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The place of geology in the French wine business: a preliminary investigation by exploring information from wine labels

La place de la géologie dans l'industrie viticole française : une approche préliminaire par exploration des étiquettes de vins

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Mots-clés : Vin, Géologie, Toponymie, Terroir, France.

Abstract

Wine producers and wine businesses utilise geological information in different ways and geological terms, fossil names, or illustrations, often appear on wine labels. Browsing the commercial database Vivino®, we analysed 9,204 different French wines that mention geological terms either in appellation, estate/brand, or vintage names. This means that, in France, at least five percent of commercial wine products mention geologic provenance. The references to geology are first linked to soil (82.8%), secondarily to rock substrates (lithology, 14%) and more marginally to other elements taken from geological maps (fossils, geological processes, geological ages, minerals). The terms used to illustrate soil properties are usually not extracted from scientific data but rather from century old toponyms and traditional descriptions of soils by farmers. The words may vary among regions to describe similar things. As an example, pebbles and rock fragments of the soils may be named "perruches" in the Loire Valley, "grès" in Languedoc, "galets" in the Rhône Valley, "cailles", "chaillots", "cras" in Burgundy, etc. This reflects past rural tradition and inheritance of local languages, which remains informal geology. References to geology have been integrated since the settlement of the appellation system in 1936. The centuries old, complex partitioning of vineyards into small production units have been transcribed in the appellation system. These can be found in Burgundy, where "Climats" are named after soil properties and are found in the names of several 1er Cru and one Grand Cru. A major appellation of Bordeaux is named "Graves" after the alluvial deposits of the Garonne banks. There are very few appellation named after geological substrates (IGP Landes - Sables Fauves, IGP Landes - Sables de l'Océan, IGP Sables-de-Camargue). The names or ages of geological formations are occasionally used by wine producers on the labels and in their marketing, though this is not mandatory. As an example, several producers of Muscadet area connect their vintage to local rock substrates (amphibolite, gabbro, gneiss, granite, orthogneiss, schists). The use of substrate lithology, interval of the geological time scale, geological processes, or fossil organisms

is always relevant to local geology. The geological information is often taken from geological maps or other scientific resources. It is used by producers to emphasize the identity of their wine and the link between the wine and the local environment. The way wine producers consider geological information varies highly from one region to another. The regions with a very strong reputation like Bordeaux and Bourgogne ascribe long-term traditions into wine nomenclature, including many references to soils. The Champagne region does not often promote local geology in the differentiation of their products, although Champagne is often associated with chalk. Less prestigious regions (Languedoc-Roussillon, Jura, Loire) are more likely to utilize references to local geology for promotion of the products as they search for identity and added commercial value.

Résumé

Des références à la géologie apparaissent à différentes étapes de la production vinicole ou du commerce du vin. Les bouteilles de vin font souvent mention de termes géologiques, des noms de fossiles ou des illustrations sur les étiquettes. Des requêtes de la base de données commerciale Vivino® ont permis de récolter et d'analyser des informations sur 9 204 vins différents faisant référence à des termes géologiques dans le nom de l'appellation, du producteur ou de la cuvée. Cela implique qu'en France, au moins 5 % des vins disponibles dans le commerce ont quelque chose à voir avec la géologie. Dans l'ordre d'importance, les références à la géologie concernent avant tout les sols (82,8 %), puis la nature du substratum (lithologie, 14 %) et plus rarement d'autres éléments tirés des cartes géologiques (fossiles, pro-

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cessus géologiques, âges, minéralogie). Les termes utilisés pour caractériser les sols ne sont que rarement dérivés de données scientifiques, mais plutôt de toponymes centenaires, ou des langages traditionnels utilisés par les agriculteurs pour décrire leurs sols. Les mots peuvent ainsi varier d'une région à une autre pour décrire les mêmes objets. Par exemple, les galets ou les cailloux du sol sont communément nommés « perruches » dans la vallée de la Loire, « grès » dans le Languedoc, « galets » dans la vallée du Rhône, « cailles », « chaillots », « cras », ou autres en Bourgogne. Ces différences reflètent les traditions rurales passées ou l'héritage de termes des dialectes locaux, ce qui reste une géologie très informelle. Des références à la géologie ont été intégrées lors de la mise en place du système des appellations à partir de 1936. La tradition centenaire du découpage des vignobles en petites unités de production, les climats, que l'on trouve en Bourgogne, a été transcrite dans le système actuel des appellations d'origine. Ainsi les noms de nombreux climats traduisent des propriétés de leurs sols. Une importante appellation de Bordeaux est nommée « Graves » d'après la nature des dépôts alluviaux des rives de la Garonne. Quelques appellations ont été nommées en référence au substratum géologique (IGP Landes - Sables Fauves, IGP Landes - Sables de l'Océan, IGP Sables-de-Camargue). Le nom ou l'âge de formations géologiques sont occasionnellement indiqués sur les étiquettes ou les médias promotionnels par des producteurs de vin, même si cela n'a rien de d'obligatoire. Par exemple, différents producteurs de la région du Muscadet nomment leurs cuvées en référence à des types de roches locales (amphibolite, gabbro, gneiss, granite, orthogneiss, schistes). Les mentions de la lithologie du substratum, d'un intervalle du calendrier des temps géologiques, d'un processus géologique, ou d'un organisme fossile sont toujours reliées à la géologie locale. Les données géologiques sont souvent extraites des cartes géologiques ou d'autres sources scientifiques. Elles sont utilisées par les producteurs pour justifier l'identité de leurs vins et le lien entre les caractéristiques du vin et l'environnement local. La manière dont les producteurs considèrent les données géologiques varie fortement entre régions de production. Les régions avec une importante renommée historique, comme Bordeaux ou la Bourgogne, ont intégré des termes traditionnels dans la nomenclature de leurs vins, en particulier les termes liés à la description des sols. La région Champagne, en revanche, ne promeut que rarement la géologie locale pour la différenciation de ses produits, bien que le Champagne soit souvent associé à la craie. Des références à des données scientifiques plus modernes sont plus commune dans les régions moins prestigieuses qui sont souvent à la recherche d'une identité ou d'une plus-value commerciale et qui utilisent la géologie locale pour promouvoir leurs produits (Languedoc-Roussillon, Jura, Loire).

1. Introduction

Geologists have long questioned the relationships between wine production and geology, and many books describing the geology of wine regions have been published (e.g., for France: Pomerol, 1986; Fanet, 2008; Bousquet, 2011; Frankel, 2014; Campy, 2017; Giresse 2017). One can evidence that in many regions, the vineyard extension matches that of specific geological substrates. It has been suggested that elements in the geological substrate, imprint on vines, and

the taste of the wine. As an example, it has been written that silica brings finesse, limestone roundness, and clay strength and structure to the wine (De Wever *et al.*, 2009), but such a simple relationship remains unlikely (Maltman, 2003; Huggett, 2006). Indeed, the geology of the vineyard is a natural parameter that contributes to some aspects of wine production and is of importance to the winegrower, but only through an indirect and complex relationship, when combined with other environmental factors (van Leeuwen *et al.*, 2004; Deloire *et al.*, 2005; Huggett, 2006; Sommers, 2008; White, 2009).

Wine production in France is structured by a system of "Appellation of Origin". Regions are differentiated so that each production area is associated to distinct combinations of grape varieties, working processes at vineyards, winemaking, and wine types. Each region is associated with specific tastes. It is assumed that wines reflect the taste of their region. The combination of climate and geology, are elements of the primary parameters driving the link between a place and the typicity of locally produced wines, which is summarized in the concept of Terroir (van Leeuwen and Seguin, 2006; Rouvellac, 2008). Climate, through light, temperature and rainfall regimes, have direct consequences on grape development and maturity at harvest time so that experts easily segregate wines from cool and warm climate at a global scale but also at the scale of regions within a country like France (Sommers, 2008), or at the scale of vineyard plots (Vaudour, 2006). The contribution of geological factors remains difficult to access, mostly because geology acts at different scales and at different steps of wine production, from regional to local geomorphology, permeability of the substrate, soil structure, water availability, chemical properties of soil water, etc (van Leeuwen *et al.*, 2004; Maltman, 2018). However, it is well demonstrated that the history of wine production and collective choices of wine producers are major triggers of the regional wine identity (Lucand, 2019).

Wine producers are recognizing soils and rocks as part of their natural environment. Many places have been named after the local rocks or the soil properties that have been present for centuries. The inherited structure of wine production still reflects the way winegrowers considered geology in the past. The place names, derived from geological properties, are often used in the wine estate names, the wine names or the appellation (Garcia *et al.*, 2019).

The French wine appellations are settled to precisely delineated territories. The regulation authority of appellation system in France (INAO: Institut National de l'Origine et de la Qualité) defines the production area of each appellation. Although the rules have changed over the 20th century and the situation varies from one appellation to another, the retained area always compromises agronomical, technical, and juridical criteria (Humbert, 2010; Vincent, 2018). Geological mapping offers objective information for delineation of appellation area (Vaudour and Shaw, 2005; Vaudour, 2006; Rouvellac, 2008). In many cases, the local knowledge is transcribed in the appellation nomenclature, so that names of Burgundy 1er Cru and Grand Cru most often receive the name of a "Climat".

Different types of reference to geology can be found on wine labels: illustration of geological objects (sketches, logotypes, pictures, photos), names of the producer's estate, brand, appellation name, name of the commercial product

(cuvées/vintage), and descriptive texts of the back labels (De Wever *et al.*, 2009). The diversity of references to geology can be illustrated with an example (Figure 1). In 2003, an appellation “AOC Languedoc – Grès de Montpellier” was erected for red wines produced on the hill slope facing the Mediterranean Sea around the city of Montpellier. The word “grès” does not refer here to sandstone (“grès” in French) but to an Occitan word for stones/pebbles. A local wine estate was named long ago after the local place name “Domaine de la Perrière”, probably in reference to the past location of a quarry. This estate sells a wine vintage “Les Silices” the label of which exhibits the sketch of a fossil in the background. The vineyards, from which “Les Silices” is derived, grow on siliceous pebble stones and fossiliferous limestones.



Figure 1. Example of a wine bottle exemplifying references to geology. Here, the estate name “domaine de la Perrière” is derived from a toponym indicating the past location of a quarry. In the appellation “Languedoc – Grès de Montpellier”, the word “grès” refers to the pebbly soils of the area, “Les Silices” to the mineralogy of the local pebbles, and the background illustration is fossil sketch.

Figure 1. Exemple de bouteille de vin mettant en avant des références à la géologie. Ici, le nom du domaine « domaine de la Perrière » dérive d'un toponyme qui indique la présence ancienne d'une carrière. Dans l'appellation « Languedoc – Grès de Montpellier », le terme « grès » fait référence au sol pierreux de la région, « Les Silices » souligne la minéralogie des pierres locales, et l'image d'arrière-plan est le schéma d'un fossile.

There is abundance of literature describing the geology of wine producing regions, but little information on how geology is utilized in the wine business (Maltman, 2018). Wine producers often make references to soils and geological substrates in their advertisements, but this has never been investigated at a broad scale using an analytical approach. The goals of this paper are to investigate how geology is used in French wine production and the wine industry through the analysis of wine labels. Large databases of wine references are currently available. Information was taken from the database Vivino®, seeking geological references in estate names, appellation, and vintage names. These terms can be related to geological objects (rocks, soils, geological maps), either in scientific or common language. The dataset allows us to address several previously uninvestigated questions. How often the wine business uses geological terms? What geological terms are

most commonly used? Are they written in common or scientific language? Are the terms intentionally chosen or incidentally transcribed through the place names? Is there a disparity among regions in the use of geological terms? How the information of the labels illustrates the way geology is considered at operational (wine producer's choice) and administrative levels (definition of the appellations)?

2. Methods

In order to explore the transfer of geological information into the wine business, a list of wine names that mention geology has been established. The list was extracted from the online commercial database Vivino® (www.vivino.com). In this database, the information on wines is obtained mostly from OCR reading of bottle labels scanned by users, or direct entry by wine producers and users. The database does not provide an exhaustive picture of wine production, but it is assumed to represent a significant sample. Only wines sold in bottle are referenced. A total of 185,830 entries with exhaustive geographic information were available for France as of July 27th, 2021.

The database Vivino® was queried with terms extracted from geological lexicons. Only wines with complete descriptions have been selected and the information copied into a table. Geological terms can appear in the producer's or estate names, the wine's commercial name (brand, vintage), or the appellation name. Other reference to geology (illustration, back label) are not consistently transcribed in the database and have not been considered. The survey was designed to tackle the technical information available from the geological maps and publications as well as the words from the common language used to describe the soils and geological substrate. The primary resource for technical terms is the geological time scale and the lithology lexicon of BRGM, representing 275 and 287 words respectively (<https://infoterre.brgm.fr/page/lexiques-geologiques-brgm>). The list is augmented with some palaeontological terms and types of geological structures taken from “dictionnaire de géologie” (Foucault *et al.*, 2014). Many words used to describe soils in viticulture vary among regions. A summary of local traditions of landscape descriptions, including soil properties can be found in the names used to designate local area, land plots, or villages. The common language terms referring to soil nature have been extracted from a toponym dictionary for France (Pégoriet, 2006). Dictionaries restricted to specific regions were excluded to avoid oversampling of those regions. Words associated with landscape rather than soil or geology were excluded, although they are of common use (e.g., roche=rock, champagne=cuesta landscape on chalk, côte=slope).

The data matrix has been handled using a spreadsheet for preparation of figures and data summary tables. Accuracy of information on wines was verified and corrected if necessary. Duplicate lines were deleted unless the same wine label referred to two or more distinct geological concepts. Ultimately, each line, represents a commercial product, with its producer, vintage, and appellation name. Information is complemented with the region of production following the IAO standards, and the reference glossary (lithology, stratigraphy, palaeontology, soil or other).

3. Results

3.1. Diversity and relative frequency of the geological terms

The database of 185,830 wines retained a list of 9,402 distinct wine names with some reference to the geological environment. This represents 5.0% of the wines considered for the analysis. Nearly half the records account for appellations, about 30% for the vintages and 20% for the winery estate names. A total number of 226 different words from the assembled glossaries were encountered, plus some spelling variants (appendix). The frequency of words is highly variable, and only 18 words represent more than one percent of the records (table 1). The word “graves” is by far the most popular term, accounting for 40.8% of the records. The main reason is that “graves” is used in the names of major appellations of the Bordeaux region, but also in local producer’s and vintage names. “Grave” describes the alluvial sand in the Bordeaux area. Vineyards are grown on similar alluvial deposits in other regions, which can be traced on wine labels using variations of this name (e.g., gravières, grèves, varennnes) according to the regions or the grain size and the

main rock type. The most frequently used words indicate pebbles or gravels in the soils (e.g., pierres, perrières, cailloux, caillerets, cras, grès, silex, lavières, stein). Some terms used in both scientific and common language relate to both the rock substrate and soil components (schiste=schist, argile=clay, calcaire=limestone, sable=sand, grès=sandstone).

More than 82.8% of the references are related to soil properties but when looking at the diversity of the words used, references to soil represent only 48.2% of the terms (table 2). A hundred and nine words describe soil properties, out of which 49 are for soils rich in stones or pebbles. The words are often synonyms or have very close meaning and describe the abundance and type of pebbles. Lithology of substrate accounts only for 14.3% of the wine records with reference to geology. The most frequent words are words of common usage: gravel, schist, sand, limestone, clay, but can also point out very precise scientific data (e.g., peridotite, dacite, dolomite, travertine). A minimum percentage (2.2%) illustrates local palaeontology or stratigraphic terms, but the terms used are often very specific and likely extracted from primary or secondary scientific resources (geological maps, geological guidebooks).

Term	Occurrences	Field	Scientific term	Meaning
Graves	3823	Soil	No	Alluvial sandy deposits
Pierres	712	Soil	No	Stone
Perrières	642	Soil	No	Limestone quarry
Cailloux	247	Soil	No	Small stone
Gravières (=gravieras)	227	Lithology	No	Sand pit, alluvial sandy deposits
Lavières	193	Soil	No	Stone or stony soil
Schiste	186	Lithology	Yes/no	Schist (either metamorphic or laminated sedimentary rocks)
Grèves	167	Soil	No	Gravelly or sandy alluvial deposits
Caillerets (=cailleret)	151	Soil	No	Stone or stony soil
Cras	140	Soil	No	Stone or stony soil
Grès	133	Soil	No	Stone
Sable	131	Lithology	Yes/no	Sand
Silex	110	Lithology	Yes	Flintstone
Argile	106	Lithology	Yes/no	Clay
Varennnes (=varannes)	104	Soil	No	Sandy alluvial soil
Calcaire	100	Lithology	Yes/no	Limestone
Grès	94	Lithology	Yes	Sandstone
Stein (in Steingrubler, Steinklotz, Steinert, steinweg, steinbach)	94	Soil	No	Stone

Table 1. List of the terms each accounting for more than 1% of the labels identified as linked to geology. Spelling variants are given for each term, as well as the number of records in the database, an English translation or definition, and its field of usage (either from the common language, the scientific language, or both).

Tableau 1. Liste des termes qui comptent chacun pour plus de 1 % des étiquettes identifiées comme liés à la géologie. Chaque terme est décrit par ses variants orthographiques, son nombre d'occurrences dans la base de données, la traduction ou une définition en anglais et son champ d'usage (dans le langage commun, le langage scientifique, ou les deux).

Reference	Number of occurrences	Percentage of occurrences	Number of words	Percentage of words
Soils	7787	82.8	109	48.2
Lithology	1347	14.3	54	23.9
Paleontology	142	1.5	29	12.8
Stratigraphy	62	0.7	29	12.8
Other	64	0.7	5	2.2
Sum	9402		226	

Table 2. Types of geological information transcribed in the names of French wines. For each type of feature the table summarizes the number and the percentage of records within the references made to geology, and the number and percentage of associated terms. Information on soils is by far the most common. Geological substrates are described primarily with their lithology, secondarily with their paleontological content, then with geological age and other information (mineralogy, geological processes, etc.).

Tableau 2. Types de données géologiques transcrites dans les noms des vins français. Pour chaque catégorie, le tableau indique le nombre et le pourcentage d'occurrences au sein des références à la géologie, et le nombre et le pourcentage des mots associés. Les références à la nature des sols sont de loin les plus abondantes. Les substratums géologiques sont décrits principalement par leur lithologie, et secondairement par leur contenu paléontologique, puis leur âge géologique, et d'autres informations (minéralogie, processus géologiques, etc.).

3.2. Geology in the appellation names

In 2021 the INAO recognizes 437 wine appellations (363 AOC/AOP, 74 IGP). The appellations are all named after geographical reference, occasionally complemented with other detail. Only 8 appellation names could be related to geology. Criots-Bâtard-Montrachet is an appellation of Bourgogne for which the term “criots” marks the abundance of pebbles in the soils. However, many “climat” toponyms used for naming of “1er cru” in the appellations of Burgundy are linked with soil properties or that the land was formerly used as a limestone quarry. Languedoc - grès de Montpellier is a geographic specification of Languedoc AOP in which “grès” is the local name of the pebbles of the soil. “Graves”, “graves de Vayre” and “graves supérieures” are three AOCs of Bordeaux region characterized by a substrate of alluvial deposits locally known as “graves”. Sables de Camargue is an appellation associated with the sand deposits of the Rhône delta. The Landes IGP recognizes two geographic specifications associated to sand substrate, one on Miocene fluvial sands “Landes - sables fauves”, and the other on the coastal sand dunes: “Landes - sables de l’océan”.

3.3. Origin of the geological information

All words extracted from toponym lexicons are associated with the description of soils. Only a few can also be found in geosciences literature or are used otherwise in the description of geological substrate (clay, marl, sand). Only references to the word “grès” have been split between toponyms and geological information, because the word may refer either to sandstone or to soil stones, depending on local usage. No scientific word used specifically for description of soils was found on wine labels. References to soil being inherited from ancient, centuries old practices, illustrate the long-standing interest producers have with vineyard soils. References to soil have been integrated with establishment of the appellation and estate. Vintage names are more volatile, and prone to change with commercial management.

Words related to geological processes, paleontology, and stratigraphy, and most words related to lithology were only found within scientific resources. Several words of common usage, like schist, granite, limestone, flintstone, sandstone and several others are considered here as derived from geological knowledge wherever consistent with local geology. Thus, 1,615 wine names are assumed to derive from geological maps or scientific data, which represents only 0.9% of the entire wine production. A major part refers to sedimentary rocks, and much less to metamorphic and magmatic rocks

(table 3). There is a correlation between the surface area on geological maps and the occurrences of main rock types in vine labelling (table 3). There is a slight excess of references to metamorphic rocks and a deficit to magmatic rocks. Magmatic rocks are common in elevated regions (Central Massif, Alpes, Pyrénées) and in Armorican Massif (Britany) where vineyards are rare. Places famous for wine production on magmatic rocks are limited to Beaujolais, northern Rhône Valley, higher Loire Valley and to a lesser extent to Corsica or Alsace. In comparison, lower lands with metamorphic basement host important wine production areas (Pyrénées, lower and higher Loire Valley, northern Rhône Valley, north-west part of Languedoc area) The correlation between the geology of vineyard area and the geological terms quoted on labels is an indication that wine producers have been interested in searching in local geology a key information for marketing of their wines.

3.4. Spatial patterns

French wine is concentrated in large production regions (Languedoc-Roussillon, Bordeaux, Champagne, etc.). One can assume that if the interest in geology is widespread and relied on random individual initiatives of the producers, then the more a region produces wines the more references to geology should be expected. The data show a significant correlation between the number of wines referenced in a region and the number of references to geology on the wine labels (Figure 2). The most represented regions Bordeaux and Bourgogne have many more references to geology than the other regions (Figure 2A). The Champagne region does not reflect this relationship and has a lower number of geological references than expected. When only references to scientific data are considered, a correlation between the number of wines and the number of references to geology is still well supported. However, Jura, Loire Valley and Languedoc-Roussillon diverge from this trend (Figure 2B). Those three regions tend to have a higher affinity to modern geological information than other regions with similar diversity of wine production.

The most represented regions of Bordeaux and Bourgogne have many more references to toponyms and historical names than the other regions, because the references are found for a large part in the appellation names (table 4). Bordeaux is marked by the high diversity of production under the Graves appellation, and the structure of Bourgogne production implies diverse and abundant references to toponyms in the appellation names. In comparison, there is no traditional use of geological term in the

Associated substratum	Number of occurrences	Percentage	Geological map percentage
Sedimentary	1202	74	77
Magmatic	124	8	12
Metamorphic	307	19	11
Other	18		
Sum	1651		

Table 3. Comparison of the relative frequency of sedimentary, metamorphic and magmatic rocks in the wine label database and on the geological map of France. Many of the descriptive terms used on wine labels directly or indirectly allow inference on the geological substrate, either sedimentary, magmatic and metamorphic. Geological data for France has been extracted from the simplified geological map of France (Nehlig et al., 2005), and a percentage of sedimentary, magmatic and metamorphic rock calculated.

Tableau 3. Comparaison de la fréquence des types de roches sédimentaires, magmatiques et métamorphiques entre les bases de données des étiquettes de vins et la carte géologique de la France. De nombreux termes utilisés sur les étiquettes de vins permettent une interprétation directe ou indirecte de la nature géologique du substratum, soit sédimentaire, soit magmatique, soit métamorphique. Les données géologiques pour la France ont été extraites de la carte géologique simplifiée de la France (Nehlig et al., 2005) et des pourcentages de roches sédimentaires, magmatiques et métamorphiques calculés.

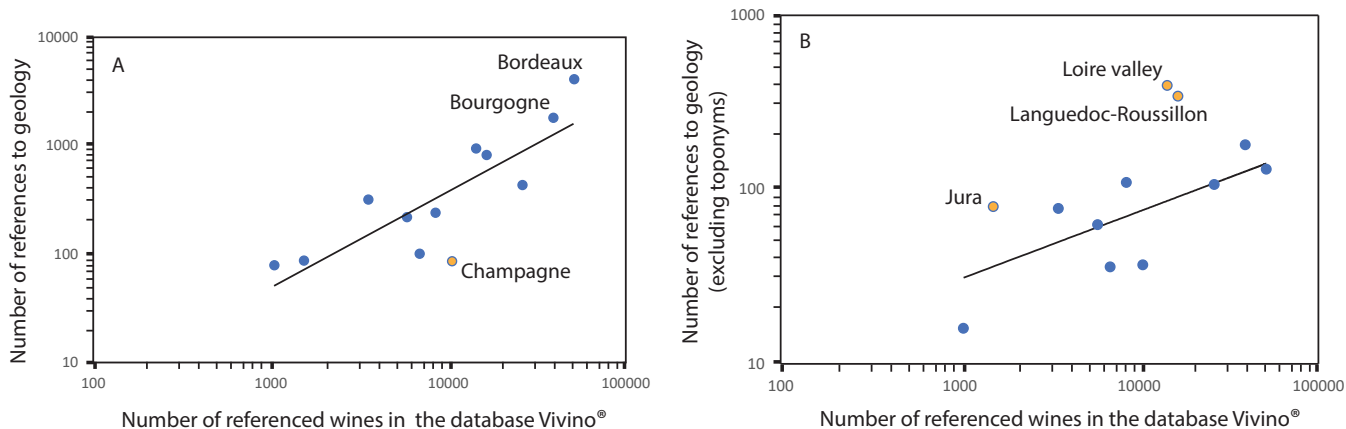


Figure 2. Relationship between total number of wines referenced in the database Vivino® (www.vivino.com) and the number of those references associated to geology. Each individual point represents a wine producing region of France. A – All data. B – Only the data related to scientific terms, and excluding toponyms. The points labelled with region names are outliers of the positive correlation between the number of wines and geological references.

Figure 2. Relation entre le nombre total de vins référencés dans la base de données Vivino® (www.vivino.com) et le nombre de ces références qui sont liées à la géologie. Chaque point représente une région de production vinicole française. A – Toutes les données prises en compte. B – En ne tenant compte que des références à la géologie issue de données scientifiques, et excluant les toponymes. Les points identifiés par le nom de la région sont ceux qui se distinguent de la tendance générale.

Region	Appellation	Estate/Brand	Vintage
Alsace	93	4	144
Beaujolais	0	131	195
Bordeaux	3824	273	108
Bourgogne	1146	126	573
Champagne	0	23	64
Jura	0	51	37
Languedoc-Roussillon	138	228	503
Loire	0	334	640
Provence	0	49	53
Rhône	0	144	300
Savoie	5	52	36
Sud-Ouest	11	98	108

Table 4. Number of wine labels of each producing region quoting geological terms in either appellation, estate or vintage names. A few regions integrated mostly common language in their appellation (Bordeaux, Bourgogne). References to local geology in vintage names acknowledge current interest of the producers, which is highly variable among regions. Geological terms used in estate names may have different origins depending on estate history. Ancient estate names usually come from toponyms, whereas younger estates translate an interest to local soils or geological substrates.

Tableau 4. Nombre de vin, pour chaque région de production, qui cite un terme géologique, soit dans les noms de l'appellation, de domaine ou de cuvée. Un nombre réduit de régions ont intégré des mots hérités des usages locaux dans le nom d'appellation (Bordeaux, Bourgogne). Les références à la géologie dans les noms de cuvées reflètent l'intérêt des producteurs, ce qui varie énormément d'une région à l'autre. Les termes utilisés dans les noms des domaines dépendent de l'histoire des domaines. Les noms des domaines anciens viennent habituellement de toponymes, alors que ceux de domaines plus récents traduisent un intérêt pour les sols ou les substrats géologiques locaux.

Champagne production, and very few estate or vintage names use geological terminology. Here, mentions of the chalk and the associated fossils or geological ages are occasional. Instead, the region typically relies on words that are indicative of geomorphology (“Champagne” and “côtes” for example). Among the regions that recently incorporate geological terms, Jura is notable for the large number of estate names (Les Dolomies, domaine du Gypse, domaine des Marnes Blanches, domaine des Bélemnites). The Loire Valley and Languedoc-Roussillon also host numerous estate names linked to geology, but most importantly an exceptional number of vintage names.

4. Discussion

4.1. Toponyms and the descriptive heritage of vineyard environments

The understanding of place names (toponymy) provides insightful information on the history of wine production. In countries with centuries of history, local habits have often been trans-

cribed in the name of place. In France, it was demonstrated that the old practice of wine production resulted in numerous names of towns, landscape units, roads, fields or vineyards (de Planhol, 1988). The locality names quoting vineyards are not often consistent with current wine producing areas but are just reminiscence of past activity, whether significant or not (Chabot, 1943). Historical evidence shows that wine merchants referred to the origin of the wines since antiquity. Quality wines were often ranked according to their cities of origin (Dion, 1959; Tchernia, 1986; d’Andeli cited in Germès, 1997). Mention of the cities were primarily references to marketplaces, not necessarily of specific wine production area or even producers. With refinement of wine hierarchy, there was a trend toward a more precise delineation of the production areas and of product origins. One can assume that the words related to topography or geomorphology are the most common in the wine world. As an example, “côte” (=slope) is likely the most common word in the nomenclature of French wines integrated within the appellation system, that refers vineyard landscapes. However, links to local geology can be traced in at least 5% of the wines available on the market. Soil related

terms appear mostly in old appellation names, and in estate names, which express the strong historical link of wine producers to their environment and the soil on which they grow their vines. This can be studied indirectly from the local place names (toponymy) and their utilization by the wine business. Then geology can emerge as a shared, collective knowledge, promoted in administration of the wine production as well as commercial advertisement. However, the way geology is considered differs from one region to another.

In Burgundy, the properties of the landscape and soils have been used in vineyard partitioning since the 15th century (Garcia and Labbé, 2011). Expressions of wines differ from one place to another, so that a complex partitioning of vineyards into small production units, the “climats” system, emerged. The “climats” names became toponyms, names of the places recorded on maps as “Lieux-dits”. Many “Climats” are named after soil properties, but many other toponyms describe aspects of landscape, and land use (Garcia, 2010, 2014). Vineyards have historically incorporated descriptions of local soils into the names of their wines, and the resulting toponyms hold a record of the understanding of the local geology (Garcia, 2013). The hierarchy of Burgundy wines settled progressively and during the 20th century was fixed in the appellation system. Thus, the appellation system perpetuated the centuries-old place names reflecting soil properties. As an example, the recognition of 1er Cru and Grand Cru follows the previous practices and the zoning of “Climats” (Landrieu-Lussigny and Pitiot, 2014). The toponym lexicon used to query the database includes many soil-related words used in Burgundy: aiges, argilières, aubuis, bélouses, boulaïses, caillerets, cailles, caillettes, cailloux, cailloutes, chailles, chaillots, crais, cras, crayères, crays, créots, crêts, criots, crots, grèves, lavières, mollières, perrières, perrons, pierres, pierreux, rougeons, varennnes, but the exhaustive “Climats” catalogue records even more names related to the soils (Landrieu-Lussigny and Pitiot, 2014). Additional references to geology emerged in the 20th century during and after the settlement of appellation system, and the development of direct bottling and selling by small wine producers. “Climats” names appear, or reappear, as geographic information on labels of village appellations throughout Burgundy, even in places where they were not necessarily traditionally used. Old “climats” or lieux-dits” names can be revived.

The history of wine names has not been investigated with the same level of detail outside of Burgundy. However, the appellation system also transcribes old practices of the natural description of vineyard landscapes. As an example, gravely soils derived from the alluvial deposits of the Dordogne, Garonne and Gironde are described by numerous common words in the Bordeaux area (cailloux, graves, gravelles, graviers, gravières, sables, sablières, sablons), words that often occur in estate or vintage names. Other toponyms found in vintage or estate names (i.e., canteranes, margagnis) highlight vineyards that have been planted on former muddy swamps, drained during the 17th century (Dion, 1959). General descriptive terms also occur in the Bordeaux area: perrières, pierres. The main difference with Bourgogne is that, in Bordeaux, those words are more often assigned to estates than to appellations, with the exception of “graves”. From an historical point of view, the number of estate names in Bordeaux started to rise in the mid-19th century, far earlier

than settlement of the appellation system (Roudié, 1984). Toponyms appear in all wine producing areas, including Bordeaux and Bourgogne, as names for commercial wines. Those names are not mandatory for regulation, and names are more volatile, subject to fashion. The differentiation of vintage names is recent and related to the development of direct sale during the 20th century.

The informal geological terms (cailloux, pierres, pierreux, perrières, chailles, garennes, moullières, varennnes) are found in many regions. The words shared by several regions divide southern and northern France, following the logic of former Oc and Oïl languages as well as local dialects. For example, the word “peire” is common to the Rhône Valley, Provence and Languedoc and designates stones in Oc language. Its equivalent in northeast France (Bourgogne, Beaujolais or Jura) would be “crêts” and all its derivatives. Several toponyms are found unique to wine producing regions: arroucats, boubées, bouldènes in South-West France, aubuis, cailleries, cosses, galettes, galuches, perray, perruches in the Loire Valley, creisses, cresses, criottes, falaises, grès in the Languedoc, crottes, peyron, safres in the Rhône Valley, or cruetts in Savoie.

4.2. Geological science hidden in the wine appellation system

The appellation system currently used in France started in 1936 with the initiation of the “appellations d’origine contrôlée” classification system. Each production area receives a name, chosen by the producers themselves in agreement with the administrative institution (INOA). References to geological formations have been integrated in a few appellations, validating the tradition of naming the wines after the natural environment or local geological substrates. This is the case for the major appellation of Bordeaux named “Graves”, because it was inherited from long usage. Ultimately, there are very few appellations named after geological formation or substrate types (IGP Landes - Sables Fauves, IGP Landes - Sables de l’Océan, IGP Sables-de-Camargue).

Beside appellation names, geological information has been considered a primary objective criteria to delineate the geographical limits of appellation (Vaudour, 2006). Numerous references to geology might be found in the official decrees defining the appellations (from 1936 to 2007) or in the AOC specifications. In the current system of AOC/AOP, specifications include a section on “lien à la zone géographique” that must justify how the wines produced in an area differ from others and how it is linked to the local conditions (natural environment or historical wine making processes). This section was formerly designed as a definition of “terroir”. The link to geographical origin could be understood under the concept of terroir, assuming that terroir combines all aspects of wine identity (Wilson, 1998; Van Leeuwen and Seguin, 2006; Hinnewinkel, 2008; Rouvellac, 2008). In the definition of appellation, some references to geology are found in different regions or different times, and may or may not be obvious just from the wine labels. Since 1941, the small appellation of Palette is defined as the lands of three communes (Aix-en-Provence, Meyreuil, Le Tholonet) that have the “Calcaires de Langesse” Formation as the geological substrate. However, no Palette wines have been identified

referring to geology in their labels. In 2011, the INAO recognised the geographic denominations within the developing Muscadet region. The village names are retained, but the specifications refer formally to soils and geological substrates. Muscadet “Goulaine” is associated with micaschist and gneiss, “Monnières – Saint-Fiacre” with highly weathered gneiss, “Gorges” and “Mouzillon – Tillières” with gabbro, “Le Pallet” with highly fractured rocks, and “Clisson” with granite. Several Muscadet producers label their vintages after rock substrates so that one can find wines with the name amphibolite, gabbro, gneiss, granite, orthogneiss, or schists. In a less formal way, the eight village appellations of Beaujolais are described in official decrees with reference to the geological substrates. Beaujolais wine labels use 30 different words related to local geology, either to igneous, metamorphic, volcanic, sedimentary rocks or even to the soil properties. Morgon is an appellation name derived from the village of Villié-Morgon and it is the local name of clay soil on weathered schists.

Indeed, striking evidence of a close relationship between geologic maps and delineation of appellation boundaries is found in Chablis. Since the early zoning attempts, the extension of the Kimmeridgian marls and the ‘Marnes à *Exogyra virgula*’ formation were considered suitable criteria to define Chablis as an appellation. After numerous revisions of the zoning and changes in the status of geological information in the process, the delineation of Chablis appellation is now settled (Vincent, 2011). The social and economic constraints take over the naturalist approach (Humbert, 2010). However, the marketing of Chablis wines utilises the Kimmeridgian marls as major factor in their identity. Numerous names, labels or advertisements of Chablis wines, illustrate the Kimmeridgian rocks or fossils that are common in the vineyards (oysters, ammonites, bivalves), and even vintages are named after the geological stages of the Kimmeridgian (but also Portlandian and Hauterivian) (De Wever *et al.*, 2009).

4.3. Geology as an element of wine marketing

Except for mandatory wine nomenclature imposed by the appellation system, any other term of the label related to geology illustrates producer’s choices, and in a sense an advertising intention. The geological terms used in wine names have become increasingly specific, and the number of references to geology more abundant (Maltman, 2018). There are examples in all wine producing regions. The terms used may illustrate toponyms, soil properties, substrate lithology, geological time scale intervals, geological processes, or fossil organisms. Technical words are always relevant to local geology and appear in vintage and estate names. Very few typos or mistakes were found. Mineral names are only occasionally mentioned for their colour or image of luxury, but not for geologic purpose.

The way wine producers consider geological information varies highly from one region to another. The regions with a very strong and long standing reputation like Bordeaux and Bourgogne account for a limited number of references to geology outside of appellation names and the traditional use of toponyms. Champagne does not often promote local geology in the differentiation of their products, either from old traditions or modern appropriation. Champagne vineyards are

associated chalk, Eocene sands, and the distinct cuestas of the upper Jurassic, but this is rarely mentioned on the label on the front of the bottle. Champagne is a territorial brand product associated to luxury that benefits from numerous marketing campaigns (Charters and Spielmann, 2014). Geology is part of the shared value but not often a distinctive factor. However, most producing regions (Alsace, Champagne, Loire Valley, Beaujolais) highlight geological features in building their identity, but it is not necessarily accessible from the bottle labelling.

Reference to geology is common in regions with less prestigious reputation than Bordeaux, Bourgogne or Champagne. Almost all references to specific geological data are at the initiative of the individual producer, whatever the estate size. The geological information is often taken from geological maps, or at least from local geological knowledge. The regions of Jura, Loire Valley and Languedoc-Roussillon incorporate geology on their wine labels more than any other. By digging into local geology, producers emphasize the identity of their wines and the link between the wines and the local environment. The product identity is reinforced, and adds commercial value (Barham, 2003). In other words, the geology is involved in linking the wine taste to their geographic origin, under the concept of Terroir (Wilson, 1998).

5. Conclusion

Although geologists have long demonstrated an interest for wine and hypothesized a putative relationship between wine and geological substrate of the vineyards (Huggett, 2006), it also appears that vine growers, and wine producers have incorporated geology into their practices. At least 5% of the French wines currently available on the market have a name related with directly or indirectly to geology. This is evidenced by the centuries-old toponyms and names of locally produced wine that have incorporated properties of the natural environment and soil. Many vineyards or appellations have been named after toponyms during the 20th century, thus incorporating geological information. The settlement of the appellation system early in the 20th century cemented the use of soils references in the wine world.

Appellations defined as geographical units; geology has been used in several cases as a criterion for zoning the appellation territories. Numerous references to geology can be found in the official specification documents of appellations, which is inherent in the natural concept of Terroir, the environmental conditions primarily linking the wine taste to its place of origin. Several estates or wine names, chosen by the producers during the past decades incorporate new references to geology. The geological information can be very specific and is almost always linked to the vineyard environment. Inspiration stems from the scientific knowledge of soil and geological substrate of the producing area. All wine producing regions consider geology in their business, but all regions do not make use of the same geological terms, mostly because of a distinct history communication strategies. Champagne marketing expresses only a limited interest in geology, whereas producers of Jura, Languedoc-Roussillon and Loire Valley often promote geology in the advertisement of their wines.

The large commercial databases of wines allowed us to investigate the relationship between wine production and geological information. The approach developed in this paper remains exploratory and inevitably incomplete. Data are biased by the inherent heterogeneity of the database, of the exploration process and the lexicon used for query. Further developments of the approach should consider geolocation of the data, and historical studies should help explain the historical role of geology in the design of the French wine business. References to geology in wine making is not restricted to France. Soil or rock-related wine names could be found in other European countries and in production countries of the New World. It would be interesting to compare the prevalence of geological information in countries with distinct wine production history.

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APPENDIX/ ANNEXE

Lexicon / Lexique

Term	Meaning	Field	Scientific term	Occurrences
Aalénien	Aalenian (a geological stage)	Stratigraphy	Yes	1
Achaux	Limestone	Soil	No	1
Aige	Wet soil	Soil	No	1
Albien	Albian (a geological stage)	Stratigraphy	Yes	1
Alios	Oxyde crust, deep in the soil	Soil	No	5
Altérite	Alterite (rock derived from weathering process)	Lithology	Yes	1
Alvéoline	Alveolina (a benthic foraminifera)	Paleontology	Yes	3
Amalthée	Amaltheus (a jurassic ammonite)	Paleontology	Yes	1
Ammonite	Ammonite (a group of fossil cephalopod)	Paleontology	Yes	31
Ampelomeryx	Ampelomeryx (a Miocene mammal)	Paleontology	Yes	2
Amphibolite	Amphibolite (metamorphic rock)	Lithology	Yes	3
Andésite	Andesite (volcanic rock)	Lithology	Yes	1
Anthracite	Anthracite (coal)	Lithology	Yes	1
Ardilières	Clay-rich soil	Soil	No	2
Ardoise	Slate	Lithology	Yes/no	21

Term	Meaning	Field	Scientific term	Occurrences
Ardoisière	Slate pit	Lithology	No	15
Arénite	Arena (argillaceous sand produced by granite weathering)	Lithology	Yes	1
Argile	Clay	Lithology	Yes/no	106
Argillère	Clay pit	Soil	No	81
Arkose	Arkose (sedimentary rock)	Lithology	Yes	1
Arroucat	Stony soil	Soil	No	6
Arzelle	Argillaceous soil	Soil	No	3
Aspres	Stony soil	Soil	No	44
Astéries	Sea stars	Paleontology	Yes	4
Aubuis (=aubus, aubues)	Soil of weathered chalk	Soil	No	10
Aubuisière	Place with soils of "aubuis"	Soil	No	15
Bajocien	Bajocian (a geological stage)	Stratigraphy	Yes	1
Basalte	Basalt (a volcanic rock)	Lithology	Yes	10
Bégudien	Begudian (a former late Cretaceous geological stage)	Stratigraphy	Yes	1
Bélemnites	Belemnite (a group of fossil cephalopod)	Paleontology	Yes	12
Bélouse (=bélouze)	Yellow soil on weathered limestone	Soil	No	17
Blanquières	Soil on marl substrate	Soil	No	2
Boubée	Sandy and argillaceous soil	Soil	No	1
Boulaise	Cold, clay-rich soil	Soil	No	1
Boulbène	Sandy and argillaceous soil	Soil	No	8
Bournais	Rich-clay soil	Soil	No	4
Caillerets (=cailleret)	Stone or stony soil	Soil	No	151
Cailleries	Stony soil	Soil	No	2
Cailles	Calcareous stones	Soil	No	34
Caillottes	Stone	Soil	No	6
Caillon (=caillonne)	Stone	Soil	No	7
Caillou	Small stone	Soil	No	247
Cailloutis (=cailloute)	Soil covered with gravel	Soil	No	11
Calcaire	Limestone	Lithology	Yes/no	100
Cambrien	Cambrian (a geological period)	Stratigraphy	Yes	1
Canterane	Low, swampy land	Soil	No	18
Caquin	Coarse sand, gravels	Soil	No	1
Caradocien	Caradocian (a geological stage)	Stratigraphy	Yes	1
Carbonifère	Carboniferous (a geological period)	Stratigraphy	Yes	2
Cascaille (=cascaillou, cascaï, cascaillon)	Stony soil	Soil	No	6
Caussan	Soils on limestone plateau	Soil	No	3
Caussarelle	Red clay produced by limestone weathering on plateau	Soil	No	3
Chailles	Stones or stony soil	Soil	No	12
Chaillots (=chailloux, = chaillottes)	Stone or rock slab	Soil	No	65
Charriage	Thrust (low angle fault with displacement of the overlying block)	Other	Yes	1
Chirat	Large stone, rocks	Soil	No	2
Clapas	Stony soil or stone piles	Soil	No	11
Conglomérat	Conglomerate	Lithology	Yes	1
Coquillage	Sea shell	Paleontology	No	1
Corail	Coral	Paleontology	Yes	2
Cosses	Schist stones	Soil	No	4
Craie	Chalk	Lithology	Yes/no	30
Crais	Limestone pebbles, stony soil	Soil	No	59
Craon	Dry, stony soil	Soil	No	1
Cras	Stone or stony soil	Soil	No	140
Crau	Pebbly alluvial soil	Soil	No	24
Crayères	Chalk pit	Soil	No	37
Crays	Chalky stones or soils	Soil	No	46
Creisses	Stones of stony soils	Soil	No	3

Term	Meaning	Field	Scientific term	Occurrences
Créot	Limestone pebbles	Soil	No	7
Cresses	Soil with limestone stones	Soil	No	4
Crétacé	Cretaceous (a geological period)	Stratigraphy	Yes	1
Crêts (=crêts)	Poor stony soil	Soil	No	25
Crinoïdes	Crinoid (sea lilies)	Paleontology	Yes	1
Criots	Limestone pebbles	Soil	No	46
Criottes	Soil rich in limestone stones	Soil	No	2
Crots	Pit	Soil	No	34
Crottes	Stones of stony soils	Soil	No	3
Cruet	Pit	Soil	No	36
Cussol	Pit, cave	Soil	No	1
Dacite	Dacite (a volcanic rock)	Lithology	Yes	1
Deinonychus	Deinonychus (theropod dinosaur)	Paleontology	Yes	2
Diaclase	Open fracture	Other	Yes	1
Diapir	Diapir (deformed rocks by upward movement of saline rocks)	Other	Yes	2
Dinosaure	Dinosaur	Paleontology	Yes	4
Diorite	Diorite (a magmatic rock)	Lithology	Yes	1
Dolomie	Dolomite (a sedimentary rock)	Lithology	Yes	23
Doussin	Deep marly soil	Soil	No	2
Doussinière	Place with soils of "doussin"	Soil	No	1
Eocène	Eocene (a geological epoch)	Stratigraphy	Yes	2
Épidote	Epidote (a mineral of metamorphic rocks)	Lithology	Yes	1
Évaporite	Evaporite (a sedimentary rock)	Lithology	Yes	1
Exogyra	Exogyra (fossil oyster)	Paleontology	Yes	2
Faloise	Sandy or gravelly soil	Soil	No	2
Falun	Shell rich sand	Lithology	Yes/no	3
Ficus	Ficus	Paleontology	Yes	1
Fossiles	Fossils	Paleontology	No	34
Gabbro	Gabbro (a magmatic rock)	Lithology	Yes	5
Galette	Poor, shallow soil	Soil	No	1
Galuches	Stony soil	Soil	No	11
Gapan	Red clay	Soil	No	2
Glaïse	Soft clay	Soil	No	1
Gneiss	Gneiss (a metamorphic rock)	Lithology	Yes	11
Granite (=granit)	Granite (a magmatic rock)	Lithology	Yes	57
Granulite	Granulite (a metamorphic rock)	Lithology	Yes	3
Gravelle	Gravel	Soil	No	28
Graves	Alluvial sandy deposits	Soil	No	3823
Gravière (=gravieras)	Sand pit, alluvial sandy deposits	Lithology	No	227
Graviers	Gravels	Soil	No	67
Grès	Stone	Soil	No	133
Grès	Sandstone	Lithology	Yes	94
Grèves	Gravelly or sandy alluvial deposits	Soil	No	167
Grison	Sandstone	Soil	No	6
Groies	Soil on weathered limestone	Soil	No	3
Grouas	Stony soil	Soil	No	5
Gryphée	Gryphaea (fossil oyster)	Paleontology	Yes	14
Gypse	Gypsum (a sedimentary rock)	Lithology	Yes	7
Hauterivien	Hauterivian (a geological stage)	Stratigraphy	Yes	1
Helix	Helix (snail genus)	Paleontology	Yes	3
Helvétien	Helvetian (a geological stage)	Stratigraphy	Yes	1
Herrebouc	Ferruginous soil	Soil	No	9
Jalet	Pebble	Soil	No	4
Jaspe	Jasper (jewelry name for a siliceous rock/mineral)	Lithology	Yes	1
Jaunis	Soil with a clay level	Soil	No	1

Term	Meaning	Field	Scientific term	Occurrences
Jurassique (=jurassic)	Jurassic (a geological period)	Stratigraphy	Yes	8
Kimmeridgien	Kimmeridgian (a geological stage)	Stratigraphy	Yes	6
Labassère	Slate pit	Soil	No	2
Lachat	High with poor stony soil	Soil	No	8
Lauses	Large schist or limestone slabs	Soil	No	7
Lauzes	Large schist or limestone slabs	Soil	No	29
Lavières	Stone or stony soil	Soil	No	193
Leimen (limengrub, leimenthal)	Silt	Soil	No	5
Limon	Silt	Lithology	Yes	2
Loess	Loess (eolian sedimentary deposits)	Lithology	Yes	1
Lumachelle	Shell bed	Lithology	Yes	4
Lydienne	Basanite (a siliceous sedimentary rock)	Lithology	Yes	1
Machefer	Oxyde crust deep in the soil	Soil	No	2
Manganite	Manganite (a mineral)	Lithology	Yes	1
Marbre	Marble (a metamorphic rock)	Lithology	Yes/no	5
Marganis	Clay, swamp soil	Soil	No	2
Marne	Marl	Lithology	Yes	75
Météore (=météorite)	Meteor	Other	Yes	18
Meulière	Millstone	Lithology	Yes/no	2
Micaschiste	Micaschist (a metamorphic rock)	Lithology	Yes	1
Micraster	Micraster (a fossil heart urchin)	Paleontology	Yes	2
Migmatite	Migmatite (a metamorphic rock)	Lithology	Yes	1
Miocène	Miocene (a geological epoch)	Stratigraphy	Yes	6
Moulières (=moullières, molières)	Soft, swamp soil	Soil	No	34
Muschelkalk	Muschelkalk (a former geological period)	Stratigraphy	Yes	1
Nanogyra	Nanogyra (a fossil oyster)	Paleontology	Yes	1
Natic	Natica (a fossil marine snail)	Paleontology	Yes	4
Nautilus	Nautilus	Paleontology	Yes	2
Nummulites	Nummulites (a benthic foraminifera)	Paleontology	Yes	1
Oligocène	Oligocene (a geological epoch)	Stratigraphy	Yes	3
Ordovicien	Ordovician (a geological period)	Stratigraphy	Yes	1
Orthis	Orthis (a fossil brachiopod)	Paleontology	Yes	1
Orthogneiss	Orthogneiss (a metamorphic rock)	Lithology	Yes	3
Ostrea	Ostrea (a fossil oyster)	Paleontology	Yes	5
Pallet	Pebbly soil on a river bank	Soil	No	8
Payra	Stone or quarry	Soil	No	27
Peire (peïre)	Stone	Soil	No	6
Peirecède	Stony soil	Soil	No	3
Pentacrinus	Pentacrinus (a fossil crinoid)	Paleontology	Yes	1
Pépérite	Peperite (a volcanic rock)	Lithology	Yes	1
Péridotite	Peridotite (a magmatic rock)	Lithology	Yes	1
Permien	Permian (e geological period)	Stratigraphy	Yes	1
Perray	Stone or stony soil	Soil	No	31
Perrières	Limestone quarry	Soil	No	642
Perrons	Large stones or stone piles	Soil	No	7
Perruches	Soils with flint pebbles	Soil	No	33
Pétayre	Exposed rock or rocky soil	Soil	No	1
Peygueroles (=peyguerol)	Stone or rock clusters	Soil	No	2
Peyra (=pera, peyral, peyrat)	Stone	Soil	No	15
Peyrabon	Place of stony soil	Soil	No	3
Peyrade	Stone or rock piles	Soil	No	1
Peyraguet (=peyragué)	Place of stony soil	Soil	No	4
Peyrassol	Place of stony soil	Soil	No	5
Peyregous	Pebbly field	Soil	No	1
Peyron	Stone	Soil	No	2

Term	Meaning	Field	Scientific term	Occurrences
Peyroux (=peyrouse)	Stony soil	Soil	No	11
Pierres	Stone	Soil	No	712
Pierreux	Stony soil	Soil	No	22
Pliocène	Pliocene (a geological epoch)	Stratigraphy	Yes	1
Portlandien	Portlandian (a geological stage)	Stratigraphy	Yes	3
Poudingue	Conglomerate (a sedimentary rock)	Lithology	Yes	2
Pouvray	Poor sandy soil	Soil	No	5
Quartz	Quartz (a siliceous mineral)	Lithology	Yes	22
Quartzite	Quartzite (a metamorphic or sedimentary rock)	Lithology	Yes	1
Rhyolite	Rhyolite (a volcanic rock)	Lithology	Yes	2
Roubine	Ravine with altered soil	Soil	No	25
Rougeon	Red slit and clay-rich soil	Soil	No	4
Rudistes	Rudist (a group of fossil bivalves)	Paleontology	Yes	1
Ruffe	Red permian claystone/siltstone (a sedimentary rock)	Soil	No	11
Sablas	Coarse sand	Soil	No	6
Sable	Sand	Lithology	Yes/no	131
Sablère	Sand pit	Soil	No	56
Sablon	Sandy soil	Soil	No	62
Safres	Calcareous sand	Soil	No	19
Saurin	Raw land	Soil	No	1
Scheifer (in Schaefferstein, Schiefferberg, Schieferkopf)	Schist (either metamorphic or laminated sedimentary rocks)	Soil	No	8
Schiste	Schist (either metamorphic or laminated sedimentary rocks)	Lithology	Yes/no	186
Sénonien	Senonian (a former geological stage)	Stratigraphy	Yes	1
Serpentine	Serpentinite (a metamorphic rock)	Lithology	Yes	7
Sidérolithique	Siderolithic (paleogene alterite rich in ferruginous minerals)	Lithology	Yes	3
Silex	Flintstone	Lithology	Yes	110
Silice	Silica	Lithology	Yes	7
Sodalite	Sodalite (a mineral of some metamorphic and volcanic rocks)	Lithology	Yes	1
Stein (in Steingrubler, Steinklotz, Steinert, steinweg, steinbach)	Stone	Soil	No	94
Terrefort	Hardly cultivated soil	Soil	No	56
Thanétien	Thanetian (a geological stage)	Stratigraphy	Yes	1
Tithonien	Tithonian (a geological stage)	Stratigraphy	Yes	1
Toarcien	Toarcian (a geological stage)	Stratigraphy	Yes	1
Travertin	Travertine (a sedimentary rock)	Lithology	Yes	1
Tremadocien	Tremadocian (a geological stage)	Stratigraphy	Yes	1
Trias	Triassic (a geological period)	Stratigraphy	Yes	11
Trigonia	Trigonia (a fossil bivalve)	Paleontology	Yes	1
Tuf (=tuffe, tuffeau)	Tuff/tufa (sandy chalk)	Lithology	Yes	36
Tuffière (tuffeloire, tufera, tuffolière)	Tufa pit	Lithology	No	14
Turitelle	Turitella (a fossil marine snail)	Paleontology	Yes	4
Turonien	Turonian (a geological stage)	Stratigraphy	Yes	1
Turrilites	Turrilites (an ammonoid genus)	Paleontology	Yes	1
Tyrannosaurus	Tyrannosaurus (a theropod dinosaur)	Paleontology	Yes	1
Urgonien	Urgonian (a former geological stage)	Stratigraphy	Yes	1
Varennes (=varannes)	Sandy alluvial soil	Soil	No	104
Villafranchien	Villafranchian (a former geological stage)	Stratigraphy	Yes	1
Volcan (adjective: volcanique)	Volcano	Other	No	42
Sum				9402