



The *peperino* rocks: historical and volcanological overview

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Abstract

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 Cimino 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 (Menziés 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 volcanoclastic deposits with unconsolidated, typically wet sediments (Skilling et al. 2002; Sigurdsson et al. 2015).

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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 volcanoclastic 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.

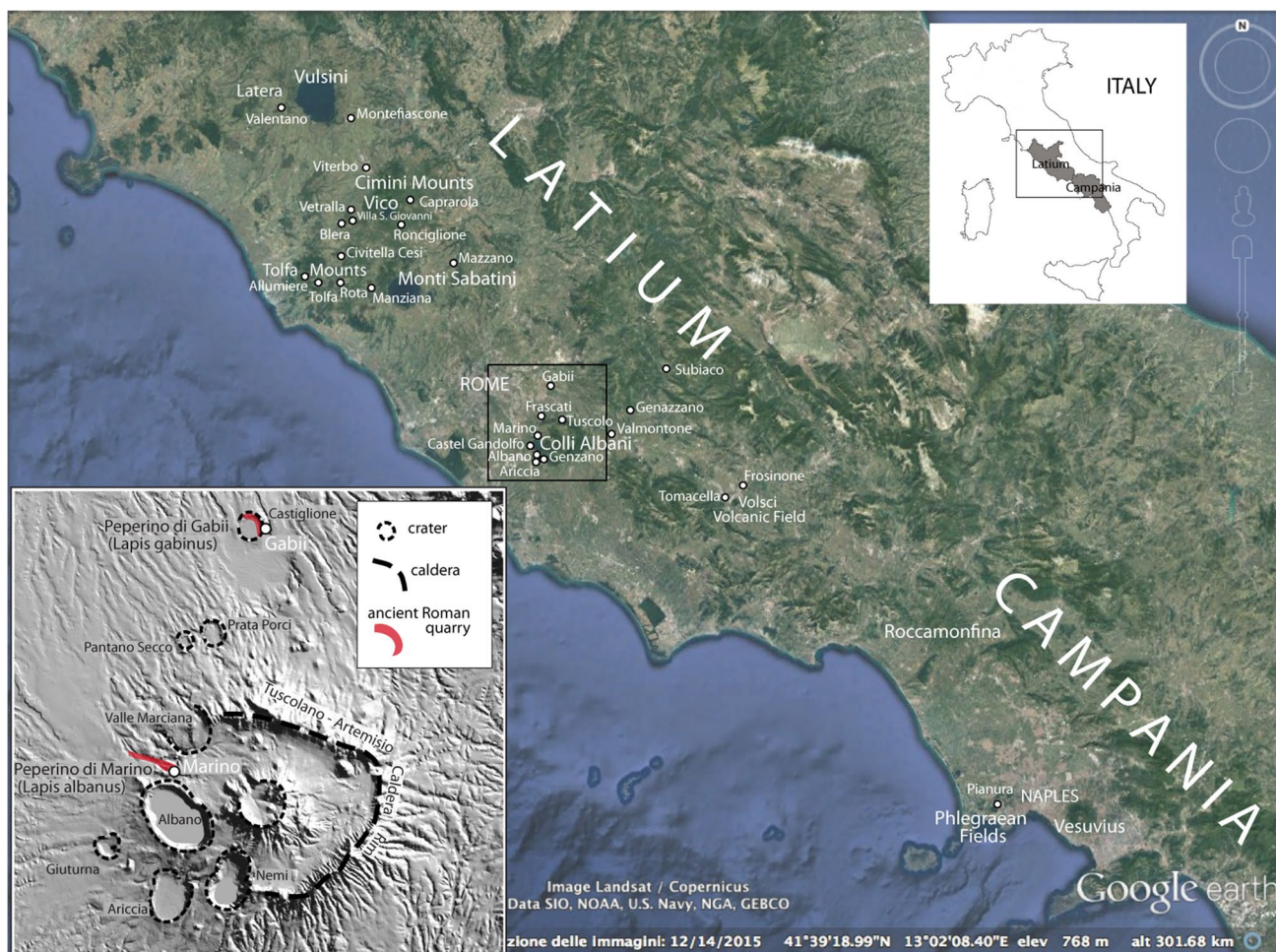


Fig. 1 Satellite image of central Italy showing location of the high-potassic volcanic districts of the Roman and Campanian Provinces, the calc-alkaline districts of Cimini and Ceriti Mts., and of the sites

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

2005; Jackson and Marra 2006; Farr et al. 2015; Diffendale et al. 2018). 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* (Breislak 1786) for a genetically distinct volcanic rock from the Phlegraean 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 Chaîne des Puys and Limagne graben (Auvergne), were excavated:

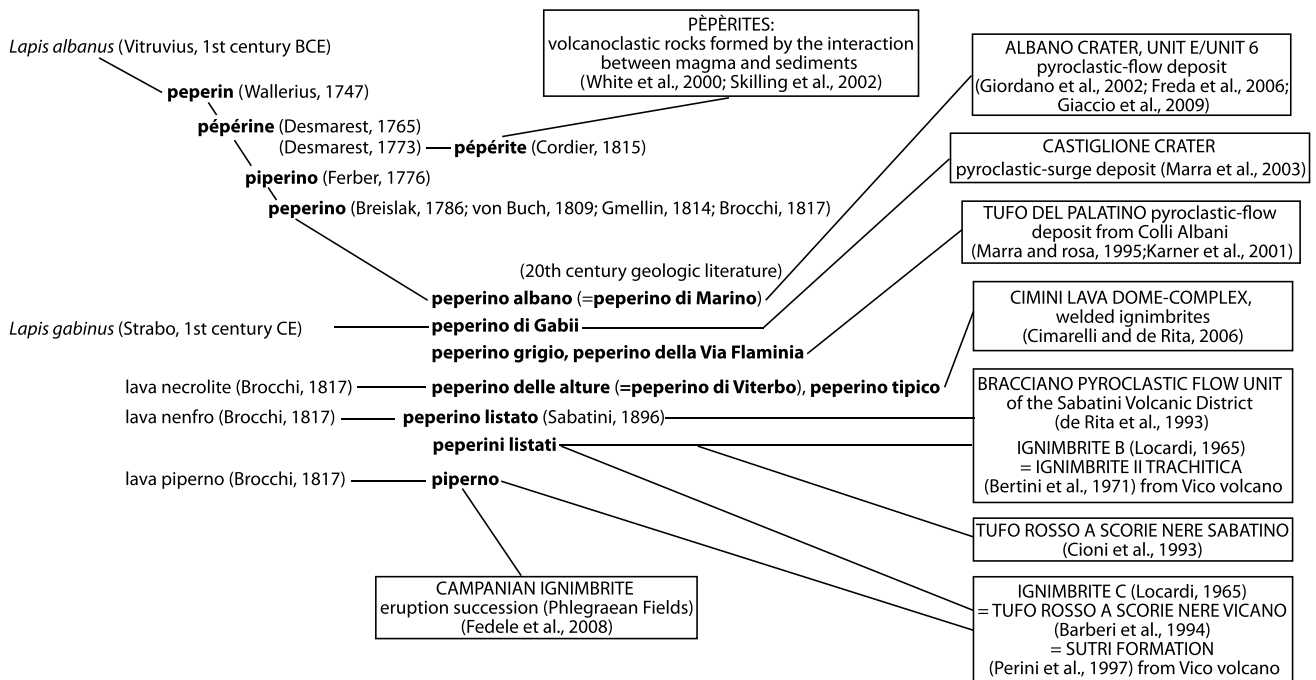
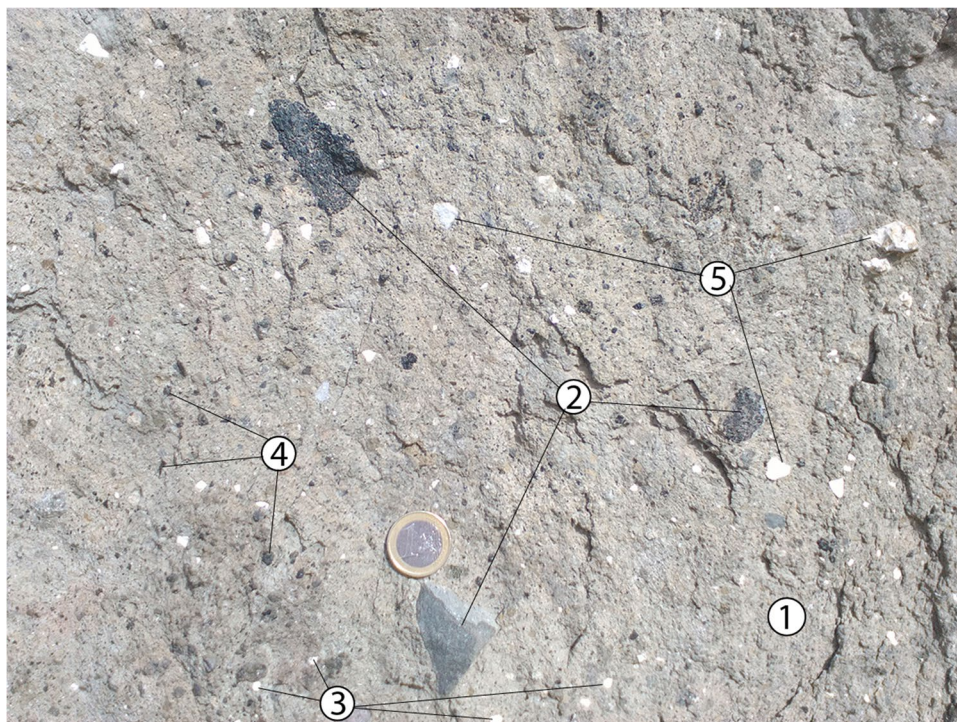


Fig. 2 Timeline of the term *peperino* in the geologic literature

Fig. 3 Detail of a block of the *Subura* wall in Rome (Forum of Augustus, first century BCE) showing the macroscopic textural and compositional features of *Lapis albanus*. 1 = lighter, olive-grey glass matrix (with zeolite cement), 2 = numerous lava rock fragments, 3 = leucite and analcime crystal fragments (hexagonal shapes), 4 = biotite (black mica) crystal fragments, 5 = limestone rock fragments; smooth, fairly durable stone surface



"(...) 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 scoriae, 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 *pépérites* represent a standalone group of rocks and are not the subject of this review. Instead, a modern volcanological description and classification of the *pépérites* 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 sherd

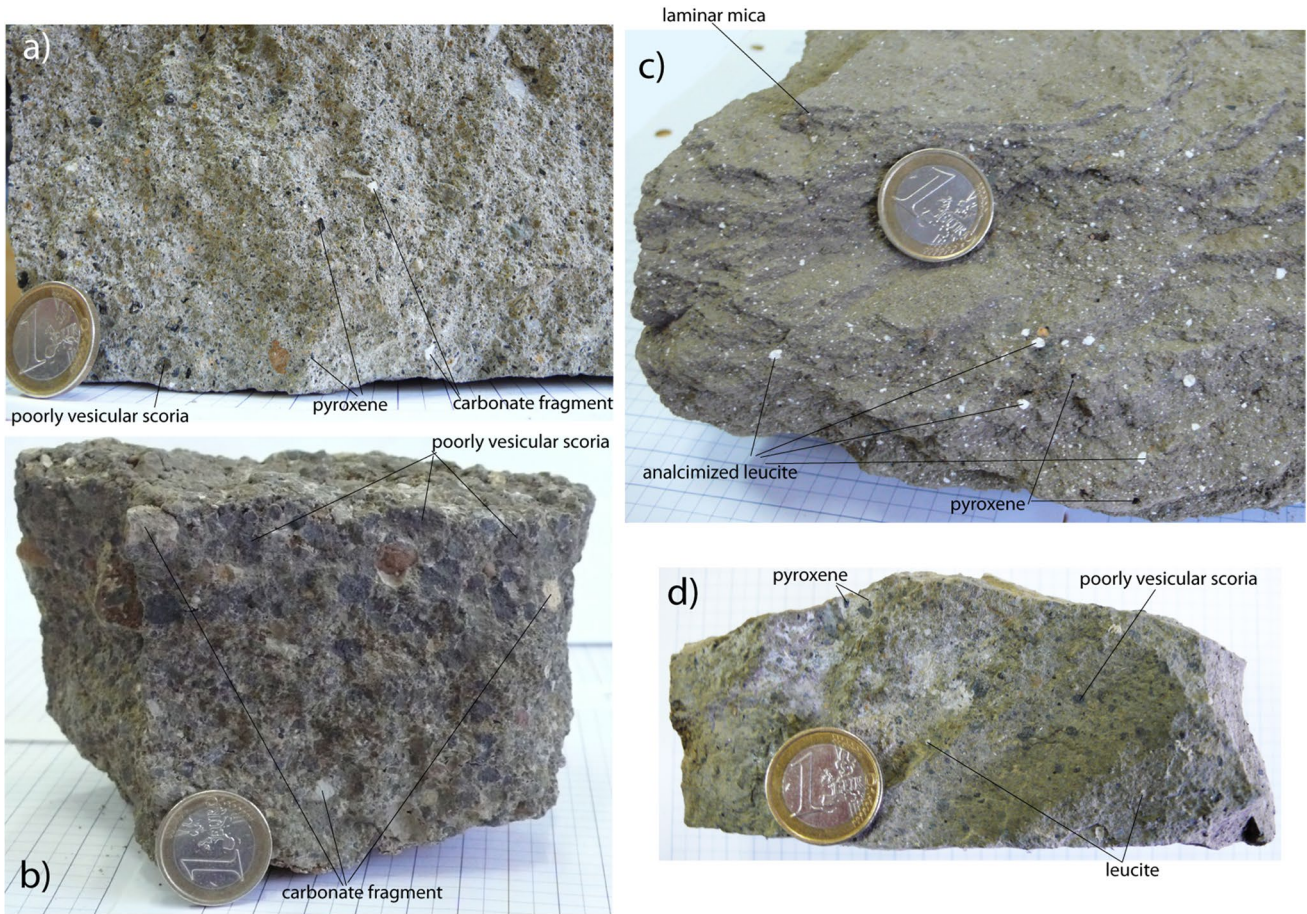


Fig. 4 Macroscopic aspects of the Rome's *peperino* rocks. **a)** Peperino albano (*Lapis albanus*): 2nd Eruptive Cycle—Unit e (36 ± 1 ka) of Albano Crater. **b)** Peperino di Gabii (*Lapis gabinus*): phreatomagmatic unit (ca. 285 ka) from Castiglione Crater. **c)** *Peperino grio*:

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

in oblong parallelepiped crystals; much black shermica, and some lava".

However, he specified:

"Properly the name of Piperino belongs only to indurated volcanic ashes or tufo with sherm-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 Phlegraean 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; Scarpata et al. 2020). It is exposed along the eastern sector of the caldera rim of the Phlegraean Fields and in the city of Naples (Rittmann 1950; Perrotta et al. 2006; Fedele et al. 2008; Scarpata 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 damage. In the second, all is dull, dead and destroyed [here Von Buch (1809) remarks on the relatively

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. Albano; 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 (1814b):

"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 componentry, 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 Apennine 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/piperino, 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

Brocchi (1817)		This work
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 pyroxena crystals, minimal laminae of mica and some angular pieces of Apennine limestone	Phreatomagmatic deposit of the Castiglione Crater (Marra et al. 2003); Peperino di Gabii (<i>Lapis gabinus</i>)
Near the Stella convent outside Albano	Peperino of grey colour, with bits of yellowish, compact or porous lava, fragments of pyroxene, amphibole, laminae 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 (<i>Lapis albanus</i>)
At Marino quarries	Peperino identical to that of Stella, except that it lacks fragments of primitive limestone	
At Lake Albano near Palazuolo	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 amphibole and pebbles of Apennine limestone	
On the eastern side of the Aricia Valley basin, in the place known as the Petrarra	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 laminae of black mica, some amphibole 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 amphibole and some mica laminae. 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

Table 1 (continued)

Location	Description	This work
Brocchi (1817)		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, amphibigene, mica and oolytic 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 amphibigena, mica and pyroxene	
In Val di Cona, two and a half miles from Subbiaco	Peperino seeded with vitreous amphibigene, 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 Tolfa	Grey peperino with yellowish spots, shiny black mica laminas, pyroxene fragments, blackish lava bits and limestone pebbles	"Braicciano 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 felspati, but greatly altered by the decomposition which made it friable, and reduced most of the felspati themselves to the earthy state	Tolfetano 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 felspati	Peperino delle Alture
On the top of Monte S. Angelo	Grey, with particles of mica and with minutes and large felspati	
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 felspate, 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 felspati. The other ingredients are similar to those of the previous lava, but felspati 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 felspati, amphibigene and pyroxene grains	

Table 1 (continued)

Location	Description	This work
At Pianura [<i>Phlegraean Fields, Campania</i>]	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 felspati	Part of the 39 ka Campanian Ignimbrite eruption succession (Campi Flegrei)
Columns of the ancient soldiers' quarter in Pompeiia	Pale languid colour, light, with granular fracture, with felspati and parts of blackish scoriaceous lava	
LAVA NENFRO		
Half a mile from the Ponte della Lenta on the road from Canale to Rota	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 felspati and fragments of a white and crumbly earthy substance	"Bracciano pyroclastic flow unit" of the Sabatini Volcanic District (de Rita et al. 1993)
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 felspates and pyroxene particles. It is analogous to that of Rota	"Peperino listato" (Sabatini 1896); "ignimbrite B" (Locardi 1965) or "ignimbrite II trachitica" (Bertini et al. 1971) from Vico volcano
LAVA SPERONE		
On the top of the Tusculum above the Camaldoli. In that place, it constitutes a large cliff, and is excavated like a chisel stone, which is employed in Frascati and in the neighbourhoods	Yellowish in colour, arid, with a coarse granular texture, scattered with whitish globes, which seen with a lens, are known to be amphi-gene, 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)
At Villa Falconieri near Frascati	Yellow-brown, solid, with a lumpy granular texture, and in some places slightly porous, with vitreous amphi-gene	Lava spero, Pietra sperone, Pietra gabina [improp.] (Lugli 1957)

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 *nenfro* is also used locally in the Vulcini Volcanic District (southern Tuscany–northern Latium; Fig. 1). Moderni (1903) first used *nenfro* 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 volcanoclastic rocks outside of Italy. Scrope (1825), for example, proposed the term "*calcareous 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 Mergoïl-Daniel 2012). Scrope (1825) also used "*calcareous 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 "peperitic 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 Vulcini volcanoes was proposed by Moderni (1904), who aimed to

"demonstrate that the origin of this tuff, so widely represented among the materials of the Tyrrhenian 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

a) Sheet 150—Roma—1:100,000 Geological Map of Italy—Servizio Geologico d'Italia	Stratigraphic unit	<i>Tufi grigi granulari, stratificati, orizzonte inferiore</i>	Granular grey tuffs, stratified, lower horizon	Description	Equivalent unit in modern geologic and archaeological literature
"Peperini" inferiori	lower peperini			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)
<i>Manifestazioni eruttive finali</i>	Final eruptive episodes			Coarse explosion breaches with xenoliths (paleogenic and Mesozoic limestones, leucitic lavas, etc.)	Phreatomagmatic products of Castiglione Crater (Marra et al. 2003); <i>Lapis gabinus</i> (Peperino di Gabii, pietra gabina; Lugli 1957; Farr et al. 2015)
				Compact, grey-greenish facies with small allotigenic elements	Distal products of the 2nd Albano eruptive cycle cropping out near Santa Procula (Freda et al. 2006; Giaccio et al. 2009)
				Explosion pyroclastic breaches, with lapilli, leucocrate ejecta, ultrafemic, biotitic pyroxenites; xenoliths of leucitic lavas and of the substrate (Plioclabrian 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 Ariccia, Albano, Nemi, Castiglione-Osa, Valle Marciana, Prata Porci, Pantano Secco, Pavona and Giuturna	Several phreatomagmatic products of Colli Albani, including "Peperino di Marino" or "Peperino di Albano" (<i>Lapis albanus</i>) (Marra et al. 2003; Freda et al. 2006; Giordano et al. 2006)
b) Sheet 143—Bracciano—1:100,000 Geological Map of Italy—Servizio Geologico d'Italia	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)	Tufo di Bracciano (Mattias and Ventriglia 1970); "Bracciano pyroclastic flow unit" (de Rita et al. 1993)
c) Sheet 137—Viterbo—1:100,000 Geological Map of Italy—Servizio Geologico d'Italia	Stratigraphic unit			Description	Equivalent unit in modern geologic literature
"Peperino delle alture" Auct				Quartz-laticite lava in domes, sometimes laticite-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-laticite 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)
d) 1:100,000 Geological map in "La regione vulcanica dei Colli Albani" (Fornaseri et al. 1963)	Stratigraphic unit			Description	Equivalent unit in modern geologic literature

Table 2 (continued)

<i>Prodotti di bocche eccentriche</i> 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 <i>lapis albanus</i> and <i>lapis gabinus</i>	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 <i>"Peperino tipico" del Viterbese</i>	Description Latic or quartz-latic ignimbrite; compact greyish lithified sometimes with columnar cracks, with small scoriae and flattened pumice of yellow to blackish colour	Equivalent unit in modern geologic literature Ignimbrite Cimina (e.g. Cimarelli and de Rita 2006; (Sheet 345—Viterbo, 1:50,000 Geological Map of Italy—CARG project, in press)
<i>Peperino delle alture</i>	Lava domes with variable composition, dark alkaline trachytes, dark quartzolates and dark labradorite riolacites, 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 <i>"Peperini listati"</i>	Description 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	Equivalent unit in modern geologic literature "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 <i>"Peperino della Via Flaminia"</i>	Description Lithoid grey tuff rich in various inclusions	Equivalent unit in modern geologic literature Tufo del Palatino (Karner et al. 2001a, b; Farr et al. 2015; Difendale et al. 2018)
<i>Tufi stratificati varicolori di Sacrofano</i>	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 ("fiammae"), 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 tufts 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)

"In the Sabatini Volcanoes this tuff is not part of the materials that ordinarily constitute the cones, but it is found stratified more or less horizontally always at a certain distance from the eruptive centers: in the Roccamonfina Volcano and in the Vulsini Volcanoes, it also contributes to forming the skeleton of the cones".

Moderni (1904) stated that:

"The *peperino* of Montefiascone is very different from that of Cimino Mounts and that of Latium; of ash gray or iron gray color, consists of volcanic sands at times very fine but more often coarse, and contains fragments of lava, pieces of scoria, lapilli, crystals of augite, leucite and other volcanic minerals embedded in the tuffaceous paste fragments of Eocene rocks."... "The whole large cone of Montefiascone... is mainly made up of this rock".

The Montefiascone *peperino* actually consists of distinct eruptive products, including the Ignimbrite Basale di Montefiascone (WIM, Tuscania and Viterbo sheets of the 1:50.000 geologic map of Italy, CARG project) and the Formazione de La Berlina (WBE; previously known as Ignimbrite di Montefiascone; Vernia et al. 1995).

In addition, Moderni (1904) described three *peperino* occurrences near Valentano village, in the area of the Latera caldera (western Vulsini). These are characterized by a grey tone and contain yellowish scoria clasts, lava and limestone lithics. Abundant small leucite, augite and mica crystals are also present. These deposits possibly correspond to a lithified facies of the Tufi di Poggio Pinzo phreatomagmatic-Strombolian succession (Vezzoli et al. 1987; Palladino and Simeì 2005).

It was mainly in the twentieth century, the term *peperino* entered in the official geologic literature as an informal name for a number of pyroclastic deposits (Fig. 2). In Table 2a–d, we list all stratigraphic units for which the local definitions of *peperino* (or, in a few cases, *piperno*) have been reported in the 1:100.000 geological mapping completed by the Servizio Geologico d'Italia (Geologic Survey of Italy). The term was also endorsed by two volcanological studies for the Latium region in the 1960s (Fornaseri et al. 1963; Mattias and Ventriglia 1970).

Following Mattias and Ventriglia (1970), the geological map of the Sabatini Volcanic District (de Rita et al. 1993) then also used the *piperno di Mazzano* label for a welded facies locally found in the lower part of the Tufo Rosso a Scorie Nere. This unit is distinct from the *peperini listati*, which represent deposits from an earlier eruptive event in the western Sabatini (see also Cioni et al. 1993).

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 Cimino 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* examples from Baccano and Montefiascone, or to carbonate-seated maar–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);
- 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 Cimino 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 Phlegraean 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

Table 3 Interpretation of peperino units in recent volcanological literature (see references for details)

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, <i>Unit e</i>)	Valley-pond phreatomagmatic pyroclastic currents (base surges), locally associated with sin-eruptive lahars		Giordano et al. (2002); Freda et al. (2006); Giaccho 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-Artemisio (or Vulcano Laziale) period (<i>Tufo del Palatino</i>)	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. Grottarossa 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)	Volsi Volcanic Field (different maar/diatreme centres: e.g. Tomacella, Patrica, Fosso di Monteacuto)	Phreatomagmatic pyroclastic currents (base surges)		Cardello et al. (2020)
Piperno di Mazzano (Monti Sabatini area)	Sabatini, Southern Sabatini activity (<i>Tufo Rosso a Scorte Nere Sabatino</i>)	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)
Peperini listati (Monti Sabatini area)	Sabatini, Southern Sabatini activity (<i>Peperini listati</i>)			de Rita et al. (1993)
Peperino listato (Blera-Vetralla area)	Vico (<i>Ignimbrite B</i>)			(Locardi 1965); (Bertini et al. 1971)
Peperino (Rota-Tolfa area)	Sabatini, Bracciano caldera (<i>Tufo di Bracciano</i> or <i>Bracciano pyroclastic flow unit</i>)	Valley-pond, lithified facies from pyroclastic flow activity		de Rita et al. (1993)
Peperino (Valentano area)	Vulsini, Latera caldera (<i>Tufi di Poggio Pinzo</i>)	Alternating phreatomagmatic pyroclastic currents (base surges) and Strombolian fallout activity		Vezzoli et al. (1987); Palladino and Simeì (2005)
Peperino (Montefiascone area)	Vulsini, Montefiascone volcano (<i>Ignimbrite Basale di Montefiascone; Ignimbrite di Montefiascone</i> or <i>Formazione della Bertina</i>)	Phreatomagmatic pyroclastic currents, associated with caldera collapse		Nappi et al. (1991)
Peperino Tipico (Viterbo area)	Cimini (<i>Ignimbrite Cimina</i>)	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 (<i>Lave di Canepina</i>)	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

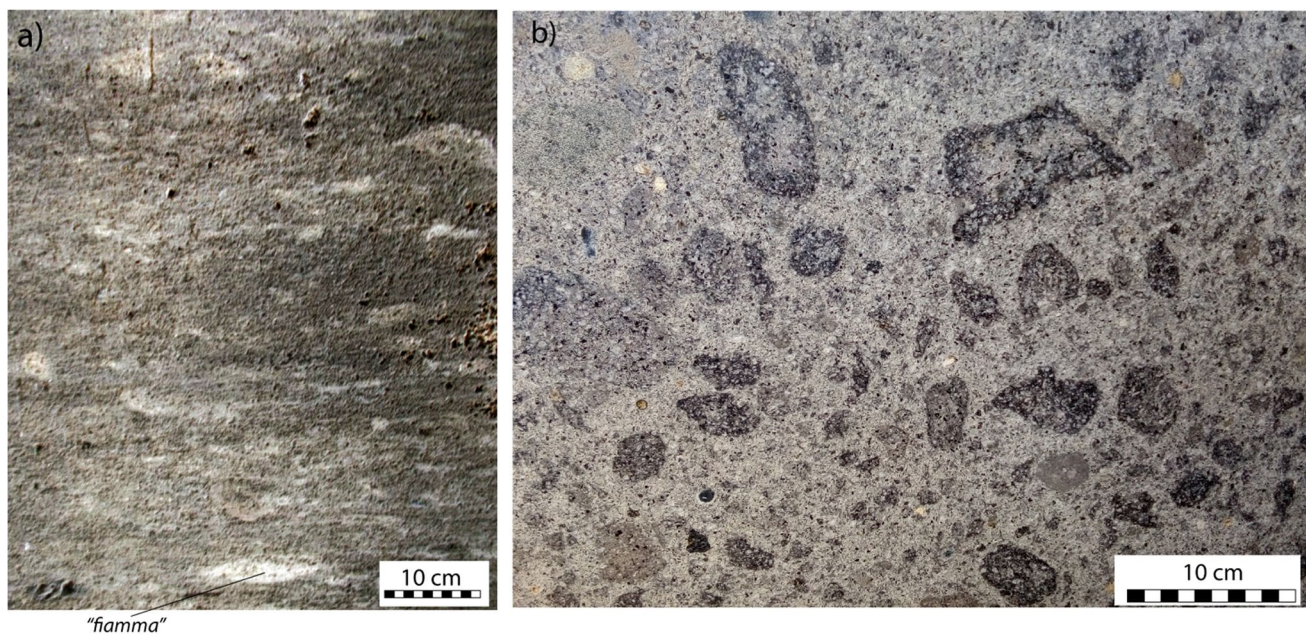


Fig. 5 The *Peperino di Viterbo* is a grey, porphyritic rock derived from both quartz-latic domes (*Peperino delle Alture*) and associated ignimbrites (*Peperino tipico*) of the Cimini volcanoes. **a)** Section normal to depositional surface: welded pyroclastic flow deposit show-

ing 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

Fig. 6 The perimeter wall that divided the temple of Augustus from the *Subura* quarter is one of the most imposing *peperino* works of ancient Rome



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*,

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
<i>LAPIS ALBANUS</i>	
6–fifth century BCE (?)	<i>Carcer Tullianum</i>
fifth century BCE	platform of temples of <i>Fortuna</i> and <i>Mater Matuta</i> in the Sant'Omobono sacred area
264 BCE	cippus of consul <i>Marcus Fulvius Flaccus</i> at Sant'Omobono
third century BCE (?)	walls of <i>Bovillae</i> village, near <i>Marino</i>
mid-third century BCE	sarcophagi of <i>Lucius Cornelius Scipio Barbatus</i> father and son
180–150 BCE	sarcophagus of <i>Publius Cornelius Scipio</i>
mid-second century BCE	sarcophagus of <i>Lucius Cornelius Scipio</i> ; temple of <i>Magna Mater</i> ; pre-Sillan temple of <i>Vesta</i> ; altars of Temple A and C in <i>Area Sacra di Largo Argentina</i>
144 BCE	<i>Acqua Marcia</i> aqueduct
post 139 BCE	sarcophagus of <i>Gneus Cornelius Scipio Hispanus</i>
end of second century BCE	facade of sepulcher of <i>Scipions</i>
end of second century BCE	Ariccia viaduct of <i>Via Appia</i>
108 BCE	sepulcher of <i>Sulpicius Galba</i>
2nd–first century BCE	several tombs along <i>Via Appia</i>
first century BCE:	villas of <i>Clodius</i> and <i>Pompeus</i> at mile 14 and 15 of <i>Via Appia</i>
100–80 BCE	pavement of <i>Forum Romanum</i>
90 BCE	temples <i>settentrionale</i> and <i>mediano</i> at <i>Forum Holitorium</i> ; temple at 1st mile of <i>Via Ostiense</i>
80–50 BCE	doric temple at <i>Forum Holitorium</i>
78 BCE	Sillan restoration of temple of <i>Jupiter</i> ; <i>Tabularium</i>
55 BCE	theatre of <i>Gnaeus Pompeus Magnus</i>
~ 50 BCE	temple of <i>Bellona</i>
42 BCE	podium of temple of <i>Saturn</i> ; house of <i>Livia</i>
17 BCE	altar of <i>Dis Pater et Proserpina</i> in <i>Campus Martius</i>
31–2 BCE	perimeter wall of Forum of Augustus (Fig. 5); circus and theatre of <i>Bovillae</i>
2 BCE	temple of <i>Mars Ultor</i> ; Augustan restoration of temple of <i>Iuppiter Stator</i> ; arches of <i>Aqua Virgo</i> aqueduct
70 CE	<i>Forum Pacis</i>
~ 138 CE	temple of <i>Divus Adrian</i> , <i>Adrian's Mausoleum</i>
141 CE	temple of <i>Antoninus</i> and <i>Faustina</i>
202 CE	<i>Castra Albana</i>
<i>LAPIS GABINUS</i>	
third century BCE (?)	walls of <i>Gabii</i>
~ 200 BCE	temple of <i>Juno</i> at <i>Gabii</i>
144 BCE	<i>Acqua Marcia</i> aqueduct
142 BCE	<i>Emilius</i> bridge
109 BCE	<i>Milvius</i> bridge
~ 80 BCE	terminal section of <i>Cloaca Maxima</i>
78 BCE	<i>Tabularium</i>
62 BCE	<i>Fabricius</i> bridge
55 BCE	theatre of <i>Gnaeus Pompeus Magnus</i>
~ 50 BCE	tomb of <i>Cecilia Metella</i> ; <i>Amato</i> bridge; <i>Nona</i> bridge
46 BCE	Forum of <i>Caesar</i>
30 BCE	Forum of <i>Augustus</i> ; <i>Aqua Virgo</i> aqueduct

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*.

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 Cimino 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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