

## **THE "CAREOS" FROM ALPUJARRA (GRANADA, SPAIN), A HISTORICAL EXAMPLE OF ARTIFICIAL RECHARGE PREVIOUS TO XIII CENTURY APPLICABLE TO THE XXI CENTURY. CHARACTERIZATION AND INVENTORY.**

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### **Abstract**

The "*careos*" system canals constitute one of the first devices for artificial recharge of aquifers of the Iberian Peninsula. Operative from the Muslim period, they present a construction system and distribution still operative at the present what constitutes an example to keep in mind on groundwater management. This paper present a bibliographical recompilation of their origin, construction and operation. We had upgraded the inventory on the field and finally present practical recommendations in order to the design and management of systems of superficial artificial recharge of aquifer. This paper arise from the pH Thesis of the first author.

### **keywords**

*Careos* canals, artificial recharge of aquifers, Alpujarra, Sierra Nevada, Granada.

## **INTRODUCTION**

The "*careos*" canals, traditionally dug in soils or rock, are used like a technique for artificial recharge of aquifers in the Alpujarra area, mainly by mean of waters of thaw of Sierra Nevada range. Although their origin goes back, at least a year 1139 (*Espinar, 1988*), its most extensive employment was reached in the last centuries of the Muslim time, XIII to XV centuries, when it was developed an intricate canalisation system for the maximum use of the water (*Díaz Marta, 1989*).

In the year 2000 the Autonomous Organism of National Parks, National Park of Sierra Nevada, carried out an inventory and reconstruction of *careos* canals, work executed by the Company of Agrarian Transformation (TRAGSA) of Granada. The performances of repair of the inventoried canals are in the address that marks the National Park, like one of their key objectives of management in the administration of the patrimony of canals (*Cano-Manuel and Grupo Tragsa, 2000; González Ayestarán, 2000*).

Their recovery and maintenance has demonstrated that they help to maintain a vegetation of great interest, they serve for support to a particular fauna and collaborate from a very important way to regulate the hydrological cycle of the region, conditioning a future line of unavoidable performances to be envisaged by the agents of the National Park.

## OBJECTIVES

This article, offers an inventory of the net of the *careos* canals of the Alpujarra. The constructive and administration approaches of the *careos* give ideas to the management of current systems and devices of artificial recharge of aquifer, carried out at the present time in similar scenarios. The study area, it has been limited to the canals located in the south hillside of Sierra Nevada National Park. The following works have been carried out:

- Inventory of the current situation of the net of *careos* canals.
- Inventory of Communities Users that use this system.
- Study of the geology to know the permeability of the materials and the effectiveness of the *careos*.
- Determination of the type of materials and the used techniques, for their reconstruction and maintenance.

## INVENTORY

According to the inventory of the year 2000 (*in Cano-Manuel and Group Tragsa, 2000*), the *careos* canals are more frequent and more important in East side of Sierra Nevada, area where the smallest altitudes in the mountain range are located, and therefore, smaller precipitation are registered and consequently, the necessity of regulation of the water is bigger. According to the function that they carry out, we find two types of canals:

- *Careo* canals: They facilitate the infiltration of the water. For it, the water of the rivers and streams, is diverted by these canals during the winter and the spring, to the flat areas where it finally infiltrate (*Figure 1*). Each canal has its area of recharge called *simas* or *cimas*.

-Irrigation canals: They transport the water, generally from the streams to terraces lands (*Navarro Pérez, 1983*). In these canals the infiltration also has great importance.

From the Muslim period up to the present the "*acequero*" remains yet like the person in charge of the *careos* administration and the only authorised to control the floodgates (*Al- Mudayna, 1991 and Vidal, 1995*).

They have been classified and defined a total of 23 *careos* canals from 127 inventoried (Table 1). Their position is located in figure 3.

Name	Diverted river	Community Users	Observations
Del Espino	Chico de Bérchules	YES	Well conserved
Bérchules	Trevélez	YES	Almost abandoned
Mecina	Grande de Bérchules	YES	Well conserved Urban water supply

De la Mogea	Nechite	YES	Well conserved
Del Horcajo	Mecina	YES	Well conserved
Yegen	Mecina	YES	Sealed by concrete Irrigation and <i>careo</i>
De los Vadillos	Valor	YES	Well conserved
Del Monte	Valor	YES	Well conserved. Irrigation and <i>careo</i>
De la Loma	Valor	YES	Well conserved. Earth
De la Fuente del Espino	Nechite	YES	Well conserved
Del Boy	Laroles	YES	Well conserved Concrete and earth
Nueva de Bayarcal	Bayarcal	YES	Very well conserved
De las Hoyas	Andarax	YES	Well conserved Small <i>careo</i> made by earth
Del Pecho	Andarax	YES	Well conserved. Small <i>careo</i> made by earth
Del Maguillo	Río del Pueblo	YES	Well conserved. Close the line, there is a pathway
Del Prado Llano	Río del Pueblo	YES	Well conserved
Del Prado Largo	Río del Pueblo	YES	Well conserved
De <i>careo</i> de Beires	Andarax y Ohanes	NO	Fair conserved. Stability problems
Del Garbanzal	Ohanes	NO	Fair conserved
Del Canal	Ohanes	NO	Well conserved. Partly it takes advantage of an old channel of hydropower station.
De Tices	Ohanes	YES	Whit careless
Del Corazón	Alhorí	YES	Abandoned recently.
Del Jaral	Alhorí	YES	Well conserved

Table 1. Inventory of “*careos*”.

The *careos* canals considered more important for their size and preservation degree are:

- Canals of Mecina-Bombarón. It has a system of canals very well developed. The canal of Mecina is the biggest canal of Sierra Nevada. It has 20 simas where the water is distributed (Cara, 1989; Ben Sbih and Pulido-Bosch, 1996).
- Canals of Trévez. Good conservation state (Delaigue, 1995) and with scarce presence of “new materials” employees in maintenance works.
- Canals of Bérchules. It has big irrigation canals and two *careos*.
- Canals of Valor. The Users Community negotiates three *careos* canals: canals of the Vadillos, La Loma y El Monte. These *careos* are used for the urban supply.

One overlapping GIS between the *careo* nets and the geologic map has been carried out in order to study their effectiveness, also adding other geographical coverings. The study reveals that there is a general tendency to build *careos* from fluvial beds to: 1) limestone outcrops, with simas and ponors; 2) metamorphic areas with weathering zone superficial zone, where the regolit acquires aquifer potentiality (Castillo et al, 1996) and 3) quaternary detrital aquifer of diverse typology (piedmont, etc.), under which carbonated or metamorphic formations of low permeability underlie (in general phyllites, schists and calc-schists).

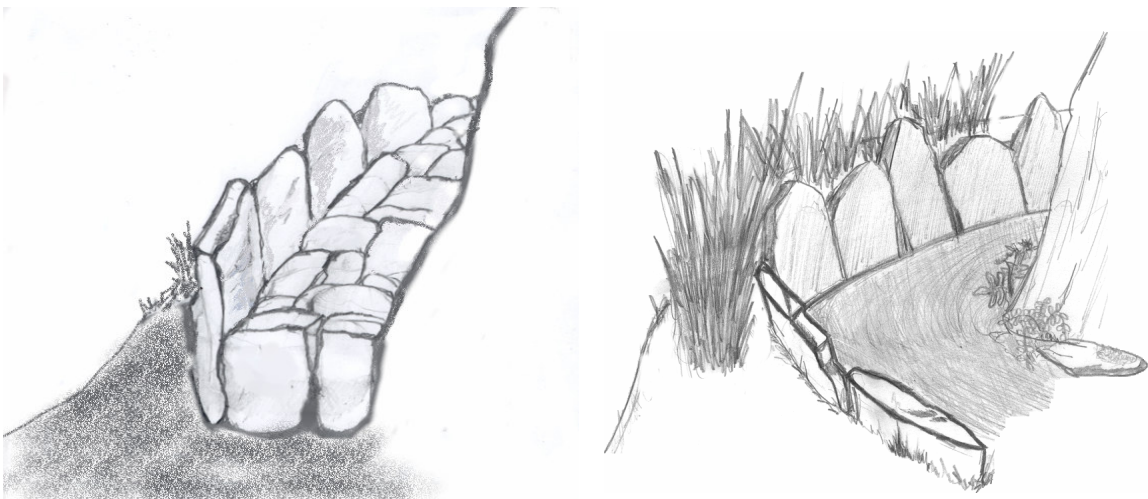


Figures 1 a) and b). Examples of careo's morphology. Lanjarón and Mecina sites.

## MAINTENANCE AND RECOVERY

In general, the *careos* require an important maintenance. They are usually affected by diverse problems: hillside movements, fall of solids that cut or break the conduits, rill erosion, bad lands, etc. The most important recovery tasks that they carrying out are the following ones:

- Excavation of the bottom of the channel and rebuilt by buried stones (*Ayuso et al., 1986, Rodríguez de Velasco, 1993 and Medina, 1996*), (Figure 2 a) and protection of the borders of the channel with flagstones (Figure 2 b).



Figures 2 a) and b). Drawings of hydraulic masonry (for courtesy of Cano Manuel and Group Tragsa of Granada). A). Structure of the channel protected by stones buried in tracts of great slope and subject to a strong erosion B). Flagstones protecting the external border of the channel.

- Enlarge of the channel in specific points and amplification of the longitude of the canal increasing this way the infiltration surface and construction of earth channel, by means of the opening of ditches, in order to improve the artificial recharge of the aquifer for direct infiltration in device type grave.
- Homogenisation of the slope to avoid damming in not wanted areas and construction of masonry aqueduct in the points where the canals cross ravines in those that lose great quantity of water.

## CONCLUSIONS

- The *careos* canals, constitute a specific system of artificial recharge of aquifer. Of the 127 inventoried canals, 23 are *careos*. The most important are those of Trevélez, and Bérchules, Mecina-Bombarón and Valor. These arise from the XII-XIII centuries.
- They have a joint administration with a person in charge "the acequero" who is responsible for the floodgates. In general, the Communities of Users, main protectors of the system of canals, have scarce resources for their maintenance, so a part of the conservation expense is supported by the National Park.
- In the study area, the best favourable geologic materials for the artificial recharge by mean of *careos* are the limestone and formations permeable detrital formations in crop areas. The topography is a strong condition of the design and layout of the canals.
- It would be important to preserve and to maintain these systems of *careos*, given their high historical and environmental value, appealing if it is necessary to the externalities of the expenses in concept of environmental costs.

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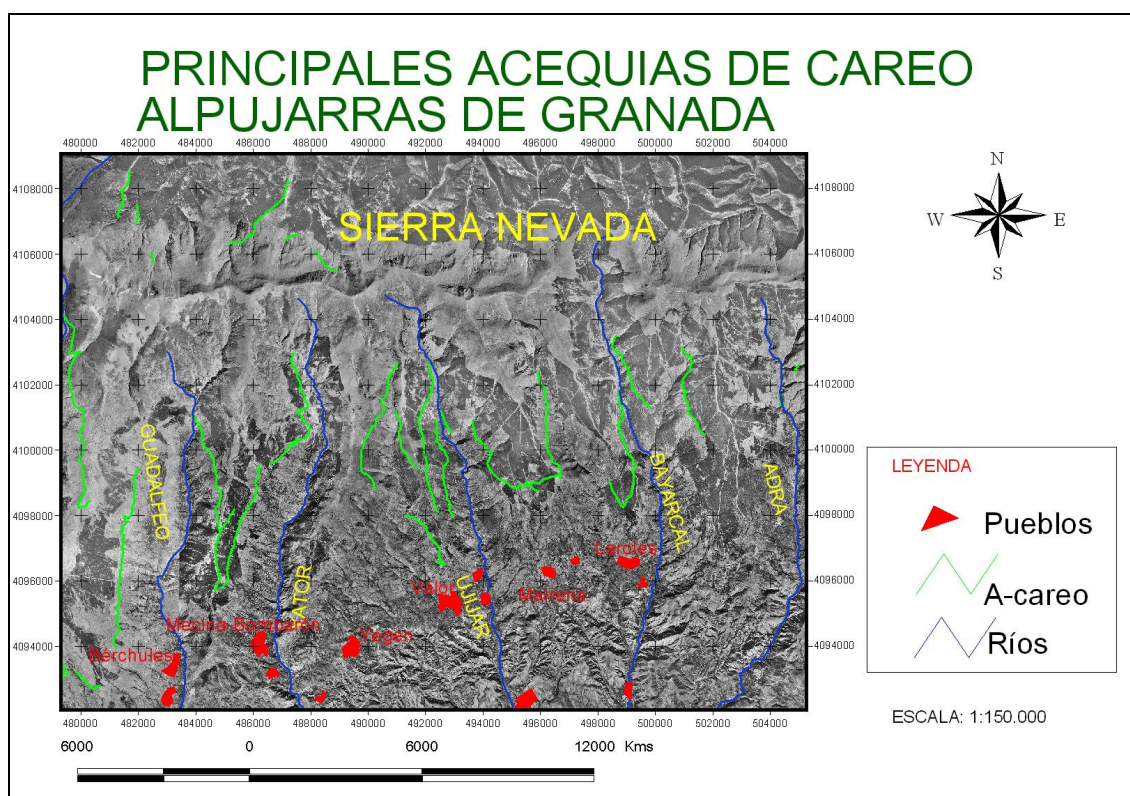


Figure 3. Inventory of “careos” map