The name *peperino* derives from the Italian word *pepe* (from the Latin word *piper*, pepper) and has been used in the common language for lithified volcanic deposits characterized by light grey through dark grey tones and granular textures, resembling that of ground pepper. Among these, the best-known examples are represented by some phreatomagmatic deposits of the Colli Albani Volcanic District, near Rome (Italy), and ignimbrite deposits of the Cimini Mountains near Viterbo (Northern Latium, Italy), which have been widely employed in artefacts of historical and archaeological interest. In particular, these resistant volcanic rocks have been widely employed by the Etruscans and Romans since the seventh century BCE to produce sarcophagi and dimension stones, as well as architectural and ornamental elements. These rocks are still in use for building ornaments, street furniture and artworks in central Italy today. In this review, we provide an overview of the use of this term, and an exhaustive review of the different rocks of central Italy defined as *peperino*, describing their distinctive textural features, as well as their eruptive sources and outcrop areas. Indeed, despite the common macroscopic aspect, *peperino* rocks can be associated with several different eruptive styles and emplacement mechanisms. Our review is also addressed to archaeologists concerned with restoration initiatives and provenance studies, as well as to volcanologists studying the genetic processes of pyroclastic rocks and related naming conventions.

**Keywords** Peperino · Phreatomagmatic rocks, ignimbrites · Dimension stone · Ornamental stone

**Introduction**

The term *peperino* (from the Latin root *piper*, pepper) was originally established in Italy to define peculiar light porous volcanic rocks with a granular texture (resembling ground pepper), used as construction stones since pre-Roman times. Generally speaking, *peperino* is a kind of “diamictite” (sensu Flint et al. 1960), that is a lithified, poorly sorted, deposit consisting of “floating” clasts suspended in a fine-grained matrix (Menzies 2009). According to the Penguin Dictionary of Geology (1972), *peperino* is defined as: “A rock of mixed pyroclastic and sedimentary origin, including pyroclastic material, and weathered and eroded volcanic material (including scoriae, cinders, etc.) cemented together”. In the Oxford Dictionary (1982) *peperino* is defined as: “n. light porous (usu. Brown) volcanic rock formed of small grains of sand, cinders, etc.”. The French dictionary Le Petit Robert suggests the date of 1694 for the arrival of the word *péperin* in the French language to refer to a volcanic tuff employed as construction stone in the Roman region. However, Scrope (1827) extended the use of the term *peperino* to describe clastic rocks from Limagne, in the Auvergne region of central France, which comprise mixtures of lacustrine limestone and basalt and resemble ground pepper. Scrope (1858) interpreted them as having originated by a “violent and intimate union of volcanic fragmentary matter with limestone while yet in a soft state”. To refer to the rocks from this type locality, the term *peperino* then shifted to *peperite*, which is now commonly used for clastic rocks comprising both igneous and sedimentary components, which were generated by essentially in-place disintegration and active mixing of intrusive magma, lava flows or hot volcaniclastic deposits with unconsolidated, typically wet sediments (Skilling et al. 2002; Sigurdsson et al. 2015).
The term peperino (sometimes also reported as piperino) has been used as a rock descriptor in the international geologic literature and volcanology textbooks (e.g. Rittmann 1967; MacDonald 1972; Kilburn and McGuire 2001). Other major textbooks usually describe peperites, yet seldom mention peperino. For example, Cas and Wright (1988) mention peperino in their chapter 4 on volcaniclastic deposits, while Fisher and Schmincke (1984) refer only to the piperno (another rock term derived from peperino, see below) from the Phlegraean Fields type locality, near Naples, as an example of welded fallout tuff (agglutinate). However, since its early definition, the term peperino has been applied to a variety of volcanic products that, beyond a generic common aspect, derived from quite different genetic processes. Given the widespread use of the term peperino, yet broad sense of its definition, we here complete a full review of the origin and development of the term. We also describe the lithofacies sub-types, as well as the source conditions, compositions and eruption types to which the rock can relate.

**Establishment of the term peperino in Italy**

In the Italian geologic literature, the term peperino has been applied in referring to several different volcanic rocks of the Latium region of central Italy (Fig. 1) that share similar appearance, as well as similar textural and mechanical features (see Farr et al. 2015). For the most part, they are represented by either phreatomagmatic deposits of the Colli Albani Volcanic District, near Rome, or ignimbrite deposits of the Cimini Mountains near Viterbo (Northern Latium) (Fig. 1). The name peperino derives from the Italian word pepe (pepper), and has been used in the common language since the seventh century BCE, for rocks used to produce sarcophagi and as building stones (Jackson et al. mentioned in the text. Inset shows a detail DEM of the Colli Albani region, where the ancient Roman quarries of peperino (Lapis albanus and Lapis gabinus) were located.
They are still used as architectural and ornamental elements today. Indeed, these rocks are characterized by a speckled light grey to dark grey tone and granular texture, resembling that of ground pepper. The same Latin root, *piper*, is at the base of the local name *Piperno* (Breilslak 1786) for a genetically distinct volcanic rock from the Phlegrean Fields, near Naples, which is a welded lithofacies of the Campanian Ignimbrite (Fedele et al. 2008).

The ancient Romans used the word *lapis* (stone) for the *peperino* rocks, as well as for all the hard rocks, either volcanic or sedimentary, employed as dimension stones in building construction. In particular, the two types of rock cropping out in the surroundings of Rome that are today referred to as *peperino*, i.e. the *Peperino di Marino* (or *Peperino albano*) and the *Peperino di Gabii*, were called *Lapis albanus* (Vitruvius, De Architectura, 2.7) and *Lapis gabinus* (Strabo, Geography, 5.3.10; Tacitus, Annales, 15.43), respectively, by the ancient Romans.

Here, we present an overview of the origin of the term *peperino* and its use, in both the common and scientific language, as based on an extensive bibliographic search, given as Supplementary Material #1. The original language versions of the definitions, translated herein into English, are also given in Supplementary Material #1. Moreover, we provide a complete review of the rocks of Latium that have been named *peperino* in the scientific literature, describing their textural aspects, their eruptive centres, areal distributions and type localities. While the family tree for the development and application of the term *peperino* is given in Fig. 2, examples of *peperino* rocks are given in Figs. 3 and 4. This sets the guidelines for unambiguous distinction of *peperino* types and related source areas.

**Early definition of *peperino* rocks**

The first attested use of the word *peperino* in the scientific literature seems to be in an essay by the Swedish mineralogist Johan Gottschalk Wallerius, as reported by Desmarest (1765) (for this and the following citations, see also Online Resource 1 for extended text). Desmarest (1765), however, argued against the similarity with the *Tiburtine* rock (i.e. the travertine from Tivoli near Rome) proposed by Wallerius, going on to describe *pépérine* as:

"a compound stone, which is based on a terracotta, which envelops materials altered or not altered by fire; this cooked paste, of a whitish or reddish gray, is more or less friable. There are, mixed in different proportions, scoriaceous and melted materials, a few blades of glass, mica, gabbro or schorl, pieces of limestone, quartz, etc".

Desmarest (1773) then used the same term for the volcanic rocks into which the cellars of the French city of Clermont-Ferrand, in the region of the Chaine des Puys and Limagne graben (Auvergne), were excavated:

![Graph showing the timeline of the term peperino in the geologic literature](image-url)
"(...) The hill where the city is built, is composed of similar dense lava beds and of pépérine, comprising whitish material, pulverulent or solid, as small red spots or hazy tracks, as well as big pieces of limestones with their original grain. (...)"

Today this hill is known to be part of a maar rim on which the cathedral of Clermont-Ferrand stands (Boivin et al. 2015). Several decades later, Scrope (1825, 1827) used peperino for an ensemble of rocks occurring in the Auvergne:

"In giving the name of peperino to a volcanic conglomerate consisting of fragments of basalt and scoria, without pumice, tufa, or any trachytic matter, united either by simple adhesion or a calcareous or argillaceous cement, I follow the Italian geologists, who have continued this trivial term to a similar rock, which also, like that under consideration, occasionally contains fragments of limestone and primitive rocks, bituminized wood, &c., &c.-Vid. Brocchi Catalogo ragionato di Rocce, pp. 45, 47".

Ten years previously, the French naturalist Cordier (1815) had used the term Pépérite to identify tuffs. Originally, the term pépérite was thus closely related to the term peperino as used by the Italian geologists and archaeologists. For some time, the two terms were used as synonyms by French geologists and applied to special types of volcanic tuffs and breccias found in the Limagne (Guérin 1839).

Since the nineteenth century, the term pépérite has suffered a strong “semantical drift” (De Goër De Herve 2000), being extended to other kinds of rocks produced by a wide range of geological processes, and not exclusively those connected to volcanism. The French pépèrites represent a standalone group of rocks and are not the subject of this review. Instead, a modern volcanological description and classification of the pépèrites is provided in White et al. (2000) and Skilling et al. (2002). White et al. (2000) proposed the adoption of peperite as a genetic term: “... applied to a rock formed essentially in situ by disintegration of magma intruding and mingling with consolidated or poorly consolidated, typically wet sediments”.

Breislak (1786) provided another definition of peperino as being like "a fragmented lava", while Ferber (1776) used piperino (from the Latin root piper) to name the volcanic rock outcropping in the surroundings of the Albano and Nemi lakes (southeast of Rome, Italy). He classified the rock as tufo (tuff) and described it as "greenish-grey rusty ashes, with black sherd-lamelles, white garnet-like sherds, and small pumice-stones". Ferber (1776) also stated that "The quarries of Piperino, employed at Rome in buildings and sculpture, are near Marino", allowing us to unambiguously identify it with the Lapis albanus. Ferber (1776) also mentioned.

"Piperino or Granito di S. Fiora; a particular sort of lava, composed by a large quantity of white sherl
in oblong parallelepiped crystals; much black ser-
mica, and some lava”.

However, he specified:

“Properly the name of Piperino belongs only to
indurated volcanic ashes or tufo with sherl-crystals;
accordingly, the above-described of S. Fiora, being a
lava, should not be called by that name”.

Both Ferber (1776) and Breislak (1786) also discussed
the similarity of the rock locally called piperno occurring
at Pianura, near Naples (in the Phlegrean Fields Volcanic
District, Fig. 1). This rock was extensively used since the
Greek–Roman age to pave roads, and was the main building
stone in the Campania region until the cessation of
quarry activity at Soccavo and Pianura at the beginning of
the twentieth century (Calcaterra et al. 2000, 2005). The
name piperno derives from the Latin name of the Roman
village Pipernus (modern Priverno, southern Latium) which,
in turn, is a distortion of the Latin term piper (pepper). The
local use of the word piperno can be traced to the earliest
written documentation dating to 1428 CE (de’ Gennaro et al.
2000; GeoPortale 2009). This rock is a proximal deposit of
the Campanian Ignimbrite, the highest magnitude explosive
eruption of the Mediterranean area in the last 40 ky (Fedele
et al. 2008; Scarpati et al. 2020). It is exposed along the eastern
sector of the caldera rim of the Phlegrean Fields and
in the city of Naples (Rittmann 1950; Perrotta et al. 2006;
Fedele et al. 2008; Scarpati et al. 2020) and consists of alternating beds of welded tuff with flattened scoriae (fiamme)
and coarse lithic breccia with grey lava clasts (Fedele et al.
2008). Von Buch (1809) distinguished the term peperino
from “tuff” as follows:

“It is easy to distinguish the peperino from the tuff. In
the first almost all is fresh, perfect and without dam-
age. In the second, all is dull, dead and destroyed
[here Von Buch (1809) remarks on the relatively

Fig. 4 Macroscopic aspects of the Rome’s peperino rocks. a) Pepe-
rino albano (Lapis albanus): 2nd Eruptive Cycle—Unit e (36±1 ka)
of Albano Crater. b) Peperino di Gabii (Lapis gabinus): phreato-
magmatic unit (ca. 285 ka) from Castiglione Crater. c) Peperino gri-
gio: Palatino Eruption Unit (533±2 ka) from Colli Albani Volcanic
District. d) Peperino della Via Flaminia: Palatino Eruption Unit
(534±2 ka) from Colli Albani Volcanic District
fresh, unaltered character of the *peperino* with respect to the higher degree of alteration and/or vapor-phase transformation (zeolitization) that usually affects the glass matrix of tuffs, accompanied by analcimization of leucite crystals]. *The angular pieces of limestone that characterize* Peperino *from Mt. Albanò; big basalt masses sometimes rounded, sometimes with angular boundaries suddenly appear in* Peperino *[here Von Buch (1809) points out the widespread occurrence of carbonate and lava lithic clasts in* Peperino *].

An accurate description of the petrographic and lithologic features of the "Peperino albano" was provided in Gmelin et al. (2015), as discussed below.

"Peperino is a fragile stone, very fit to building, of an earthy texture, and not heavy. It seems to consist of a congeries of very different bodies, particularly fragments of augite of a dirty green, dark green mica, iron sand, compact limestone, basalt, and a kind of lava very resembling pumice. These seem to be agglutinated by an earthy cement. Sometimes it contains fragments of stones. These fragments are always sharp-edged, generally small, but sometimes weighing several pounds, especially those consisting of basalt and limestone. Sometimes, though rarely, fragments of feldspar, and a scoriaceous matter of a dark green color are mixed into the peperino".

**Scientific classification of peperino rocks**

The first classification of the *peperino* rock type within the volcanic petrographic nomenclature is provided by Brocchi (1817) in his "Catalogo ragionato di una raccolta di rocce per servire alla geognosia" (Geological catalogue of rocks). Brocchi (1817) classified three types of volcanic rocks: *lava, tufa* (tuff), and *peperino*. Moreover, he distinguished several lava varieties, including "lava necrolite", "lava piperno", "lava nenfro", and "lava sperone", all of which have relationships, to different degrees, with the *peperino* rocks. We note, though, that most of these rocks, with the exception of "lava necrolite", are not effusive products and thus do not comply with the modern definition of lava (cf. Sigurdsson et al. 2015), as discussed below.

Brocchi (1817) also distinguished two types of tuff:

*"one is friable, dusty, usually yellowish in color, including variable amount of amfigena [leucite] and pirossena [pyroxen] and often lava pebbles"; "the other one is solid, hard, stony"*. He named the latter as "tufa pietrosa" (lithified tuff) and then he stated: "peperino is nothing but a tufa pietrosa which, apart for the color, is similar to that of the Capitoline Hill and Monteverde [i.e. Tufo lionato pyroclastic-flow deposit, see Marra et al. (2018)], but harder, and does not contain fragments of pumiceous lava [i.e. scoria clasts] since the yellowish ones are of lava sperone [see below for a description of this rock]. Amfigene crystals are mostly glassy, while in tufa they are commonly floury [i.e. turned to analcime]".

It is worth noting that the remark on the unaltered character of the *peperino* with respect to tufa mirrors the distinguishing criterion already outlined by von Buch (1809).

Based on the above criteria, Brocchi (1817) described several *peperino* rock types from different areas of central-western Italy in his rock catalogue (Table 1). All had the common characteristic of a highly heterogeneous component, comprising juvenile angular fragments of massive and/or vesicular lava or scoria, and wall rock fragments (*roccia primitiva*). In addition, free crystals and fragments of pyroxene, haüyne (*lazialite*), leucite (*amfigena*), magnetite (*ferro magnetico*), *Ti-magnetite* (*ferro titanico*) and brown to black *mica* were identified. These were found in the rock along with angular clasts of Appennine limestone, with or without tremolite, and were supported by a calcareous matrix. Due to the abundant calcite veins found in some places, Brocchi (1817) advocated an origin from underwater eruptions for the *peperino* rocks.

Brocchi (1817) also argued against the improper use of the term *peperino* when applied to the volcanic rocks cropping out near Viterbo, in the Cimini Mountains, "distinguished by the local inhabitants with the word *peperino*" (i.e. *Peperino delle Alture Auct.*, *Peperino tipico*) (Peperino of the heights; Typical Peperino), "as it has been already adopted in books to indicate a particular variety of tuff".

Indeed, Brocchi (1817) identified these rocks from Cimini as a lava, which he named "lava necrolite" (from the Greek words *necros*, death, and *lithos*, rock), on account of the use by the Etruscans to carve their sarcophagi and excavate their burial chambers into this rock type. However, Brocchi (1817) also introduced the name "lava piperno" for the welded ignimbrite deposits cropping out in northern Latium at Ronciglione and Caprarola (part of the Vico volcano), based on the close resemblance with the *piperno* occurring at Pianura, near Naples, described by Breislak (1786). It is not clear whether Brocchi was aware of the fact that the terms *piperno* and *peperino* should be considered synonymous. With the definition of "lava piperno" and the statement that it is cognate to the "lava nenfro" (see below), Brocchi (1817) created the scientific basis linking all rocks included in Table 1 to the term "peperino".

Brocchi (1817) also used "lava nenfro" (from an untranslatable local word) to apply to two welded ignimbrite deposits cropping out in northern Latium, i.e. at Villa San Giovanni in Tuscia (near Blera and Vetralla) and in between
Table 1  List of Peperino rock types, also including lava rocks reported with the local name of peperino/piperno, from the "Catalogo ragionato di una raccolta di rocce per servire alla geognosia" by Brocchi (1817). Site of occurrence (see Fig. 1 for location) and original description of the rock are reported in the first two columns. Attributions to the stratigraphic unit and name(s) of the rock according to modern geological and archaeological literature are in the third column.

| Location                              | Description                                                                                                                                                                                                 | Stratigraphic unit/geological name |
|---------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|
| **PEPERINO**                          |                                                                                                                                                                                                            |                                   |
| On the bank of Gabii Lake             | Peperino of a grey-brown colour, filled with pieces of black, brown and reddish lava, with fragments of pyroxene crystals, minimal laminas of mica and some angular pieces of Apennine limestone. | Phreatomagmatic deposit of the Castiglione Crater (Marra et al. 2003); Peperino di Gabii (*Lapis gabinus*)                                          |
| Near the Stella convent outside Albano| Peperino of grey colour, with bits of yellowish, compact or porous lava, fragments of pyroxene, amphibene, laminas of mica, angular debris of primitive limestone and some pebbles of Apennine limestone. | Albano Crater 2nd eruptive cycle, unit e (Freda et al. 2006) Peperino di Marino, Peperino di Albano (*Lapis albanus*)                               |
| At Marino quarries                    | Peperino identical to that of Stella, except that it lacks fragments of primitive limestone.                                                                                                                |                                   |
| At Lake Albano near Palazzuolo        | Ordinary Peperino                                                                                                                                                                                          |                                   |
| On the small road that leads from Castel Gandolfo to the Fishermen's House, located on the shore of Lake Albano | Peperino filled with angular fragments of brown and reddish lava. It is a variety of peperino similar to that of Lake Giuturna. | Albano Crater 1st eruptive cycle, unit b2 (Freda et al. 2006); lava-like                                                                |
| At Lake Giuturna                      | Grey peperino with bits of brown, yellowish and tobacco coloured lava, and with pyroxene, some amphibene and pebbles of Apennine limestone.                                                              |                                   |
| On the eastern side of the Aricia Valley basin, in the place known as the Petrara | Peperino of grey-black colour, very solid, heavy, mixed with large quantities of more or less porous brown lava fragments, which look like grains of lapillus tightly joined together. It also contains fragments of reddish and yellowish lava, large crystals of greenish pyroxene, large laminas of black mica, some amphibene and pieces of primitive white limestone. The large quantity of the above mentioned fragments of lapillus differs from the ordinary peperino | Nemi Crater 1st eruptive cycle                                                                                  |
| On the lower, southwestern rim of the Aricia Valley | Grey Peperino, composed of a combination of fragments of pyroxene, pieces of grey-yellowish and reddish lava, and fragments of white limestone, with some amphibene and some mica laminas. It is very similar to ordinary peperino. It differs from this, in addition to the ingredients, in that it is insensitive to the magnet, when the other is very attractive | Nemi Crater 2nd eruptive cycle                                                                                  |
| Location | Description | Stratigraphic unit/geological name |
|----------|-------------|-----------------------------------|
| Along the descent of the Refera near Cave, on the via di Valmontone | Coarse peperino of mud brown colour, with bits of bluish, brown, yellowish lava, pyroxene, amphibene, mica and oolitic earthy globules of the colour and substance of the mass | Tufo del Palatino (Tufo grigio granulare, "cappellaccio") |
| At Genazzano. It is the rock on which the village is planted | Brown peperino with bits of yellowish lava of a darker brown, some fragments of limestone, some amphibene, mica and pyroxene | |
| In Val di Cona, two and a half miles from Subbiaco | Peperino seeded with vitreous amphibene, pyroxene crystals and black mica laminas, with some pieces of brown lava. It is similar to Marino’s peperino | |
| At Gaetanella, four miles from Frosinone | Peperino grey, composed of lapillus and calcareous grains together with gluten, with fragments of pyroxene and mica laminas | Phreatomagmatic deposits of the Tomacella vent in the Volsci Volcanic Field (Ernici Auct.) (Marra et al. 2021) |
| Two miles from Rota, between this town and the Tolf | Grey peperino with yellowish spots, shiny black mica laminas, pyroxene fragments, blackish lava bits and limestone pebbles | “Bracciano pyroclastic flow unit” of the Sabatini Volcanic District (de Rita et al. 1993) |
| **LAVA NECROLITE** | | |
| On the top of the Tolfa mountain where the fortress is located. It constitutes the mass of that cliff. It is similar to that of Manziana | Grey in colour, scattered with feltspatia, but greatly altered by the decomposition which made it friable, and reduced most of the feltspatia themselves to the earthy state | Tolletano lava dome-complex, locally associated with welded ignimbrites |
| Viterbo–Cimini Mounts | Grey-yellowish, arid, easily brittle, with parts of brown lava, porous, semi-smoky and seeded with black mica laminas, and pyroxene grains with rare feltspatia | Peperino delle Alture |
| On the top of Monte S. Angelo | Grey, with particles of mica and with minutes and large feltspatia | |
| **LAVA PIPERNO** | | |
| Near Ronciglione, in the place called Costa dell’Acqua di Cristo | Of languid violet colour, sonorous, very dry, easily breakable, with laminas of mica, grains of pyroxene and feltspate, and with parts of cellular black lava now in the form of elongated splinters and now of indeterminate shape. It is analogous to the piperno of Pianura near Naples, described by Breislak Ignimbrite C (Locardi 1965); Tufo Rosso a Scorie Nere Vicano (Barberi et al. 1994); Sutri formation (Perini et al., 1997) from Vico volcano | |
| At Fosso della Ferriera below Ronciglione | Grey, of coarse grainy texture, with large splinters, or rather with limbs in the form of splinters of black lava strewn with feltspatia. The other ingredients are similar to those of the previous lava, but feltspatia are much more abundant | |
| Three miles from Caprarola, at the place called Tezzavolto | Grey in colour, with parts of blackish porous lava in the form of splinters, and with feltspatia, amphibene and pyroxene grains | |

*Table 1 (continued)*
| Location | Description | Stratigraphic unit/geological name |
|----------|-------------|-----------------------------------|
| At Pianura [Phlegraean Fields, Campania] | Grey-ashy colour, minutely porous, crossed by veins and by streaks of blackish lava, which is mostly in the form of splinters. Both this and the remainder of the mass contain shiny felspathi | Part of the 39 ka Campanian Ignimbrite eruption succession (Campi Flegrei) |
| Columns of the ancient soldiers' quarter in Pompeii | Pale languid colour, light, with granular fracture, with felspathi and parts of blackish scoriaceous lava | “Bracciano pyroclastic flow unit” of the Sabatini Volcanic District (de Rita et al. 1993) |
| LAVA NENFRO | Grey-blackish, with a dull and earthy fracture, which easily breaks into layers, and thus approaches the schistose structure. It contains parts of lava in the form of veins or flat splinters, of black colour, of a little greasy lustre, resembling an imperfect glaze, brilliant felspathi and fragments of a white and crumbly earthy substance | “Peperino listato” (Sabatini 1896); “ignimbrite B” (Locardi 1965) or “ignimbrite II trachitica” (Bertini et al. 1971) from Vico volcano |
| At S. Giovanni di Bieda, three miles from Vetralla | Dusky-brown, fractured coarse, uneven, moderately hard, dull and earthy in texture, traversed by veins in the form of tortuous, undulating splinters, branched, now linear and now very large, of very black lava, which approaches the enamel. It also contains bright felspathi and pyroxene particles. It is analogous to that of Rota | “Bracciano pyroclastic flow unit” of the Sabatini Volcanic District (de Rita et al. 1993) |
| LAVA SPERONE | Yellowish in colour, and, with a coarse granular texture, scattered with whitish globes, which seen with a lens, are known to be amphigene, and with very minute cubic crystallines of hyacinth colour | Welded scoria lapilli of the Villa Senni post-caldera phase of activity from several vents along the Tuscolano-Artemisio caldera rim (Fornaseri et al. 1963; Marra et al. 2009) Lava spero, Pietra sperone, Pietra gabina [improp.] (Lugli 1957) |
| At Villa Falconieri near Frascati | Yellow–brown, solid, with a lumpy granular texture, and in some places slightly porous, with vitreous amphigene | |
Canale and Rota (Fig. 1). These rocks were exploited locally for building and sculpture stone, with Brocchi (1817) stating that "this rock is nothing but a lava that holds a middle place between the lava piperno and ordinary lava". However, these are not lavas. The first deposit (later named “peperino listato” by Sabatini 1896) is actually a welded facies of “ignimbrite B” (Locardi 1965) or “ignimbrite II trachitica” (Bertini et al. 1971) from Vico volcano. The second deposit is a valley-confined, lithified facies of the Bracciano pyroclastic flow unit of the Sabatini Volcanic District (de Rita et al. 1993), also named locally as peperino (Bertini et al. 1971).

The term nefro is also used locally in the Vulsini Volcanic District (southern Tuscany–northern Latium; Fig. 1). Moderni (1903) first used nefro to name welded ignimbrites characterized by the occurrence of flattened black pumices (fiamme) in a dark grey to reddish-purplish, strongly lithified ash matrix (Alberti et al. 1970; Nappi and Marini 1986). These deposits were emplaced during the Paleovulsini activity at ca. 0.6–0.5 Ma (Vezzoli et al. 1987; Palladino et al. 2010).

Finally, Brocchi (1817) defined "lava sperone" as an intermediate rock type between compact and porous lava. This term was introduced by Gmelin (1814) after the local name for the welded scoria lapilli fall deposits (from Strombolian activity) exploited around the Tuscolo archaeological site along the Tuscolano-Artemisio caldera rim of Colli Albani. The term "sperone" (spur) has been erroneously reported by Lugli (1957) as an archaeological name for the Lapis gabinus, probably because of a faint resemblance between these genetically and petrographically different rocks (Farr et al. 2015).

In Table 1, we report all peperino rock types listed by Brocchi (1817), with the identification of the corresponding stratigraphic units from the modern geological literature. Besides the canonical Lapis gabinus and Lapis albanus, which correspond to the phreatomagmatic deposits of the Castiglione maar and of the Albano multiple maar (second eruptive cycle), respectively, Brocchi (1817) lists a number of other peperino rocks. These include pyroclastic deposits of the Albano (first eruptive cycle) and Nemi multiple maars (Colli Albani), as well as of the Tomacella eruptive centre, located near Frosinone (central-southern Latium) in the Volsci Volcanic Field (Cardello et al. 2020; Marra et al. 2021). These rocks all have a common phreatomagmatic origin and similar field appearance. For example, they are all characterized by carbonate and lava clasts in a lithified grey ash matrix containing loose clinopyroxene, dark mica, leucite and/or feldspar crystals.

In addition, Brocchi (1817) classified as peperino some distal occurrences of the pyroclastic-flow deposits of the Tufo del Palatino to the east of Rome (Table 1). In the same way, the popular definition of peperino was attributed to the same unit in the central and northern sectors of Rome (i.e. "Peperino della Via Flaminia", “Peperino grigio”); see sheet 149—Roma of the geological map of Italy; Table 2).

Brocchi (1817) rejected the use of the term peperino for other volcanic rocks of northern Latium, which instead he considered as different varieties of lava, with the only exception being the deposits between Rota and Tolfa, which he termed peperino. These rocks correspond to a valley-confined, lithified facies of the Bracciano pyroclastic flow unit of the Sabatini Volcanic District (de Rita et al. 1993) and are named locally as peperino (see also Bertini et al. 1971).

Following the acceptance by the scientific community of the classification proposed by Brocchi (1817), the term peperino was subsequently used to describe volcaniclastic rocks outside of Italy. Scrope (1825), for example, proposed the term "calcareaous peperino" to label the characteristic alternations of beds of carbonates with those containing abundant volcanic fragments (see above) as occurring at the Gergovie plateau (Auvergne, France; also cf: Chazot and Mergoil-Daniel 2012). Scrope (1825) also used "calcareaous and conchiferous Peperinos" for similar sedimentary successions of Veneto (i.e. Veronese, Vicentino, and Euganean hills; northern Italy) and southern Sicily.

Roth (1887) also reported:

"the local name of the tuff of the Albano Mountains, Peperin (where the pieces of black leucitophire emerge as peppercorns from the lighter soil mass), has sometimes been transferred to other tuffs without connecting them with a well-defined term. Boricky (1873–74, p. 42; Kostenblatt, now Kostomlaty) called the basaltic tuff of Bohemia, which he regards as hardened lava, a "peperinit basalt".

More than one century later, Le Maitre (2002) reviewed the term “peperin-basalt”, describing it as "an obsolete name for a tuff which forms mud flows and contains large crystals of augite and hornblende".

However, apart from some sporadic uses outside of Italy, such as those mentioned above, until the end of the nineteenth century the term peperino remained generally a name used in the volcanic areas of Colli Albani, Sabatini and Cimini-Vico. The diffusion of this term to the Roccamonfina and Vulsini volcanoes was proposed by Moderni (1904), who aimed to.

"demonstrate that the origin of this tuff, so widely represented among the materials of the Tyrhenian volcanoes, can be as different as its position is different in different locations".

In particular, with respect to the "position" of the peperino, Moderni (1904) referred to its proximal (near-vent) versus distal occurrence:
**Table 2** List of volcanic units termed “Peperino” and “Piperno” in the official 1:100,000 Geological Map of Italy (a, b, c) and in two basilar volcanological studies of Latium region (d, e), with equivalent nomenclature in the modern literature

| Stratigraphic unit | Description | Equivalent unit in modern geologic and archaeologic literature |
|--------------------|-------------|---------------------------------------------------------------|
| Tufo grigi granulari, stratificati, orizzonte inferiore | Sometimes lithoid tuff (improperly called "peperino") | Tufo del Palatino (Marra and Rosa 1995; Karner et al. 2001a, b); “Cappellaccio”, “Tufo granulare grigio” (Lugli 1957; Farr et al. 2015) |
| Granular grey tuffs, stratified, lower horizon | | |
| “Peperini” inferiori | Coarse explosion breaches with xenoliths (paleogenic and Mesozoic limestones, leucitic lavas, etc.) | Phreatomagmatic products of Castiglione Crater (Marra et al. 2003); Lapis gabinus (Peperino di Gabii, pietra gabina; Lugli 1957; Farr et al. 2015) |
| lower peperini | Compact, grey-greenish facies with small allotogenic elements | Distal products of the 2nd Alban eruption cycle cropping out near Santa Procula (Freda et al. 2006; Giaccio et al. 2009) |
| Manifestazioni eruttive finali | Explosion pyroclastic breaches, with lapilli, leucocrite ejecta, ultrafemic, biotitic pyroxenites; xenoliths of leucitic lavas and of the substrate (Pliocalabrian clays, paleogenic marls and sandstones, Mesozoic metamorphosized limestones); cineritic facies stratified in the upper portion, in layers and banks, ±consolidated (= "peperino", Auct.). From the craters of Anica, Albano, Nemi, Castiglione-Osa, Valle Marciana, Prata Porci, Pantano Secco, Pavona and Giuturna | Several pheatomagmatic products of Colli Albani, including “Peperino di Marino” or “Peperino di Albano” (Lapis albanus) (Marra et al. 2003; Freda et al. 2006; Giordano et al. 2006) |
| a) Sheet 150—Roma—1:100,000 Geological Map of Italy—Servizio Geologico d’Italia | | |
| b) Sheet 143—Bracciano—1:100,000 Geological Map of Italy—Servizio Geologico d’Italia | | |
| c) Sheet 137—Viterbo—1:100,000 Geological Map of Italy—Servizio Geologico d’Italia | | |
| d) 1:100,000 Geological map in “La regione vulcanica dei Colli Albani” (Fornaseri et al. 1963) | | |

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| Stratigraphic unit | Description | Equivalent unit in modern geologic literature |
|--------------------|-------------|------------------------------------------------|
| "Ignimbrite" (l.s.), phonolithic-tephritic or trachytic, with a light grey micropumice matrix and various types of inclusions: biotite and pyroxene crystals, pumice of various colours and sizes, fragments of lava of various kinds, frequent limestone and flint, plant remains; of various consistency, now lithoid ("peperino") now inconsistent (pozzolana) | | |
| b) Sheet 143—Bracciano—1:100,000 Geological Map of Italy—Servizio Geologico d’Italia | | |
| c) Sheet 137—Viterbo—1:100,000 Geological Map of Italy—Servizio Geologico d’Italia | | |
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| Stratigraphic unit | Description | Equivalent unit in modern geologic literature |
|--------------------|-------------|------------------------------------------------|
| "Peperino delle alture" Auct | Quartz-latitic lava in domes, sometimes latitic-quartzitic and trachyte-quartzitic. Massive rocks in various shades of grey, mostly light. Porphyritic, have large sanidine phenocrysts. Frequent irregular fractures and, at the margins of the domes, divisions into blocks | Lave di Canepina (Sheet 345—Viterbo, 1:50,000 Geological Map of Italy—CARG project, in press) |
| "Peperino tipico" | Quartz-latitic ignimbrites, with variations to rhyolites and quartziferous trachytes. Grey, porphyritic rocks, without large phenocrysts. Lenses and bands roughly stratified and agglomeratic. Varying degree of compactness, almost always present flattened pumices. Various lithic inclusions, mainly of "peperino delle alture". Quarried as an ornamental and building stone | Ignimbrite Cimina (e.g. Cimarelli and de Rita 2006; (Sheet 345—Viterbo, 1:50,000 Geological Map of Italy—CARG project, in press) |

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**Table 2** List of volcanic units termed “Peperino” and “Piperno” in the official 1:100,000 Geological Map of Italy (a, b, c) and in two basilar volcanological studies of Latium region (d, e), with equivalent nomenclature in the modern literature

| Stratigraphic unit | Description | Equivalent unit in modern geologic literature |
|--------------------|-------------|------------------------------------------------|
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| b) Sheet 143—Bracciano—1:100,000 Geological Map of Italy—Servizio Geologico d’Italia | | |
| c) Sheet 137—Viterbo—1:100,000 Geological Map of Italy—Servizio Geologico d’Italia | | |
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| Stratigraphic unit | Description | Equivalent unit in modern geologic literature |
|--------------------|-------------|------------------------------------------------|
| "Peperino delle alture" Auct | Quartz-latitic lava in domes, sometimes latitic-quartzitic and trachyte-quartzitic. Massive rocks in various shades of grey, mostly light. Porphyritic, have large sanidine phenocrysts. Frequent irregular fractures and, at the margins of the domes, divisions into blocks | Lave di Canepina (Sheet 345—Viterbo, 1:50,000 Geological Map of Italy—CARG project, in press) |
| "Peperino tipico" | Quartz-latitic ignimbrites, with variations to rhyolites and quartziferous trachytes. Grey, porphyritic rocks, without large phenocrysts. Lenses and bands roughly stratified and agglomeratic. Varying degree of compactness, almost always present flattened pumices. Various lithic inclusions, mainly of "peperino delle alture". Quarried as an ornamental and building stone | Ignimbrite Cimina (e.g. Cimarelli and de Rita 2006; (Sheet 345—Viterbo, 1:50,000 Geological Map of Italy—CARG project, in press) |

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**Table 2** List of volcanic units termed “Peperino” and “Piperno” in the official 1:100,000 Geological Map of Italy (a, b, c) and in two basilar volcanological studies of Latium region (d, e), with equivalent nomenclature in the modern literature

| Stratigraphic unit | Description | Equivalent unit in modern geologic literature |
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| a) Sheet 150—Roma—1:100,000 Geological Map of Italy—Servizio Geologico d’Italia | | |
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| d) 1:100,000 Geological map in “La regione vulcanica dei Colli Albani” (Fornaseri et al. 1963) | | |

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| Stratigraphic unit | Description | Equivalent unit in modern geologic literature |
|--------------------|-------------|------------------------------------------------|
| a) Sheet 150—Roma—1:100,000 Geological Map of Italy—Servizio Geologico d’Italia | | |
| b) Sheet 143—Bracciano—1:100,000 Geological Map of Italy—Servizio Geologico d’Italia | | |
| c) Sheet 137—Viterbo—1:100,000 Geological Map of Italy—Servizio Geologico d’Italia | | |
| d) 1:100,000 Geological map in “La regione vulcanica dei Colli Albani” (Fornaseri et al. 1963) | | |
Table 2 (continued)

| Prodotti di bocche eccentriche | Description | Equivalent unit in modern geologic literature |
|--------------------------------|-------------|---------------------------------------------|
| Products of peripheral vents   | Mainly grey, consisting of a mixture of ashes with abundant ejecta, among which the white calcareous ones are characteristic; if cemented, they are called (locally) "peperini" and include *lapis albanus* and *lapis gabinus* | Several phreatomagmatic products of Colli Albani (Marra et al. 2003; Freda et al. 2006; Giordano et al. 2006) |

e) 1:100,000 Geological map in “La regione vulcanica dei Sabatini” (Mattias and Ventriglia 1970)

PRODOTTI DEL VULCANO CIMINO

| Stratigraphic unit | Description | Equivalent unit in modern geologic literature |
|--------------------|-------------|---------------------------------------------|
| “Peperino tipico” del Viterbese | Latitic or quartz-latitic ignimbrite; compact greyish lithified sometimes with columnar cracks, with small scoriae and flattened pumice of yellow to blackish colour | Ignimbrite Cimina (e.g. Cimarelli and de Rita 2006; Sheet 345—Viterbo, 1:50,000 Geological Map of Italy—CARG project, in press) |
| Peperino delle altitude | Lava domes with variable composition, dark alkaline trachytes, dark quartzolatites and dark labradorite riodacites, forming the reliefs of M. Cimino, M. Palanzana, M. S. Valentino, etc | Lave di Canepina (Sheet 345—Viterbo, 1:50,000 Geological Map of Italy—CARG project, in press) |

PRODOTTI DEL VULCANO DI VICO

| Stratigraphic unit | Description | Equivalent unit in modern geologic literature |
|--------------------|-------------|---------------------------------------------|
| “Peperini listati” | Blera, Mignone, Civitella Cesi, etc.; trachytes, lithoid, light grey to dark grey in colour, with lava fragments and abundant flattened black and locally yellow scoriae | “Peperino listato” (Sabatini 1896); “ignimbrite B” (Locardi 1965) or “ignimbrite II trachitica” (Bertini et al. 1971) from Vico volcano |

PRODOTTI DEI VULCANI SABATINI

| Stratigraphic unit | Description | Equivalent unit in modern geologic literature |
|--------------------|-------------|---------------------------------------------|
| “Peperino della Via Flaminia” | Lithoid grey tuff rich in various inclusions | Tufo del Palatino (Karner et al. 2001a, b; Farr et al. 2015; Diffendale et al. 2018) |
| Tufi stratificati varicolori di Sacrofano | From cineritic to lapillaceous, mainly incoherent. Some levels have a notable thickness, if grey lithoids are locally called “peperini” | Grottarossa Pyroclastic Sequence (Karner et al. 2001a, b; Farr et al. 2015) |
| Grey brownish to purplish tuff, rich in flattened scoria if close to its point of emission ("fiamme"), rounded in the more distant areas. If cemented, locally called "piperno di Mazzano" | Welded facies of Tufo Rosso a Scorie Nere Sabatino (de Rita et al. 1993) or Tufo Grigio Sabatino (Campobasso et al. 1994) |
| Tufo di Bracciano | Mainly lithoid known locally as "peperino" | “Bracciano pyroclastic flow unit” (de Rita et al. 1993) |
| Predominantly lithoid grey tuff, called (locally) "peperino", rich in fragments of lava, scoriae and sedimentary rocks | Phreatomagmatic products of the Baccano crater (Sottili et al. 2010) |
| Finely stratified grey tuffs made up of ashes with abundant inclusions of volcanites (lava and scoria) and sedimentary rocks (limestone, marly limestone, etc.) belonging to the underlying Flysch formation. Locally called "peperini", when cemented | Products of the Hydromagmatic centres (Sottili et al. 2010) |
Eruptive and emplacement processes of peperino rocks

The term peperino and its derivation piperno have been used in reference to a variety of volcanic rocks that differ in terms of their formative eruptive and emplacement mechanisms, source areas and ages. With the exception of the Peperino delle Alture, which is a lava rock type related to the effusive activity of the Cimini Mountains dome complex, all the other cases of application are for rocks derived from the products of explosive eruptions with different styles and magnitudes (Table 3). There are three cases of peperino application when assessed by eruption style and magnitude:

i) for rock types derived from small-scale (≤1 km³) phreatomagmatic eruptions. These rocks mainly represent the proximal facies of base surge deposits and are usually lithified, massive to faintly stratified, and rich in aquifer lithics. They can be related to maar–tuff rings, as for the “Peperino di Gabii” from the Castiglione maar in the Colli Albani (Marra et al. 2003), to small caldera systems, as is the case for the peperino samples from Bacano and Montefiascone, or to carbonate-seated maars–diatremes, as in the examples from the Volsci Volcanic Field (Cardello et al. 2020; Marra et al. 2021). In other cases, peperino rocks are related to massive, thickened facies of phreatomagmatic pyroclastic currents locally channelized in topographic lows, as is the case for the “Peperino albano” at the type locality of the Marino quarries (Giordano et al. 2002; Freda et al. 2006);

ii) for rocks resulting from the emplacement of widespread (1–10 km³) ash-rich, accretionary lapilli-bearing, “wet” pyroclastic currents. This applies to, for example, the Tufo del Palatino, resulting from a large-scale explosive event with a significant hydromagmatic component during the early activity of Colli Albani (Marra and Rosa 1995; Karner et al. 2001a; Palladino et al. 2001); and

iii) for rocks consisting of fiamme-bearing, welded pyroclastic deposits from magmatic hot pyroclastic currents. These can be associated with small-scale lava dome collapse, as is the case for the “Peperino Tipico” from the Cimini Mountains (Cimarelli and de Rita 2006) or with moderate-to large-scale (1–100 km³) caldera-forming events, which include the peperino and piperno examples from Vico, Sabatini and the Phlegrean Fields (Table 3).

The application of the peperino term also spans a range of compositions. While all cases from i) and ii) were fed by mafic ultrapotassic magmas of the Roman Province...
| Peperino unit | Volcanic source area (and eruptive event) | Eruption and emplacement mechanisms | Age | References |
|---------------|------------------------------------------|------------------------------------|-----|------------|
| Peperino di Albano, Peperino di Marino | Colli Albani, Albano multiple maar (2nd eruptive cycle, Unit e) | Valley-pond phreatomagmatic pyroclastic currents (base surges), locally associated with sin-eruptive lahars | | Giordano et al. (2002); Freda et al. (2006); Giaccio et al. (2007); Sottili et al. (2009) |
| Peperino di Gabii | Colli Albani, Castiglione maar | Phreatomagmatic pyroclastic currents (base surges), | | Marra et al. (2003) |
| Peperino della Via Flaminia, Peperino Grigio | Colli Albani, early Tuscolano-Artemisia (or Vulcano Laziale) period (Tufo del Palatino) | Ash-rich pyroclastic currents, with hydro-magmatic component | | Karner et al. (2001a, b); Farr et al., (2015) |
| Other peperino examples of the Roman area | Colli Albani (e.g. Albano 1st eruptive cycle; Nemi multiple maar); Sabatini (hydromagmatic phase: e.g. Baccano centre; early activity: e.g. Grottanossa Pyroclastic Sequence) | Magmatic and phreatomagmatic pyroclastic currents | | Freda et al. (2006); Sottili et al. (2009); Karner et al. (2001a, b); Sottili et al. (2012) |
| Peperino (Frosinone area) | Volsci Volcanic Field (different maar/diatreme centres: e.g. Tomacella, Patrica, Fosso di Monteacuto) | Phreatomagmatic pyroclastic currents (base surges) | | Cardello et al. (2020) |
| Peperino del Mazzano (Monti Sabatini area) | Sabatini, Southern Sabatini activity (Tufo Rossos a Scorie Nero Sabatino) | Moderate- to high-grade welded facies (often valley-pond) from pyroclastic flows associated with major caldera-forming explosive eruptions | | de Rita et al. (1993); Palladino et al. (2014) |
| Peperino listati (Monti Sabatini area) | Sabatini, Southern Sabatini activity (Peperini listati) | Moderate- to high-grade welded facies (often valley-pond) from pyroclastic flows associated with major caldera-forming explosive eruptions | | de Rita et al. (1993) |
| Peperino listato (Blerta-Vetralla area) | Vico (Ignimbrite B) | | | (Locardi 1965); (Bertini et al. 1971) |
| Peperino (Rota-Tolfa area) | Sabatini, Bracciano caldera (Tuf di Bracciano or Bracciano pyroclastic flow unit) | Valley-pond, lithified facies from pyroclastic flow activity | | de Rita et al. (1993) |
| Peperino (Valentano area) | Vulsini, Latera caldera (Tuf di Poggio Pinzo) | Alternating phreatomagmatic pyroclastic currents (base surges) and Strombolian fallout activity | | Vezzoli et al. (1987); Palladino and Sime (2005) |
| Peperino (Montefiascone area) | Vulsini, Montefiascone volcano (Ignimbrite Basale di Montefiascone; Ignimbrite di Montefiascone or Formazione della Berlina) | Phreatomagmatic pyroclastic currents, associated with caldera collapse | | Nappi et al. (1991) |
| Peperino Tipico (Viterbo area) | Cimini (Ignimbrite Cimina) | Moderate- to high-grade welded ignimbrite from high-temperature pyroclastic flows | 1.31–1.30 Ma | Capaccioni et al. (2001); Cimarelli and de Rita (2006); Sheet 345—Viterbo (1:50,000 Geological Map of Italy—CARG project) |
| Peperino delle Alture (Viterbo area) | Cimini (Lave di Carepina) | Effusive activity: lava dome complex | 1.33–1.29 Ma | Sheet 345—Viterbo (1:50,000 Geological Map of Italy—CARG project) |
(Freda et al. 2006; Marra et al. 2009, 2021), the “Peperino Tipico” example is part of the Pliocene–Lower Pleistocene silicic magmatism of Tuscany and northern Latium. However, the other cases from iii) resulted from the eruption of phonolites and trachytes associated with the potassic magmatism of the Roman (Vico, Sabatini) and Campanian (Phlegraean Fields) provinces (Fedele et al. 2008; Palladino et al. 2014).

The use of peperino rocks in Roman and Etruscan monuments

In the City of Rome, systematic quarrying of Tufo del Palatino for dimension stone (i.e. a natural rock that has been selected and finished to specific sizes or shapes) began in the archaic period (8th–third century BCE; Lanciani 1897; Coarelli 1974; Lugli 1957; Cifani 1994). However, the designation of peperino for the Tufo del Palatino (commonly known as “Cappellaccio”) has been used only in a few scientific publications (e.g. “peperino grigio”, sheet 149—Roma of the geological map of Italy; Ventriglia 1971). The Tufo del Palatino is typically affected by pronounced and rapid weathering due to its relative softness and pervasive cleavage. For this reason, its use as building material ceased at the beginning of the fourth century BCE, when improved quarrying techniques and access to deposits further from Rome allowed the exploitation of more durable rocks. The two peperino rocks, Lapis albanus and Lapis gabinus, are characterized by higher uniaxial compressive strength than all other tuffs from the Colli Albani and Sabatini volcanic districts. As a result, they are less prone to weathering. This favoured their widespread employment in architectural elements that are subject to high pressures, such as piers, weight-bearing walls, and arches (Jackson and Marra 2006). According to Tacitus (Annales, 15, 43), Emperor Nero promulgated an edict that ordered the use of Lapis albanus and Lapis gabinus in the reconstruction of the basements and ground floors of buildings destroyed by the 64 CE great fire of Rome, the reason being that these rocks were reputed as fire-proof. Such a notion must have been retained from earlier times, since Augustus built the retaining wall of his Forum with these two rocks so as to protect it from the devastating fires that frequently occurred in the nearby Subura quarter (Figs. 5 and 6). These rocks were also used to construct the Tabularium in 78 BCE, which hosted the state archive (Lugli 1957). Lapis gabinus was also systematically used for the pillars and arches of ancient bridges and aqueducts (Lugli 1957). A full chronology of the principal Roman monuments in which the two peperino stones (Lapis albanus and Lapis gabinus) have been employed is summarized in Table 4. Here we complete a short review as to how three types of peperino (Lapis albanus, Lapis gabinus and Peperino di Viterbo) became historically and archaeologically important by being used in the construction of ancient monuments in Rome and Latium. This is also relevant for

Fig. 5 The Peperino di Viterbo is a grey, porphyritic rock derived from both quartz-latitic domes (Peperino delle Alture) and associated ignimbrites (Peperino tipico) of the Cimini volcanoes. a) Section normal to depositional surface: welded pyroclastic flow deposit showing light coloured, iso-oriented, flattened pumice clasts (fiamme). b) same, section parallel to depositional surface showing sanidine-rich fiamme with dark rims and various lithic inclusions
interdisciplinary research in geo-archaeology and cultural heritage dealing with provenance studies and restoration interventions.

**Lapis albanus**

Lugli (1957) and Holloway (1994) proposed that *Lapis albanus* began to be used as building material in the third century BCE. However, recent geochemical analysis from the Sant’Omobono Sacred Area demonstrated that this date should be moved back to the early fifth century BCE (Diffendale et al. 2018; Farr et al. 2015). In fact, *Lapis albanus* occurs in the facing of the first-phase (fifth century BCE) platform supporting the twin temples of *Fortuna* and *Mater Matuta* and in part of the eastern edge of the platform at its southern end. The use of *Lapis albanus* was confirmed for several monuments within the temple platform, spanning the 4th through third centuries BCE (Diffendale et al. 2018). Moreover, Karner et al. (2001b) suggested an early use (fifth century BCE) of *Lapis albanus* for the *Tullianum*. *Lapis albanus* was also extensively used as the base for inscriptions carved in stone, since the oldest known example for Consul *Appius* in 264 BCE (Torelli 1968) through the first century BCE. Since the mid-third century through the end of the second century BCE, *Lapis albanus* was systematically used to produce the sarcophagi of Scipions' sepulchre, and was used in construction of several tombs and villas built along the Via *Appia* in the second and first centuries BCE (Lugli 1957). It was largely used during the late Republican and the early Imperial age in several buildings and temples (Table 4). *Lapis albanus* was used during the mid-second century CE in the construction of Adrian's temple and mausoleum, the temple of Antoninus and Faustina. Its employment was, however, abandoned towards the end of the second century, its last use being attested in the year 202 CE at the permanent legionary fortress of *Castra Albana*, close to the original quarrying site at Alba (Lugli 1957).

**Lapis gabinus**

In the site of *Gabii*, located on the rim of the Castiglione maar (Fig. 1), the local deposit (*Peperino di Gabii* or *Lapis gabinus*) was exploited since at least the tenth century BCE to produce blocks employed in the construction of walls and long after the Roman conquest in 493 BCE. In the late Republican period, the town of *Gabii* was depopulated due to the extensive quarrying activity of the *Lapis gabinus*. According to Lugli (1957), the earliest use of *Lapis gabinus* in Rome was in the arches of the *Acqua Marcia* aqueduct in 144 BCE. However, Farr et al. (2015) identified the occurrence of *Lapis gabinus* blocks in a small staircase abutting the fifth century BCE main podium of the twin temples at Sant'Omobono, although it was probably added in a later period. Probably due to the greater distance from Rome to the quarry site, with respect to that of the *Lapis albanus*,...
the *Lapis gabinus* was employed to a lesser extent in the City (Table 4). The most prominent buildings in which it occurs are the state archives (*Tabularium*), and the Forums of Caesar and Augustus.

### Table 4. Chronological list of Roman monuments (in Rome city and surroundings) in which the Peperino di Marino (*Lapis albanus*) and Peperino di Gabii (*Lapis gabinus*) were employed

| AGE MONUMENT | AGE MONUMENT |
|--------------|-------------|
| *LAPIS ALBANUS* | *LAPIS GABINUS* |
| 6–fifth century BCE (?) | third century BCE (?) |
| fifth century BCE | ~ 200 BCE |
| 264 BCE | ~ 200 BCE |
| 264 BCE | 144 BCE |
| 264 BCE | 144 BCE |
| third century BCE (?) | 144 BCE |
| mid-third century BCE | 144 BCE |
| 180–150 BCE | 144 BCE |
| mid-second century BCE | 144 BCE |
| 144 BCE | 144 BCE |
| post 139 BCE | 144 BCE |
| end of second century BCE | 144 BCE |
| end of second century BCE | 144 BCE |
| 108 BCE | 108 BCE |
| 2nd–first century BCE | 108 BCE |
| first century BCE | 108 BCE |
| 100–80 BCE | 108 BCE |
| 90 BCE | 78 BCE |
| 80–50 BCE | 78 BCE |
| 78 BCE | 55 BCE |
| 42 BCE | 55 BCE |
| 17 BCE | 55 BCE |
| 31–2 BCE | 55 BCE |
| 2 BCE | 55 BCE |
| 70 CE | 55 BCE |
| ~ 138 CE | 55 BCE |
| 141 CE | 141 CE |
| 202 CE | 141 CE |

### Peperino di Viterbo

The Peperino di Viterbo (also known as “Peperino Tipico”) in northern Latium was used as a building material, as early
as the Palaeolithic age, as a substrate for rock sculptures. In addition, there are rock tombs with monumental altars documented in central-southern Etruria and dated between the sixth and third centuries BCE (Bianchi et al. 1963). Peperino di Viterbo (although often reported as “nenfro” in archaeological texts) was also used in a large number of Etruscan sarcophagi (e.g. from the burial chambers of Tarquinia and Tuscania) between the seventh and first centuries BCE, as well as sculptures mainly representing fantastic animals (Bianchi et al. 1963). Lugli (1957) reported erroneously the occurrence of the Peperino di Viterbo in ancient Rome, in the “portichetto” at Foro Olitorio (actually made up of an intrusive rock).

Conclusions

The term *peperino* was originally used for volcanic rocks of grey tone and granular texture, with resemblance to ground pepper, derived from phreatomagmatic eruptions of Colli Albani (i.e. Peperino di Marino, Peperino di Gabii). However, the term *peperino* (with the *piperno* variety) was extended to other volcanic rocks of central Italy that span a range of magma compositions, eruption styles and magnitudes. *Peperino* examples are mainly related to the potassic and ultrapotassic magmatism of the Roman and Campanian provinces (Middle to Upper Pleistocene), with mafic (K-foidites) to differentiated (trachites and phonolites) compositions, with a few exceptions related to silicic magmatism of Pliocene-Lower Pleistocene (e.g. Peperino di Viterbo from the Cimini Mountains). With one exception, *peperino* rocks are related to explosive eruptions ranging from small-scale phreatomagmatic events associated with diatremes, maars and tuff rings to moderate to large pyroclastic currents associated with major caldera-forming events (Table 3).

The different magma compositions, eruptive styles and geological settings with which *peperino* rocks are associated result in a range of componentry. The unifying features of all *peperino* rocks are the grey tone, the granular appearance, and the lithified ash matrix. However, the juvenile components may vary from dark, poorly vesicular scoria in phreatomagmatic cases to flattened scoria or pumice (fiamme) in welded ignimbrite cases. Early authors, such as Gmelin (1814) and Brocchi (1817), also pointed to the characteristic occurrence of both black (accessory lava) and white (accidental limestone) lithic clasts in some *peperino* examples (e.g. Peperino di Marino).

*Peperino* stones play a major role in the history of construction, sculpture and archaeology, yet the term lacks a rigorous geologic definition. *Peperino* can only be used informally as a generic, purely descriptive term, which cannot be related to a specific composition or volcanic process. In this regard, attempts to use its offshoot term, *peperite*, remain ambiguous and lack general consensus among geologists.

The reference *peperino* examples from central Italy volcanoes may be useful for comparison with similar rock types that are common in volcanic environments worldwide. However, we do not claim for a broad use of the term in place of, or in addition to, the existing well-established terminology for volcanic lithofacies. We suggest that *peperino* can be used mainly in geo-archaeological and cultural heritage contexts to describe a light, porous, poorly sorted pyroclastic rock consisting of lapilli-sized juvenile and accessory and accidental lithic clasts, supported in a lithified ash matrix typically grey in tone. Detailed textural and compositional characterization may allow identification of a specific *peperino* type and its source area, relevant for provenance studies and restoration interventions.

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