems managed either by a particular single group or by water-sharing multiple clans prove them to be inextricably linked with specific forms of local clan procedure of water allocation. The archaeological surveys done in the Balearic Islands[6] demonstrate this unequivocally. Less well-developed research in the peninsula[7] tends also to point to a peasant responsibility for the construction and maintenance of hydraulic systems. But the problem of the great *huertas* has remained unstudied and unsolved. Glick, for example, in a recent synthesis (2007), expresses reservations as to whether the great size of the *huertas*, developed at an unspecified time, could, as well as the more modestly sized irrigated clan areas, be attributed to peasant origins. The contiguity of the *huertas* to cities figured large in these reservations. But recent field surveys have begun to reveal the nature of some of the *huertas*, showing that their initial formation was of a modest size and similarly associated with peasant clan organization (Barceló et al. 1997; Esquilache 2007; Glick and Kirchner 2000; Guinot 2005).

On the basis of past and current research on the irrigation systems of al-Andalus conducted by the Universitat Autònoma de Barcelona, amounting to just under 200 cases (Sitjes 2006), it can safely be said that they were conceived, created and managed by peasant groups without any significant state intervention whatsoever. Consequently the diffusion of eastern plants (Watson 1983) and the water technologies associated with them are best understood as a part of peasant knowledge, a technical transmission that took effect outside the Wittfogelian paradigm (Barceló 1998; Retamero in press).

This paper will deal mainly with the Balearic Islands, where intensive field surveys in different regions have achieved significant results (Fig. 1). The vast majority of tribal and clan groups that migrated to the Balearic Islands came from mainland al-Andalus and settled there after 'Isam al-Khawlâni established political dominion in the name of the Umayyad emirs of Cordoba in 902 AD. This was an islander society with a precise beginning, the Islamic conquest (902 AD), and a precise ending also, the latter determined

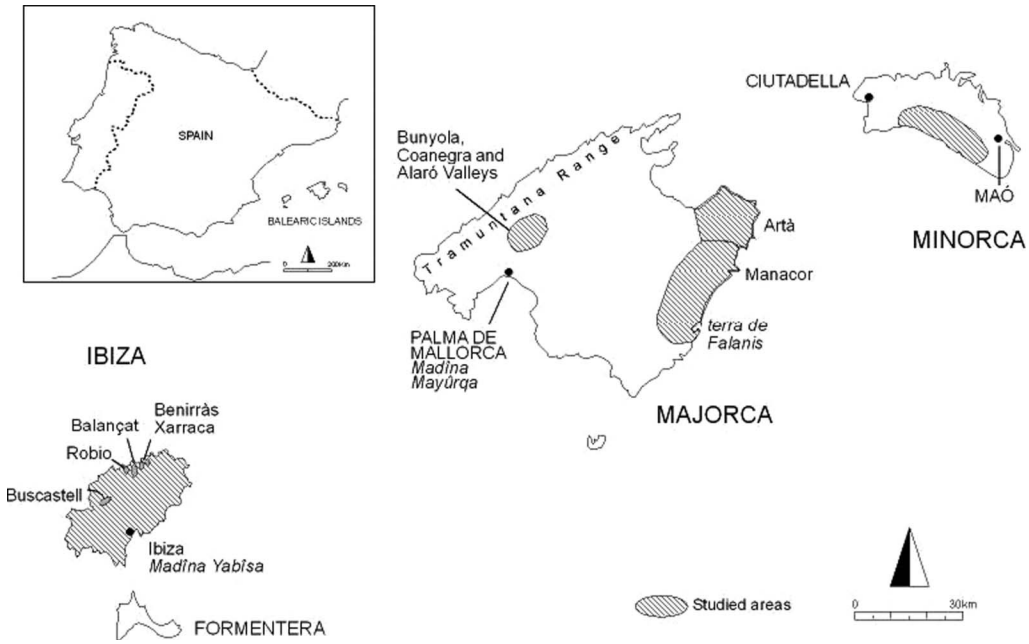


*Figure 1* The Balearic Islands and studied areas.

by the feudal conquests of the thirteenth century. The distribution of settlements and agricultural areas we find in the thirteenth century, at the time of the Catalan conquests (Majorca in 1129, Ibiza in 1235 and Minorca in 1287), enables us to reconstruct the basic features of the choices made by the earliest Andalusian immigrants. By around 940 AD, the main structure of peasant establishments seems to have been consolidated. The subsequent modifications of the forms of settlement neither masked nor significantly modified the initial choice (Barceló 2001).

In the north of Majorca, a series of three valleys on the southern slope of Majorca's northern mountains (Serra de Tramuntana) have been studied (Kirchner 1997). The logic of these initial settlements emerges clearly from the placing of irrigated fields. Up to thirty-one settlements were located, mainly along the primary and secondary streams, with a close relationship to the points where water was obtained for irrigation. It is a region where there are high chances of tapping aquifers by means of *qanâts*[8] in almost every stream-bed. So almost all settlements, most of them with clan and tribal place names, appear to be linked to irrigated areas.

A very similar situation is found in the south of the island of Minorca, where a series of gorges were colonized by clan groups who constructed irrigated areas on the flattest terrain available between the margins of the stream and the rocky cliffs that border it (Retamero 2000; Barceló and Retamero 2005).

The settlements on the island of Ibiza have been studied in their entirety, and it has been possible to draw a map reconstructing the process of migration and colonization of the island by different Berber and Arab clan groups. This research has brought to light the persistent relationship between Andalusian settlements and irrigated areas (Barceló 1997, 2001; Kirchner 1998, 2002).

However, there are regions where the scarcity of springs or any other aquifers made the hydraulic option difficult for the majority of groups. Not all of them had the opportunity to build hydraulic systems. For instance, in the recently studied area of the south east of Majorca (Sitjes 2008; see also Barceló and Kirchner 1995), or in the north of Minorca (Barceló and Retamero 2005), the larger part of peasant settlements are not linked to irrigated areas but to dry farming or to livestock husbandry. Both dry crop areas and pastures appear frequently around marshes.

In this paper I will try to show that size of the irrigated area mattered and that its modifications are key aspects for our understanding of the peasant management of the hydraulic systems of al-Andalus. This requires that we be clear what is meant by the 'original design' of the hydraulic systems (Barceló 1989). The original design is the planned articulation of the water source, the main and secondary distribution canals that permit the watering of all the plots, the construction of fields and, if present, tanks and water-mills (Fig. 2).

Any design of a hydraulic system requires a previous process of observation:

- to localize the aquifer or superficial water sources which can be channelled
- to identify slopes that will allow the circulation of water
- to estimate the volume of water available
- to evaluate the area that can be irrigated by the aforementioned volume of water and slopes, and to modify it in order to construct fields. Fields have to be built up because soil without any modification is not necessarily well adapted to cultivation and irrigation.

In Andalusian hydraulic systems it appears that 'maximizing' the ratio of the irrigated area to the volume of water was not an issue. The irrigated area, as originally designed, never exhausted the possibilities of the available water flow. This is a constant factor, observed in a large quantity of cases studied, mainly in the Balearic Islands (Barceló 1997; Barceló and Retamero 2005; Kirchner 1997, 1998; Retamero 2006), and it would tend to reinforce

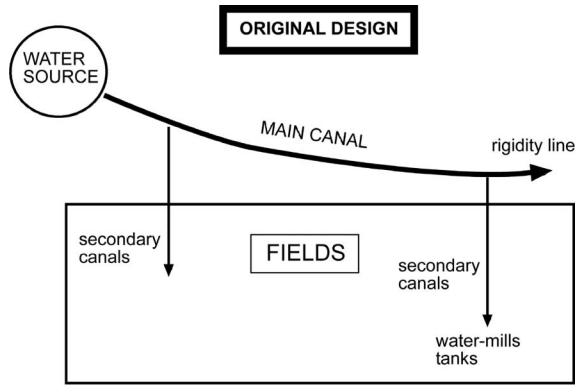


*Figure 2* The articulation of the water source, main canal and built fields: the original design of a hydraulic system.

the principle, put forth by Barceló, of the congruence between the size of the peasant settlements and the dimensions of the irrigated area, this being a result of precise estimates made by the founders of their own subsistence needs (Barceló 1995).

The original design thus sets constraints on the further demographic possibilities of development of the kin group. Retamero, in his field-work on Minorca, has formulated that strategy precisely as a 'solution to reduce risks', which implies the 'persistence of the initial patterns' as a factor governing the selection of places where small standard hydraulic systems could be constructed. In addition, this persistence proves the success of the initial option over successive generations (Retamero 2006: 307). This might be the main reason why there is no evidence of modifications or extensions of the irrigated areas until after the feudal conquest and, in fact, until the modern era (eighteenth and nineteenth centuries). In the feudal period, the modifications introduced to the small-sized hydraulic systems are mainly confined to changes in the procedures of social management of the system: in the new water distribution regulations, a clear primacy for water-mills is established over the irrigation of plots; new water-mills are built and orchard crops characteristic of Andalusian agriculture are substituted for cereal and vines, as if watering could no longer be regularly assured (Argemí et al. 1997; Barceló and Retamero 2005; Kirchner 1995, 1997).

No extensions of irrigated areas are documented immediately after the feudal conquest of the first third of the thirteenth century. Instead, for later periods, we can observe by plan reconstruction that abundant extensions and modifications had been made to the original Andalusian designs. These more recent changes have had clearly visible consequences for water distribution networks and for the morphology of the field systems. By means of written documents we can often determine the chronology of these modifications, most of them dating to the eighteenth and nineteenth centuries (Buscastell, Ibiza: Argemí et al. 1997; Majorca: Kirchner 1995, 1997, 2003; Minorca: Barceló and Retamero 2005) or even to the twentieth century (Balançat, Ibiza: Kirchner 2007). These modifications usually consist of extending the irrigated area by adding new plots to the original nucleus. In 1989, Barceló already noticed that the original design determined the directions of any further growth, which would depend on the volume of water and on slopes adequate to allow water movement to be managed. Thus, as Barceló claims, 'the enlargement will always be a perceptible addition to the initial structure' and, consequently, 'the correct identification and analysis of the structure of the original design makes it possible to establish the growing stages of a concrete system' (1989: 25).

## Enlargements of different types of irrigated areas

In archaeological terminology, the 'stratigraphy' of the irrigated area must be established in order to distinguish the phases of construction and the new sets of irrigable plots that have been added to the rigid limits of the original design. The identification of such changes is an unavoidable part of archaeological field-work: morphological analysis of field systems and water distribution networks must be checked against documentary references in order to discriminate between the original design and the later modifications.

There are basically four possibilities for enlarging an irrigated area:

1. Lengthening the main canal. This can be done if the gradient and the water flow allow the circulation of water further away. New plots are built under the new stretch of canal.
2. Making a secondary diversion canal off the main one, with the objective of watering a new area juxtaposed to the prior irrigated perimeter.

   In Buscastell (Ibiza), for example, the irrigated Andalusian area consisted of four parcels which were delimited by the stream meanders and closed off by a water-mill. The 2.47ha extension was shared by four Berber groups: the Banû Maymûn, the Banû Qarbûz, the Banû Farda and the Banû Hawwâra. Nowadays, after successive enlargements made between the eighteenth and twentieth centuries, the irrigable extension covers 12.09ha. All the additions are made from the same water catchment, diverting secondary canals from the main one or lengthening the main canal. To make up for the system failures caused by so many plot additions, it has been necessary to introduce large storage tanks, especially in the zones furthest away from the water source. These tanks permit the accumulation of several water allocations to ensure efficient succession of waterings (Argemí et al. 1997) (Fig. 3).
3. Adding new water sources, necessarily located higher up than the original catchment, thereby permitting the establishment of a new main canal above the former one. Tapping a new water source amounts, in fact, to the creation of a new hydraulic system neighbouring the old one and eventually connected to it. In case of connection, a new procedure of water allocation will be established in accordance with both the increase in the volume of water and the further extension of fields.

   The example of Guájar Faragüit (Granada) can well illustrate this type of enlargement. The original system is fed by a natural spring, situated in the middle of the slope. The water emerging from the spring is collected in a tank and distributed among the terraces from two main canals flowing in opposite directions. A new canal was built in the nineteenth century, tapping the Toba river water. The new canal passes above the spring, thus enveloping the Andalusian irrigated area within the more recent one. A secondary canal opened in the new main canal brings water to the ancient tank that can be filled up more rapidly than previously. In addition, the faster filling frequency of the tank has also permitted the lengthening of one of the original main canals and the building of new plots beside the existing terraces (Barceló et al. 1998) (Fig. 4).
4. Modifying the slope of a main canal, originally made of earth, making it more gentle and compensating for the resulting reduction in the velocity of flow by making the canal impermeable. Sometimes, the height of the catchment place is changed and located on a higher level. Both solutions imply raising the rigidity line of the system – that is the main original distributing canal that conditions all the subsequent network of flowing water – and adding a strip of irrigable land between the new and the old main canals. That sort of modification is not frequent, and forces the re-establishment of water circulation through plots even if the original part of the plots has not been altered. Changing the trajectory of the main canal,

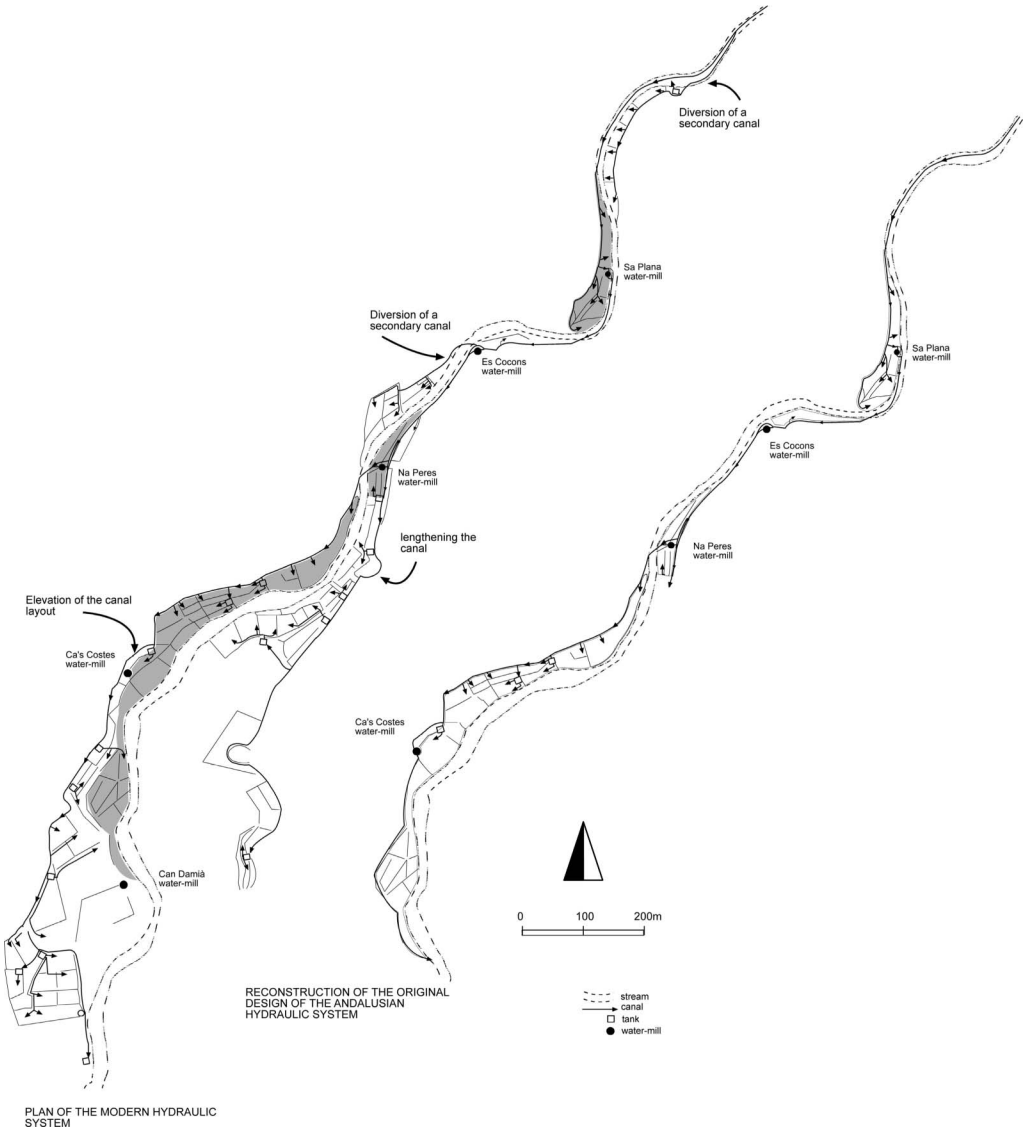


*Figure 3* The hydraulic system of Buscatell (Ibiza) (Argemí et al. 1997).

and building new plots immediately above, means that the original plots, which used to have direct access to the main canal, will be watered from secondary canals. This is why the main difficulty lies with the possibility of users not accepting the modification. So it is not strange that this type of modification, when it has been found, has always been of very recent, twentieth-century, date.

In Balançat (Ibiza) (Kirchner 2007), for instance, a well was sunk in the stream where water had traditionally been diverted from many springs. The slope of the main canal was modified giving it a gentler gradient. Some new rectangular plots were constructed with cement walls above the original main canal, and 0.89ha of irrigable land were added. The ancient main canal can be recognized in today's

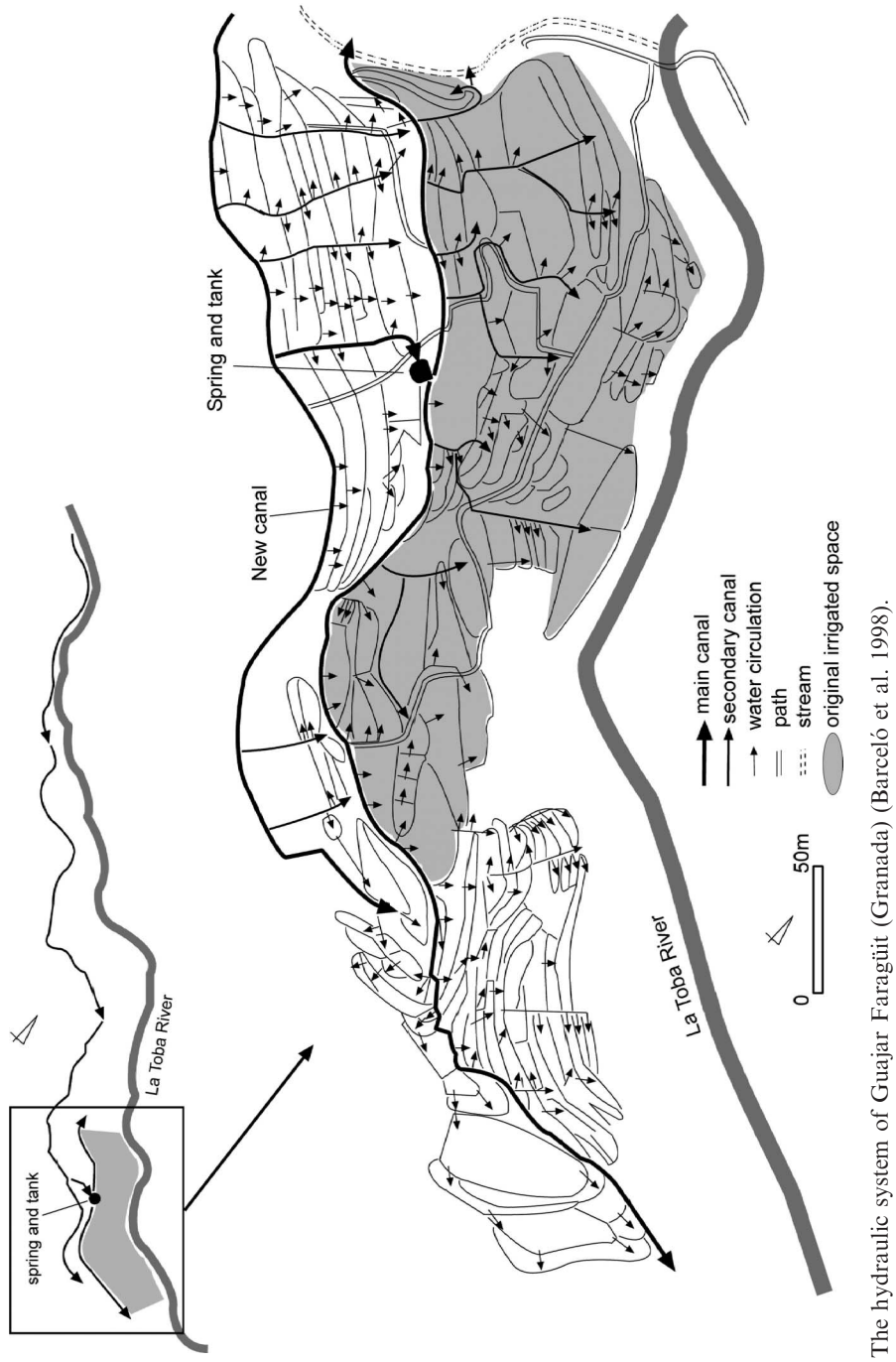


*Figure 4* The hydraulic system of Guajar Faragüit (Granada) (Barceló et al. 1998).

secondary canal, which has its origin in a point in the middle of the main canal layout and flows immediately below the ancient St. Miquel de Balançat pathway. From this ancient main canal another secondary canal starts which feeds three water-mills. The terraced fields located below this ancient main canal – now secondary canal – are well distinguished because they are adapted to the relief, built in dry stone walls and are of small sizes. Some of these terraces have been destroyed recently in order to build up more extensive plots that are superimposed on the ancient ones. The original system used to have an extension of 3.61ha. The area irrigated from the canal on the right side of the valley is also an addition, created simultaneously with the sinking of the well and the modification of the main canal (Fig. 5).

On the basis of the hydraulic survey and the resulting map, it is possible to establish the relative chronology of successive phases of construction. Analysis of aerial photographs reveals only the limits of the irrigated area and the field morphology, and is insufficient to reconstruct either the original design or the formation sequence of a hydraulic system. All

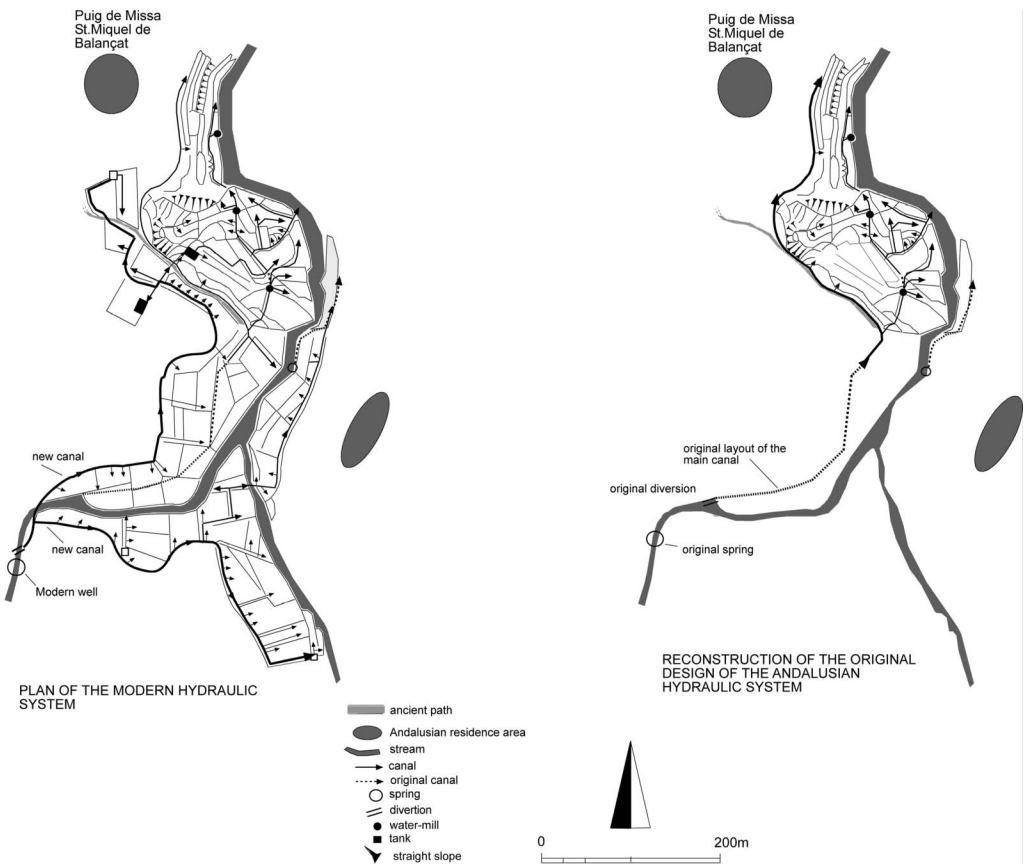


*Figure 5* The hydraulic system of Balançat (Ibiza) (Kirchner 2007).

hydraulic appurtenances must be identified and connected through field survey and meticulous mapping to understand fully any irrigated system.

Full remodelling of the irrigated area is a type of radical modification that merits particular attention. For that to happen, a whole new design has to be created. This is why it would be erroneous to think that the stability of the hydraulic systems, first noticed by Glick (1992) and repeatedly proved (Barceló 1989: 27–8, 1996: 29–31), means that they are indestructible or immutable. The stability of design is, precisely, the other side of an extreme fragility: any partial modification of its structure has serious repercussions on its physical layout and on the water allocation procedures. Modifications that involve the reorganization of water allocation can severely impair the efficiency of the system and will be rejected by users.



## How did the Andalusian peasant communities enlarge the irrigated area?

Since the vast majority of hydraulic system enlargements were made in recent times, except for a few dated in the later Middle Ages, we can raise the question of how Andalusian peasants solved the need to increase their own irrigated area. If there were available aquifers, either on the surface or by tapping them, new hydraulic systems could be constructed. All the known evidence suggests that the irrigated areas were kept at a size that never exhausted the volume of water of the initial source. Consequently, the construction of complementary crop areas should be understood as a response to an increase in the size of the peasant group. Kin segmentation, properly described first in the society of al-Andalus by Guichard (1976), could plausibly be viewed as an expedient to do away with increasing population. Given the stability of the irrigation layouts, and the intensive character of the agricultural work involved, which also concerned small units, excess population will tend to move out. That form of kin-based division was observed in al-Andalus by Barceló (1989), who suggested a connection with the rigidity of irrigated areas. Thus the fraction of the group moving will carry away the kin name and fix it to the new settlement. In the Balearic Islands these segmentations were of a short-distance character (Barceló 1995).

The problem lies in determining whether short-distance segmentations, like those effected by the Banû Aǧǧer in the adjacent valleys of Bunyola and Coanegra in Majorca by means of three settlements (Beniatzar, Beniatdars, Beniacar), took place during the period of migration and colonization in the tenth century or whether, starting from one initial settlement in the island, they later founded the other two. No matter which of these two possibilities is correct, the Banû Aǧǧer built irrigated areas that were congruent with the size of the group and this estimation included the strategy of not exhausting the water flow available in each hydraulic system. The objectives were not to damage the efficiency of the hydraulic systems and to reinforce the social continuity of the group (Kirchner 1998).[9]

Alongside numerous clear cases where clans split, becoming discontinuous in space while reduplicating the name, there is a distinct phenomenon of enlarging the working areas of the group out of the initial irrigated spaces that has, until now, not been well understood. In the rich collection of documents, mostly notarial, written after the Catalan conquest of the islands (Majorca 1229, Ibiza 1235, Minorca 1287), constant use is made of

the terms '*alqueria*' and '*rafal*', alluding to Andalusian agrarian units. In the wide continental region of Valencia (conquered after 1230) the same terminology occurs. Guichard (1990–1) considered *alqueria* (from the Arabic *qarya*) as a peasant settlement which clan or tribal name reveals to be part of a wider social organization based on kin solidarity. *Rafal* (from the Arabic *rahl*) referred rather to a type of farm belonging to individuals, preferably located in the rural area around a city.

In my opinion, Guichard's definition of *alqueria* is too narrow as it accounts only for the residential aspect of the peasant settlement. The archaeological surveys in the islands suggest that the notion of *alqueria* included a specific territorial dimension claimed by the kin group. The evidence gathered is unequivocal. For instance, in the 'terra de Falanis' ('the land of Falanis' or Banû Furânik's territory in the south east of Majorca), according to post-Catalan conquest documentation, forty-eight groups were settled, fourteen of which had clan or tribal names (Barceló and Kirchner 1995). *Alqueria* was more than a rural dwelling. It was a politically controlled territory, eventually shared with other groups, sometimes with well-defined boundaries. Besides intensive farming in the irrigated fields, hunting, gathering and domestic pastures activities were developed in it. It is in the social frame of *alquerias* that *rafal* appears in the earliest Catalan documentation: '*alqueria cum suo rafallo*' was a common expression used in the texts.

Research in the valleys of Serra de Tramuntana in Majorca (Kirchner 1997), in Felanitx, in Majorca (Barceló and Kirchner 1995), and in the island of Ibiza (Kirchner 2002) proves that the frequent association between *alqueria* and *rafal* was not a colonizer's invention but, on the contrary, a relic of the Andalusian agrarian settlement. Good examples of *rahals* associated with an *alqueria* are: the *rahal* Margi, pertaining to the Beniforani *alqueria* (Banû Furânik), the *rahal* Montueri, pertaining to Beniadars *alqueria* (Banû Ağğer) (both located in the valley of Bunyola, Majorca); the *rahal* Cuchar, pertaining to Padrina, the *rahal* Naya, in the *alqueria* of Benizoracha (both inside the territory of the Banû Furânik or *Terra de Falanis*, Felanitx, Majorca); in Ibiza, the *rahals* of Cutella and Beniagost were included in the limits of the Beniçalona *alqueria*'s territory. This documentary association has been substantiated by meticulous field surveys. The *rafals* studied were always located inside the limits of the *alqueria's* territory or immediately nearby.

At this point I shall briefly comment on the word *rafal*. While the meaning of the Arabic *qarya* as village has been readily accepted for historians and archaeologists working on al-Andalus, the sense of *rafal* has generally eluded discussion. In Andalusian Arabic *r.ḥ.l* conveys a sense of departing, of moving out (Corriente 1997: 204), and as a noun signifies 'relay', 'ranch' and eventually 'village' as well. The word, then, clearly refers to an outpost, an offshoot of a settlement. I suggest that we should think of *rafals* as working areas complementary to *alquerias*. Catalan notaries tended in some instances to cause confuse through their punctiliousness in registering conquered lands. An extreme case concerns the mention of an '*alqueria* Rafalgar'. By the time of this mention Rafal al-Gar had already become a place name and so promoted to the rank of *alqueria* by a notary (Barceló and Kirchner 1995). Evidently both notaries and their clients might blur initial distinctions between the two rural entities. One factor contributing to the confusion was that in some cases *rafals* had become stable settlements, analogous to early Andalusian *alquerias* before the Catalan conquest.

An example of this sort is Rafal Cauhas, with an irrigated area of 1ha, located near the Coanegra valley (Majorca), where four kin groups built and shared a hydraulic system of 7.23ha. Probably the irrigated area of Cauhas was built by one of those groups initially settled in Coanegra valley. When Rafal Cauhas was registered by Catalan notaries, it was already considered as an independent *alqueria* (Kirchner 1997) (Fig. 6). But most of the cases of *rafals* studied were dry areas of agriculture or cattle relays as outposts of bigger settlements. How far this process of *alqueria* formation had gone by the time of the Catalan conquest is not clear for want of any study to ascertain it. But on the existing archaeological surveys it can be suggested that *rafal* settlements were a way of coping with possible population pressures.

I want finally to consider the well-recorded case of several irrigated areas within the same *alqueria* land. In the north of the island of Ibiza three *alquerias* with clan names, Robio (unidentified), Benirràs (Banû Rasn) and Xarraca (Banû Zurâg), and well-delimited territories each contained multiple hydraulic systems and diverse dwelling places. The abundance of springs made possible this local extension. The names of these particular kin segments went unrecorded by the Catalan notaries. Only the clan names have left written and oral trace up to the present (Kirchner 1998) (Fig. 7).

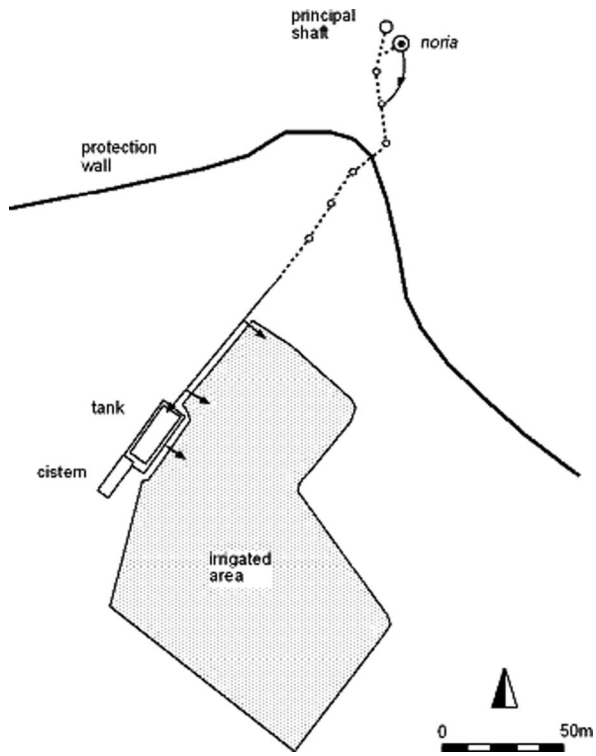


*Figure 6* The hydraulic system of Rafal Cauhas (Coanegra, Santa Maria del Camí, Majorca) (Kirchner 1997).

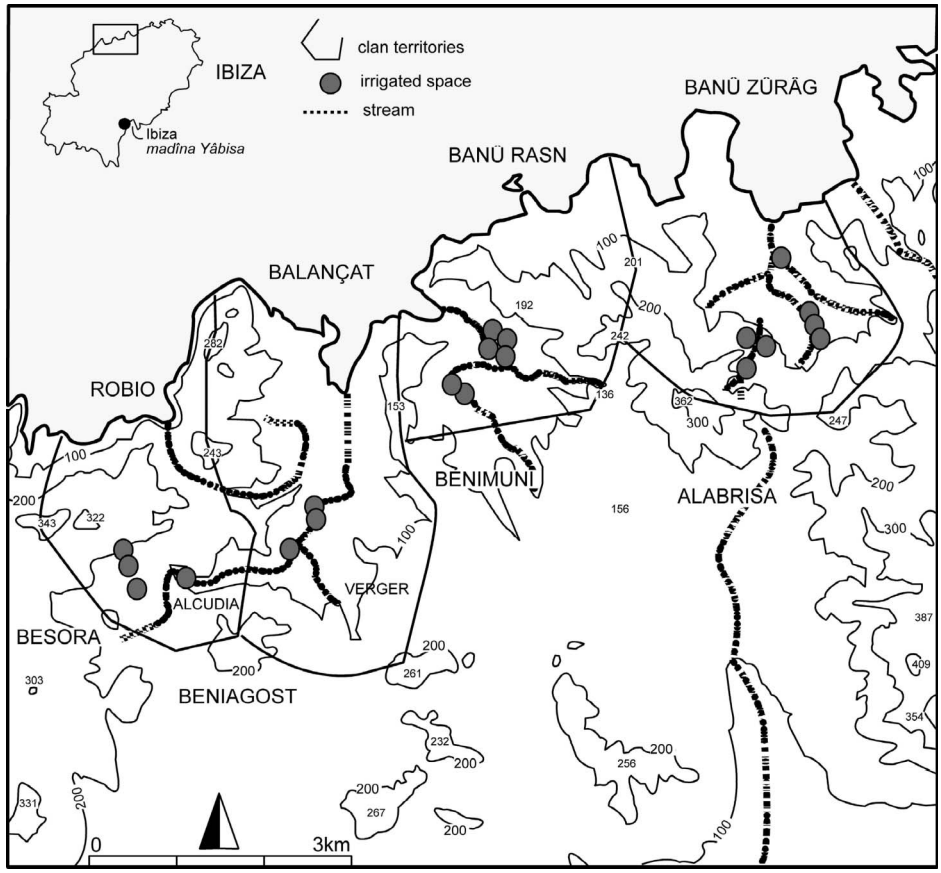


*Figure 7* The clan territories of the north of Ibiza (Kirchner 1998).

## Concluding remarks

From 902 AD onwards, following a formal political domination of the Balearic Islands by 'Isam al-Khawlânî representing the Umayad amir in Cordoba, a process of migration of Andalusian settlers unfolded. Coming mostly from the peninsula, these peasants were organized as Arab and Berber clans and, as far as can be ascertained, their settlement and spatial distribution were determined by immediate local factors, such clan alliances, dimension of groups, order of arrival. No state intervention has been ever discerned (Barceló 2001).

By means of extensive archaeological surveys, and especially by the study of hydraulic systems, maps of *alqueria* networks in many regions of the Balearic Islands have been produced.[10] They clearly show how irrigated areas were the basic building blocks of rural society and how *alquerias* formed groupings. This clustering indicates that interrelating was a primary concern of the migrant peasants. Maps also offer a detailed spatial representation of the selective nature of settlements. Migrants seem not to have had to compete initially for land position.

The choice of settlement was made possible by an integrated knowledge of physically managing water supply and institutionally arranging water allocation (Glick 1992). Once completed, this choice of settlement, as revealed by the maps recording the last Andalusian layer just after the Catalan conquest, conditioned all other possible alternatives to intensive agriculture. Dry farming or domestic herding areas would ring around the irrigated areas, being clearly a second-best settlement choice.

Only common, shared, water technology will explain the homogeneity in structure and size of the irrigated areas. The patterns of their structures have been discerned sufficiently as to make possible a typological classification (Glick and Kirchner 2000). The mean size, in a sample of more than 160 hydraulic systems (Sitjes 2006), has been found to be less than 1ha. That might seem small, but it was so frequent that it should also be considered to have been as big as was necessary.

What the maps do not show is how the settlement distribution evolved, in what phases, and, more significantly, at what point the hydraulic possibilities of settlement were all used up. If, for example, the initial Andalusian migrations were thick enough to produce an extensive distribution, later evolutions would have been lower in number and sluggish, given the stable quality of the irrigated spaces and the limited nature of water sources, be they surface or underground aquifers. Any further development of settlement will have been severely conditioned by the initial pattern. Similarly, no Andalusian deserted settlement has ever been recorded in archaeological surveys before the Catalan conquest.

I have examined the possibilities of *rafal* development as a limited way to increase agricultural production. I have also observed that hydraulic networks were so constructed as never to push the water supply to its limits. That precautionary approach has been also found by Retamero (2006: 307) in his study of Andalusian rural settlements in the gorges of the south of the island of Minorca. Peasants there had found ways 'of restricting eventual growth of the cultivated areas' as a means of controlling their own population increase. In the semi-arid conditions of the islands those were meaningful ways of preventing risk. It seems that the only principle governing the clustered settlements was that of efficient local control over hydraulic systems, as expounded by the geographer Maass (Anderson and Maass 1978: 368). Until the early thirteenth century, the Andalusian peasants succeeded in preventing their settlements from courting risks. But they were unable to foresee or prevent sea-borne feudal armies and Catalan conquerors coming to stay.

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## Notes

1 Al-Andalus was the proper name of what currently is alluded to as Muslim Spain. I will use 'Andalusian' as the adjective of al-Andalus and not of modern Andalucía.
2 The method has been also tested for Catalan feudal society (Batet 2006; Kirchner 1995, 2006; Kirchner et al. 2002) and for pre-Islamic Yemen (Barceló 2003, 2004; Barceló and Torró 2003; Barceló et al. 2000).
3 Diverse morphological types of irrigated field systems have been described: valley-floor systems occupying the flattest terrain available between the margins of a stream or

gully and the valley slopes, and slope systems built on valley slopes by terracing. Both types have several subtypes depending on the location of water source: in the gully bed or on the middle of the slope (Glick and Kirchner 2000; Kirchner 1997, 1998, 2008).

4 See also Glick (1995, 1996).

5 Historians and archaeologists of al-Andalus have also observed the existence of tight links between peasant settlements and hydraulic systems active up to the present (Bazzana and Guichard 1981).

6 Argemí (1998, 1999), Argemí et al. (1997), Barceló and Kirchner (1995), Barceló and Retamero (2005), Barceló et al. (1997, 1998), Kirchner (1997, 1998, 2007) and Sitjes (2006, 2008).

7 Bazzana (1993), Cressier (1989, 1995), Martín-Civantos (2007), Navarro (1995), Piera (1998), Selma (1991, 1993), Teixeira (1995), Torró (1998, 2007) and Vea (1995).

8 *Qanât* is an oriental technique of tapping underground aquifers by means of a horizontal gallery that brings water to the surface. For Balearic Islands, see Barceló et al. (1986).

9 Retamero (2006) has gone further by saying that peasant groups took the decision to keep themselves between narrow margins of demographic growth as a way of avoiding risk.

10 Argemí (1998, 1999), Barceló and Retamero (2005), Barceló and Kirchner (1995), Kirchner (1997, 2002) and Sitjes (2008).

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