

Article

Limestones in the Roman Architecture of Oderzo and Concordia Sagittaria (Italy): Petrography and Provenance

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Abstract

This paper presents the results of a research project on the use of stone in Roman architecture in Oderzo and Concordia Sagittaria, located between the Tagliamento and the Piave rivers (Italy). The study involved a documental survey, material sampling and analysis, provenance identification, and interpretation of results to reconstruct ancient stone trade routes. During sampling, 33 carbonate rock specimens were collected from archaeological sites and architectural elements in Oderzo, and 52 from Concordia Sagittaria. In both cities, these rocks were primarily used for architectural elements such as columns and capitals, whereas these lithotypes were less frequently employed in structures and infrastructures. The analysis revealed a significant reliance on regional limestones. Petrographic examinations (PLM-TL) identified six main limestone groups, many of which were linked to quarries located in the Aurisina and in the Triestine Karst region, as well as in the Prealps and Berici Hills. The study encountered several challenges: many analysed samples displayed petrographic characteristics consistent with multiple sources, complicating the precise identification of their extraction site. Despite a detailed understanding of the region's geology, reference geological datasets often overlook outcrops that may have been exploited in antiquity. Consequently, when samples lacked distinctive features, tracing them to a particular quarrying basin proved difficult. In conclusion, the research underscores the extensive use of local limestones while acknowledging the challenges posed by limited petrographic reference data, which hinder the precise identification of the source basins of the materials used in Roman construction.

Keywords: Roman architecture; Oderzo; Concordia Sagittaria; stone materials; PLM-TL

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1. Introduction

Since 2010, within a broader research project on Roman architecture in Regio X—Venetia et Histria, the Department of Cultural Heritage, in collaboration with the Department of Geosciences at the University of Padua, has been investigating the construction techniques of Roman towns in northeastern Italy. The project focuses on a comprehensive study of building techniques [1] and stone and mortar technology [2–9], with the aim of reconstructing the distinctive features and technical expertise of the ancient craftsmen who worked in this region, as well as the origin of construction materials (local and imported) used in construction. Some interesting developments in the study of the archaeology of construction and stone materials have also been occurring beyond Italy's borders, particularly concerning the use of local stones [10–12].

This paper aims to investigate the differences in exploitation and use of local limestones for architectural purposes during the Roman period in the cities of Oderzo (*Opitergium*) and Concordia Sagittaria (*Iulia Concordia*) (Figure 1). The region is, in fact, naturally rich in resources, including stones, which have been widely exploited since pre-Roman times. These resources consist primarily of sedimentary rocks, specifically limestones, which outcrop in the Berici Hills, the Venetian Prealps, the Triestine Karst, and the Istrian peninsula.

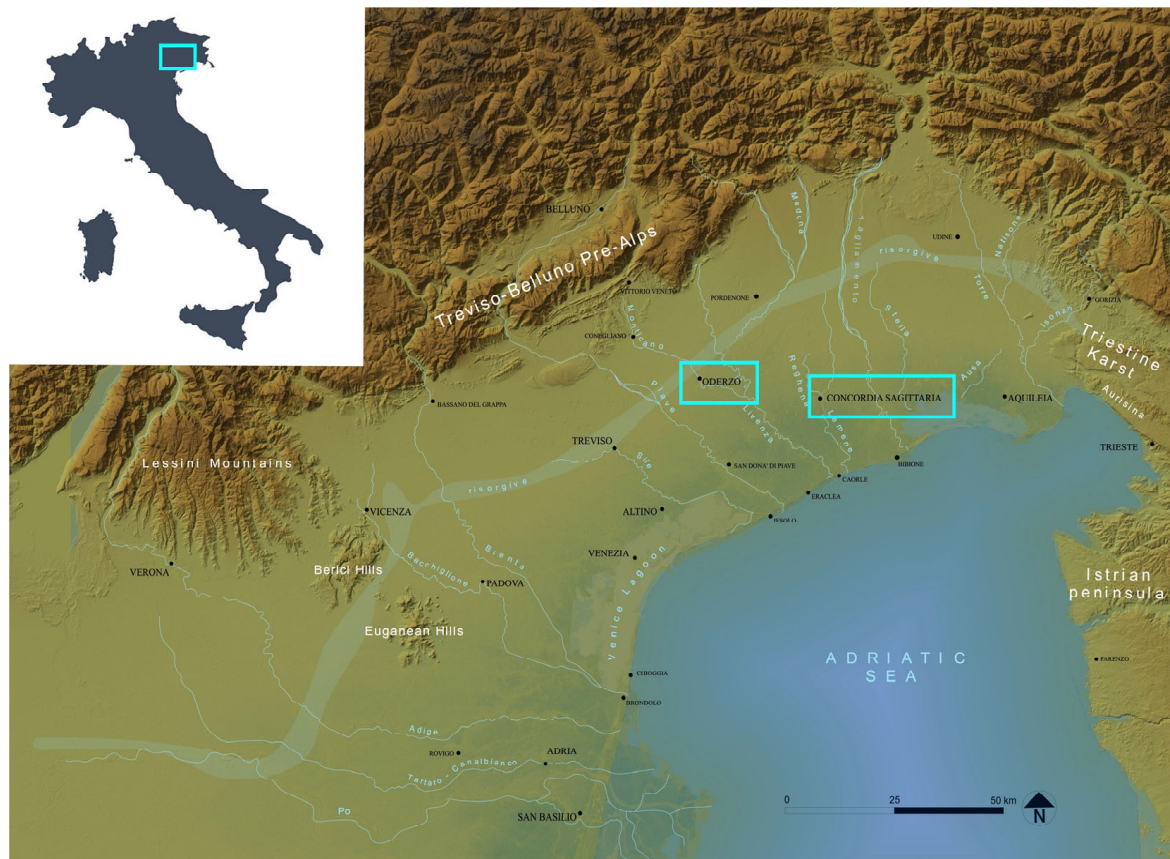


Figure 1. Geographic map of eastern Veneto Region, with indication of the 2 cities which are the object of the research, Oderzo—*Opitergium* and Concordia Sagittaria—*Iulia Concordia* (edited by C. Girotto; basemap by P. Kirschner and J. Bonetto).

This new research expands on a previous study—*The Use of Stone Resources in the Roman Architecture of Oderzo (Treviso, Italy)* [9]—by integrating additional data, thereby enhancing our understanding of the origins of construction stone materials. A key development in this research is the inclusion of a second urban centre, which enables a more detailed analysis of the relationships between various limestone types and their specific architectural applications within urban settings. The earlier publication thus provides a foundational framework for this extended investigation into the construction decisions made by ancient builders.

Reconstructing such dynamics is in fact crucial for estimating the impact that stone quarrying, transportation and use had on the local economy during the Roman period. As part of a broader sampling, it emerged that limestone is the predominant type of stone. A more in-depth analysis was therefore conducted to determine the number and types of limestone present and their origin.

1.1. Oderzo in the Roman Age

From its origins between the 10th and 9th centuries BCE [13], Oderzo developed as a vital regional hub for both trade and communications routes. Strategically located in

the Venetian plain between the Piave and Livenza rivers [14], the city adapted early to Roman urban models: by the 2nd–1st centuries BCE, in fact, the first forum had already been built [15]. A significant phase of urban and architectural development followed during the 1st century CE, including the construction of public buildings such as baths [16], temples [17], a new *forum* complex [18] and luxurious residences (*domus*) [19], alongside an expanded network of roads [20], a river quay [21], and city walls [22] (Figure 2). Although a theatre has not yet been identified, a semicircular structure allegedly found in Via Roma may relate to one [23].

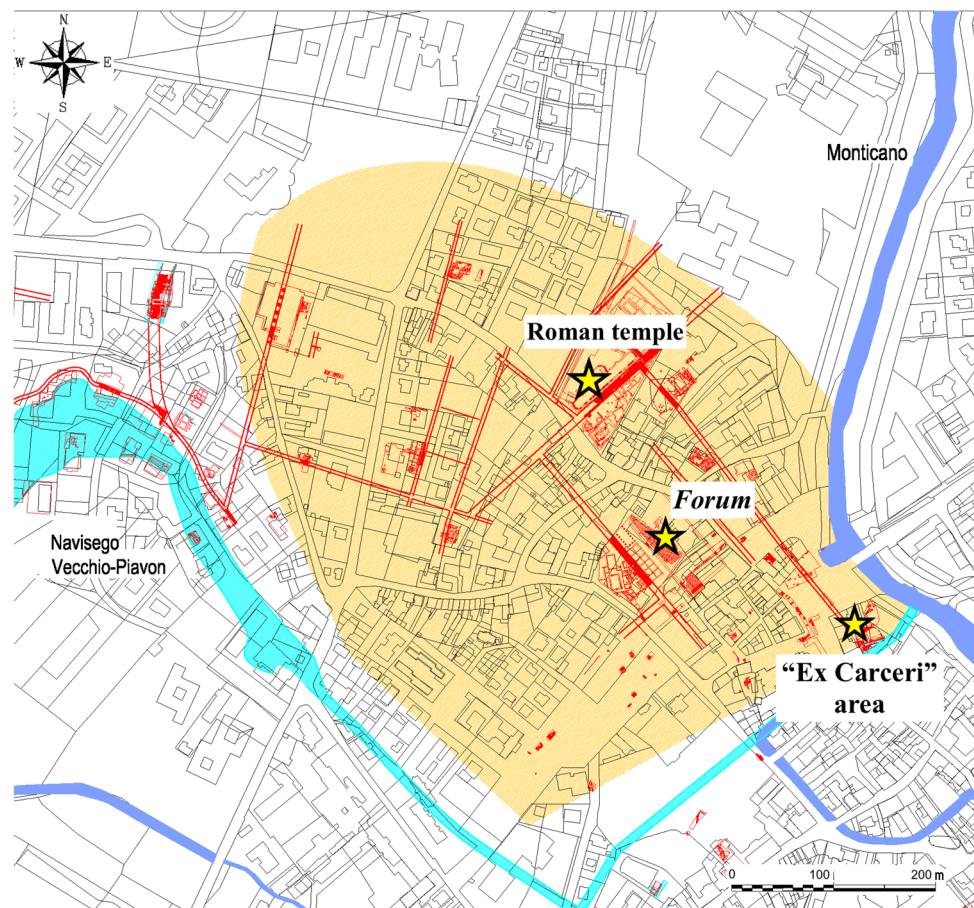


Figure 2. Map of Roman Oderzo (*Opitergium*), showing the archaeological areas analysed in this study (modified from [24]). Blue and light blue: rivers; yellow: ancient city area; red: ancient structures and infrastructures.

Invasions by foreign groups such as the Quadi and Marcomanni in the 2nd century CE disrupted Oderzo’s seemingly uninterrupted growth, as evidenced by fire damage across the city [24]. Reconstruction in the 2nd–3rd centuries CE brought renewed building efforts, including a grand architectural complex near the “Ex-Stadium Area” [17] and a mosaic with hunting scenes [25] discovered among the remains of a large *domus*, possibly marking the final phase before widespread decline.

Key insights into late antique and post-Roman Oderzo come from the “Ex Carceri” Area [26], where a 7th-century CE urban wall [22] was constructed atop older structures using almost exclusively ancient Roman ashlar blocks and funerary gravestones and altars [27]. This defensive renewal reflects the instability of the period, notably the Longobard destruction of Oderzo in 667 CE, as recorded by Paul the Deacon (*Hist. Lang.* 4.38.45).

1.2. Concordia Sagittaria in the Roman Age

Concordia Sagittaria is situated on a hill, bordered in antiquity by the Lemene River to the east and the palaeo-Regghena to the west. In prehistory, this area marked the innermost point of a lagoon inlet, later filled by alluvial deposits from the Tagliamento River [28]. Like other pre-Roman settlements in the region, Concordia's integration into the Roman world was peaceful. The settlement's importance as a commercial hub was also highlighted by the convergence of two major Roman roads—the *Via Annia* and *Via Postumia*—just west of the site [29,30]. By 42–40 BCE, Concordia Sagittaria was fully under Roman influence and became a Roman colony, adopting the name of *Iulia Concordia* [23].

The new Roman settlements occupied the entire hilltop, and was enclosed by walls with a rectangular perimeter, interrupted by two diagonal sections [22,31] (Figure 3). The city included a *forum* complex [32], a theatre near the north-western walls [33,34], two bath complexes [33] and residential areas including at least seven *domus* [35,36]. Urban infrastructures included paved streets, city gates [37], and a drainage system.

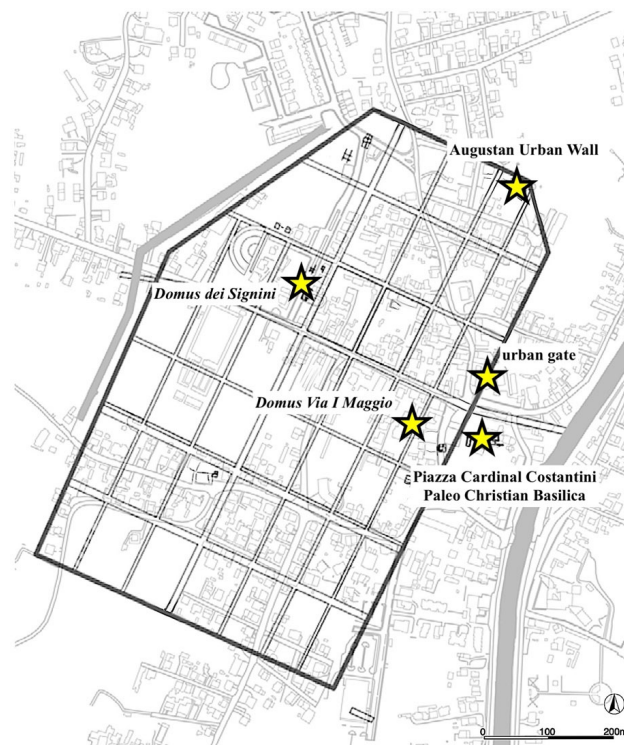


Figure 3. Map of Roman Concordia Sagittaria (*Iulia Concordia*), showing of the archaeological areas analysed in this study (modified from [38]).

During the Imperial age, Concordia Sagittaria underwent a general urban reorganisation, with new constructions as well as the dismantling of existing buildings and monuments. By the 3rd century CE, the theatre had been abandoned, and its materials were stripped, presumably for the construction of other structures. As Roman buildings decayed, an early Christian complex began to develop in the area that would later become Piazza Cardinal Costantini [39]. Religious buildings erected from the 4th century CE onwards created a complex archaeological context that remains difficult to interpret.

2. Materials and Methods: Sampling and Analytical Equipment

In order to better understand limestones' quarrying and trading strategies, the associated trade routes, and possible preferential relationships with certain quarries, we collected and analysed, through Polarized Transmitted Light Optical Microscopy (PLM-TL) 33 carbonate rock

specimens collected from archaeological sites and architectural elements in Oderzo, and 52 from Concordia Sagittaria. The procedure involved the mechanical removal of centimetre-sized stone fragments from architectural elements using a chisel. Wherever possible, preference was given to elements with pre-existing gaps, as these allowed for easier identification and removal of material while minimising impact on the structures (Figure 4). All samples were taken from structures and artefacts dated to the Roman period. In buildings with multiple construction phases, samples were collected—where feasible—from each distinct phase, in order to identify patterns of continuity or discontinuity in the selection and use of stone materials (Table 1). All analyses were carried out using equipment housed at the Department of Geosciences, University of Padova. PLM-TL analyses were conducted on rock samples prepared as 30 µm thin sections, using a Leica DM750 P microscope equipped with an integrated FLEXACAM I5 digital camera (Leica Geosystems, Heerbrugg, Switzerland).

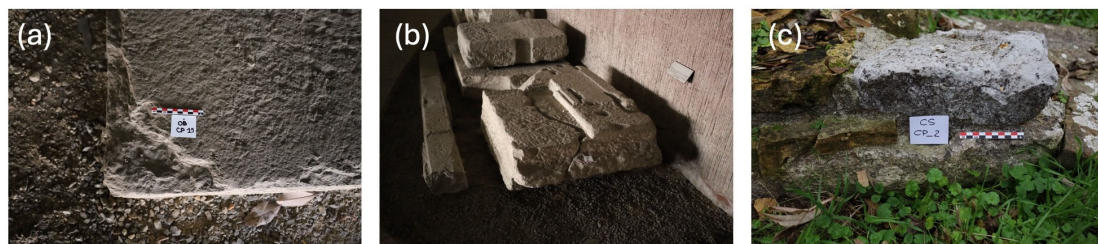


Figure 4. Selection of archaeological structures sampled in the archaeological areas of Oderzo and Concordia Sagittaria and in the Museo Nazionale Concordiese in Portogruaro: (a) OD_19 = paving stone (*Basilica*); (b) OD_20 = threshold (*Basilica*); (c) CS_02 = masonry block (Domus dei Signini) authorised by the Ministry of Culture—Superintendency for Archaeology, Fine Arts and Landscape for the Provinces of Padua, Treviso, and Belluno—Reproduction Prohibited.

Table 1. List of the analysed samples and their inferred provenance based on petrographic analysis.

Sample	Artefact/Structure	Context	Chronology	Lithotype	Provenance
OD_06	paving stone	Oderzo, urban gate ("Ex Carceri" Area)	3rd-4th c. CE	Scaglia Rossa	Lessini Mountains/Euganean Hills/Treviso-Belluno Prealps
OD_08	ashlar block	Oderzo, urban gate ("Ex Carceri" Area)	3rd-4th c. CE	Scaglia Rossa	Lessini Mountains/Euganean Hills/Treviso-Belluno Prealps
OD_10	paving stone	Oderzo, urban gate ("Ex Carceri" Area)	3rd-4th c. CE	Scaglia Rossa	Lessini Mountains/Euganean Hills/Treviso-Belluno Prealps
OD_12	<i>cavaedium</i> threshold (NW)	Oderzo, urban gate ("Ex Carceri" Area)	3rd-4th c. CE	Aurisina Limestone	Aurisina, Trieste Karst
OD_15	ashlar block	Oderzo, medieval tower (reuse) ("Ex Carceri" Area)	8th c. CE	Istrian Stone	Istrian peninsula
OD_16	ashlar block	Oderzo, medieval tower (reuse) ("Ex Carceri" Area)	8th c. CE	Scaglia Rossa	Lessini Mountains/Euganean Hills/Treviso-Belluno Prealps
OD_17	sarcophagus lid	Oderzo, medieval tower (reuse) ("Ex Carceri" Area)	8th c. CED	Scaglia Rossa	Lessini Mountains/Euganean Hills/Treviso-Belluno Prealps
OD_19	paving stone	Oderzo, <i>Basilica Forum</i>	1st c. BCE–1st c. CE	Scaglia Rossa	Lessini Mountains/Euganean Hills/Treviso-Belluno Prealps
OD_20	threshold	Oderzo, <i>Basilica Forum</i>	Roman Age	Aurisina Limestone	Aurisina, Trieste Karst
OD_23	ashlar block	Oderzo, <i>Basilica Forum</i>	Roman Age	Aurisina Limestone	Aurisina, Trieste Karst
OD_36	ashlar block	lot. Forlin, Oderzo	Roman Age	Istrian Stone	Istrian peninsula
OD_37	column base	Oderzo	Roman Age	Karst Limestone	Trieste Karst
OD_38	column base	Oderzo	Roman Age	Karst Limestone	Trieste Karst
OD_39	frieze	Oderzo	Roman Age	Aurisina Limestone	Aurisina, Trieste Karst
OD_41	column	Oderzo	Roman Age	Vicenza Stone	Berici Hills
OD_42	semi-column	Oderzo	Roman Age	Karst limestone	Trieste Karst
OD_43	capital	Oderzo	Roman Age	Karst limestone	Trieste Karst
OD_44	architrave	Oderzo	Roman Age	Aurisina Limestone	Aurisina, Trieste Karst
OD_45	architrave	Oderzo	Roman Age	Aurisina Limestone	Aurisina, Trieste Karst
OD_49	capital	Oderzo	Roman Age	Istrian Stone	Istrian peninsula
OD_50	column	Oderzo	Roman Age	Karst Limestone	Trieste Karst
OD_51	<i>acroterion</i>	Oderzo	Roman Age	Aurisina Limestone	Aurisina, Trieste Karst

Table 1. Cont.

Sample	Artefact/Structure	Context	Chronology	Lithotype	Provenance
OD_52	cornice	Oderzo	Roman Age	Aurisina Limestone	Aurisina, Trieste Karst
OD_53	cornice	Oderzo	Roman Age	Aurisina Limestone	Aurisina, Trieste Karst
OD_54	capital	Oderzo	Roman Age	Vicenza Stone	Berici Hills
OD_55	capital	Oderzo	Roman Age	Vicenza Stone	Berici Hills
OD_56	capital	temple of Oderzo	1st c. CE	Vicenza Stone	Berici Hills
OD_57	architectural element (capital?)	temple of Oderzo	1st c. CE	Vicenza Stone	Berici Hills
OD_58	capital	temple of Oderzo	1st c. CE	Vicenza Stone	Berici Hills
OD_59	base	temple of Oderzo	1st c. CE	Vicenza Stone	Berici Hills
OD_60	capital	temple of Oderzo	Roman Age	Aurisina Limestone	Aurisina, Trieste Karst
OD_61	base	temple of Oderzo	1st c. CE	Vicenza Stone	Berici Hills
OD_64	capital	temple of Oderzo	Roman Age	Aurisina Limestone	Aurisina, Trieste Karst
CS_02	masonry block	Concordia Sagittaria, <i>Domus dei Signini</i>	3rd c. CE	Karst Limestone	Trieste Karst
CS_08	paving stone	Concordia Sagittaria, urban gate	1st c. BCE–1st c. CE	Scaglia Rossa	Lessini Mountains/Euganean Hills/Treviso-Belluno Prealps
CS_09	Augustan urban walls	Concordia Sagittaria, foundation	1st c. BCE–1st c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_10	Augustan urban walls	Concordia Sagittaria, elevation	1st c. BCE–1st c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_11	Augustan urban walls	Concordia Sagittaria, foundation	1st c. BCE–1st c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_12	Augustan urban walls	Concordia Sagittaria, elevation	1st c. BCE–1st c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_13	Augustan urban walls	Concordia Sagittaria, elevation	1st c. BCE–1st c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_14	column base	Concordia Sagittaria, <i>domus I Maggio</i>	1st c. BCE–1st c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_15	column base	Concordia Sagittaria, <i>domus I Maggio</i>	1st c. BCE–1st c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_16	column base	Concordia Sagittaria, <i>domus I Maggio</i>	1st c. BCE–1st c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_17	threshold	Concordia Sagittaria, <i>domus I Maggio</i>	1st–2nd c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_18	threshold	Concordia Sagittaria, <i>domus I Maggio</i>	1st–2nd c. CE	Scaglia Rossa	Lessini Mountains/Euganean Hills/Treviso-Belluno Prealps
CS_19	threshold	Concordia Sagittaria, <i>domus I Maggio</i>	1st–2nd c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_27	Ashlar block	Concordia Sagittaria, Paleochristian Basilica (reuse)	Roman Age	Vicenza Stone	Berici Hills
CS_28	architrave	Concordia Sagittaria, Paleochristian Basilica (reuse)	Roman Age	Aurisina Limestone	Aurisina, Trieste Karst
CS_29	architrave	Concordia Sagittaria	1st–2nd c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_30	column base	Concordia Sagittaria	Roman Age	Vicenza Stone	Berici Hills
CS_31	column base	Concordia Sagittaria	Roman Age	Aurisina Limestone	Aurisina, Trieste Karst
CS_34	column	Concordia Sagittaria	Roman Age	Karst Limestone	Trieste Karst
CS_35	column base	Concordia Sagittaria	Roman Age	Vicenza Stone	Berici Hills
CS_36	architectural element	Concordia Sagittaria	Roman Age	Aurisina Limestone	Aurisina, Trieste Karst
CS_39	architectural element	Concordia Sagittaria	Roman Age	Aurisina Limestone	Aurisina, Trieste Karst
CS_40	capital	Piazza Cardinal Costantini	1st–2nd c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_42	capital	Concordia Sagittaria	1st–2nd c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_43	capital	Concordia Sagittaria	1st c. BCE–1st c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_44	architrave	Concordia Sagittaria	1st–2nd c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_45	architrave	Concordia Sagittaria, Roman theatre	1st c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_46	<i>mensola</i>	Concordia Sagittaria	End of 1st c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_47	capital	Concordia Sagittaria, Roman theatre	1st c. BCE–1st c. CE	Vicenza Stone	Berici Hills
CS_49	capital	Concordia Sagittaria	2nd–3rd c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_51	architrave	Concordia Sagittaria, Roman theatre	1st c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_53	colonna	Concordia Sagittaria	1st c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_54	column base	Concordia Sagittaria	1st c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_55	pillar	Concordia Sagittaria	1st–2nd c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_56	pillar	Concordia Sagittaria	1st–2nd c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_57	pillar	Concordia Sagittaria	1st–2nd c. CE	Aurisina Limestone	Aurisina, Trieste Karst

Table 1. Cont.

Sample	Artefact/Structure	Context	Chronology	Lithotype	Provenance
CS_58	capital	Concordia Sagittaria	1st c. CE	Vicenza Stone	Berici Hills
CS_59	<i>mensola</i>	Concordia Sagittaria	Beginning og 1st c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_60	<i>acroterion</i>	Concordia Sagittaria	1st c. BCE–1st c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_61	frieze	Concordia Sagittaria	Second half of 1st c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_62	frieze	Concordia Sagittaria	1st c. BCE–1st c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_66	cornice	Concordia Sagittaria	1st–2nd c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_68	base	Concordia Sagittaria	1st c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_69	column	Concordia Sagittaria	1st c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_72	column	Concordia Sagittaria	Roman Age	Aurisina Limestone	Aurisina, Trieste Karst
CS_74	architrave	Concordia Sagittaria	Roman Age	Aurisina Limestone	Aurisina, Trieste Karst
CS_77	cornice	Concordia Sagittaria	Roman Age	Aurisina Limestone	Aurisina, Trieste Karst
CS_79	cornice	Concordia Sagittaria	Roman Age	Aurisina Limestone	Aurisina, Trieste Karst
CS_80	architrave	Concordia Sagittaria	Roman Age	Aurisina Limestone	Aurisina, Trieste Karst
CS_81	base	Concordia Sagittaria	Roman Age	Aurisina Limestone	Aurisina, Trieste Karst
CS_83	column	Concordia Sagittaria	1st c. CE	Aurisina Limestone	Aurisina, Trieste Karst
CS_84	cornice	Concordia Sagittaria	Roman Age	Aurisina Limestone	Aurisina, Trieste Karst

3. Results—Petrofacies

The analytical approach used for studying the sedimentary rocks involved PLM-TL analysis of the samples to establish petrographic profiles. These profiles were then compared with databases of samples of known provenance to identify the original extraction basins. Six *petrofacies* were identified during the study. Some of these are easily distinguishable, such as the Aurisina limestone, Scaglia Rossa and Pietra di Vicenza. Others, such as the Karst limestone, *cortoid limestone* and Istrian stone, cannot be unambiguously attributed to a specific regional outcrop.

Aurisina Limestone is the most frequently attested lithotype, with 43 samples from Concordia Sagittaria and 12 from Oderzo (Table 1). The examined specimens from both cities are mainly classified as grainstone, characterised by a high concentration of rudist fragments, together with a smaller proportion of benthic foraminifera, including members of the Miliolida and Textulariida orders (Figure 5a). Additional components include green algal fragments (*Thaumatoporella parvoovesiculifera*), echinoderm remains, peloids, and occasional intraclasts. These characteristics are consistent with material from the quarry basin of the Municipality of Duino-Aurisina, the largest and most extensively exploited site in the Trieste Karst region since ancient times [1,40]. The lithological formation quarried in this area dates to the period between Turonian and the Early Campanian (Late Cretaceous) and consists of compact limestones, notably rich in *Radiolites*, Neitheidae, and Chondrodontidae fragments, typically displaying light grey tones [41–43].

Eight of the analysed samples in this study (6 from Oderzo; 2 from Concordia Sagittaria) are predominantly classified as wackestone, featuring a high abundance of planktonic foraminifera (such as Globotruncanidae, Globigerinidae, and Heterohelicidae), along with occasional calcispheres and rare traces of iron hydroxides and clay minerals concentrated along stylolitic sutures (Figure 5b). These features are consistent with the Scaglia Rossa Formation.

In the Veneto region, outcrops of the Scaglia Rossa Formation occur in areas such as the Euganean Hills [44,45], the Lessini Hills [46], and the Possagno–Valdobbiadene area (Treviso and Belluno Prealps) [47]. This formation is typically identified as wackestone, rich in planktonic foraminifera and micritic matrix. Smaller amounts of calcispheres, radiolarians, and dinoflagellates are present, whereas calpionellids, echinoderms, and bivalves occur only rarely.

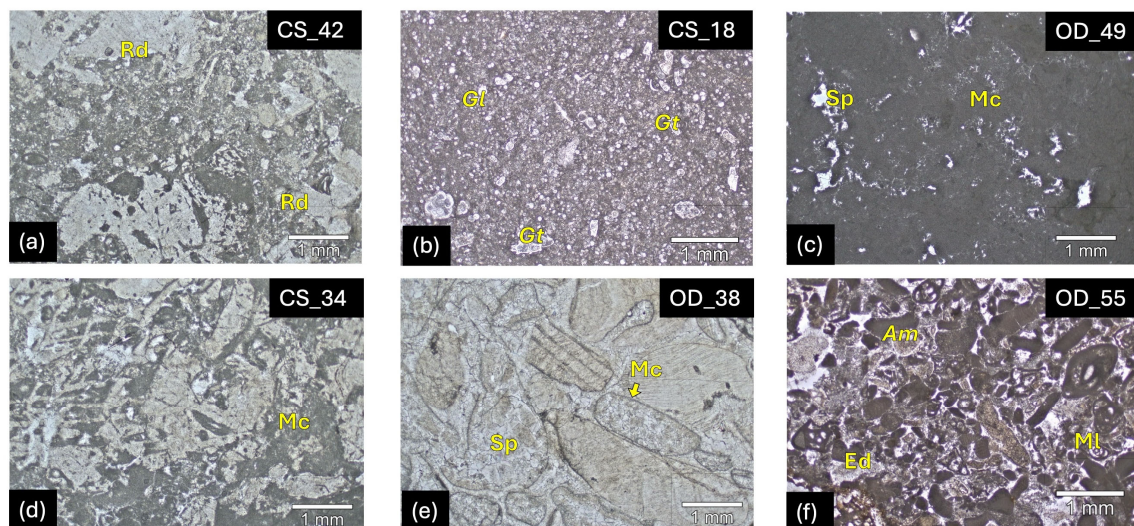


Figure 5. PLM micrographs (plane polarised light) of a selection of samples of sedimentary rocks. (a) Aurisina Limestone; (b) Scaglia Rossa; (c) Istrian Stone; (d) Karst Limestone; (e) Cortoids Limestone; (f) Vicenza Stone; Rd, Rudists; Gt, *Globotruncana*; Gl, *Globigerina* sp.; Am, *Amphistegina* sp.; Ml, Miliolida; Ed, Echinoderms, Mc, micritic carbonates; Sp, Sparite (elab. by C. Girotto).

Twelve (7 from Oderzo; 5 from Concordia Sagittaria; Table 1) of the analysed samples are identified as Vicenza stone, a soft limestone primarily quarried in the Berici Hills [45]. These specimens are grainstones rich in red algae fragments and contain a high concentration of benthic foraminifera (notably Miliolida), along with Rotaliida such as *Amphistegina* and *Asterigerina*. Hyaline foraminifera are present in smaller amounts. Additional components include fragments of echinoderms, bivalves, and bryozoans. A notable feature of these samples is their high porosity [48–50] (Figure 5f).

The origin of three samples from Oderzo remains uncertain. These samples (Table 1; OD_15; OD_36; OD_49) are classified as mudstone and display features such as *fenestrae* filled with sparry calcite and a sparse presence of peloids. Rare fossil fragments are also observed, though they are non-diagnostic and difficult to identify (Figure 5c). The petrographic characteristics show similarities with compact limestone extracted from the Istrian peninsula [51].

The provenance of five samples (3 from Oderzo; 2 from Concordia Sagittaria) could not be determined with certainty. The available petrographic evidence does not support a clear attribution to any specific quarry, primarily due to the absence of diagnostic features and index fossils typically used for lithotype identification. Nonetheless, their petrographic traits partially align with lithotypes extracted from the Trieste Karst area. These samples are predominantly grainstones, containing numerous well-rounded clasts—some of which show signs of recrystallisation—and are often bordered by a micritic coating of microbial origin. Crystalline limestone intraclasts are present in nearly all samples, alongside well-developed sparry calcite cement (Figure 5d).

Lastly, four samples (OD_37; OD_38; OD_50; CS_31) stand out as significantly different from the others. They can be classified as *cortoid grainstones*, characterised by well-rounded rudist clasts, the presence of intraclasts (including fragments of crystalline limestone), well-developed sparry calcite cement, and a micritic coating of microbial origin (Figure 5e).

4. Discussion

4.1. Quarry Basins and Transport Routes

The study encountered a number of issues, primarily due to the widespread presence of limestone outcrops in the region, which analytical techniques cannot always distinguish reliably. The results of the analyses indicate the use of a wide variety of limestone types,

including Aurisina limestone and other lithotypes from the Karst region, as well as limestones from the western basins of the Berici Hills, the eastern Lessini Mountains, and possibly the Euganean Hills, where Vicenza stone and Scaglia Rossa were quarried (Figure 6). An additional area that may have supplied some of the materials described here is the Treviso-Belluno Pre-Alps (Figure 1). For example, limestones from the Scaglia Rossa Formation, known as Castellavazzo stone, have been quarried since Roman times at Castellavazzo (originally named *Castrum Laebactium*), along the Piave River, where a Roman necropolis with tombs containing rich grave goods has been found. Tombstones, a stele dedicated to Nero, and a slab bearing a votive dedication to Asclepius (also known as *Aesculapius*, the Roman deity of health) were all made of red and grey Castellavazzo stone.

Lithotype		Description	Geological Age	Regional outcrops
Vicenza stone		This slightly clayey, organogenic limestone consists of clastic material and fossil remains (such as montmorillonite and foraminifera) and has a highly heterogeneous structure. It is composed of 80–90% calcium carbonate, along with significant amounts of silicon oxide, aluminium and iron.	Eocene-Oligocene	Berici Hills
Scaglia Rossa		Red Scaglia is a marine sedimentary rock formed mainly in pelagic environments. It has a fine-grained, marly, calcareous lithology. It is predominantly brick red in colour, but can vary to white, yellow or ash grey. Its microfossil content mainly comprises planktonic foraminifera, including <i>Globotruncana</i> , <i>Heterohelix</i> and <i>Rosita contusa</i> .	Upper Cretaceous – Lower Eocene	Lessini Mountains / Euganean Hills / Treviso-Belluno Prealps
Aurisina Limestone		This sedimentary limestone rock has a light grey background colour that sometimes tends towards hazelnut brown. It is characterised by its high purity, compactness and homogeneity. It contains an abundance of Rudists, as well as radiolites and Chondrodontae.	Upper Cretaceous	Aurisina, Trieste Karst
Karst Limestone		Gray-white sedimentary limestone rock that is compact and characterised by abundant bioclastic fragments.	Upper – Lower Cretaceous	Trieste Karst
Istrian stone		Mudstone originated from the diagenesis of calcareous mud, which is composed of very fine-grained calcite crystals. It is highly compact with rare, small, generally globular or elongated pores.	Mesozoic	Istrian peninsula

Figure 6. Image showing the macroscopic and petrographic features of the six distinct limestone types identified in the study (elab. by C. Girotto).

The data collected from Oderzo and Concordia Sagittaria suggest a higher incidence of imported Aurisina limestone, whereas Vicenza stone and Scaglia Rossa, whether extracted from the western basins or from the Treviso-Belluno pre-Alpine, appear to be less common (Figure 7).

To reconstruct the trade routes likely followed by these stone shipments, it is useful to recall the main overland and endolagoonal routes of the *X Regio*. The area corresponding to present-day Veneto region was traversed by several major rivers—the most important being, from west to east, the Po, the Adige, the Brenta, the Piave, the Livenza, the Lemene, and the Tagliamento. Numerous tributaries and smaller watercourses ran between them, crossing the lowlands and often passing through or near major urban settlements. All these major rivers, as well as and many of their tributaries, were navigable and connected to an endolagoonal navigation system, comprising a network of canals and lagoons along the coast that in Roman times extended from Ravenna to Aquileia [52].

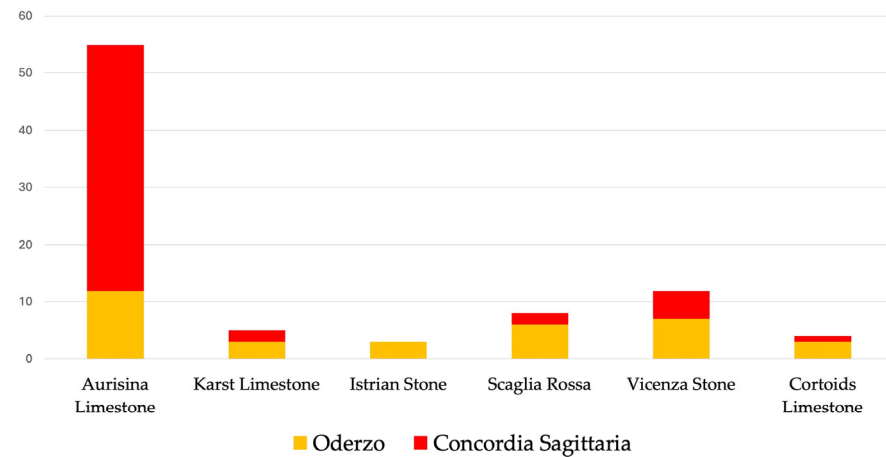


Figure 7. Graphic representation of the number of samples of sedimentary lithotypes documented in Oderzo and Concordia Sagittaria (elab. by C. Giroto).

The close integration of waterways and overland routes—such as the *Via Annia* and the *Via Postumia* [29]—formed a comprehensive communication and exchange network, within which urban centres such as Oderzo and Concordia Sagittaria acted as commercial hubs and distribution points for goods in transit. It is therefore unsurprising that building materials—particularly stones—could have reached construction sites in these cities from distant areas connected by both land and water routes.

For example, given the proximity of the quarries to the coast [1] and considering the economic advantages of sea transport at the time [53], it is likely that materials from the Karst region near Trieste (including Aurisina limestone and other lithotypes), located approximately 90–100 km away from Oderzo and Concordia Sagittaria, and from the Istrian Peninsula (notably Istrian stone), roughly 140 km away, arrived via the aforementioned complex endolagoonal system.

Following this route, loads destined for Oderzo would have reached *Portus Liquentiae* [54], a coastal landing point from which it was possible to sail up the Livenza and Monticano rivers to reach *Opitergium*. Goods bound for Concordia Sagittaria, meanwhile, could have been offloaded at *Portus Reatinum*, the coastal port of *Iulia Concordia*, located at the mouth of the Lemene River (Plin. Nat. [Hist.] 3.126) (Figure 8).

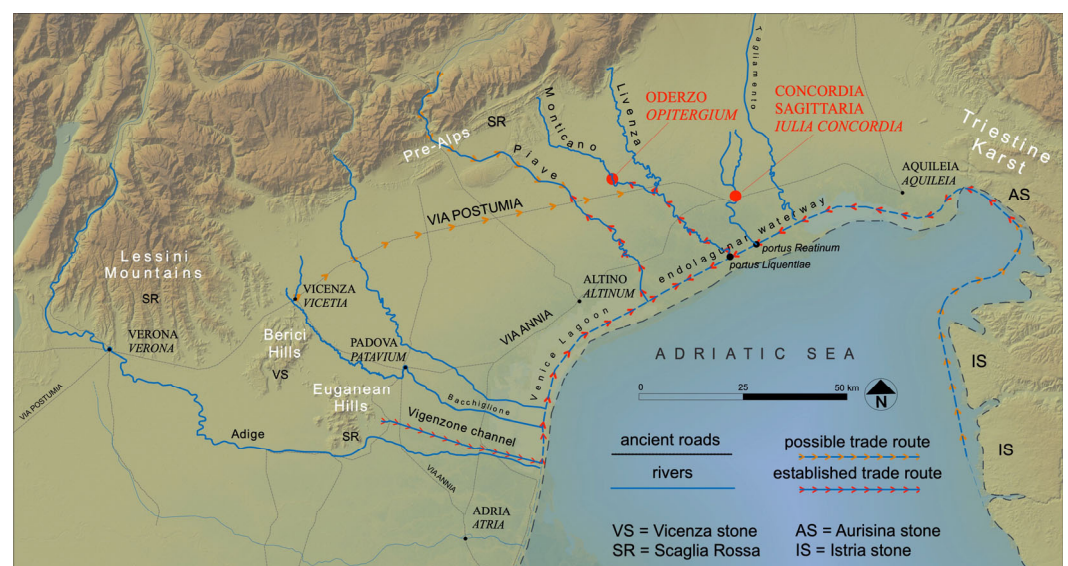


Figure 8. Map of the X Regio depicting the extraction basins and trade networks used by ancient Oderzo and Concordia for stone supply (modified from [9]; basemap elaboration by P. Kirschner, J. Bonetto).

Alternative solutions can be envisaged for the transport of limestone from the Berici Hills to Oderzo and Concordia Sagittaria, located approximately 80–100 km west of these settlements. It is possible—if not highly probable—that the Bacchiglione River, which flowed at the foot of the Berici Hills and thus close to the quarry sites, was initially used to transport the quarried stone. This hypothesis is supported by the relatively recent discovery of a shipwreck whose load comprised unfinished architectural elements, demonstrating that the river was used as a trade route for stone in Roman times [55].

The Bacchiglione River bordered the north-eastern sector of the Berici Hills before continuing eastward toward the Venice Lagoon. From there, the stone could have followed the endolagoonal route to reach the mouth of the Piave River near the coastal town of Eraclea. It could then have been delivered either by land or via artificial canals to its final destination—or alternatively, continued to *Portus Reatinum*.

A third hypothesis should also be considered, although it is less likely due to the economic disadvantages involved. To the northwest of the Berici Hills ran the *Via Postumia*, which continued through Vicenza and then continued eastward, just south of Oderzo [29]. Limestone quarried from the Berici Hills may have been transported by cart to Vicenza and from there to Oderzo. This scenario is plausible, particularly given the relatively small quantities of material indicated by the archaeological samples analysed in this study. In such cases, the overland route—approximately 70 km—may have been more economically viable due to lower transshipment costs [53].

It is also reasonable to assume that Scaglia Rossa was transported by river, whether sourced from the Euganean Hills, the Lessini Mountains, or the Treviso-Belluno Pre-Alps. In the first case, loads may have been shipped via the Adige River, specifically along a palaeo-channel that once flowed just south of the Euganean Hills—considerably north of its present-day course—and was connected to the endolagoonal system. In this scenario, Scaglia Rossa may have arrived in Oderzo alongside large shipments of Euganean trachyte, the most extensively quarried volcanic rock in the Euganean Hills, which has been identified in both the cities [9].

If Scaglia Rossa originated from the Treviso-Belluno Prealps, the materials may have been transported along the course of the Piave River. This waterway was already in use during the Roman period, likely in the manner described by the Renaissance humanist Pierio Valeriano in his *Antiquitatum Bellunensium sermones quattuor* (1528). Skilled raftsmen used logs floated down from Cadore to construct rafts and steer them along the most dangerous section of the Piave River to *Bellunum* (modern Belluno), after which other raftsmen took over the navigation. After passing the area of present-day Valdobbiadene and Possagno, the river descends into the plain, coming within a relatively short distance from both Oderzo and Concordia Sagittaria (approximately 7–10 km).

4.2. The Use of Limestones in the Main Roman Cities of Eastern Veneto

In both Oderzo and Concordia Sagittaria limestones were primarily used for the production of architectural elements (Figure 9). In both centres, Aurisina limestone appears to be the most used material for this purpose, followed by Vicenza stone, Karst limestone and Scaglia Rossa. Istrian stone, the use of which seems to be suggested through archaeometric analysis only in the context of Oderzo (Table 1; OD_15; OD_36; OD_49), is far less documented.



Figure 9. Selection of archaeological artefacts included in the study: (a) architrave (n. inv. C.10459; CS_74); (b) column (n. inv. C.10401; CS_72); (c) cornice (n. inv. C. 10481; CS_81); (d) frieze (s.n.inv.; CS_80); all images are taken from SIGECweb catalogue—Cataloging campaign promoted as part of the Project Interreg IV Italia-Slovenia “Parsjad—Parco Archeologico dell’Alto Adriatico”—CB017.

Specifically, Aurisina limestone was chosen in both cities mostly for the production of columns, column bases, capitals, architraves, cornices, *acroteria*, and friezes (Figure 10). The use of this stone is well attested both in private and public buildings: two architraves (CS_45; CS_51) and one column (CS_69) were found in Via San Pietro, Concordia Sagittaria, near the ancient theatre, and may therefore have belonged to the architectural decoration of the large building, considering their size [56]. From excavations in Piazza Cardinal Costantini also come a Corinthian capital (CS_40) and two frieze fragments, perhaps once belonging to the city gate through which the Via *Annia* passed—an entrance that likely featured an architectural decoration of some importance [37].

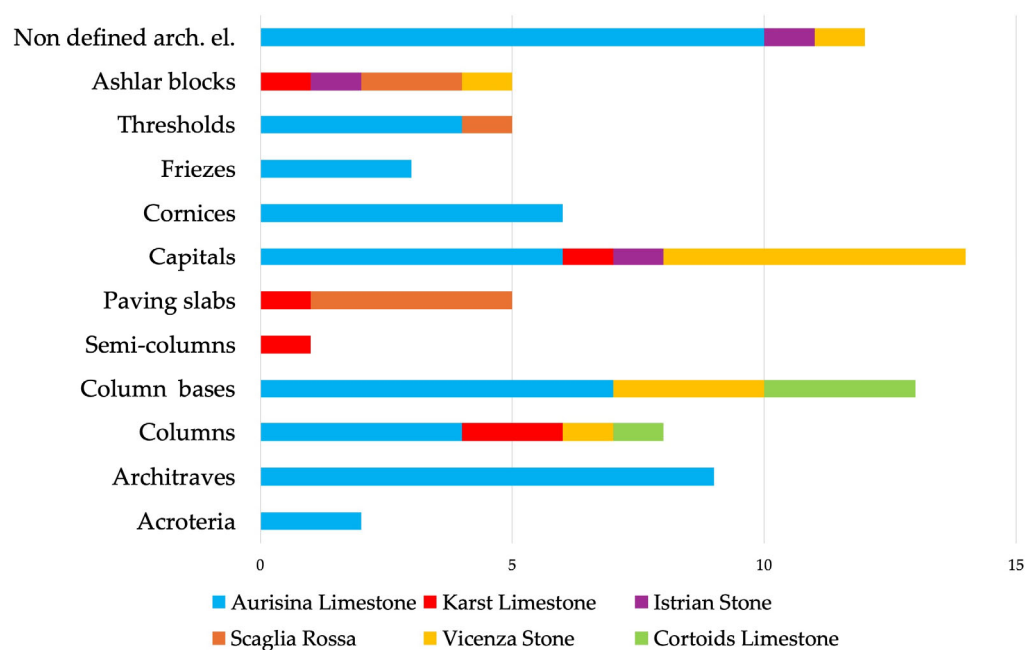


Figure 10. Correlation between limestones and the architectural element types subjected to analysis (elab. by C. Girotto).

Unfortunately, the vast majority of Aurisina limestone architectural elements analysed from both Oderzo and Concordia Sagittaria lack any useful information regarding their findspot or date of discovery, preventing a deeper investigation into the strategies behind their use. Nevertheless, it is clear that Aurisina limestone accounted for a significant portion of the stone imported for construction and decorative purposes in both cities.

Aurisina limestone was not the only lithotype from the eastern quarrying basins to be imported. Among the analysed samples, five fragments were identified whose petrographic profile matches outcrops from the Trieste Karst, although their features do not allow for a precise source attribution. This category includes three examples from Oderzo: a column (OD_50), a capital (OD_43), and a half-column (OD_42), for which the place of discovery is unknown. Similar samples were taken from Concordia Sagittaria, including a column of unknown origin (CS_34) and an ashlar block used in the construction of a wall in the *Domus dei Signini* in its 3rd phase (CS_02).

Vicenza stone too seems to have been largely the preferred lithotype for producing capitals, probably due to the stone's ease of working and its undoubted aesthetic qualities. The architectural decoration of the so-called "Ex Stadio" Area temple in Oderzo, of which numerous fragments have been found during excavation (OD_56; OD_58; OD_59; OD_61), was made of Vicenza stone. In Concordia Sagittaria, this lithotype was used exclusively for architectural elements. Of the five analysed artefacts (two column bases, two capitals, and one block reused as a door jamb), only one—an Italic-Ionic capital (CS_47)—can be linked to a monument in the ancient city and is thought to have originally come from the theatre area.

It is more difficult to identify clear trends in the use of other lithotypes, such as Scaglia Rossa. Certainly, the lower number of samples compared to Aurisina limestone and Vicenza stone complicates attempts to identify repeated associations between lithotype and artefact. Nonetheless, the very absence or low frequency of this stone type is itself noteworthy: with the exception of some large squared blocks reused in the walls of the medieval tower in Oderzo—including the only sarcophagus lid sample (OD_17)—Scaglia Rossa does not appear to have been used for architectural elements in the same way as other identified limestones.

Examples of the use of limestone for structural or infrastructural purposes are not lacking in either city. During the general renovation of the Ex Carceri complex in Oderzo between the 3rd and 4th centuries CE, a threshold in Aurisina limestone was installed. The same is documented for the *basilica* in the *forum* of Oderzo, where a threshold of Aurisina limestone dates to a renovation phase between the 2nd and 3rd centuries CE.

In Concordia Sagittaria, the use of limestone for structural purposes is documented in private buildings. In the *domus* of Via I Maggio, for example, two column bases (CS_15; CS_16) marking a small courtyard were made from squared blocks of Aurisina limestone. In the same house, two thresholds (CS_17; CS_19) of the same material were found: one marking the entrance to the large mosaic room built in the second construction phase of the house (1st–2nd century CE), and the other found nearby but not connected to any structure.

The use of Scaglia Rossa in other contexts is also documented: the lithotype was employed for the paving slabs (CS_08) of the *cavaedium* of the city gate identified in Via Faustiana (Concordia Sagittaria).

Finally, *cortoid limestone* was used for the production of two identical column bases (OD_37; OD_38) and a column (OD_50) from Oderzo, as well as a column base from Concordia Sagittaria (CS_31). Since these are the only known examples of this specific petrofacies, it is difficult to identify recurring patterns of use. However, the fact that two identical artefacts were made from the same material suggests a deliberate choice by the

ancient craftsmen, or that these architectural elements originated from the same stock of stone supplied by the quarry or workshop that received the order.

The reconstruction of the diachronic evolution of the importation and use of the lithotypes identified in the two urban centres is more complex. Unfortunately, many of the artefacts included in the study lack precise dating because they derive from secondary uses, thus often generically attributed to the “Roman Age” (Table 1). It should also be noted that these considerations are based on the analysis of a selection of elements, which undoubtedly constitute only a small proportion of the stone construction that must have characterised the two urban areas.

The use of Vicenza stone is documented in Oderzo from the middle of the 1st century BCE, while in Concordia Sagittaria it first appears towards the end of the same century (Figure 11). Imports of Karst limestone began in both centres at the beginning of the 1st century CE. The data collected so far suggests that the trade ended in Oderzo within the same century. However, it is highly likely that this is due to the lack of information gathered thus far. However, they resumed in Concordia Sagittaria during the 3rd century CE.

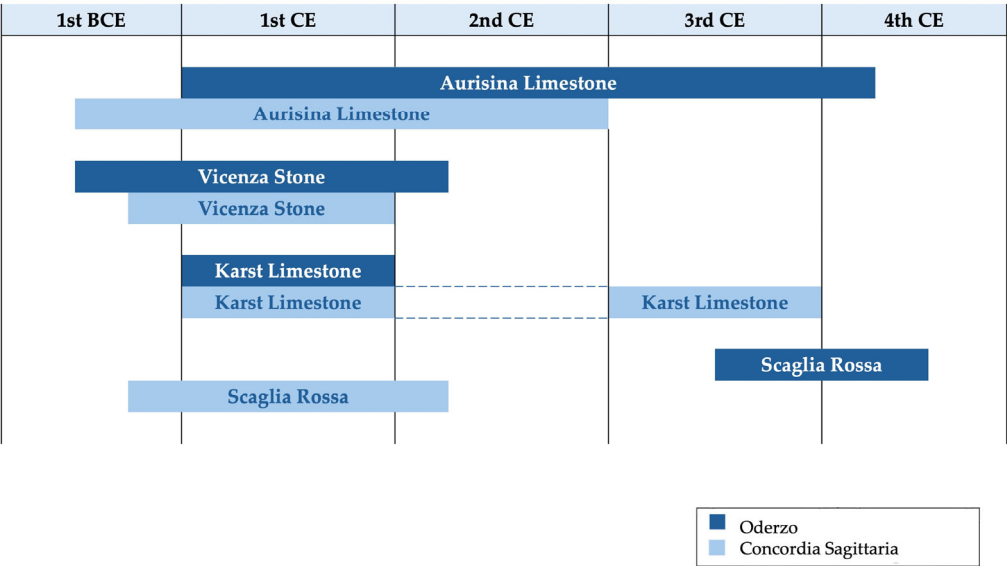


Figure 11. Diachronic evolution of limestone use at Oderzo and Concordia Sagittaria construction sites (elab. by C. Giroto).

It seems that the trend for Aurisina limestone was reversed, as it appears to have been used in construction sites in Concordia Sagittaria in the middle of the 1st century BCE, half a century earlier than the first record in Oderzo. Imports continued until at least the beginning of the 4th century CE in Oderzo, whereas in Concordia Sagittaria, they appear to have ceased by the end of the 2nd century CE.

The chronology of the use of Scaglia Rossa appears to be completely different in the two centres. In Concordia Sagittaria, this stone first appears at the end of the 1st century BCE and was in use until at least the beginning of the 2nd century CE. However, the same lithotype does not appear to have been imported in Oderzo before the 3rd century CE. It cannot be ruled out, though, that Scaglia Rossa was present in Oderzo’s construction sites in previous centuries, and that this gap in the data is due to a lack of documentation.

Unfortunately, nothing can be said about the chronologies of import of the Istrian stone and *cortoid limestone*, as no chronological information was available for the artefacts from which they were collected. We may speculate that Istrian stone represents a phase of extraction activity and commercialisation of this material or may simply represent the

exploitation of a specific lithostratigraphic horizon among the numerous exploited from the Trieste Karst in Roman times.

This brief summary of how stone was exploited and used in Roman architecture in the two main cities of eastern Veneto highlights that these urban centres shared many of the same strategies for procuring and using stone, partly in terms of chronology, despite the stone coming from quarries located at a considerable distance.

The question now arises as to what prompted the ancient builders to go so far to find these essential raw materials. Interestingly, the most attested lithotypes are those outcropping in quarry basins located farther from the two cities. The Trieste Karst, for example, lies 60–90 km from Concordia Sagittaria and Oderzo, respectively, while the Berici Hills and Lessini Mountains are approximately 80–100 km to the west of the two settlements. Several factors may explain why the builders and patrons of *Opitergium* and *Iulia Concordia* sourced stone from such distant areas rather than exploiting the nearer outcrops, located just 30–40 km away and aligned with the pre-Alpine arc, which appear to have been used to a much lesser extent.

The first and most evident reason concerns the physical and mechanical properties of the rocks found in each basin. The limestones from the Treviso-Belluno Prealps, although characterised by good resistance, compaction, and a certain aesthetic appeal, cannot match the quality of the Aurisina limestone [57]. Furthermore, their wide distribution, even beyond the borders of the *X Regio*, suggests that a well-established network of transport and trade must have developed over time to facilitate the movement of such heavy loads, which would have required vehicles with significant load capacity. Various studies [58,59] indicate that this network largely coincided with the region's dense system of waterways. Given that the two cities are located approximately 20 km apart, and both imported stone from the same quarries, it is reasonable to assume that some of the material transported to Concordia Sagittaria rather than to Oderzo followed the same transport routes, which presumably differed only in the final stretch.

In addition, it is probable that only the most heavily exploited basins in antiquity were integrated into the complex trade networks of building materials. Clients likely chose these quarries because they were efficiently organised in both extraction and distribution, offering a level of reliability that justified the considerable costs involved.

5. Conclusions

In conclusion, in both Oderzo and Concordia Sagittaria, limestones—especially Aurisina limestone and other Karst limestones—were widely used for architectural elements such as columns, capitals, architraves, and cornices. Vicenza stone was also commonly used, particularly for capitals, due to its ease of carving and aesthetic qualities. Other stones, such as Scaglia Rossa and Istrian stone, were used less frequently.

In both cities, Aurisina limestone was employed for both decorative and structural elements in public and private buildings. Some fragments, including column bases and capitals, indicate use in major monuments such as the theatre and city gates. Other Karst limestones and Vicenza stone were also imported and used exclusively for architectural elements.

Lastly, it is interesting to note that despite the availability of closer stone sources, builders in Concordia and Oderzo frequently selected materials from more distant quarries—such as those in the Trieste Karst and Euganean Hills—likely due to the superior strength, workability, and aesthetic qualities.

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