# MICROPALEONTOLOGY AND CULTURAL HERITAGE: THE STONE CLADDING MATERIALS OF THE RELIGIOUS BUILDINGS OF PRATO (TUSCANY-ITALY)

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## ABSTRACT

Microfossils are a group of small size fossil organisms commonly used by geologists in relative age determination and paleoenvironmental reconstructions. More recently, micropaleontology has found applications as an archaeometric tool in the field of archaeology and architecture providing a minimally invasive method for the study of artifacts and building phases. The purpose of this paper is to apply micropaleontological analyses of calcareous nannofossils and calpionellids assemblages to establish the provenance of carbonate lithotypes widely used as ashlars in religious buildings of Prato. The monumental architecture of Prato extensively used a local limestone, the Pietra Alberese. It is a grey marly limestone, which upon exposure to atmospheric agents, becomes whitish or it takes on a brownish colour. This brownish chromatic alteration is found distributed both randomly in isolated ashlars but also appears in linear patterns, particularly in religious buildings. Materials taken from the façade of San Francesco Church in Prato document that the different pattern of alteration arises from the use of two different calcareous lithotypes, namely Pietra Alberese (Eocene) and Calpionella Limestone (Lower Cretaceous). The Pietra Alberese sometimes suffers an ochre colour of alteration, powder to the touch and the altered ashlars show a random distribution on San Francesco Church façade, while Calpionella Limestone regularly suffers of ochre colour of alteration, not powdery to the touch, and is distributed according to a linear pattern.

## INTRODUCTION

Microfossils refer to a heterogenous group of microscopic size organisms that occur in the geological record from the Precambrian to Recent ages. Their general widely geographical distribution, abundance and rapid evolution were applied by geologist to establish the relative age of sedimentary successions, in the stratigraphic field termed as biostratigraphy. More recently, the study of microfossils found applications also as an archaeometric tool in a range of archeological and architectonical studies including provenance analyses, technological studies on manufacturing and interpretations of their function, study of the different building phases (Quinn, 2008).

Calcareous nannofossils refer to fossil remains of calcium carbonate plates secreted by coccolithophores, a group of planktonic single-celled algae. Nannofossils represent one of the main components of marine rocks such as marls, chalks and limestone starting from Late Triassic (Bown et al., 2004). Their high abundance together with the small size (<30 $\mu$m), makes nannofossil analysis applicable also on small amount (few mg) of sample material. The potential to obtain samples using a minimally invasive method makes calcareous nannofossil analysis a powerful tool for examining various archaeological materials, including building stones, statues, ceramics and grounds of painting (e.g., Von Salis, 1995; Fiorentino, 1998; Wilkinson et al., 2010; Lübke et al., 2018; Calderón Mesén et al., 2023; Falkenberg et al., 2023).

Calpionellids are planktonic protozoans which have an urn-shaped calcareous test. Their rapid evolution and short stratigraphic distribution across the early Tithonian to late Valanginian, make Calpionellids good biostratigraphic markers for Upper Jurassic to Lower Cretaceous successions of Tethyan Realm (Benzaggagh, 2020).

The traditional building material of Prato, Pistoia and of the countryside between Siena and Florence is the Pietra Alberese (Fig. 1). It has a light grey colour in the fresh cut that upon exposure to weathering becomes whitish and sometimes the stone, to the untrained eye, looks like marble. However, the presence of ashlars that develop an ochre colour can also be observed, in open dissonance with the intent of the ancient builders. These ashlars may be randomly distributed but also appear in a linear pattern, testifying different construction phases, as in the façade of San Francesco Church in Prato (Fig. 1a and b) and in Prato Cathedral (both on the façade and on the two outer sides of the nave) (Fig.1c, d and e).

In many cases these ochre ashlars are also found alternating with dark serpentinite layers (see Fig. 1b and c). It is not plausible that at the time of construction these buildings appeared with such chromatic alteration. In addition, the replacement can be excluded considering the high durability of this compact, fine-grained limestone.

Therefore, the chromatic alteration has developed over the years with exposure to the action of atmospheric agents. Remarkably, this alteration does not entail a decay of the material, which is compact. Moreover, the surface of the randomly distributed altered ashlars is powdery to the touch, which is not the case of the ashlars distributed according to a linear pattern.

This difference in the alteration behaviour suggests a possible different provenience for the two types of ashlars, as hypothesized also by Coli et al. (2022) and Verdiani (2010) for the Prato Cathedral. However, as evident from a careful reading of their articles, these authors based their hypothesis solely on macroscopic features (which can sometimes be misleading) without the support of analytical data such as mineralogical-petrographic, micropaleontological, or elemental analyses.

Two formations containing carbonate lithotypes aesthetically similar to Pietra Alberese, namely the Calpionella Limestone and the Palombini Shales, crop out north of Prato, near the village of Figline di Prato (Fig. 2). The occasional use of these carbonate lithotypes would justify the differences in the chromatic alteration phenomena, in particular those distributed according to a linear pattern.

The aim of the present study is to test this hypothesis by analyzing samples of ashlars from the façade of San Francesco Church (Prato) with respect to their provenience by


Fig. 1 - Religious buildings in Prato (Italy). a) Façade of San Francesco Church with ochre ashlars forming light bands alternating with the dark serpentinite. b) Detail of the San Francesco Church façade showing the ochre ashlars with a random distribution together with that having a linear distribution pattern. The white elliptic line indicates the location of samples (SF-4, SF-5). c) Santo Stefano Cathedral in Prato. d) Southern lateral aisle of Santo Stefano Cathedral in Prato displaying ochre ashlars displayng ochre ashlars according to a linear pattern with those aligned in the limestone layers one next to another. e) Detail of Santo Stefano Cathedral in Prato with a random ochre ashlar. f) Basilica of Santa Maria delle Carceri in Prato.

applying micropaleontological analyses of calcareous nannofossils and calpionellids assemblages. We will thus verify the provenance of the carbonate lithotypes used in the religious buildings of Prato in order to justify the observed differences in the chromatic alteration phenomena.

## THE PIETRA ALBERESE IN THE TUSCAN HISTORICAL ARCHITECTURE

The Tuscan naturalist Targioni Tozzetti (1768) described Pietra Alberese as a fine-grained stone, grey to hazelnut in colour in the fresh cut that becomes lighter for alteration, with conchoidal fracture and including frequent calcite veins (Fratini et al., 2022). The name Alberese was traditionally given because of the presence of "small tree figures" (tree = albero in Italian) due to concentrations of iron oxides and manganese in the form of dendrites. This stone crops out around the tectonic basin of Florence-Prato-Pistoia and in the Chianti mountains (Fig. 2a) (Carmignani et al. 2004).

During the Middle Age, the Pietra Alberese was used as stone material in the structures and façades (e.g., as ashlars and cladding) of many public and religious buildings of Prato and Pistoia (Fig. 1). Conversely, in Florence the Pietra Alberese was regarded only to produce lime (Fratini et al. 2020).

In Prato, located at the foot of the Calvana ridge (where Pietra Alberese crops out extensively), it can be found in Emperor Castle (1237-1245), in the most recent part of the Palazzo Pretorio (XIV$^{th}$ century), in the external cladding of Santo Stefano Cathedral (XII$^{th}$-XIV$^{th}$ century) in alternating strips with serpentinite (Fig. 1c), as well as in the façades of the churches of San Francesco, San Domenico and San Niccolò.

The church of Santa Maria delle Carceri, Renaissance masterpiece designed by Giuliano da Sangallo at the end of the XV$^{th}$ century, with Greek cross plan, is also cladded in Pietra Alberese with linear serpentinite decorations outlining the architectural parties (Fig. 1f). The city walls are also built in Pietra Alberese, both in roughly shaped blocks and pebbles.

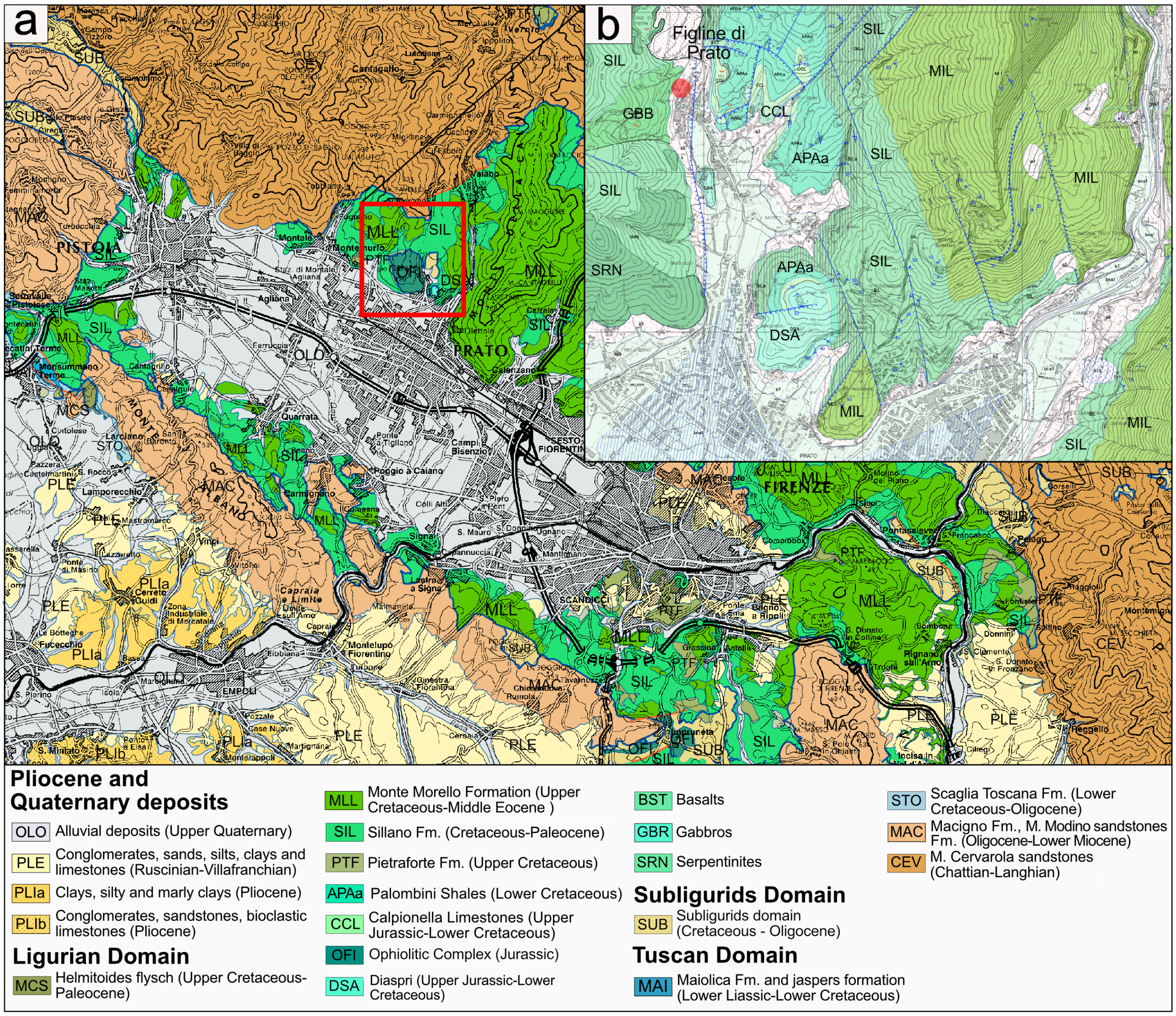


Fig. 2 - a) Geological map of Florence-Prato-Pistoia basin: 1:250,000 (modified after Carmignani, Lazzarotto and Coordinators, 2004). b) Geological map of Figline di Prato (red dot) and Monte Ferrato area, showing the ophiolite succession and related sedimentary cover (modified from CARG, 2012).

In Pistoia, the Pietra Alberese is not the main building material (because close to the town there are important outcrops of Pietra Serena sandstone, Rodolico, 1964). Nevertheless, it is used as dressed stone in numerous civil structures and prominent religious buildings, such as the San Zeno Cathedral (XII$^{th}$-XIII$^{th}$ century), in the lower part of the façade of San Andrea (XII$^{th}$ century), in the churches of San Francesco and San Salvatore. Similar to Prato, the Pietra Alberese is often associated in bichromie with the green serpentinite (Fratini et al., 2022).

Concerning serpentinite, we should recall that the plain between Florence and Pistoia is the territory with the highest use of this material in the architectural decoration of the religious buildings (Fratini et al., 2022). This use dates to the XI$^{th}$ century with the flowering of Romanesque architecture (Gurrieri, 1989; Ruschi, 1989). Moreover, serpentinite decorations can be observed in Empoli, Siena, Volterra, and in the churches of many countryside villages. It is generically called "Green marble" and locally, in the territory of Florence-Prato-Pistoia, "Verde di Prato" or "Nero di Prato" (Repetti, 1839). The use is mainly for polychrome cladding and for floors, more rarely as column drums as in the Prato Cathedral. It is clearly a local use linked to outcrops of limited extension widespread in the territory of the region. For the Florentine plain and Empoli, the serpentinite comes from the large outcrop of Mt. Ferrato, near Prato, for Siena the serpentinite was quarried at Crevole and Vallerano, near Murlo, 25 km south of Siena (Giamello et al., 1992), for Volterra from the nearby outcrop of Ulignano (Fratini et al. 2022).

## GEOLOGICAL SETTING OF PIETRA ALBERESE, CALPIONELLA LIMESTONE AND PALOMBINI SHALES

The Pietra Alberese belongs to the Eocene Monte Morello Formation of the Monte Morello Tectonic Unit (Bortolotti et al., 2008; 2010) which was deposited in the Ligurian-Piedmontese Ocean. The Monte Morello Formation is made mostly by turbiditic sequences of limestones, marly limestones and marls (Fig. 3a) (Bortolotti, 1962; 1964; Ponzana 1993).

The limestones and slightly marly limestones are light grey in the fresh cut and characterized by conchoidal fractures. The beds are centimetre to some meters thick and rarely enclose bands and nodules of grey to black chert strips. The marly lithotypes are grey in colour with "soap"-type lenticular splitting whose thickness varies from few decimetres to about 15 m. The fossiliferous content is generally in the range 6-20% with respect to the micritic-marly groundmass. Locally, grey decimetre (max 40 cm-thick) biocalcarenitic beds at the base of the marly beds occur. The early to middle (Lutetian) Eocene fossiliferous content in the calcareous-marly beds consists in microforaminifera (e.g. *Globorotalia* and *Globigerina*) and calcareous nannofossils, sometimes with reworked Late Cretaceous and Paleocene species, whereas in the calcarenitic beds, macroforaminifera (e.g., Nummulites, Alveolina and Discocyclina) are also present (Bortolotti, 1962; Bortolotti et al., 2010). The thickness of the formation is at least 700 m.

The Calpionella Limestone and the Palombini Shales are two pelagic formations that, like the Pietra Alberese, were deposited in the Ligurian-Piedmontese Ocean. They are therefore part of the Ligurian successions but they belong to the Val di Vara tectonic unit, which overlies the Monte Morello tectonic unit. In the Northern Apennines, together with the Monte Alpe Cherts, they constitute the lower part of the sedimentary succession that was deposited directly over the ophiolitic rocks of the oceanic basement (Bortolotti et al., 2008).

The ophiolitic successions of the Ligurian-Piedmontese Ocean crop out near the Monte Ferrato ophiolitic massif north of Prato. These include serpentinites, gabbros and basalts together with their sedimentary cover consisting of Monte Alpe Cherts, Calpionella Limestone and Palombini Shales (Chiari, 1994). The ophiolite succession exposed in the Monte Ferrato area was quarried since the 11$^{th}$ century providing claddings stone known as "Verde di Prato" (Fratini and Rescic, 2014), often combined with white marble and/or red limestone for the realization of the polychrome façade of religious buildings.

The Calpionella Limestone, formerly Figline Formation (Merla et al. 1967), consists of whitish to light grey calcilutites and calcisiltites in layers varying in thickness from 15 cm to 3 m with conchoid fracturing, with generally grey

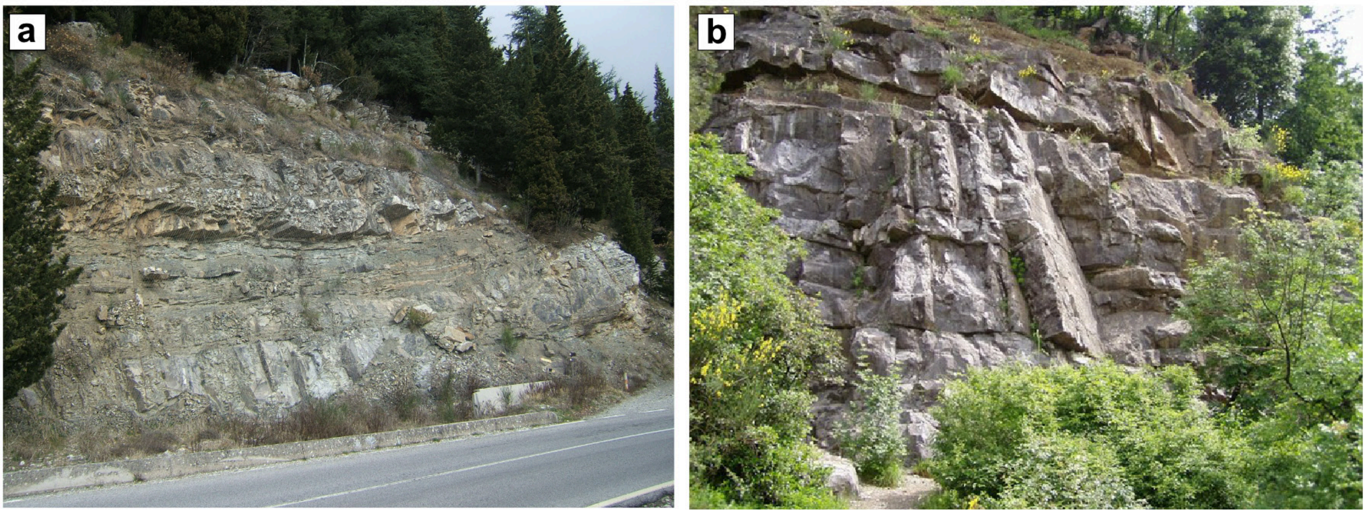


Fig. 3 - a) Field photograph of Monte Morello Formation of turbiditic sequences: limestones, marly limestones and marlstones; b) field photograph of Calpionella Limestone near Figline di Prato.

cherty strips and nodules containing Calpionella, radiolarians, sponge spicules and calcareous nannofossils. Between the limestone layers are generally interspersed thin pelitic layers that increase in thickness towards the top of the formation (Fig. 3b).

In Graveglia Valley (Liguria), Cobianchi et al. (1994) subdivided the Calpionella Limestone into four lithozones: the basal lithozone **A** is a transitional facies to the underlying Monte Alpe Cherts, characterised by red and/or varicoloured shales interspersed with decimetric layers of silicified micritic limestones, sometimes with chert, white and more rarely pinkish and greenish; lithozone **B** consisting of white to greyish micritic limestones from 15 cm to 3 m thick with pelitic intervals of up to millimetric /centimetric thickness; lithozone **C** with limestones similar to the previous ones and layers of 'granular' limestones; lithozone **D** with thinner and darker limestone layers, rusty on alteration. The thickness of the formation in the Figline di Prato area reaches about 80 m. At the top, the formation of the Calpionella Limestone pass to the Palombini Shales with the progressive increase of shale intercalations. In the same area, Cobianchi and Villa (1992) and Cobianchi et al. (1994) indicate an age of late Titonian for the basal part of the Calpionella Limestone, i.e. the transition between the Chitinoidella zone and Remane's (1985) subzone A1, for lithozone B the late Titonian-Berriasian (zone B), for lithozone C the Berriasian (subzones D1 and D2), for lithozone D, the late Berriasian-early Valanginian (subzone D3).

The Palombini Shales consist of predominant shales interspersed with grey micritic limestone more or less siliceous, with a conchoidal fracture, a rusty alteration colour and the characteristic anvil erosion (Palombini). This is because the silicification is more intense near the bedding planes. These carbonate layers are more abundant towards the base of the formation. They tend to disappear towards the top to leave place to layers of fine-grained quartz sandstones and siltstones interbedded in the shales. At the top, the formation passes to the Lavagna Shales Formation. The presence of radiolarians and tintinnids indicates an age between the late Hauterivian and the late Santonian for this formation (Marroni and Perilli, 1990; Cobianchi and Villa 1992; Cobianchi et al., 1994).

## MATERIALS AND METHODS

For this study, micropaleontological analyses were performed on samples of stone ashlars collected from the upper part of the façade of San Francesco Church in Prato taking advantage of the presence of a restoration yard.

Two samples were collected for this study taking advantage of fractures already present in the ashlars (Fig. 4a and b): sample SF-4 from ochre coloured ashlars not powdery to the touch, distributed according to a linear pattern, and sample SF-5 from randomly distributed ashlars that had undergone ochre colour alteration powdery to the touch.

The samples were analyzed both for calpionellid and calcareous nannofossil content. The thin section analysis was performed using a Leica DM750P microscope at 20 and 40X magnification whereas calcareous nannofossils were examined using standard light microscope techniques under cross polarizers and transmitted light at 1250X magnification (Zeiss Axioplan 2). Samples for calcareous nannofossil analysis were prepared as smear slides following the techniques described by Monechi and Thierstein (1985).

For each studied sample the total abundance of calcareous nannofossils was characterized as number of specimens per field of view, as follow: Abundant, 21-30 specimens; Common, 11-20 specimens; Few, 6-10 specimens were present in each field of view; Rare, 1-5 specimens were present in each field of view. Regarding the species abundance, it was characterized as follows: Abundant if more than 1 specimen is present in each field of view; Common if 1 specimen is present in 2-10 fields of view; Few if 1 specimen is present in 11-30 fields of view; Rare if 1 specimen is present in more than 31 fields of view.

The calcareous nannofossil preservation is affected by dissolution and/or overgrowth process. In this study, the preservation, was determined based on the following criteria: Good, little or no evidence of dissolution and/or overgrowth, and the primary morphological characters of nannofossil specimens are only slightly altered allowing species identification; Moderate, some etching and/or overgrowth, and the primary morphological characters are somewhat altered allowing, however, identification at the species level; Poor, primary morphological characters are obliterated due to a severe

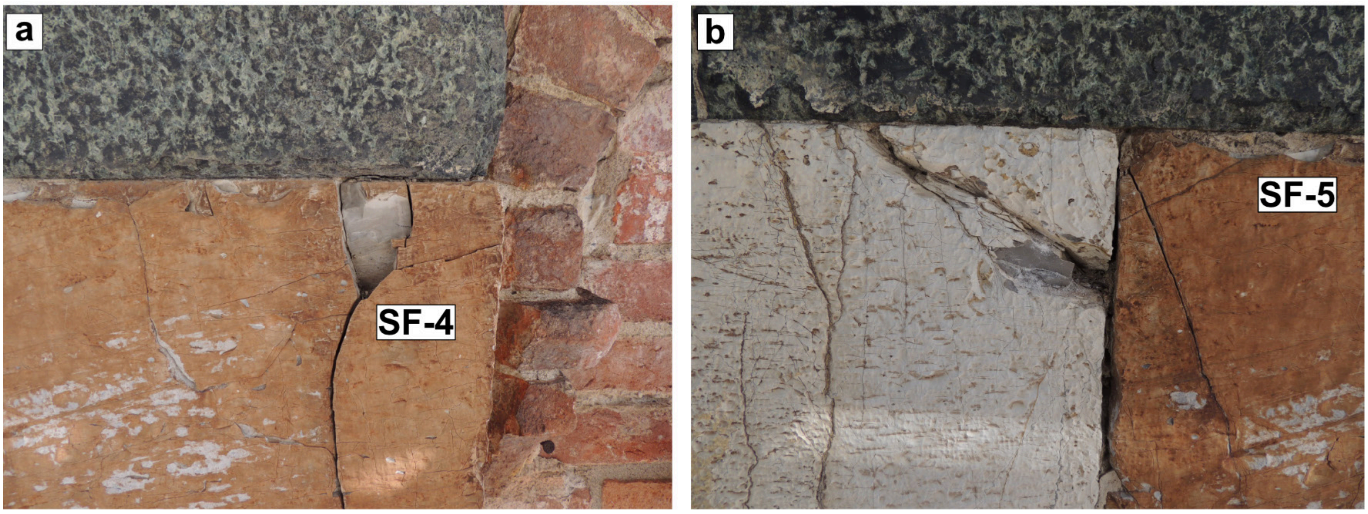


Fig. 4 - Ochre coloured stone ashlars from the upper part of the façade of San Francesco Church in Prato: a) ochre coloured ashlar distributed according to a linear patern - sample SF-4; b) randomly distributed ochre coloured ashlar - sample SF-5.

etching and/or overgrowth not allowing the identification at the species and/or even generic level.

## RESULTS

### Sample SF-4

The analysis of the thin section of sample SF-4 reveals the presence of calpionellids and calcified radiolarians. The calpionellid assemblage is characterized by the occurrence of *Calpionellopsis* sp., *Remaniella* sp., *C. simplex* and *C. oblonga* (Fig. 5).

The calcareous nannofossil analysis of sample SF-4 reveals a rare and moderately to poorly preserved assemblage, primarily consisting of a small number of *Watznaueria barnesiae* and *Nannoconus steinmannii steinmannii*. Rare species include *Braarudosphaera regularis, Cruciellipsis* sp. cf. *C. cuvillieri, Cyclagelosphaera centrumelliptica*, *Micrantholithus obtusus, Nannoconus infans, N. steinmannii minor, Percivalia* sp.*, Watznaueria biporta, W. communis, W. manivitiae, Zeugrhabdotus embergeri* (Fig. 6).

### Sample SF-5

Sample SF-5 shows a rare and poorly preserved assemblage mainly composed of a few *Sphenolithus radians* and *Sphenolithus* sp., whereas rare species include *Coccolithus pelagicus, Coccolithus* sp. 1, *Coccolithus* sp. 2, *Discoaster barbadiensis*, *Ericsonia* sp.*, Neochiastozygus* sp.*, Zygrhablithus* sp. and reworked Paleocene specimens (Fig. 7).

### Biostratigraphy and provenance determination

The occurrence, in the sample SF-4, of *Calpionellopsis simplex* and *Calpionellopsis oblonga* enables the identification of the *Calpionellopsis* Zone, D2 subzone (Benzaggagh, 2020). The calcareous nannofossils analysis show the occurrence of *N. steinmannii steinmannii* and the absence of *Retecapsa angustiforata* allows the identification of the NK1 biozone of Bralower et al. (1989). Thus, the micropaleontological analysis points out a Berrasian age (Early Cretaceous) for sample SF-4 showing a general agreement between the calcareous nannofossil and calpionellids records.

This result is similar to the age of late Tithonian-early Berrasian to early Valanginian-late Hauterivian suggested by Cobianchi and Villa (1992) for the Calpionella Limestone Formation in the Graveglia Valley (Liguria). Moreover, the biostratigraphic data of this study allow for identification of Calpionellid subzone D2 which corresponds to the lithozone C of Cobianchi et al. (1994).

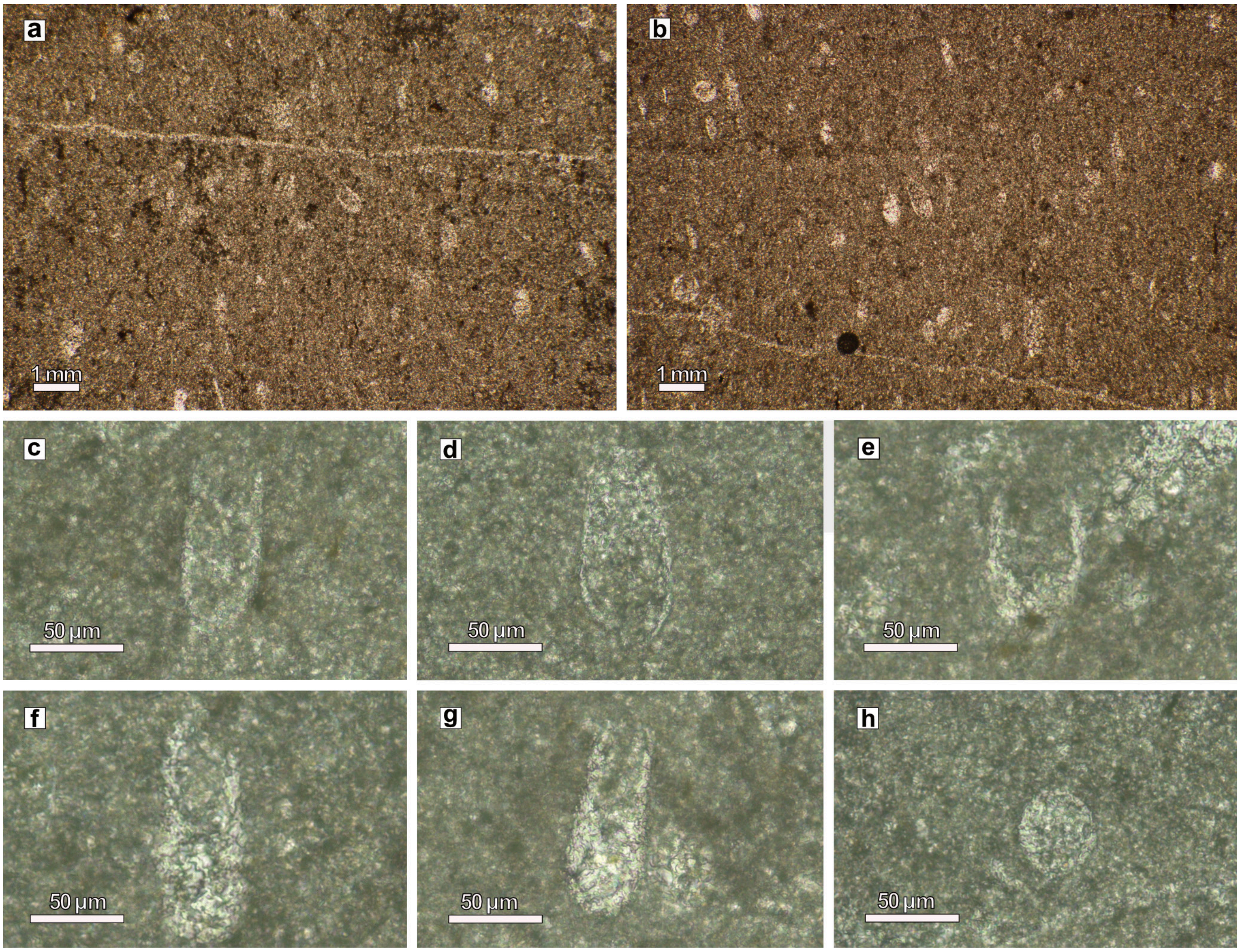


Fig. 5 - Photomicrographs of calpionellid limestone (sample SF-4): a-b) Calpionellid microfacies with radiolarians; c) *Calpionellopsis* sp.; d) *Calpionellopsis* sp.; e) *Remaniella* sp.; f) *Calpionellopsis simplex*; g) *Calpionellopsis oblonga*; h) Calcified radiolarian.

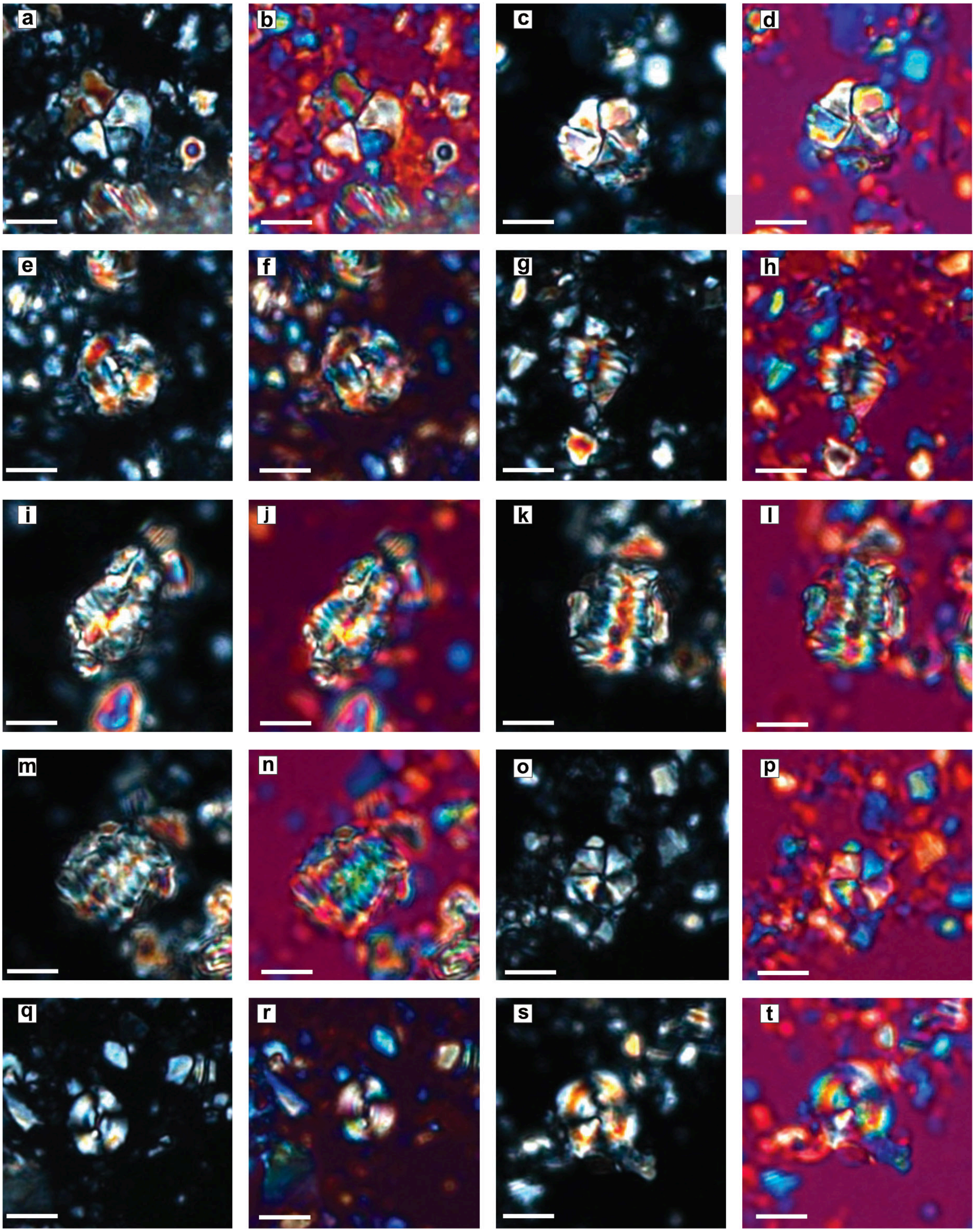


Fig. 6 - Selected calcareous nannofossils from sample SF-4. XPL = cross-polarized light. GP = gypsum plate. Scale bar 5 µm. a-b) *Micrantholithus obtusus*, a - XPL, b - GP; c-d) *Micrantholithus hoschulzii*, c - XPL, d - GP; e-f) *Cyclagelosphaera centrumelliptica*, e - XPL, f - GP; g-h) *Nannoconus infans*, g - XPL, h - GP; i-j) *Nannoconus steinmannii steinmannii*, i - XPL, j - GP; k-l) *Nannoconus steinmannii steinmannii*, k - XPL, l - GP; m-n) *Nannoconus steinmannii minor*, m - XPL, n - GP; o-p) *Nannoconus* sp. top view, o- XPL, p - GP; q-r) *Watznaueria barnesiae*, q - XPL, r - GP; s-t) *Watznaueria manivitiae*, s - XPL, t - GP.

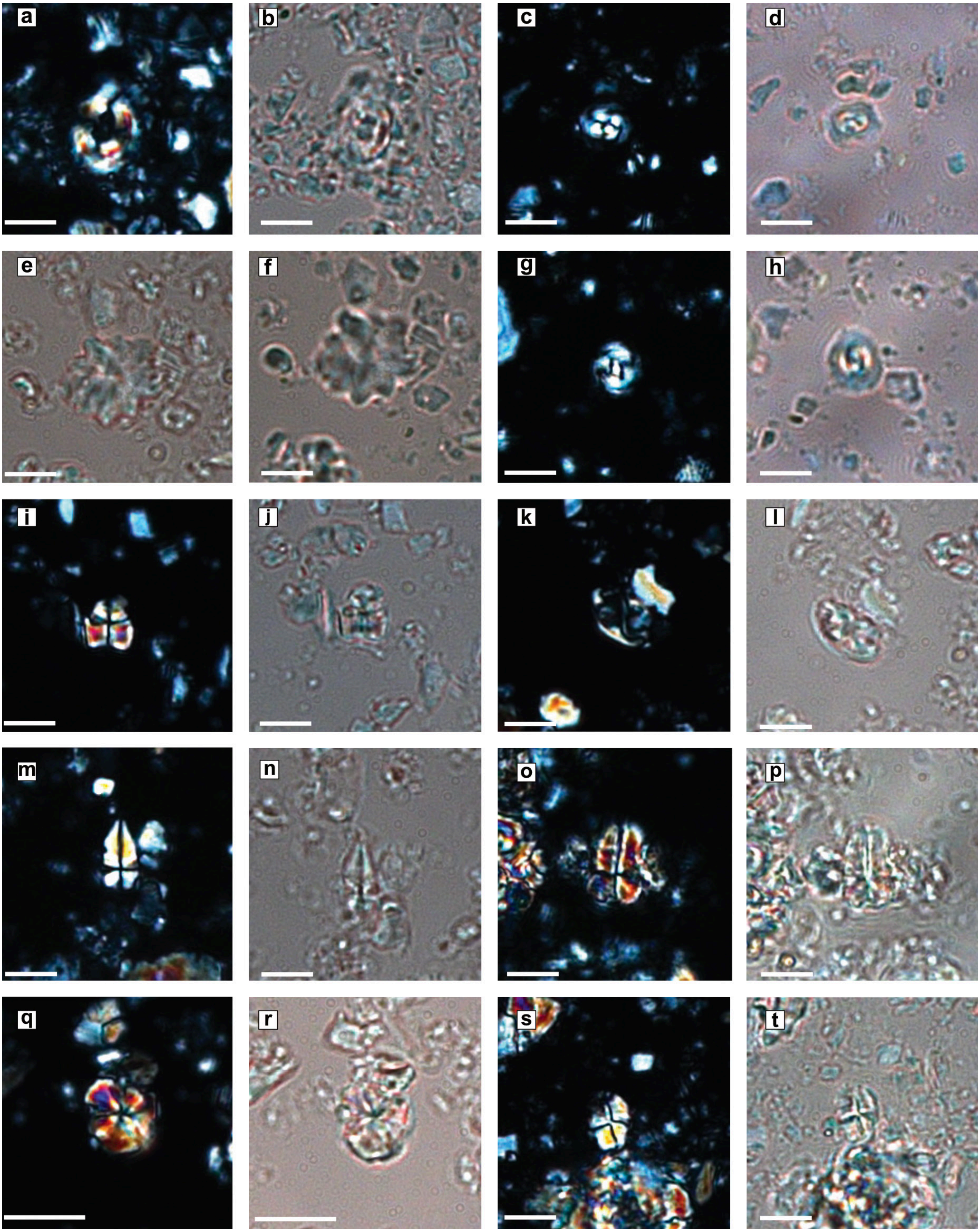


Fig. 7 - Selected calcareous nannofossils from SF-5 sample. XPL = cross-polarized light. PL = plane light. Scale bar 5 μm. a-b) *Coccolithus* sp. 1, a - XPL, b - PL; c-d) *Coccolithus* sp. 2, c - XPL, d - PL; e-f) *Discoaster barbadiensis*, PL; g-h) *Ericsonia* sp. g - XPL, h - PL; i-j) *Lithoptychius ulii* (reworked), i - XPL, j - PL; k-l) *Neochiastozygus* sp. (k) XPL, (l) PL; m-n) *Sphenolithus radians*, m - XPL, (n) PL; o-p) *Sphenolithus radians*, o - XPL, p - PL; q-r) *Sphenolithus* sp. top view; s-t) *Zygrhablithus* sp. s - XPL, t - PL.

However, it is important to note that the age of Calpionella Limestone of the Graveglia Valley was based exclusively on the calpionellid content because it was found to be barren of calcareous nannofossils by Cobianchi and Villa (1992) and Cobianchi et al. (1994). Whereas, our findings reveal the presence of both calpionellids and calcareous nannofossils, with assemblages suitable for age determination.

An early Eocene age was established by Bortolotti et al. (2010) for the lower portion of the Monte Morello Formation, according to the occurrence of calcareous nannofossil *Discoaster lodoensis* e *Tribrachiathus ortostylus* that define the NP12 Zone of Martini (1971).

The calcareous nannofossil assemblage of SF-5 sample is compatible with the Early-Middle Eocene age of the Monte Morello Formation (Bortolotti et al., 2010). Indeed, the occurrence of rare *D. barbadiensis* and few *S. radians* would indicate an indefinite Eocene age for this sample. Therefore, an Eocene age for samples SF-5 point out to the Pietra Alberese as possible source for this ashlar.

The results demonstrate how the Calpionella Limestone and Pietra Alberese undergo different alterations of their calcareous lithotypes when exposed to weathering. The Pietra Alberese, besides a more common whitish colour of alteration, can produce also an ochre alteration, powdery to the touch. This particular alteration is being studied by some of the authors and appears to be linked to a higher concentration of iron in the more marly beds, as indicated by ongoing analyses of iron content, particularly the determination of its oxidation state (ferrous or ferric). In contrast, most of the outcrops of Calpionella Limestone show an ochre coloured alteration which is always not powdery.

Therefore, it is possible that during the construction of the façade of the San Francesco Church, at certain times and for various reasons (economic, convenience of supply, etc.), the construction site sourced materials from the Calpionella Limestone outcrop at Figline di Prato, which is only five kilometers away from the Pietra Alberese outcrop at the foot of the Calvana Mountains (see Fig. 2b).

Unfortunately, without knowing the potential aesthetic consequences for the façade.

In this context, it is worth noting the Pisa Cathedral (Fig. 8a), where the cladding of the lower part of the south side of the nave features ochre-coloured ashlars that starkly contrast with the original design concept. Their provenance has been documented as the Calpionella/Palombini limestone outcrops in the hills near Livorno (Fabiani et al., 2001) (Fig. 8b).

## CONCLUSIONS

In this study we have analyzed the calpionellid and calcareous nannofossils content of two samples collected from limestone ashlars of San Francesco Church in Prato. The San Francesco Church is an example of 13th century architecture with a duotone decorated façade made of alternating strips of darker serpentinite "Verde di Prato" and lighter limestones. However, several limestone ashlars on the façade, upon exposure to atmospheric agents, developed an ochre colour of alteration that lies both with a random and a linear pattern of distribution.

The calpionellids and nannofossil assemblage analyses provided two well distinguished ages. The sample with a Berrasian age was attributed to the Calpionella Limestone Fm. (Val di Vara tectonic unit) whereas the other sample providing an Eocene age was assigned to Pietra Alberese (Monte Morello Tectonic Unit).

This study also demonstrates how Pietra Alberese sometimes suffers an ochre colour of alteration powdery to the touch, while Calpionella Limestone regularly suffer a not powdery ochre colour of alteration giving rise to a linear pattern of distribution when these Limestone are used along the construction phases of the yard, clearly visible in the façade. Both these lithotypes are aesthetical similar and outcrop in the surroundings of Prato, namely Pietra Alberese in the Calvana ridge and Calpionella Limestone in Figline di Prato area where quarries activities are known to be present from the Middle age.

The application of micropaleontological analyses was essential for discriminating between limestone originating from Pietra Alberese and those from Calpionella Limestone. Therefore micropaleontology can represent an excellent archaeometric tool in the field of archaeological and architectonical studies. The microfossil content allows to determine the relative age of the rock used to produce the ashlar, thus establishing a correlation with the provenance area in a quicker and minimally invasive way compared to petrographic and geochemical analysis. Future work should therefore focus on the reasons behind the use, in the same building, of both Pietra Alberese and Calpionella Limestone for the façade ashlars.


Fig. 8 - a) Detail of south side nave of Pisa Cathedral; b) Field photograph of Palombini Shales outcrop near Quercianella (Leghorn).

## DECLARATIONS

**Conflicts of interest/Competing interests: none**

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