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# Dry stone structures and Penedès geology. A pilot study

## Abstract

Dry stone constructions have traditionally been made only from geographically close materials. Usually, farmers and shepherds used stones in the soil of their farmlands, where they were useless, to build new useful structures directly related to their productive activities.

Different types of stones allowed a wide variety of constructions. Furthermore, due to their origin related to economical activities, the presence of each kind of construction depends on the needs of the local people. So, these are the reasons why, regarding shape and utility, in each town is possible to find different dry stone buildings.

We hypothesized that there could be a clear relation between the information from types of stones in geological maps of a region and the dry stone constructions present in that region, so we could make a first prediction of the possible dry stone constructions in a town before looking them in the field, using geological maps.

In this paper, we confirm this hypothesis in the case of the Catalan region of Penedès, in Spain.

**Keywords:** dry stone, dry-stone construction, penedès, geological map, hut, limekiln, cistern, well

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## Introduction

### Dry stone: diversity of constructions

Dry stone constructions are characterized to be made only of stones which are encased and carved without any kind of mortar binding them[1] Traditionally, dry stone structures were erected using stones in the soil of the farmlands that made difficult the cultivation.[2] Thus, as well as removing an unnecessary element, these stones can be used to develop structures in the place, either to parcelling or to building cultivation terraces, especially in sloped areas to avoid the loss of the soil and increase the crop surface.[3]

Other dry stone structures were also built to improve productivity with these "surplus" stones, such as huts, wells, cisterns, or limekilns.[2,3] In the case of dry stone huts, they were made to give a shelter to the farmers and the draft animals along their working day. It can be used as an accommodation to rest at the most insolation hours, a place to make a meal, or a refuge when it was cold or raining. Wells and cisterns were made to stock up on water to have this resource when needed.[3]

Dry stone constructions were not used only in a relatively private sphere, but there are also communal dry stone infrastructures as stone pavement roads. These kinds of roads were useful to increase the efficiency of goods transports and people movements, and they also reduced the risk of accidents, especially when raining. Finally, there are some dry stone constructions for industrial or proto-industrial purposes, such as lime kilns or juniper kilns.[3]

This diversity of dry stone constructions is closely related, on the one hand, to the nature of the territory,[4] and on the other, to the management needs of the people who inhabit it. Thus, in the case of the Penedès region, it is observed that each type of construction is not homogeneously distributed throughout the territory, but this distribution is intimately linked to the existing geology. The presence or absence of constructions such as limekilns or cisterns is highly conditioned by the availability of certain types of rock, but even in the case of huts and dry stone walls, it is observed a variable presence in different territorial areas.

This relationship between dry stone structures and the geology also determines the technique dry stone builders use in each place, and thus, differences in morphology of the structures can be observed. In the Penedès, maybe the most obvious case of that is in dry stone huts, quite diverse along the region (Figure 1). This situation was also observed by Powell et al.[5] and Feroldi et al.,[6]


**Figure 1** Sub regions and geographical features in Penedès. Authors: Guillén-Villar, Abraham; Traver-Vives, Montserrat.

## Material and methods

### Origin of the data

To carry out this analysis, we used a public database called Wikipedra (http://wikipedra.catpaisatge.net/#0), where available an inventory of dry stone constructions in Catalonia and south of France. Concretely, there is available detailed information about dry stone huts, limekilns, dry stone wells and cisterns and some references to significant stonewalls and other constructions. Wikipedra is a communal project, open to citizen participation, leaded by the

Observatori del Paisatge (an office of Catalan Administration) and a cultural association called El Drac Verd. We restricted the observation only to Penedès region.

We also used geological maps of Penedès available on the website of Institut Cartogràfic i Geològic de Catalunya, ICGC (https://www.icgc.cat/en/). It is the Administration office for the study of local Cartography and Geology. In these maps we found the geological composition about the substrate in each sub region, which give us information about the nature of the available stones in the locality.

### Subregions

Penedès, sited in Catalonia, Spain, is an area composed of 3 whole regions (*comarcas*, in Spanish Administration distribution) called Alt Penedès, Baix Penedès and Garraf, and the meridional part of other *comarca* called Anoia. Its total extension is about 1745 $Km^2$,[7] and its location is 41° 17′ 36″ N, 1° 44′ 58″ E. Penedès borders with Mediterranean Sea in the South-East, and there are some geographic features, as mountain ranges, a plain and water courses inside.

However, to a better understanding of geological data, we have defined 4 Penedès subregions based on geographic features:

1) North Serrelada Prelitoral – Inland mountain ranges, at the North of the site.
2) South Serrelada Prelitoral – Inland mountain ranges, at the South of the site.
3) South Serrelada Litoral – Coastal mountain ranges, at the South of the site.
4) Plana del Penedès – Plain sited between inland and coastal ranges, with access to the sea.

## Methods

To do this pilot study, we superposed the information of types and frequency of constructions in each defined subregion, collected from Wikipedra, with the information about geological substratum from geological maps from the area.

We obtained data about number of dry stone huts, limekilns and dry stone wells and cisterns in all Penedès, and its location. After this, we looked at the geological maps the composition of the substrate in each location to know if a relation between types of buildings and geological materials happened.

This pilot study is not intended to be exhaustive, but rather a first approach in order to find out the possibilities for more precise research, on the ground and using statistical analysis, to determine more exactly the relations between the geology of each location and the presence or absence of each kind of dry stone constructions.

## Results

### Dry stone huts

Most part of Penedès dry stone huts listed on the Wikipedra were in areas with marls and marly limestone (Tk) substrates, limestones and dolomites with intercalations of marls (Tm) substrates and aragonites or conglomerates with uncemented clayey matrix (NMca) substrates. These materials are mainly found in the Serralada Prelitoral. Precisely, the towns that rest on rich conglomerate land are those that have a higher density of huts, such as Sant Quintí de Mediona (Alt Penedès) and la Bisbal del Penedès (Baix Penedès).

The geologic substrate in the North of the Serralada Prelitoral, towards the Anoia area, is different from that found in the South. The huts in this subregion are found in those places with sandy marls (PEmg), biomicritic limestones (PEc) and clays and sandstones with some chalks (PEag) substrates. These huts, moreover, are morphologically different. They are built mainly with marls and sandstones, and these materials allow to get morphological regular stones, with the shape of bricks. Other aesthetic difference in these constructions is the usual presence of protection structures to rain, called *voladis.*

In the Serralada Litoral, there is a significant presence of huts in the areas with marls with limestone intercalations substrates, and reef calcarenites, biomicrites and biorudites (NMm or NMe) substrates as seen in the south of the towns of Els Monjos or Sant Miquel d'Olèrdola, respectively. These materials are characterized by being rich in calcium and containing magnesium, elements that make them more resistant to compression, and thus useful for building dry stone constructions.

Large stones are also common in this territory, and this kind of rocks made agricultural work very difficult in the past. On the one hand, it could be easy the plough dragged by a mule hit some stone and the blade to be damaged, and, on the other hand, the presence of large stones could complicate other agricultural tasks such as pruning or harvesting the fruits. The abundance of rocks in the soil also hinders crop yields, as plant roots have greater difficulty growing. For all these reasons it was important removing them.

In those areas where the substrate is sedimentary (Qv), such as in the Penedès plain, there are not stones in the soil, and, if there were, they are not usually useful for making dry stone constructions due to their fragility and low resistance. In these places people chose to make large terraces without holding them with dry stones walls, because as the terraces have a low slope this subjection is not necessary. There are not huts due to the absence of stones, and, in this case, if any refuge construction was needed, it was solved building vineyard houses or hay lofts, as in Vilafranca del Penedès, Sant Sadurní d'Anoia (Alt Penedès) or El Vendrell (Baix Penedès), among others. There are not huts in the northeast of the Penedès region, where predominate sedimentary and alluvial substrates.

### Limekilns

In Penedès region, limekilns are found mainly in the Serrelada Litoral, specifically in the areas whit limestones with dolomitic intercalations (CVBcd) substrates such as in Canyelles, Sant Pere de Ribes (Garraf), Sant Miquel d'Olèrdola or Olesa de Bonesvalls (Alt Penedès). In the area of the Serralada Prelitoral there are also some limekilns in Sant Jaume dels Domenys and in El Montmell (Baix Penedès), where the same substrate appears. These kinds of rocks can be used as raw material to obtain calcium oxides for industrial use because they contain fossil inlays of gasteropods or stromatolytes, among other organisms.

Limekilns are also observed in the Serralada Prelitoral, when the soil is rich in dolomites and limestones (Tm3) as in the case of St. Quintin de Mediona (Alt Penedès). At the north of this range, there are biomicritic limestones (PEc) substrates and dolomites and limestones (PPEc) substrates, as seen in Santa Maria de Miralles and west of Capellades (Alt Penedès). The calcium carbonate in dolomites can be relatively easily obtained, as their dissolution with water causes a chemical reaction that releases carbon dioxide, and in which magnesium carbonate and calcium carbonate are obtained.

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## Dry stone wells and cisterns

Dry stone wells are located near streams and river courses, and they are built to make use of the water below water table. This water contains fewer solid particles than that found in rivers or lakes, as during the deposition process it is filtered by the sediments of the soil which retain the larger particles.

Cisterns, which are built to store rainwater, predominate mainly in clay-rich soils and sands (NMas). These materials allow water to be filtered by the presence of sands, but at the same time they are also impermeable by the clays, which promote the capacity of water containment. There are some of these structures in La Bisbal del Penedès, Calafell, El Vendrell (Baix Penedès) or Les Roquetes (Garraf), among others. Cisterns are also found in localities such as Sant Pere de Ribes, Olivella (Garraf), Capellades, La Pobla de Claramunt (Anoia), or Olesa de Bonesvalls (Alt Penedès), where the dominant substrates are primarily sediments from streams or river terraces (Qr, Q and Qt). It is due to the presence of nearby streams, but an impermeable bedrock is also found to build the cisterns.

To sum up, looking at the type of geology of a site we could predict which dry stone structures would be expected to be found as detailed in Table 1.

**Table 1** Relation between geographic areas, dry stone constructions and geological substrate. *Sub region* category lists the main geographical features of the territory, *structures* category lists the most inventoried dry stone constructions on the Wikipedra for each sub region and *geological substrate* category shows the mainly materials in each area, with which dry stone construction has been built

| Sub region | Structures | Geological substrate |
|---|---|---|
| North Serralada Prelitoral | Huts | Marlstone (PEmg) |
| | | Pelagic limestone (PEc) |
| | | Clays and sandstones (PEag) |
| | Limekilns | Biological calcarenite (PPEc) |
| | Cistern | Argilite and limestone (Qr, Q o Qt) |
| South Serralada Prelitoral | Huts | Marlstone (Tk) |
| | | Dolomite (Tm) |
| | Limekilns | Aragonite (NMca) |
| | | Calcarenite and dolomite (CVBcd) |
| | | Calcarenite and dolomite (Tm3) |
| | Cistern | Argilite and limestone (Qr, Q o Qt) |
| | | Argilite and limestone (NMas) |
| South Serralada Litoral | Huts | Marl (NMm) |
| | | Reef calcarenites (NMe) |
| | Limekilns | Calcarenite and dolomite (CVBcd) |
| | Cistern | Argilite and limestone (Qr, Q o Qt) |
| | | Argilite and limestone (NMas) |
| Plana del Penedès | Cistern | Argilite and limestone (NMas) |

# Discussion

This study becomes a first approximation of the relationship between dry stone constructions and geology. This type of analysis can be useful to determinate which structures can be theoretically found in a place before going to the study area, which allows economic and material resources to be saved.

The determination of the connection between dry stone structures and the geology of the terrain shows that to perform certain types of constructions, the presence of stones is not the only important variable, but also their composition, which will provide them concrete physical and chemical characteristics[8] and Mandarino et al.,[9]

It should also be noted that depending on the type of rock a dry stone construction is made with, the same type of structure can differ in shape if compared to other from other region. This fact is due to the different availability of materials.

Regarding dry stone huts, they are made from different kinds of rocks in each sub region. In this case, the diversity of geological materials involves two issues. In one hand, huts can exhibit different morphologies, and in the other hand, different kind of stones require specifical building techniques. Sandstones, for example, allow to be sculpted, and this special characteristic becomes visible when the walls of the hut are made with brick-shaped stones. In the same way, people who build the huts, need to know specifically how to cut the stones. In other sub regions, stones are harder, sometimes typically rounded as pebbles. In these locations, the necessary knowledge to build a hut comprises other skills, simply because the raw material is different. By the same token, the shape and size of the huts can be variable.

In the case of limekilns, it is seen that they appear only in sub regions where limestone is abundant. It is an interesting issue because this situation shows that this typical proto-industrial structure is related to local production. In other words, people did not transport stones many kilometres away in order to process the raw material, but they build the kilns *in situ* to generate local productions. Probably, final products were which were transported.

Finally, in the case of dry stone wells and cisterns there are two significant elements to keep in mind. In one hand, the combination of permeability and impermeability in different geological substrates that allow the natural accumulation and containment of water, whether if it came from rain or of the water table. And, in the other hand, as is obvious, water availability in the location (Figure 2) (Figure 3).

**Figure 2** Dry stone hut in Rubió (Anoia). Author: Daniel Macià.

**Figure 3** Dry stone hut in El Vendrell. Authors: Guillén-Villar, Abraham; Traver-Vives, Montserrat.

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## Conclusion

As seen in results and discussion, we can conclude that after this preliminary analysis and as a starting hypothesis for a deeper study, the presence, quantity and typology of dry stone constructions in a territory can be said to be directly related to its geology.

Knowing the relationship between dry stone constructions and geology gives us different kinds of information. On one hand, when we think about doing a study in a new region, to look up geological maps supplies a first approach about possible dry stone buildings in the region before doing a field inventory. It could be relevant to know if the new region has our wanted characteristics and if to continue the study pays off while saving resources.

One the other hand, the results of this pilot study lead to a connection between raw materials and building techniques, in other words, between natural elements and social and cultural intergenerational learnings. This fact makes clear the relationship between traditional societies and their natural environment, showing that human beings were not and are not isolated of nature.

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## Conflicts of interests

Author declares there are no conflicts of interests.

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