Architecture in and on the mountains: adaptation and innovation of the historic built environment

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Abstract
Mountain areas, rich in environmental and cultural heritage, have gained importance in recent years. Historic buildings shape mountain communities, offering valuable settlement models and insights for sustainable urban planning. Mountain architecture is "intelligent", using local materials while respecting the environment. Rooted in traditional knowledge, it ensures cultural and technological continuity. This study focuses on Bergamo's High Valleys, analyzing settlement dynamics through architectural archaeology and GIS mapping to understand landscape transformations.

Keywords
Historical building archaeology, mountain architecture, construction techniques, topography, GIS

Recent Italian studies in human geography about the mountain reality

The role played by the mountain reality has become central in recent years, as a context characterized by an extraordinary variety and richness of heritage, not only concerning environment and landscape, but also historical, cultural and therefore architectural. The mountain is not a merely stereotypical image - to use the words of Armand Frémont "the sublime par excellence, the summit, posture, and the vertical vision" (Frémont 2007, 122) - but rather presents itself as an extremely articulated territorial system, characterized by a wide range of environments and ecosystems that depend on a series of factors such as terrain morphology, altitude, climate, vegetation, human settlements, and the cultural-historical aspect. Even today, however, developing an exhaustive definition of the mountain remains a complex task. Although physical and morphological characteristics represent common features shared by many mountain areas and constitute the primary scientific criteria, with elevation emerging as the predominant parameter, it is evident – as Mauro Varotto has highlighted – that this approach is neither exhaustive nor free from subjective influences, given the discretionary nature involved in defining altitudinal thresholds and the parameters adopted (Varotto 2020, 14–15). This arbitrariness becomes particularly evident when considering another crucial aspect: the specificity of mountain environments must be understood through the complex network of relationships established between the "inhabiting human being" and the mountain environment. This relationship is based on a profound sense of belonging and on a close interaction with the mountain horizon.

Osvaldo Baldacci addressed the concept of the mountain by focusing precisely on the human dimension: "The mountain – geographically considered – can be defined as an altitudinal

belt of the Earth's surface, in which the living conditions of the ecumenical area are replaced and interwoven with those of the sub-ecumenical area. The physical foundation is certainly fundamental, but it is the human component that characterizes the mountain, giving it, through typical landscapes, its own distinctive geographical identity" (Baldacci 1988, 5).

The emphasis placed on human action has indeed marked the transition from exclusively orographic studies towards an interpretation based on the relationship between human beings and mountains.

The mountain landscape does not constitute a neutral space upon which human beings act; rather, it should be understood as a constantly transforming palimpsest, in which physical and human forms mutually influence one another.

The continuous metamorphoses that have "composed, decomposed, and recomposed" the territorial fabric define a complex palimpsest, in which each element carries fragments of memory, identity, and values (Bergamo 2022, 134). An identity can be rediscovered, redefined, and transformed through a conscious acquisition of a "sense of place". Such awareness does not merely represent the preservation of past traditions, but rather an active and collective reconstruction of local identities (Vigotti 2021, 36), through which communities develop a profound and renewed relationship with their environment, contributing to the recovery and enhancement of territorial commons as vital resources for cultural and social continuity.

From this perspective, it becomes necessary to undertake a path towards what Alberto Magnaghi defined as "sense of place", understood not simply as the "defence of historical communities and past identities", but rather as the "construction of communities that grow through the experience of conflict and come together to establish a 'pact' for the care of the territorial environment, developing their identities and knowledge within a shared project" (Magnaghi 2010, 133). The focus therefore shifts towards the community dimension: "sense of place means that, among the different forms of individual identification, the one that prevails is the sense of belonging to the local society" (Becattini 2015, 163).

In a contemporary context in which original identities appear to have been progressively dissolved – a phenomenon that Giacomo Becattini defines as the "crumbling of places" ("sfarinamento dei luoghi") (Becattini 2015, 129–130) – it is therefore necessary to restore to mountain areas their original role as anthropological places. These should be understood as spaces characterized by distinctive anthropological elements, intrinsically connected to local traditions and capable of conferring identity upon the people who actively inhabit them, creating meaningful relationships both among themselves and with the places they occupy (Augé 2018, 72). This analysis of the concept of "anthropological place" forms part of a broader cultural process, through which all societies symbolically represent, organize, and attribute meaning to the spaces they inhabit, responding to a fundamental need for significance and belonging. In Italy, this dimension is embodied by municipalities, urban centres, and villages, particularly small settlements often composed of only a few families, which have developed over time in response to historical, productive, and cultural dynamics. These places have been at the heart of community life for centuries, functioning as repositories of collective memory and custodians of cultural practices transmitted across generations (Teti 2018, 194).

Identity therefore emerges as a key concept for interpreting the mechanism through which the external, concrete, and tangible reality is filtered through individual and collective experience, acquiring a subjective value that becomes deeply rooted in human consciousness.

Within the context of the Upper Bergamo Valleys, this debate on Alpine identity assumes particular significance. These territories, characterized by a challenging geography and a strong cultural rootedness, represent an emblematic example of how human adaptation to mountain environments has generated forms of belonging that combine local elements with characteristics shared across the Alpine region as a whole.

Indeed, with specific reference to the Alps, Annibale Salsa has questioned whether it is possible to speak of a unified Alpine identity or whether it would be more appropriate to refer instead to a plurality of Alpine identities. Although characterized by difficult and diverse environmental conditions, the Alps have historically constituted a space of encounter and exchange among different populations and cultures. The dialectical relationship between "Nature" and "Culture", between the environment and human action, has contributed to the formation of specific ways of inhabiting and interpreting the territory (Salsa 2007, 20–21; Salsa 2019, 81–89). The geographical, ecological, and socio-cultural specificity of the Alps derives largely from their role as the most important crossroads of the European continent. Although they cannot be considered simply as a "mosaic of diversities", they display elements of cultural continuity resulting from the adaptation strategies developed by Alpine communities. In this sense, the idea of a "cultural unity" of the Alpine world does not deny the plurality of local identities; rather, it identifies a shared set of practices, values, and symbols rooted in the relationship between humans and the environment.

When this identity-based relationship weakens, the risk is the emergence of a condition of disorientation resulting from the loss of territorial rootedness, generating what the anthropologist Marc Augé defines as "non-places": "if a place can be defined as relational, historical, and concerned with identity, then a space which cannot be defined as relational, historical, or concerned with identity will be a non-place" (Augé 2018, 93). Today, many mountain contexts are facing the risk of becoming "non-places", particularly as a consequence of globalization, mass tourism, and depopulation. Local traditions, forms of knowledge, and the relationship with nature risk being replaced by a standardized representation of the mountain, conceived merely as a tourist destination or as a setting for recreational activities. Without territorial rootedness, mountain areas lose their specificity and become anonymous spaces, comparable to any other tourist destination.

Human beings settle in mountain environments; they inhabit them and experience them. The interaction between communities and mountain landscapes has generated a built heritage that still represents a fundamental component of local realities today. Historical buildings have a profound influence on territorial dynamics, shaping the identity of places and their evolution over time. This heritage does not purely constitute evidence of the past, but rather represents a valuable resource for the design and management of contemporary landscapes, offering settlement models that remain relevant today and proposing architectural solutions capable of harmoniously integrating with the surrounding environment (Pupella 2025).



Figure 1. Taleggio, Sottochiesa, "stable-barn" (Photo by the authors)

This mountain system, simultaneously historical, landscape-related, and settlement-based, reflects the ability of populations to adapt to the geographical and climatic conditions of their territories, preserving a cultural heritage expressed through architectural language, construction techniques, and the spatial organization of settlements (Fig. 1). The configuration of mountain villages and inhabited areas is in fact determined by economic, social, and environmental factors, within a continuous dialogue between humans and nature.

Mountain architecture, similarly to rural architecture, was deeply connected to the surrounding natural environment, evolving "to measure" in order to respond to the needs of local communities. Although variations existed within the same region, reflecting the specific characteristics of individual places, each building expressed a distinctive relationship with its territory through the use of locally available materials and construction techniques rooted in territorial traditions, progressively integrated over time with elements of innovation (Braghieri 2012).

Developed in response to practical needs and to the management of the territory, mountain architecture evolved into a plurality of forms that became expressions of the cultural specificities of places (Fig. 2). In particular, the dwelling represents the pragmatic and respectful relationship that human beings established with the landscape, founded on practical knowledge ("saper fare") and on the conscious use of materials. Each building was harmoniously adapted to its function and to the natural context, giving rise to a form of "spontaneous" built environment, generated by concrete needs yet simultaneously characterized by design and aesthetic value (Matteoni, Pupella 2023, 371).



Figure 2. Taleggio, site Grasso, "stable-barn" at the Oratorio of San Francesco of Assisi (Photo by the authors)

Human settlements in mountain areas therefore do not constitute merely a material heritage to be preserved, but rather a living archive of knowledge and construction practices accumulated and stratified over time. Each building bears witness to a specific way of conceiving inhabitation, reflecting the relationship between humans and the environment, the sense of community, and the connection with the symbolic and spiritual dimensions of places.

The continued presence of historical buildings and artefacts keeps collective memory alive and establishes a bridge between generations. The value of mountain settlements does not lie exclusively in their materiality, but rather in their ability to transmit knowledge and values capable of guiding future choices concerning the management and sustainable development of territories.

Application of GIS for processing architecture in/on the mountain data

In this context, cartographic elaborations developed with the aid of Geographic Information Systems (GIS) prove to be fundamental tools for the study, conservation and valorisation of the historical building heritage. The use of digital cartography makes it possible to analyse in detail the distribution of historic buildings, their evolution over time and settlement dynamics, providing a scientific basis for territorial planning. The analyses conducted also make it possible to identify the areas of greatest historical interest, to assess the state of conservation of the built heritage and to develop targeted strategies for its protection.



Figure 3. Taleggio, at via Arighiglio, to Capo Foppa, rural complex (Photo by the authors)

Buildings are represented geometrically by means of polygons that identify their occupied surface area, on the basis of the reference Technical Maps, including the Regional Technical Map at a scale of 1:10,000 and the Base Map of the Regional Topographic Database, available for all Italian regions. A significant contribution also comes from historical cartography, in particular from the Lombardy-Venetia cadastre, whose surveys carried out in the provinces of Bergamo between 1807 and 1817 constitute a valuable source for the study of territorial transformations.

Each piece of evidence can be identified, numbered and subjected to analysis through parameters selected during the design phase: in fact, each polygon is associated with a unique identification number, necessary to relate the geometric primitives to the descriptive attributes of the relational database tables. All textual information is deduced from indirect sources (published historical documentation, iconographic studies and oral traditions) as well as from data processed during the study (photogrammetry, metric surveys, technical filing). Data are then entered for each building (CF) and architectural element (EA) surveyed, indicating the progressive number assigned during the documentation phase and the chronological range (Fig. 3).

The integration of these data makes it possible to conduct an in-depth analysis of the transformations of the built landscape, highlighting the dynamics of development and the interactions between the historical structures and the environmental context.

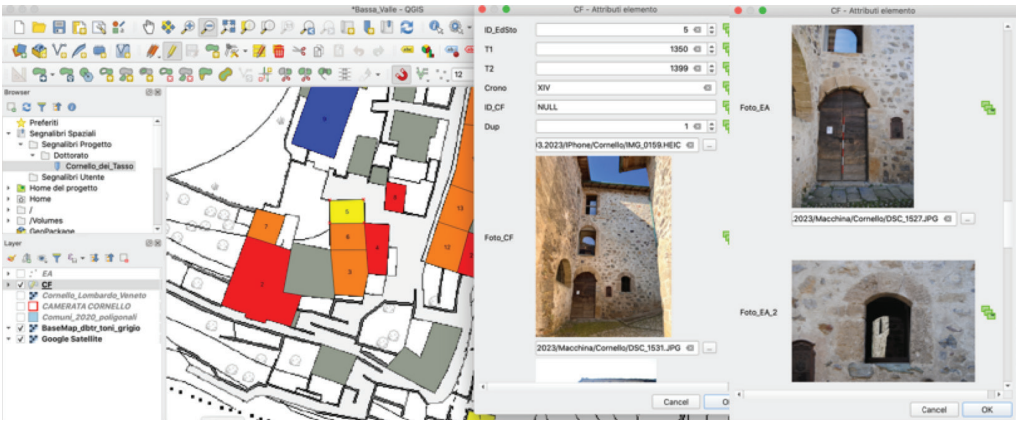


Figure 4. Example of QGIS screen (GIS elaboration by the authors)

The final product will consist of the elaboration of several thematic maps, obtained by selecting the information necessary to make explicit those implicit relationships initially admitted. In these maps, each element is represented with a specific chromatic screening, easily identifiable by means of an explanatory legend, which makes it possible to recognise the presence of ancient buildings in the area under examination and to easily understand their period of construction (Fig. 4).

The use of GIS and digital cartography therefore proves to be essential not only for historical research, but also for the management and protection of the mountain built heritage. In particular, these tools are particularly useful in contexts where historical sources and archaeological excavation data are lacking, allowing settlement scenarios to be reconstructed and interpretative hypotheses supported by objective data to be formulated. Moreover, the possibility of superimposing historical and current maps makes it possible to identify areas of greatest vulnerability and to plan restoration and valorisation interventions in a targeted and conscious manner.

The GIS-based approach is therefore not intended merely as a tool for spatial visualization, but as a means of integrating architectural, environmental, and historical data within a broader interpretative framework. By enabling the systematic organization and analysis of information collected during the survey, it provides a valuable basis for understanding patterns of settlement, building distribution, and processes of transformation across the study area.

In this perspective, the GIS analysis represents a preliminary step towards a more detailed examination of the architectural heritage of Averara. The following section explores selected building typologies and construction features, showing how the spatial patterns identified through GIS can contribute to a deeper understanding of the historical development and adaptive strategies of the local built environment.

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How does archaeology study rural mountain buildings? Some case studies in Valle Brembana

The archaeology of historical buildings represents a fundamental tool for understanding these peripheral contexts, where "poor or vernacular" architecture has been preserved. In the absence of sources or archaeological data from the subsoil, the archaeological method applied to ancient buildings becomes essential for studying and classifying masonry structures that often appear very similar to each other (Mannoni 1997, 15-24). Construction techniques have been continuous for centuries and are difficult to date, while architectural elements (doors, portals, windows, slits) have characteristics that allow them to be dated (Ferrando Cabona, Mannoni and Pagella 1989, 647-660; Boato and Pagella 2015, 101-126).

Since 2017, the Chair of Medieval Archaeology at the Catholic University of Milan has been leading the project "Archaeology of Historical Buildings in the Province of Bergamo. Research for enhancement and urban planning", which studies civil, fortified, and religious architecture from the medieval period (from the 10th to the 16th century) in the northern part of the province of Bergamo (Matteoni 2017, 193-204; Matteoni 2021, 205-214; Matteoni 2022, 55-64). So far, more than 40 municipalities in the hilly and mountainous areas have been examined, in the area encompassing Valle Imagna e Lemine (Matteoni 2023), Valle Seriana, Valle Brembana, Valle San Martino, Val Cavallina (Matteoni 2018). The project involves the participation of local cultural institutions and the community familiar with the territory, according to the principles of "participatory archaeology".

Pre-industrial mountain architecture encompasses all the knowledge of the community that produced and inhabited it: from the construction of a house to its durability, maintenance, and restoration. The choice of a building site was the result of a rational and conscious evaluation of several factors, including the availability of resources (stone, wood, water), material processing techniques, settlement organization, and accessibility. This process reflects a form of "historical sustainability", based on the exploitation of resources in a way that ensures their availability for future generations. An architectural archaeologist investigating these peripheral buildings must therefore address a series of questions: was the raw material the most suitable or the only available? Was it extracted locally or imported? How was it processed, and by whom? Over time, conventional technologies are defined, passed down in construction sites and adapted to local needs: construction methods are formed, based on empirical knowledge transmitted through repeated actions, often unintentionally, which unconsciously define the typical characteristics of a territory.

The Valle Brembana, one of the largest valleys in the Province of Bergamo, located in Lombardy in Northern Italy, is a significant context where rural architecture has been preserved with limited evidence of substantial transformation. The valley extends for approximately 60 km from the sources of the Brembo River, from Pizzo del Diavolo to the river's mouth at Villa d'Almè. Several lateral valleys branch off from the Valle Brembana (Fig. 5): Valtorta (from Piazza Brembana to the Bobbio plains); Val Taleggio (west from San Giovanni Bianco); Val Brembilla (northwest to Val Taleggio) and Valle Serina (which joins Valle Seriana to the east).

In the Carolingian period, the Valle Brembana formed part of the "comitatus" of Bergamo: at the end of the 10th century, Count Azzone of Lecco held landholdings in the valley, together

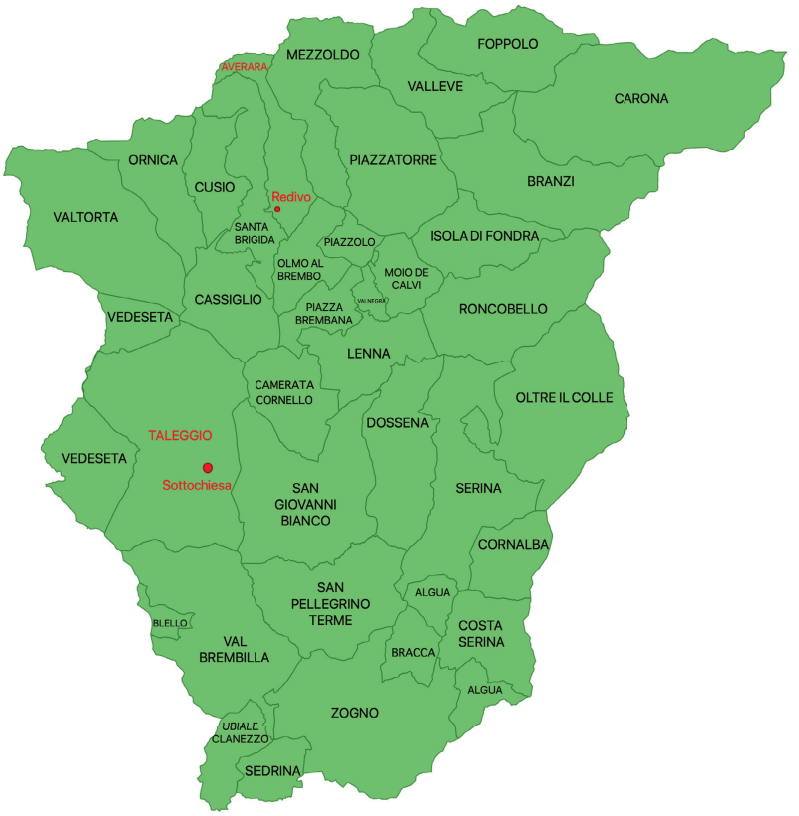


Figure 5. Map of Valle brembana with the villages mentioned in the text (edit by Pupella C.)

with the Gisalbertini counts. Documentary sources from the 11th century record several settlements located on intermediate slopes or elevated positions (Oggioni 2004, 210): Dossena (920), Stabello (1082), Zogno (1102), Piazza (1172), Camerata and Sedrina (1181), San Giovanni Bianco (1216) and San Pellegrino (1224). The valley was organized into small villages controlled by the bishop or ecclesiastical institutions (such as the monasteries of Astino and Vallalta founded between the 11th and 12th centuries by the Gisalbertini and Da Prezzate families); only from the 12th century did local lordships emerge, promoting the establishment of rural municipalities.

The city of Bergamo was unable to establish systematic control over all the surrounding valleys, because the distance and difficult access prevented the city from having direct control over these peripheral territories. In 1234 the Podestà ordered the boundaries to be set: the first municipalities were Dossena, San Pellegrino, San Giovanni Bianco, San Gallo, Zogno, Antea, Piazzo, Brembilla, Bracca, and Lepreno. From 1332 with the Visconti, the valley was divided into vicariates (Valle Brembana Inferiore-Zogno-, Valle Brembana Superiore –Serina-, Valle Brembana oltre il Goggia –Piazza- Val Taleggio –Pizzino-, Valle Averara e dell'Olmo –Averara- e Valtorta) and in the second half of the 14th century, there was a separation between Valle Brembana and Oltre alla Goggia (Riceputi 1997, 37).

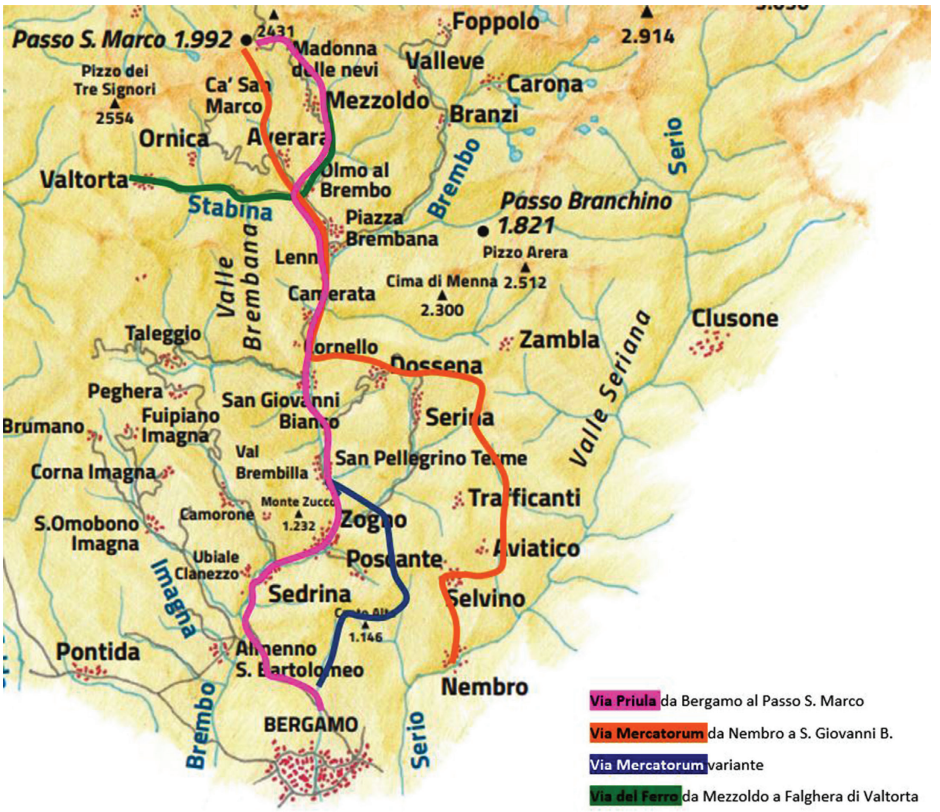


Figure 6. The ancient roads of Valle Brembana (Photo by the authors)

Among the activities practiced, in addition to pastoralism, metal extraction played a significant role. Mining activities, documented in written sources since 1223 in areas such as Ardesio and Gromo, were connected to the so-called "Iron Route", which crossed the territory between Valtorta and Mezzoldo and represented a transit route towards Valtellina through the Albarino Pass/San Marco Pass (Cucini Tizzoni 1997, 26–27; 55–58). The "Iron Route" connected Valle Brembana with Valtellina and Valsassina through San Marco Pass and Bobbio Plains (Fig. 6). The development of mining activities and their market perhaps led to the construction of the Via Mercatorum, the merchants' route, which connected Bergamo and Valtellina by climbing the lower Valle Seriana. The Via Mercatorum connected the most important centers such as Dossena - the first parish of the valley - and Cornello, the only market town in the middle Valle Brembana until the first half of the 15th century. From Cornello, the route reached the upper Valle Brembana, crossing Goggia: from Piazza Brembana, it proceeded towards Olmo al Brembo and Averara, climbed towards Valmoresca and beyond the Parisolo basin. From here, it branched towards the Verrobbio Pass to Val Gerola and towards the San Marco pass to Morbegno. After crossing the Orobie Alps, it descended towards the Grigioni, connecting northern Italy with central Europe even before the construction of the Via Priula, a new route created at the end of the 16th century (Bottani and Taufer 2007, Marcarini 2009).

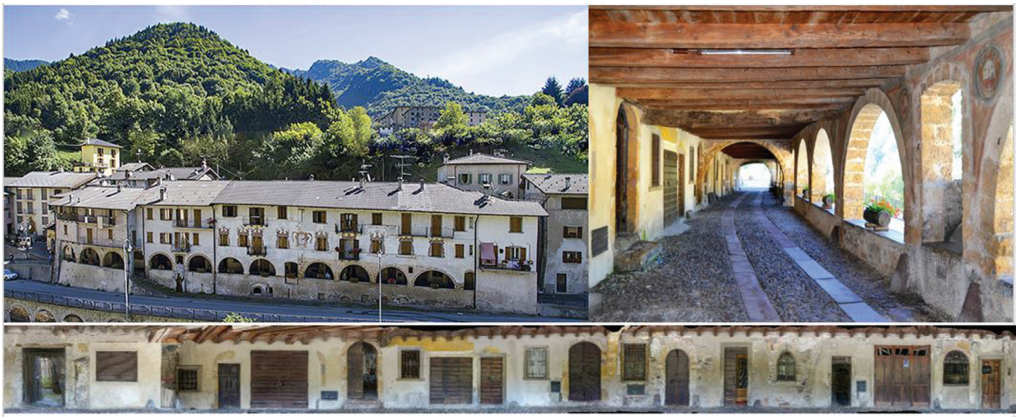


Figure 7. Averara, the porticoed street (Photo by the authors)

The Via Mercatorum passed through Averara, one of the most important centres in the Valle Brembana (Fig. 7): commercial activity developed along the famous porticoed street, extending for more than 20 m, where houses, shops, and resting points for travellers lined up. From the end of the 13th century, houses were organized in a linear arrangement along the street, while in the 15th century they were connected through arches. The façades still preserve the coats of arms of families who lived there between the 17th and 18th centuries, including the Baschenis, Mazzoleni, and Guerinoni (Angelini 1947, 16). Behind the street stands a house with twin portals on the façade, repeated on all four floors and consistently positioned along the vertical axis of the structure (for the building's arrangement of the openings). This type of portal, generally associated with commercial activities, is also found, as recorded during our survey, in a hillside house in Bastianelli - a hamlet of Averara - with twin openings on all floors and masonry with drawn mortar from the mid-14th century.

In Averara both commercial activities and transit routes contributed to the concentration of residences belonging to ancient merchant families, whose houses expressed their social status through architecture. These buildings were constructed in locally quarried stone and display distinctive architectural features that were repeatedly reproduced within the village, either because they were associated with branches of the same family or because they reflected the preferences of specific patrons. These stone masonry structures, covered with abundant extruded mortar that is styled with wide horizontal, regular and parallel tracks in between, had been stately residences, given their good workmanship and large square footage, as they generally have a courtyard in the flatter area, enclosed by masonry with an entrance portal.

Another recurring model in the area is represented by external wooden stairs: in Redivo, the Casa Bottagisi - previously interpreted as a Venetian customs house (Fig. 8) - results from two sequential buildings that, during the 15th century, were equipped with frontal wooden stairs set on two symmetrical wings. The two buildings were connected in the mid-15th century by a portico approximately four metres wide, supporting two projecting architectural elements that defined two new rooms (Arfani, Oberti 1995). From the second level, two mirrored stairs lead to two different properties up to the third level, where structured balconies with wooden supporting elements and protective coverings were located, similarly to those on



Figure 8. Redivo (fraz. Averara), Bottagisi house (Photo by the authors)

the fourth level (Fig. 9, Angelini 1947, 87). This construction type is also found in the hamlet of Valle Averara and in the nearby settlement of Foppa in Santa Brigida. Whether this represents a standardized model reproduced by specific craftsmen remains a question requiring further investigation.

In Val Taleggio, at the western end of the Valle Brembana, there are widespread stables on sloping ground. They were characterized by double-pitched roofs covered with "piode" stone slabs, placed flat with a 70% overlap in length, making the roof very heavy, which was then supported by chestnut wood scaffolding (Fig. 10). These stables all have the same style and "T" portals for the hayloft, located on the upper floor (Dematteis 1992, 40-41). Usually, the T-shaped door was on the short side, accessible via steps, or on the steeper side accessible by wooden stairs. This type of

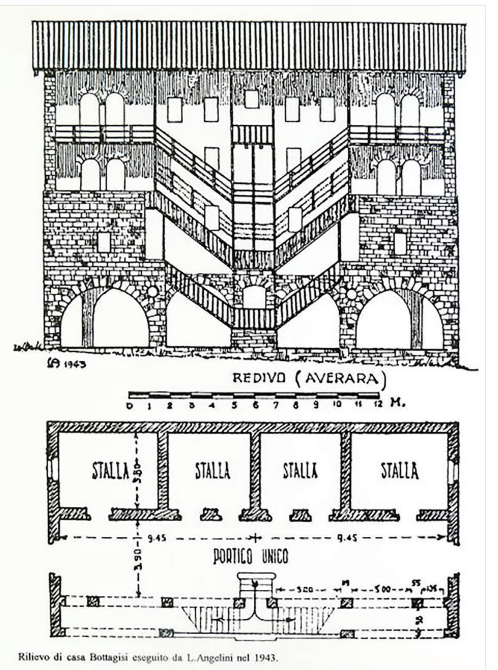


Figure 9. Survey drawing of Bottagisi house by Sandro Angelini (from Angelini 1947, 87)

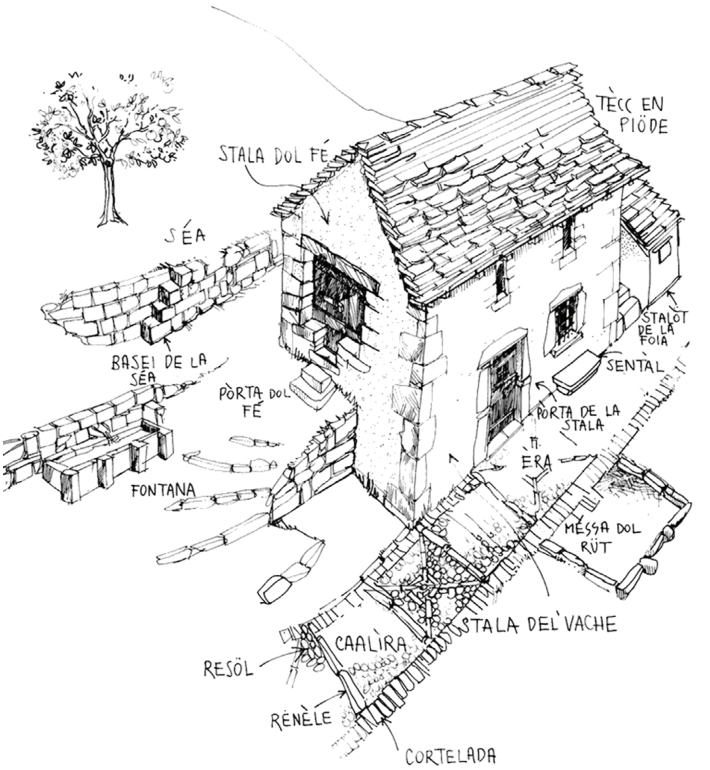


Figure 10. Survey drawing of a typical stable of Valle Imagna (https://www.aers.it/)

door, with a narrowing threshold and the presence of two seats on the sides, was functional for unloading hay placed on the farmer's shoulders, who sat down while doing this. It was also functional for thermal containment of the environments and hayloft ventilation, closing only part of the access. The door had a wooden lintel, although from the 15th century onwards lowered arches also became widespread, continuing into more recent examples (Fig. 11, Matteoni 2025).

This architectural type, originating in the Valle Imagna, is widely spread in Val Taleggio, on the western border with Valle Brembana, and on the opposite side in Val San Martino, where since the 16th century, sources document a migration of inhabitants for the production and trade of woollen cloth (Bonaiti 2021, 32-37). These communities migrated together with their cultural heritage and traditional knowledge, including established building practices, which were transferred to new territories and became part of the identity of local communities. An archaeological approach to the built environment, therefore, can also allow civil construction to be dated: if characterizing elements can be recognized for residential construction (such as twin openings or wooden staircases, as in the cases presented above), characterizing elements can also be recognized in rural construction, allowing a building pattern to be framed by subsequent changes over time. Although variations may be limited, working in geographically closed contexts, such as the valleys in this case, allows for the isolation of identity elements



Figure 11. Examples of "T-shaped" door of Sant'Omobono and Taleggio (Photo by the authors)

that are also reflected in the built environment. The repetition of patterns that are always the same depends not only on precise and already proven technical knowledge, but also on a matter of "taste," which defines a very homogeneous building landscape. However, adaptation to certain contexts, such as the occupation first of the central areas of the village and only later those at higher elevations (with some exceptions), can allow for the scaling over time of types that look very similar to each other.

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