Emerging of the mineralogy discourse in Mexico (1795-1849): a taxonomy of objects, procedures, and instruments

Discurso emergente de la mineralogía en México (1795-1849): una taxonomía de objetos, procedimientos e instrumentos

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ABSTRACT

We carry out a documentary analysis of the texts on mineralogy produced in and about Mexico from 1750-1849. The objective was to extract the names of the objects, procedures, and instruments (OPI) used in the texts for teaching, research, or improving minerals' production. OPIs names are considered as rhetorical regularities in the discursive structure of the mineralogy texts. Their identification and characterization in the texts were carried out employing a manual XML tagging differentiated by colors. The objects' names, procedures, and instruments were identified and organized as taxonomical elements and differentiated according to their frequency. The texts were analyzed according to the objective, the social sector (teaching, research, production), and the argumentative style The analysis reveals the diversification of the rhetorical functions of OPIs in the content structure of the texts. It is an emergent argumentative style that presents the results through the relationship of facts between the IPOs. Thus, the reproducibility of the results function emerges as a qualitative novelty in scientific communication. Development of the taxonomies of OPIs led to representations of the early form of the discourse in Mexican mineralogy.

Keywords: Mineralogy, oryctognosy, Royal Mining Seminar, Andrés Manuel de Río, linguistic taxonomy, Scientific communication.

RESUMEN

Realizamos un análisis documental del conjunto de textos sobre mineralogía producidos en y sobre México en el período 1750-1849. El objetivo consistió en extraer los nombres de los objetos, los procedimientos y los instrumentos (OPIs) utilizados en los textos para propósitos de enseñanza, investigación, o mejorar la producción de los minerales. Los nombres de los OPIs se consideraron como regularidades retóricas en la estructura discursiva de los textos de mineralogía. La identificación y caracterización de los OPI en los textos se realizó a través de un etiquetado manual XML diferenciado por colores. Se identificaron los nombres de los objetos, procedimientos e instrumentos y se clasificaron como elementos de las taxonomías del lenguaje, así como el nivel de significación de los nombres en función de su frecuencia. Los textos se analizaron de acuerdo con el objetivo, el sector social al que están dirigidos (enseñanza, investigación, producción), y el estilo argumentativo usado en los textos. El análisis revela la diversificación de las funciones retóricas de los OPIs en la estructura de contenido de los textos. Es un estilo argumentativo emergente que presenta los resultados a través de la relación de hechos entre los OPIs. Así, la función de reproducibilidad de resultados surge como una novedad cualitativa en la comunicación científica. El desarrollo de las taxonomías condujo a una primera representación del lenguaje de la mineralogía en México.

Palabras clave: Mineralogía, orictognosia, Real Seminario de Minería, Andrés Manuel de Río, Taxonomía lingüística, comunicación científica.

1. Introduction

1.1. EARLY TEXTS ON AMERICAN MINERALOGY

There is a set of ancient documents can be analyzed to study the evolution of argumentative style in the mineralogy literature of Mexico. They were used in colonial times for the technical procedures associated with mineral amalgamation. Two of these procedures were of general use: "patio refining process" (Lang, 1999), which was invented by Bartolome de Medina (1497-1585), and "Barba's Copper Cauldrons" (Platt, 2000), described in the book "El Arte de los metales" written by A. A. Barba (1825) (Menes-Llaguno, 1989; 2014). The ore knowledge in Mexico arose from the methods and instruments used in the mining of precious metals. In particular, the amalgamation method dated from 1555 and became the primary procedure used in the industrial production of silver and gold during the XVI-XVIII centuries (Lang, 1999). However, it should be stressed that there was an alchemist conception of the chemical and physical processes involved in this procedure. It was considered an art rather than a set of scientific and technical methods (Barba, 1825; Salazar-Soler, 2001).

In the mid-eighteenth century, some documents on social aspects, public health, lawmaking, teaching, and the industrial sector of mineralogy were written. These texts include the proposals submitted by the mining community of New Spain to reform their mining industry: essays of Domingo Revorato Solar (Moreno, 1774), Alejandro Bustamante (1748), and Francisco Xavier Gamboa (1761), as well as a statement with the "Representation on behalf of the New Spain mining, addressed to our Lord the King" by don Juan Lucas de Lassaga and Joaquin Velazquez de Leon (1774). This set of documents are integrated into "Reales Ordenanzas para la dirección, régimen y Gobierno del importante cuerpo de la minería de Nueva España y de su Real Tribunal General" (1976).

In the global context, in the second half of the 18th century, two dominant schools emerged that explained the shape and composition of the globe. The pillars of the birth of modern geology were J. Hutton and A. G. Werner, representatives of the Plutonist and Neptunist schools, respectively. The period of most significant discussion (1780-1840) between representatives of some of these schools (AM Del Rio Fernández, A. Humboldt, and RJ Haüy) is known as "the heroic age of geology" (Rio, 1992; Cserna, 1990).

Geology developed early forms of independent science organizations in Europe (Guntau, 2009; Howarth, 2020). In Europe, the first professional institutions in the area emerged, the Geological Society in London and Societät für die Ganze Mineralogie zu Jena in Germany. Specialized journals such as *Mineralogical Distractions*, *Diary for Lovers of the Stone Kingdom*, and the *Mineralogy Magazine* (Lewis and Knell, 2009) were created, geological charts were developed, and the dynamics of the debates were maintained in the face of the diversity of current of thought of the members of the field (Azuela, 2009). In this context, mineralogy was the branch of natural history that characterized all the properties and relationships of minerals and geology findings. According to G. Werner, it is divided into several branches or doctrines: Oryctognosy, geognosy, the chemistry of mineralogy, the geography of mineralogy, and economic mineralogy (Brewster, 1892). Oryctognosy organizes and describes pure minerals according to their external characters; Geognosy familiarizes us with the structure, relative position, materials, and mode of mountain rock formation. (Howarth, 2020).

The Neptunist theories of the A. G. Werner school enriched mineralogy in the United States of America in the late 18th century. Several specialists trained at the Freiberg Academy of Mines, Germany, participated in different activities in Mexico: the creation of the Royal Mining Seminary (RSM); development of teaching programs with physics, chemistry, and mathematics contents;

formation of a bibliographic fund; a collection of mineral objects, and a set of research instruments. These resources allowed the training of local specialists in mineralogy. Some documents were published as treatises and handbooks designed to contribute to the new education programs in mineralogy. A. M. del Río (1795), the coordinator of the teaching programs in RSM, published the first handbook on mineralogy in America at the end of the XVIII century, according to A. G. Werner's theories (Rio, 1795). J. Garcés Eguía published a new theory and practice of precious metal production, and F. Sonneschmidt wrote a Spain amalgamation treaty in the first years of the XIX century. The two last textbooks contained technical and scientific details on the chemical reactions involved in the amalgamation process (Garcés-Eguía, 1802; Sonneschmidt, 1825).

Geology studies evolved with the contribution of the nomenclatures and the analysis from chemistry to the study of minerals. Disuse of classification based on external characters was initiated in favor of crystallographic descriptions (Escamilla-González and Morelos-Rodríguez, 2008). Some branches of mineralogy, such as geognosy and orychtognosy, lost interest and began to be discontinued around 1820 (Howarth, 2020). A. M. del Río published the new version of the Orictognosia Manual that includes the principles of J. J. Berzelius. D. Brewster contributed to optical mineralogy techniques that study the optical properties of minerals (Escamilla-González and Morelos-Rodríguez, 2017). The transition from a colonial regime to that of an independent nation brought about significant changes. In 1826 the Real Tribunal de Minería was extinguished and was replaced by a Provisional Board, called the Mining Establishment. The forms of social organization, the institutional objectives, the teaching programs, and the specialists' profiles related to the professional practices of mineralogy changed. The decree was issued to designate the careers that would be taught at the College of Mining: Surveyor, Tester, Gold and Silver Planner, Metal Beneficiary, Mining Engineers, Geographer, and Naturalist, as part of the new study plan (Escamilla-González and Morelos-Rodríguez, 2017).

We have analyzed in the present work the documents generated in the RSM in the period 1795-1849. They consist of letters, essays, discourses, and reports on experimental research published in local or international journals. We classified them according to the characteristics of each publication: dates, place, the primary purpose, and the social sector involved. We performed an XML labeling of each document to identify the respective OPIs involved (eXtensible Markup Language) (ANSI/NISO Z39.98-2012). A normalization process was also performed of names, frequency of use, the different objectives of each document, and the respective historical taxonomies for all OPIs. This representation method could be considered as the first ontological model for the historical information on Mexican mineralogy.

There is an increasing interest in organizational systems and knowledge representation (Tauhid-Zuhori, Zaman and Mahmud, 2017; Medelyan, Witten, Divoli and Broekstra, 2013; Pieterse and Kourie, 2014). The future of these systems' study involves new research approaches, computation solutions, and new methodologies (Farrali, Stilo and Velardi, 2017; Ristoski et al., 2017; Yiming et al., 2018). There is no published work that considers the characteristics of research on historical information as far as we know. In this respect, we consider in the present study a new model associated with the system of historical representation of knowledge related to network processes of mineralogy in America.

In the present paper, we use the databases developed in the project Historical Atlas of Mexican Science (Collazo-Reyes, 2017) as our primary source of information. This Atlas is a digital set of files under construction with the general aim of reconsidering the history of science in a transdisciplinary framework and different theoretical approaches: theories of the "actor-network" (Latour, 2005; Carroll, Richardson and Whelan, 2012), the spatial turn (Finnegan, 2008; Gunn, 2001; Frenken, Hardeman and Hoekman, 2009;

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Table 1. Mineralogy text classification matrix, 1795-1849.

Publication period	Social activity	Objective	Argumentative style	Classification
XVI-XVIII centuries	Economic-industrial	Minerals exploitation	Narrative	1
Century XVIII	lawmaking	Minerals production	Standards regulations	2
	Teaching	Teaching	Academic	
		Classification	Classification	
		Observation	Descriptive	
The first half of the 19th century	Teaching Research	Description	Descriptive	3
		Experimentation	Experimental	

1 = Mineral exploitation; 2 = Teaching; 3 = Research.

McCook, 2013), the spatial scientometrics (Frenken, Hardeman and Hoekman, 2009; Maisonobe, Giglia-Mari and Eckert, 2013), and the idea that texts may be taken as publication events that reproduce spatial relations (Piazzini-Suárez, 2015). Under these approaches, we have documented, as a particular case of the universal confirmation of local knowledge, the discovery of the chemical element number 23 (Vanadio/Erythronium) at the beginning of the XIX century in the RSM (Collazo-Reyes et al., 2017). We have also studied the emergence of the scientific text under a multidisciplinary scheme, which was identified as a geohistoriometric approach (Flores-Vargas et al., 2018).

In the present paper, we continue with this line of research, and we have identified historical taxonomies as a method of knowledge representation in mineralogy. We consider this approach as the first step in order to develop a historical ontology of information. We have found that the OPIs are essential components in the structure of argumentative contents of mineralogy texts (1750-1849). They have different integration levels according to the diversification of instruments and tools used in mineralogy research and the social sector where this knowledge was produced.

2. Methods

2.1. DATA SOURCES

We performed a search query on the databases of the Historical Atlas of Mexican Science (HAMC, http://bibliometria.bfm.cinvestav.mx), and we identified 49 full-text documents that became our unity of analysis. These documents are related to different ways of knowledge production in Mexican mineralogy from 1795 to 1849.

Model for developing a system of representation of scientific knowledge based on taxonomies

We developed a critical analysis of the set of the above documents with a model based on two matrices (Table 1)—classification of texts. According to the period of publication, social activity, the objective, and the argumentative style, as categories of analysis, the texts were classified into three categories. (i) Mineral exploitation. They are sources of practical knowledge and techniques oriented to the production of minerals, dominated by the industrial-economic sector of the XVI-XVIII centuries. (ii) Teaching and classification. Texts oriented to systematize knowledge through manuals, classifications, speeches, observations, and descriptions are used in the RSM teaching

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Table 2. Classification of objects, procedures, and instruments in mineralogy, 1795-1849.

Mineral objects (O)			Procedures (P)			Instruments (I)	
Exploitation objects	Classification objects	Experimental objects	Physical	Chemical	Geological	Material	Textual
Mentioned in texts of practical knowledge related to production and exploitation processes.	They were studied for purposes of classifying them in mineralogy manuals.	Used as objects of study in experimental research works.	Processes where the structure of the materials is not modified.	Reaction process where the structure of the materials and their properties is modified.	Natural processes of the earth geology.	Names of physical instrument s and materials.	Types of bibliographic tools like a handbook, nomenclatures, taxonomies, textbooks, treatises.

O = Mineral objects, P = Procedures, and I = Instruments.

programs at the beginning of the 19th century. (iii) Research. Letters to the editor to inform of some findings in mineralogy. Generally, the three types of OPIs are rhetorical components related to empirical or experimental research in the RSM laboratory during 1795-1849.

Table 2. This matrix characterizes the OPIs in eight different subclasses. (i) The mineral objects mentioned in texts on the production/exploitation processes, for commercial purposes; ii) the objects classified in areas of knowledge and used for teaching purposes; and iii) used as objects of study in experimental research works. The procedures correspond to three types: physical, chemical, and geological, and the research instruments were divided into materials and bibliographical.

We considered the OPIs as marcs of rhetoric regularities, which structure Mexican mineralogy's historical discourse. The number of labels generated is associated with the taxonomic components that structure the historical representation system of mineralogy knowledge.

2.2. XML MANUAL LABELING OF THE DOCUMENTS

For easier reading and labeling, we transcribed 43 of the 49 documents using a text editor. The respective OPIs were identified as analytical categories using an XML manual labeling (ANSI/NISO Z39.98-2012). One label was associated with each category with the name of each OPI and a color code to identify it within the respective document. We classified each text according to the social activity involved, the objective, and the argumentative style in three types of documents (mineral exploitation, teaching, and research), as it is shown in Figure 1.

Example 1. Silver in a written text to improve the production of minerals

<study-object1 >Silver</study-object1>

Example 2. Evaporation process in a written text with an experimental objective.

<procedure3>Evaporation</procedure3 >

2.3. DEVELOPMENT OF TAXONOMIES

The information obtained in this way was organized in a local database. It includes the code associated with each document, the respective OPI, the social sector involved, the objective, the argumentative style, and a classification. We identified 499 names of minerals. This set includes variations of the same mineral name depending on the document's geographical area and language. We performed a normalization process of the names according to the nomenclature of the mineralogy field described in the following sources: Orictognosia Handbook (Rio, 1795) 1

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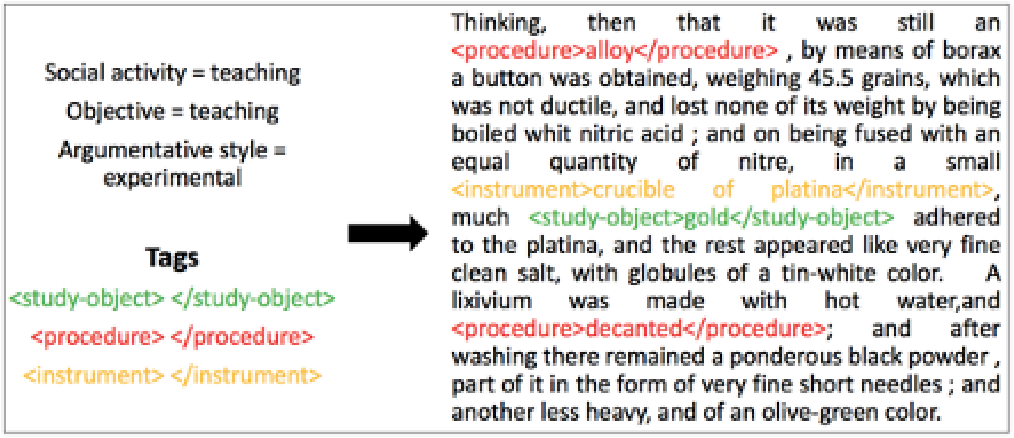

Figure 1 Example of an experimental type text with XML tags, produced with objectives of teaching. Source: Valencia-Martínez, 2018.

and Treaty 2 (Rio, 1832); Karsten Mineralogy Tables (Karsten, 1804); and English, German and French Dictionaries (Diccionario Visual, 2011).

After the normalization process, we were left with 143 different minerals organized in a hierarchical ranking of taxonomies with four levels: main class, family, genus, and species. Procedures were organized in a three-class taxonomy: physical, chemical, and geological, and instruments in two classes: material (physical) and textual (bibliographic). These are structures of the necessary information on the cognitive tree of the Mexican mineralogy. We will illustrate this process in the following section.

3. Results

3.1. OBJECTS OF STUDY

Among the 143 mineral objects left after the normalization process, only 74 (52%) were found in handbooks of mineralogy. The other 67 consist of mineral species with variations not found in the mineralogy handbooks, such as Brune de Plomb, Brown lead, Eritronio, Vanadio, Pancromo, Braun bleierz.

The 74 species were included in a taxonomic ranking of four levels: 4 main classes, 30 families, 39 genus, and one species. Metals integrated the main class with 21 different types of families. Among them, we found gold, silver, platinum, copper, iron, and tin. All of them were included in documents related mainly to teaching and, to a lesser extent, with aspects of production-exploiting. Mercury and lead were also included in production-exploiting and teaching and research with their genus vermilion and brown lead. The experimental research with brown lead, found in Zimapan (Hidalgo) mines, led to Pancromo/Eritronio discovery, as a confirmation of the local knowledge later published in international journals (Collazo-Reyes et al., 2017).

The first documents related to the exploitation of minerals include 12 different types, mainly precious stones and metals. In the centuries XVI, XVII, and XVIII, the mineralogy activities were associated with exploring these metals. However, 96% of the classes, families, and genus are mentioned in teaching documents. The 39 minerals classified as genus correspond to the most abundant: augite, emerald, quartz (silica), sapphire, and topaz (alumina). On the other hand, in documents related to experimental research, only the following five minerals were used: Pearlstone, Bruno-esparto, Cinnabar, Brown led, and Wolfram (Table 3). Among the 64 minerals not located in mineralogy handbooks, there are nine species: Anhydrite,

Table 3. Taxonomy of the objects mentioned in the mineralogy texts, 1795-1849.

Taxonomy					Word frequency	Classification
No.	Class	Family	Genus	Species		
1	Lands and stones	Siliza	Augite		1	O2
2			Emerald		1	O2
3			Hornblende		3	O2
4			Quartz	Amethyst	13	O2
5			Opal		2	O2
6			Chalcedony		4	O2
7			Flint		2	O2
8			Jasper		7	O2
9			Heliotropium		1	O2
10			Cornea-stone		1	O2
11			Pearl-Stone		1	O2,O3
12			Obsidian		3	O2
13			Feldspar		9	O2
14		Alumina	Saphire		1	O1,O2
15			Topaz		2	O1
16			Clay		1	O2
17			Basalt		3	O2
18			Slate		3	O2
19		Magnesium	Chrysolite		8	O2
20			Asbestos		2	O2
21		Lime	Limestone		8	O2
22			Brown spar		4	O2,O3
23			Apatite		1	O2
24			Fluor		3	O2
25	Salt	Carbonates			3	O2
26		Muriatos	Rock Salt		1	O2
27			Sea Salt		1	O2
28			Salt Ammonia		1	O1
29		Sulfate	Capacious		1	O1
30	Fuel	Sulfur			10	O2
31		Bitumens	Coal		9	O2
32			Diamond		1	O1
33	Metals	Platinum			5	O2
34		Gold			11	O1,O2
35		Quicksilver	Cinnabar		26	O1,O2,O3

O = Objects.

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Table 3. (continuation) Taxonomy of the objects mentioned in the mineralogy texts, 1795-1849.

Taxonomy					Word frequency	Classification
No.	Class	Family	Genus	Species		
36		Silver	Recycler		25	O1
37		Copper			17	O1,O2
38		Iron	Sulfite pyrite		23	O1,O2
39			Chlorite		1	O2
40		Lead	Brown lead		17	O1,O2,O3
41		Tin			3	O1,O2
42		Bismuth			2	O2
43		Zinc	Blende		14	O2
44			Calamine		2	O2
45		Antimony			3	O2
46		Cobalt			1	O2
47		Nickel			4	O2
48		Manganese			1	O2
49		Molybdenum			3	O2
50		Arsenic			11	O2
51		Sheelio	Tungsten		2	O2,O3
52		Uranium			7	O2
53		Titanium			3	O2
54		Tellurium			2	O2
55		Chrome			9	O2

O = Objects.

Chalcedony, "Chovellia," Dolomite, Emery, Feldspar, Opal, Flint, and Picnite. They were related to local exploitation, but there are other two missings: Mercury iodide and Silver iodide (Flores-Vargas et al., 2018). Under these circumstances, we decided that the respective taxonomies should include a list of essential words, which will allow us to relate the variations of mineral names to research documents. The following terms are related to the ontology of the discovery of Vanadio/Eritronio: Brown led ore, Brune de Plomb, Erithronium, Panchromium, Braun bleierz, Rionium, Zimapamium, and Vanadium.

3.2. PROCEDURES

The use of chemical and physical procedures does not correspond to modern science's emergence in the paper. According to analyzed texts in the present paper, these procedures were used since the middle of the XVI century. The activities related to the exploitation and production of minerals were considered artisan work rather than procedures involving experimental methods. The traditional "patio refining process" method was based on the amalgamation process (a chemical reaction that binds gold and silver with Mercury).

Table 4. Taxonomy of methods and procedures mentioned in the mineralogy texts, 1795-1849.

Taxonomy			Word Frequency	Classification
No.	Class	Family		
1	Chemical procedures	Combustion / Burning	2	P2
2		Crystallization	16	P2,P3
3		Desmercurize	1	P1,P2
4		Distillation	6	P2,P3
5		Becquerel method	1	P2
6		Leaching	2	P2
7	Physical procedures	Alloy	1	P2,P3
8		Amalgamation	2	P2
9		Azogue refining process	2	P2
10		Cohesion	5	P2
11		Condensation	1	P2
12		Decanting	1	P2
13		Boiling	2	P2,P3
14		Evaporation	17	P1,P2,P3
15		Filtration	2	P2,P3
16		Melting	5	P1,P2
17		Fusion	3	P2,P3
18		Precipitation	6	P2,P3
19	Geological procedures	Stratification	5	P2
20		Mineralization	1	P2
21		Petrification	1	P2

P = Procedures.

This process involves various physical and chemical procedures: grinding of minerals, the benefice of quicksilver, desazogue, evaporation, and melting. These procedures correspond to a long period with technical knowledge focused on economy-productive activity. At the end of the XIX century, a training scheme changed, and technical information (chemical, physical, geological) was included in the textbooks, as shown in Table 4. This level of teaching led to the use of scientific practices such as chemical and physical methods of crystallization, evaporation, filtering, fusion, and precipitation. However, the amalgamation method may be considered the starting point in developing new methodologies of the scientific text in mineralogy.

3.3.RESEARCH INSTRUMENTS AND TOOLS

Taxonomy 3 includes research instruments with two classes: materials and texts. The amalgamation method involved 12 instruments (rings, boiler, caxon, oven, pile, iron plate, among others) in achieving a clean production of metals. The training programs included 34 more instruments, which indicated an enhancement of the production and research activities. The following objects were used for this purpose: platinum spoon, mortar, blowpipe, and the porcelain bowl. It was possible to work with chemical and physical processes under control to crystallize them with these instruments. In this physical state, the metals are subdued to blowpipe fire, revealing their characteristic colors.

We registered the text tools: handbooks, taxonomies, and theories used to write textbooks, essays, discourses, descriptions, and classifications. They were also used as information sources in descriptive research work.

The appearance frequency of OPIs (Tables 3, 4, and 5) indicated the terms' weight to reveal changes in communication patterns and argumentative style of discourse in texts. More than half of the 143 identified minerals were used only once and are considered peripheral in field discourse. The most frequently mentioned minerals belong to the class of metals (Table 3). Silver, Iron, Copper, Lead, Azogue, Zinc, Gold, and Arsenic are among these. These terms are part of the texts written in the late eighteenth and early nineteenth centuries. They are written as essays, and there are no relationships between objects, procedures, and research instruments. These works written in the first person are part of a communication pattern based on discourses, observations, and descriptions, prepared mainly for teaching purposes in the RSM. They are published in printed sources in printers and journals in New Spain/Mexico (*Gazeta de México*, 1797-1802; *Imprenta M J de Zuñiga y Ontiveros*, 1804; *Diario de México*, 1811); and Spain (*Annals of Natural History*, 1800; *Annals of Natural Sciences*, 1802-1804; *Mercury of Spain*, 1819). Under these communication patterns, study objects appear to be scarcely related to procedures and instruments of mineralogy.

The circumstances that made possible the chemical analysis of minerals in the RSM at the beginning of the XIX century gave rise to other argumentative forms. A rhetorical style emerged that obeys fact-based relationships between objects, procedures, and research instruments used to obtain results. Both the procedures (Evaporation, Crystallization, Distillation, Precipitation, Cohesion, Melting, Stratification, and Fusion) (Table 4), and the research instruments (Blowtorch, Melting pot, Mortar, Furnace, Retort, Pipe) (Table 5), are related to the same research on brown lead minerals from the Zimapan mines.

This argumentative style, based on the fact-based relationships between the OPIs, allowed us to notice the formation of patterns typical of modern scientific communication in mineralogy. The texts are written as very brief experimental research reports, published mainly as letters, excerpts from letters, notes, and articles to a lesser extent. They are spread throughout international geography in different languages and magazines published in Germany (*Annalen der Physik*, 1822; *Annalen der Physik und Chemie*, 1831); France (*Annales de Chimie*, 1805; *Annales de Mines*, 1819); Great Britain (*Philosophical Magazine and Annals of Philosophy*, 1831; *Edinburgh Journal of Science*, 1831; *Journal of The Royal Institution of Great Britain*, 1832); and United States (*American Monthly Journal of Geology and Natural Science*, 1831; *American Journal of Science and Arts*, 1831).

4. Discussion

Our findings show that OPIs in the journal texts on mineralogy signals the emergence of modern science written for teaching and research purposes in Mexico. During the XVI-XVIII centuries, different instruments were referred to, such as pulleys, hammers, levers, buckets, trays, wheelbarrows, rollers, bellows, wheels, crucibles, and copper buckets, hoppers, and ovens, used in different tasks. (i) Construction of hydraulic works, channels, walls, tunnels, vaults; (ii) mechanical processes of stone mills with water; containers for stirring chemical amalgams; heating of mineral amalgamated sludge; sedimentation procedures; (iii) Bartolomé de Medina's cold amalgamation and Barba's hot amalgamation methods, considered as "patio refining process" technologies.

These instruments and procedures, mainly of

Table 5. Taxonomy of research instruments mentioned in the mineralogy texts, 1795-1849.

Taxonomy			Word frequency	Classification
Number	Class	Family		
1	Research instruments	Iron ring	1	I1
2		Boiler	1	I1
3		Tray	1	I1
4		Copela oven	1	I2
5		Melting pot	8	I3
6		Funnel	1	I2
7		Forceps	1	I2
8		Bellows	1	I2
9		Melting furnace	1	I2
10		Muffle furnace	1	I2
11		Furnace	4	I1
12		Reverberatory furnace	1	I2
13		Iron and steel instruments	1	I1
14		Vessel	1	I2
15		Hammer	1	I2
16		Mortar	5	I2,I3
17		Muffle	1	I2
18		Crockpot	1	I1
19		Pool	1	I1
20		Iron plate	1	I1
21		Rake	1	I2
22		Retort	3	I2,I3
23		Iron frying pan	1	I3
24		Round bar	1	I1
25		Blowtorch	11	I2,I3
26		Porcelain bowl	1	I3
27		Pipe	3	I2
28		Copper bar	1	I1
29		Vessel	1	I2
30	Bibliographic resources	Handbook of orictognosia according to the principles of A. G. Werner	3	I2
31		Handbook of orictognosia according to the principles of Berzelius	1	I2
32		Mineralogic tables of Karten	2	I2
33		Technical Nomenclatures	2	I2
34		Royal Bourbon Ordinances in Mineralogy	1	I2

I = Instruments.

European origin, were strengthened with practical and technical knowledge that emerged from local mining centers: Guanajuato, Hidalgo, San Luis Potosí, and Zacatecas, and regional as Potosí, Oruro (today Bolivia), and Pasco, Peru, among others, These local, regional and international knowledge matrices led to a long period of technological innovations and chemical manipulation that improved the production of gold and silver, pillars of the New Spain economy. In this long period of several centuries: theoretical changes around Mineralogy/Orictognosy have to do with the amalgamation method. The mining sector was in control of production, training, exploitation processes, and knowledge. However, this production system became expensive, with low efficiency and an increasing number of social problems.

The proposals made by the New Spain mining community integrated into the *Reales Ordenazas* served as the direction of the *Real Tribunal de Minería* to establish a new regime and government for the mining industry through the following actions. Construction of an RSM for the training of specialists in the areas of mineralogy; hiring teachers; development of teaching programs with content in physics, chemistry, and mathematics; formation of collections of research instruments, mineral objects, book collections, reports on mining districts, mines, mineral veins, collected from places visited by specialists, such as F. T. Sonneschmidt on his trips of the mining districts of New Spain. In this scenario, mineralogy texts emerged in journals published as discourses, observations, and descriptions, with references to places and local objects.

In the early 19th century, chemical analyzes of mineral objects were conducted for teaching and research purposes in Mexico. This approach to mineral knowledge allowed to obtain experimental results and locally confirmed scientific knowledge. Such is the case of the Zimapan brown lead's chemical analysis that discovered a new chemical called Erythronium in 1801 by A. M. del Río. This fact is significant because it diversifies argumentative styles and is a starting point for studies on forming the scientific text in Mexico. We identified the publication of letters, short notes, and experimental reports in local and international journals. These documents are short texts where the OPIs are used as argumentative elements that connect different facts associated with the research process. This relation allows the experimental reproducibility of the facts as a distinctive aspect of modern science. In this way, various research projects were performed in the first half of the XIX century and published in different specialized journals in the mineralogy area.

From crossing the information contained in the different tables, we identified epistemic changes related to emerging forms of approach to the knowledge of minerals, aspects reflected in the frequency of appearance, and the establishment of fact-based relationships between objects, procedures, and research instruments. These aspects gave rise to the formation of structures of modern scientific communication in Mexico.

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5. Conclusions

In this scientific communication analysis of the first decades of the 19th century, most of the OPIs were mentioned for teaching reasons. Very few were used for research purposes, and there is an absence of content related to mineral extraction and production activities. It suggests that the discourse in the texts published in journals mainly privileges OPIs related to teaching and research activities. However, some authors (Escamilla-González, 2008; Cañizares-Esguerra, 2017) point out that the lack of improvements in local methods is due to a disconnection between the logic and objectives of science with those of colonial exploration and extraction of minerals. Names OPIs, in texts published in journals, constitute rhetorical marks that account for the diversification of argumentative styles in the historical mineralogy discourse. The contents mineralogy texts for research purposes contain names of instruments and procedures related to explanations of mineral objects' chemical analysis, unlike the amalgamation/patio refining process, which did not include chemical explanations since they were oriented to the industrial production of precious minerals.

OPIs include information as a mineral family component (genus and species), a reference to the social sector, time, space, and objective of the text where those terms are mentioned. The taxonomies resultants represented the mineralogy discourse in 1750-1849, and it is the first form of a knowledge representation system.

The contribution of this paper should be valued mainly as an approach to the field of mineralogy/orictognosy, 1795-1849, from a historical perspective of scientific communication.

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Conflicts of interest

The authors declare that there is no conflict of interest with other authors, institutions or other third parties in relation to the content of this article.

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