THE GEOLOGICAL PERSPECTIVE OF ITALY AND CHILE BY ABBOT JUAN IGNACIO MOLINA BETWEEN THE 18TH AND 19TH CENTURIES

Marco MENICHETTI[1]

[1] Dipartimento di Scienze della Terra della Vita e dell'Ambiente, Università di Urbino, Italia. E-mail: marco.menichetti@uniurb.it

ABSTRACT

The first geological observations in Chile can be traced to Juan Ignacio Molina, a Jesuit priest who was born in 1740 in Chile and died in 1829 in Bologna, Italy. He received a scholarship education with a strong leaning towards philosophy, the humanities and the sciences at the Jesuit College in Concepcion. In 1767, when all the Jesuits were expelled from Chile and the Spanish colonies, he took refuge in Italy, first in Imola and then in Bologna where he taught Greek at the University and later natural sciences at the Archiginnasio. During his stay in Bologna at the end of the 18th century, the Jesuit community continued to play an important role in the teaching of the sciences in spite of the Napoleonic occupation. In Bologna, as early as the 16th century, Ulisse Aldrovandi was developing new concepts in geology with his study and systematic collection of fossils. At the beginning of the 18th century, the naturalist and oceanographer L.F. Marsili and one of the fathers of paleontology, G. Monti, built of Aldrovandi's work and contributed to the growth of the Science Institute and the Natural History Museum in the city. It was in this cultural context that in 1782 Molina published in Italian language the *Saggio sulla storia naturale del Chile*. The book was divided into four chapters, the first two of which dealt with the earth sciences. In this work Molina repeatedly compares the north-south stretched landscapes, the volcanic activity and the geology of Italy and Chile. His next work, *Memorie di storia naturale*, was published in 1821 and was based on several lectures given by him at the Bologna Academy of Sciences. It contained fourteen *Memoria* -lectures- referred to different aspects of the natural sciences and six covered geological topics. In 1815, one of Molina's lectures -later *Memoria* XIV-, was published under the title *Less noticed analogies in three kingdom of nature*. In this lecture Molina discussed the similarities between minerals, vegetables and animals within the framework of the then accepted philosophy of the Great Chain of Being. Because of his ideas and statements, apparently endowing animals and plants with human characteristics, Molina was denounced for and then cleared of heterodoxy. Abbot Molina made an important contribution to the study of Chile's Natural History, and to the South American natural sciences in general. Although Molina lived most of his life outside of Chile, he nurtured a deep love and pride for his country. The picture that emerges from his writings contributed to a large degree in acquainting the world with his native land and its native peoples.

Keywords: *Science history, geology, Europe, South America.*

RESUMEN

La perspectiva geológica del Abate Juan Ignacio Molina sobre Italia y Chile entre los siglos XVIII y XIX.

Las primeras observaciones geológicas en Chile pueden ser trazadas a través de Juan Ignacio Molina, un sacerdote jesuita quien había nacido en Chile en 1740 y murió en Bolonia en 1829. Él recibió una formación académica con un fuerte aprendizaje hacia la filosofía, las humanidades y las ciencias en el Colegio Jesuítico de Concepción. En 1767, cuando todos los jesuitas fueron expulsados de Chile y de las colonias españolas, se refugió en Italia, primero en Imola y posteriormente en Bolonia, donde enseñó griego en la Universidad y posteriormente ciencias naturales en el Archigimnasio. Durante su estadía en Bolonia al final del siglo XVIII, la comunidad jesuítica continuó teniendo un rol en la enseñanza de las ciencias a pesar de la ocupación napoleónica. En Bolonia, tan temprano como en el siglo XVI, Ulisse Adrovani desarrolló nuevos conceptos en geología con su estudio y colección sistemática de fósiles. A comienzos del siglo XVIII, el naturalista y oceanógrafo L. F. Marsili, y uno de los padres de la paleontología, G. Monti, avanzaron sobre el trabajo de Aldrovandi y contribuyeron al crecimiento del Instituto de Ciencias y Museo de Historia Natural en la ciudad. Fue en este contexto natural que Molina publicó en 1782, en italiano, *Saggio sulla storia naturale del Chile*. El libro fue dividido en cuatro capítulos, los primeros dos dedicados a las ciencias de la Tierra. En este trabajo Molina compara repetidamente los paisajes del norte y el sur, la actividad volcánica y la geología de Italia y Chile. Su próxima obra, *Memorie di storia naturale*, fue publicada en 1821 y estuvo basada en sus clases dadas en la Academia de Ciencias de Bolonia. Contenía 14 *Memoria* -clases- referidas a diferentes aspectos de las ciencias naturales, incluyendo seis tópicos geológicos. En 1815, en una de las clases de Molina -posteriormente *Memoria* XIV-, fue publicado bajo el título *Analogías menos observadas de los tres reinos de la naturaleza*. En esta clase Molina discutía las similitudes entre minerales, vegetales y anima-

les dentro del marco de la entonces aceptada filosofía de la Gran Cadena del Ser. Debido a que sus ideas y enunciados, que aparentemente dotaban a plantas y animales características humanas, Molina fue denunciado y posteriormente apartado por heterodoxia. El Abate Molina hizo una importante contribución para el estudio de la Historia Natural de Chile, y en general para las ciencias naturales de América del Sur. Aunque Medina vivió la mayor parte de su vida fuera de Chile, alimentó un profundo amor y orgullo por su país. Este cuadro que emerge de sus escritos contribuyó en un alto grado a que el mundo conociera su tierra nativa y su gente.

Palabras clave: *Historia de la ciencia, geología, Europa, América del Sur.*

INTRODUCTION

The first geological observations in Chile can be traced back to Abbot Juan Ignacio Molina, a Chilean Jesuit Priest (Fig. 1) who from the age of twenty-nine lived in Bologna, Italy. He has published two books, the first in 1776 and the second 1782, about the Civil and Natural history of Chile (Molina 1776, 1782) that included geologic descriptions of the country. These books were the first scientific descriptions of Chile and proved very useful references for 19th century researchers, such as Von Humboldt and Darwin, visiting South America. During his stay in Italy, he studied several of its localities; however, most of his time was spent in the Bologna countryside. He was a member of the Bologna Academy of Science, where in the early 19th century he gave several lectures on the different aspects of the natural features of the region.

This paper gives a general overview of Molina's life and philosophy through analysis of his books. His writings give a detailed explanation of the scientific method used by him to describe nature. Particular focus will be placed on his geological observations of Italy which are frequently juxtaposed with those of Chile. In order to place Molina's thinking within a historical scientific framework, a brief description of the state of the art scientific research in Italy and Europe between the 18th and 19th centuries is also reported.

THE LIFE OF MOLINA

Juan Ignacio Molina was born on June 24, 1740 at the hacienda of Huaraculén, located on the southern bank of the Maule River close to the present day city of Villa Allegre that was administratively dependent on Talca (Jiménez 1974). One of eight sons of Don Augustín Molina and Francisca González Bruma, he became fatherless in late 1748 or early 1749, at the age of seven. After the death of his father, he was enrolled by his mother in the Jesuit College of Talca, to begin his early training. In his earlier years, Juan received an enthusiastic early introduction to natural sciences (Molina 1782) from his father, who contributed many specimens to the Spanish royal natural history museum (Santágata 1845), awakening his curiosity.

After completing his elementary education, Molina was introduced for the first time to the Latin language and the classics, with the philosopher Cicero and the poet Ovid becoming his favourite authors. Following five years in Talca he enrolled in the Jesuit College in Concepción to complete his classical education. It was during this time that Molina experienced first-hand the May 24, 1751 Concepción earthquake and subsequent tsunamis that he described in a poem composed in Latin in 1754 at the age of fourteen. One year later he was admitted to the Jesuit Novitiate of St. Francisco Borgia in Santiago, taking vows in November 1757 (Jiménez 1974). The following years he was dedicated to an intense study of the Greek and Roman classics as well as Chile's natural history. As he says in the preface of the *Saggio sulla storia naturale del Chili* (Molina 1782), in this period he attained a more scientific approach in the observation of the rich natural history around Santiago, taking careful and systematic notes. In 1761 his life was threatened when he contracted smallpox, leaving his face visibly pock-marked for the rest of his life. It was in this time that he developed an interest in mathematics as well as French and Italian, which would prove very useful in his years in European exile. After concluding his studies, he spent a few years back at Talca as a teacher at the Jesuit school. While there, he had the opportunity to make several field trips to study the botanic and zoological riches of the area (Molina 1782). In the 1766 Molina returned to Santiago to begin the final period of preparation before ordination to priesthood, which was interrupted on February 27, 1767 when Charles III of Spain decreed the banishment of all Jesuits from the Spanish empire (de Olivares 2005). Juan Ignacio left Chile on February 3, 1768 for Lima, Peru, and in May of the same year, boarded N.S. Rosario heading for Cadiz, Spain, arriving four months later. During this trip, he made many scientific observations about flying fish, whales and, in particular, about the weather of Cape Horn and Tierra del Fuego (Molina 1782: 35).

On February 20, 1769, together with other two hundred Jesuits, he arrived in La Spezia, a harbour east of Florence, Italy. Here, the Jesuits received a warm welcome and Molina's knowledge of the Italian language proved very useful in obtaining the friendship of the governor, a student of natural history with whom he would go on several excursions to nearby regions, and his secretary. From La Spezia, on their way to their final destination of Imola to join their Chilean colleagues, the Jesuits travelled through Pisa and Florence, taking advantage of this opportunity to visit important historical monuments. By May 1769, after a journey of approximately seventeen months, the exi-

les were settled in various houses of Imola (Ronan and Hanisch 1979). In September of the same year Molina received holy orders in Bertinoro Cathedral of San Cassiano, not far from Imola (Fig. 2).
In 1774 he decided to move to Bologna, the home of a celebrated university and a city that was much more intellectually stimulating than Imola. He took up residence in Via Belmeloro, where he opened a small school with a curriculum that embraced Latin, French, geography and history, taking the time to teach a number of less privileged children free of charge. Several of his students went on long excursions in the countryside and one, Giovanni Ferrari, became his secretary and the proof-reader of his books.
During these years, teaching was not the only occupation of the Italian Jesuit community, a few of them, as Francisco Clavijero, began to write about the New World, the las Americas, their homeland (Zunino 2007). The increasing curiosity in this period together with a eurocentric culture resulted in much misinformation and the appearance of several bizarre ideas about the Americas (Ronan 2002). This, as well as the probable nostalgia for his fatherland, motivated Molina to begin writing about Chile, his country.

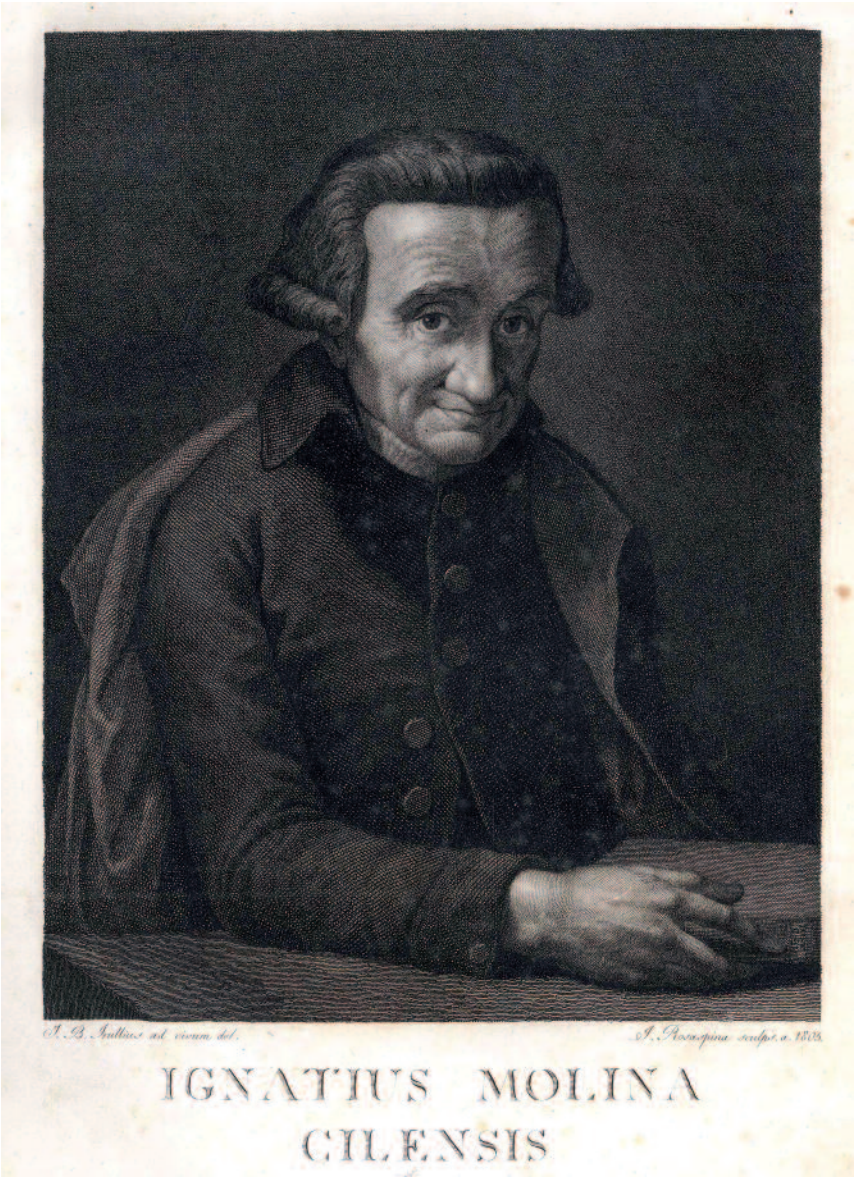

Figure 1: An 1805 line engraving portrait of Molina by Rosaspina. This image is in the first pages of the second edition of the *Saggio sulla storia naturale del Chili* (Molina 1810). Reproduction by permission of the Biblioteca dell'Archiginnasio -Archiginnasio Municipal Library- of Bologna.

THE BOOKS

Molina's first book, written in Italian, was the *Compendio della storia geografica, naturale, e civile del regno del Chile*. Most likely begun while he was still in Imola, it was published anonymously in Bologna in 1776. This book received large interest in Europe primarily because it coincided with the revolt in England's North American colonies. The book is divided into two parts: the first discusses Chile's natural history, dealing with its geographic location, climate, rivers, animals, and the vegetable and mineral kingdoms. Molina reported that Chile's name originated from "chili-chili", the song-like bird cry characteristic of a native bird heard by the first inhabitants on their arrival. The second part of the book describes the way of life of the native Auracanian Indian inhabitants as well as the Spanish population in Chile; their customs, religion, dress, and commerce. Also included in the second part is a description of Chile's fourteen provinces while the appendix contains nine illustrations of the Creole and native games and dress.
Maps of the city of Santiago as well as of the entire kingdom of Chile are also included, based on the most up to date maps of the time, as those of Louis Feuillée, Antonio de Ulloa and the pilot Varillas (Molina 1776: 227). The source materials for the *Compendio* included just a few books, Jesuit reports (Ronan 2002) and most importantly his personal incomplete, handwritten notes and papers that he was able to bring with him on his exile journey. In fact, much of the original bibliographic material was confiscated by Spanish customs agents upon his departure for European exile in 1768. Molina's seeming dissatisfaction with the 1776

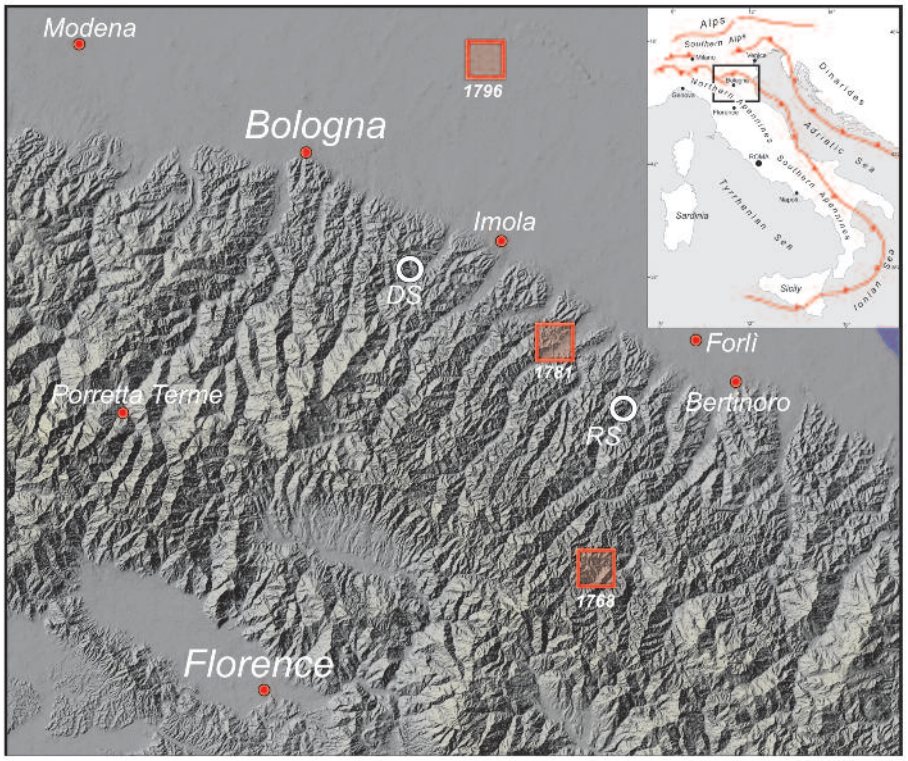

Figure 2: A digital elevation model of the Bologna area and the Northern Apennines, indicating the main localities relevant to Abate Molina's stay in Italy. RS: Rio Salso ; DS: Dragone di Sassuno; Squares are the locations of earthquakes with magnitudes between 6 and 7 that occurred in the late 18th century (data from the Italian Parametric Earthquakes Catalog CPTI04 - INGV 2004 - http://emidius.mi.ingv.it/CPTI04/).

Compendio stemmed from its lack of good references and systematic descriptions of different species. Fortunately he was able to recover most of his notes and papers over the following years, possibly with the help of his Chilean friends (Jiménez 1974).

Sometime after 1776, with a newly recovered excitement and the possibility of accessing a much larger repository of scholarly books and sources, Molina began work on his *Saggio sulla storia naturale del Chili*, which he published in 1782 in Bologna at great personal expense. This new essay was much more detailed and provided a more sophisticated treatment of Chile's natural history than the 1776 edition. The text, comprised of 306 pages and a map, is subdivided into four books -*Libri*- and includes an introduction, in which Molina compares the beauties of Chile to Italy. With this book, Molina's intent was to demonstrate to the European community that there were no significant differences between the Americas and the Old World Countries.

Libro I begins with a general description of Chile's geographic location followed by the country's seasons, rains, winds, volcanoes, earthquakes, and climate in general. The existence of at least 14 active volcanoes in the Cordillera is recorded followed by a report of the December 3, 1762 eruption of the Peteroa, which did not produce earthquakes. Also mentioned is the continuous activity of the Villarica volcano. Some geological comparisons made in this book indicate that Molina must have travelled around Italy and was familiar with the volcanic activity of the Vesuvius. He related volcanic activity to earthquakes that were considered the main scourge of the country and suggested that the main agent for the earthquakes must be underground gas and water, especially close to the coast where infiltration of oceanic water is possible. Several of these concepts were also mentioned by Darwin in his 1839 book about the Concepción earthquake. Molina reported the frequency of strong earthquakes in Chile as three to four a year, while of the strongest ones every several years. He wrote about the 1570 earthquakes (Molina 1782: 45) that hit the southern part of the country, the May 13, 1647 and July 8, 1730 earthquakes of Santiago, as a result of which several buildings was damaged, and the strongest May 24, 1751 Concepción earthquake and its resulting tsunami (Berninghausen 1962). For this latest event, Molina reported several small pre-shocks and, in particular detail, the midnight main event which lasted 4-5 minutes. In the following days, he reported many aftershocks together with strong rains. Molina pointed out that there were no deaths related with these events, while other chroniclers reported damages such as those in Chillán, where the entire city was destroyed and a river changed its course. He reported that, generally, all the main shocks were preceded by strong rumbles that allowed the people time to escape.

Molina argued that based on his observations, there was no evidence in support of the belief that the state of the atmosphere forewarns of earthquakes (Molina 1782: 47). He did not report the origin of the idea relating the state of the atmosphere and earthquakes. Today we know that the main earthquake shocks affect the local magnetic field in this way possibly influencing the atmosphere (Parrot 1994).

While in Bologna, Molina felt several earthquakes, which he described as quick compared to the stronger and longer duration earthquakes that occur in Chile. The area surrounding Bologna, from a seismotectonic point of view, is complex because it is located between the northern slope of the Apennine active thrust front and the south-eastern portion of the Po plain characterized by a low to intermediate seismicity. Historically, several epicentral areas with frequent seismicity are

known, located in the hilly region of Forlì, a few tens of kilometers SE of Bologna, in the Apennines chain (Boccaletti and Martelli 2004). Living in Bologna, Molina felt the frequent low magnitude earthquakes occurring in the Northern Apennines. It is very likely that he experienced the 1779-1780 seismicity that affected the Bologna area with intensities of VII MCS and more than 100 shocks that produced moderate damage, in particular to the churches (Boschi *et al.* 2000). Another important earthquake that occurred in the region during Molina's life included the 1781 quake, with an intensity of VII MCS and an epicenter located between Forlì and Bologna (Fig. 2).

In *Libro II*, Molina dealt with the mineral kingdom. The book provides a detailed treatment of hydrology, with rivers, lakes and mineral waters; followed by soils, rocks, salts, bitumen and the minerals of Chile. The main rivers of Chile, the Maule, the larger Bio Bio, the Cautén, the Toltén, the Valdivia, the Chaivin, the Riobueno and the Sinfondo of the Chiloé Arcipelago, are reported and described as navigable. Molina observed that the flood season is mainly between September and February and is related to the melting of snow in the Cordillera. The main lakes are described with particular attention given to those located at the so-called Mediterranean latitudes (about 40°). The Peldehue and Cauquenes hot springs, with temperatures close to 60° Reamur (75°C) and the main mineral waters, concentrated in the Copiapó and Coquimbo provinces, are also described. The soil description is closely linked with agriculture, in particular wheat production. Molina presented evidence demonstrating the uplift of the Chilean coastline and the presence of several marine caves, and the caves of the Cordillera, such as these located by the source of the Longavi River and near Puente del Inca -The Inca's Bridge- formed by action of the Mendoza River (Molina 1782: 66, Ramos 2009).

Molina stated that the fossil shells found in the Cordillera, particularly on Descabezado Grande in the Maule Region, are of marine origin although he ascribed them to the Great Flood. A geomorphologic description of the Cordillera, with its main central mountain range and two minor lateral chains, is presented, in which several terrace sediments lead Molina to suggest a rapid uplift of the Cordillera. Several pages are dedicated to a discussion of the different types of rocks, clays -largely used in that period for kitchenware- sands and limestones. Rocks are subdivided into four categories: clayey, calcareous, arenaceous and aggregates; each with a detailed description. In the description of the petroleum precursor bitumen -*Bitumen Andinum*- it is suggested that it could be the same as the product known from Persia.

In his discussion of the mineral resources of Chile, Molina referred many times to the observations of the French engineer Amédée Frézier (1682-1773) -author of *Relation du voyage de la mer du Sud, aux côtes du Chili, du Pérou et de Brésil*, *fait pendant les années 1712, 1713, et 1714*, Paris 1716 -, who visited Chile under the patronage of Philip V of Spain. He also went into great detail describing Chile's mining industry, the government regulations and procedure for opening a mine, as well as the country's mining methods, citing more than a thousand copper mines of Payén and Curicó, and estimating about five thousand tons of ore exported to Spain, Peru and Buenos Aires. Pyrite, known as *Pietra dell'Inca* -Inca stone-, mercury in the form of cinnabar, located in the Coquinbo and Quillota provinces, and numerous iron mines are reported.

Molina also talked out the largest and richest silver mine, located in the Uspallata area, which is geomorphology comparable with the Apennines between Bologna and Florence. He describes a dark claystone containing rounded pebbles -a Pennsylvanian mudstone with dropstones (López Gamundi 1983)- and argued that it was formed either during the Great Flood or by Native Indians that threw stones into clay when it was still soft (Molina 1782: 103-104). He concluded, however, that it was not very plausible that the Indians would want to transport such a large amount of pebbles a great distance into the mountains just to entertain themselves. Molina then proceeded to describe the silver ore distribution in the Uspallata mine and the industrial and traditional extraction methods as compared with those of the Potosi mines.

Molina wrote that the most abundant mineral in Chile, particularly in the region between the Biobío River and the Chiloé Archipelago, is gold. Gold that, according to the reliable French writer, Noël-Antoine Pluche (1688-1761), was the purest and most valuable in the world (Molina 1782: 108-110). Various excavation methods and the industrial extraction methods that utilize mills and the process of amalgamation are then described. The three classes of mineworkers that form the metallurgical order are described, from quarrymen, to ore transporters and foundry workers.

Libro III gives detailed treatments of the grasses, shrubs and exploitable trees, and reports that in spite of the barrenness of the mineral rich terrains, Chile's territory is covered by a luxuriant vegetation. It details the use of several alimentary plants, such as corn and potato that, in the 18th century, were beginning to be exported from the Americas and cultivated in Europe. In this period, in Bologna, the first scientific agricultural studies in the field of agriculture were being performed by Filippo Re (1763-1817) following a rational methodology. In this chapter, Molina also wrote about medicinal herbs and compares the production of Chile's best wine in the Itata Valley with similar vineyards of Europe.

Libro IV deals with mollusks, crustaceans, insects, reptiles, fish, birds and quadrupeds. The final part includes a description of the native peoples of Chile and their traditions. A few catalogs complete the chapter: *Catalogo I* catalogues all the new species listed in the chapter, including animals, rocks, minerals and fossils, according to the Linnaeus classification; while *Catalogo II* is an Italian-Arau-

canian dictionary of terms pertaining to the natural sciences.

In the years following its publication, *Storia naturale* was translated into many languages: a German edition was published in 1786 in Leipzig; a French edition, in Paris in 1789; a Spanish edition, in Madrid in 1788; and two English editions, an American edition published in Middletown in 1808 and a British edition published 1809 in London. The British edition was published in two volumes that included two appendixes: the first contained the *Description historial de la provincial de Chiloé* by Pedro González de Agüeros (1791); and the second consisted of *An account of the native Tribes who Inhabit the Southern Extremity of South America and a Further elucidation of the Araucanos*, both extracted from Falkner's (1707-1784) *A description of Patagonia* (Falkner 1774).

In 1810, the book was reprinted in a new extended and revised edition and translated into other languages. In the second edition of *Storia Naturale*, Molina (1810: 16) describes the clearness of the Chilean sky indicating the main stars and constellations, referring to the father of the Italian literature, Dante Alighieri (1265-1321), who in the *Divina Commedia* of 1321, *Canto I* - Purgatorio, described what could be identified as the Southern Cross: "*I' mi volsi a man destra, e puosi mente/ a l'altro Polo, e vidi quattro stelle/non viste mai fuor ch'a la prima gente/ Goder pareva 'l Ciel de loro fiammelle/ oh Settentrional vedovo sito,/poi che privato se' di mirar quelle!*" - I turned to the right and considered/ the other pole, and I saw four stars/ never seen except by the first people./ The sky seemed to rejoice in their flames:/ Oh northern site, widowed/ because deprived of gazing on those!-. This verse, as well as other data, is often cited as proof of European familiarity with the southern hemisphere skies prior to the 15th century, although much controversy on the topic still exists (Galeano 1984, Grasso Ibarra 1994, Cadelo 2009). This excerpt from Dante's work has also inspired one of the most important Argentinean writers, Jorge Luis Borges (1899-1986), in his essay *Nueve ensayos dantescos* (Borges 1982).

EARTH SCIENCES BETWEEN THE RENAISSANCE AND 19TH CENTURY IN BOLOGNA AND IN ITALY AS A WHOLE

During the Humanism, Renaissance and Early Baroque periods, Italy was the scene of the development of not only the liberal arts but also the mechanical arts and the sciences (Vai and Cavazza 2003). In this period the Earth Sciences received a strong boost due, in particular, to the recognition of the marine origin of fossils. In Bologna in the 16th century, Ulisse Aldrovandi (1522-1605) made new advancements in the methodologies of the study of rocks and the systematic collection of fossils, preceded by the experimental and rational scientific methods of Galileo Galilei (1564-1642) and Francis Bacon (1561-1626). In 1603, in his Testament, Aldrovandi introduced, for the first time, the Latin term *Giologia* -Geology-. He gave instructions for the printing of his manuscripts that included the *Syntaxis rerum naturalium* in three volumes: Minerals and Fossils, Plants, and Animals; *Giologia*, or rather the *Fossilibus*; *Botanologia*; and *Zoologia*. He also gave the definition of the word *Giologia*: the science of fossils. The terms *Fossilis* and *Fossilia* were used at the time to refer to any object found by digging in the subsurface or cropping out as a result of erosion by such notable figures as Georgius Agricola -Georg Pawer- (1494-1555), Alberto Magno (1193-1280) and Girolamo Fracastoro (1478-1553) (Vai and Cavazza 2003). Another pioneering figure in the sciences of the time was the Dane Nicolaus Steno -Niels Steensen- (1638-1686). Widely considered the father of geology, Steno lived, for a time, in Tuscany having converted in 1667 from Lutheranism to Catholicism. Steno embraced the Galilean scientific method and is credited with developing the three defining principles of stratigraphy: the principles of original horizontality and lateral continuity, and the law of superposition as applied to sedimentary strata within the Earth's crust. At the beginning of the 18th century, the naturalist and oceanographer Luigi Ferdinando Marsili (1658-1730) and one of the fathers of paleontology, Giuseppe Monti (1682-1760), were contributing to the further development of these concepts, and played pivotal roles in the founding of the Institute of Sciences and Arts, and the Natural History Museum in Bologna. Thus when Molina arrived in Bologna in 1774, the city was one of the most populated cities in Europe and home to its oldest University -*Alma Mater Studiorum*-, founded in 1088 (Vai 2009). The *Istituto delle Scienze e delle Arti* -Institute of Science and Art- of Bologna established in 1711 by count Luigi Fernando Marsili, incorporating the *Accademia degli Inquieti* under the new name of the *Accademia delle Scienze*, was the first publicly-funded institution employing scientists to do systematic geological field surveys (Vai and Cavazza 2006). The *Accademia delle Scienze* played a leading role in the advancement of European science and maintained close ties with and influenced the *Académie des Sciences* of Paris and the Royal Society of London (Cavazza 2002). For his treatise on the *Historia physique de la mer*, published in 1725, Marsili is also considered the father of oceanography and marine geology.

In the 18th century, the theory of the organic origin of stony shells began to be accepted by the scientific community: first in Italy, and then in France and England (Vai and Cavazza 2003). The main debate within the earth sciences of the time regarded the process by which these shells and fish remains retained their similarities to those living in the sea even when found in the mountains. The dispute revolved around the ideological thinking of Diluvialism, a theory that maintained that the Great Flood, or Noah's Flood shaped the earth's surface, which was largely accepted by scientists of the epoch in order to reconcile scientific findings with the religion (Ryan 2007, Ryan and Pitman 1998). However, it needs to

be considered that by the sixteenth century scientists such as Leonardo da Vinci (1452-1519), who was the first to successfully reconcile observations and formal reasoning regarding the nature of fossils, were already questioning the theory of Diluvialism (Pedretti 1985). In the following centuries, several other Italian naturalists and geologists challenged the theory of Diluvialism. In Bologna of the 18th century, field research, with its analytical observations and comparisons, and the classification of fossils and minerals, rather than the philosophy of models was the primary focus of scientists; they were looking for concepts rather than models (Vai and Cavazza 2003).

The school of geology in Bologna was a leading research centre with many scientists, such as Carl Linnaeus (1707-1778), coming to make use of its collections for their studies (Sarti 2003). Charles Lyell (1797-1875) in his *Principles of Geology* (Lyell 1830: 51-66, 93-107) cites the Italian geologists for their research methods and for their criticism and refutation of Diluvialism. This model was largely accepted until the proposal of the glaciation theory in the middle of the 19th century (Agassiz 1840). It is important to remember that in that period the concept of Geologic Time was far from being understood and was the object of much discussion between William Thomson -Lord Kelvin- (1824-1907) and Charles Lyell (Hallam 1989).

In *Storia Naturale*, Molina referred to "marine bodies" found in the Cordillera (Molina 1782: 65) that could be related to a slow oceanic regression. Later in *Memorie*, he made reference to the Great Flood and to the divine creation of the universe, in accordance with the scientific and catholic thinking of the time. He adhered perfectly to the teachings of the Bologna naturalist and geological school about the critical importance of using observation and reasoning in place of simple known models. Based on Molina's writing it is easy to argue that he had severe doubts about the diluvianist interpretation of the origin of fossils.

MOLINA: AN ITALIAN PERSPECTIVE

The occupation of Bologna by Napoleonic troops at the end of the 18th century coincided with a decline in the quality and renown of its scientific researches. This followed the confiscation of Church property and some troubles for the Jesuit community. In 1796, Napoleonic troops pillaged the Institute of Sciences, stealing the geo-paleontological collection, which was never recovered (Sarti 2003).

In this period the Institute of Science was directed by Luigi Galvani (1737-1798), the discoverer of animal electricity, who was removed from the university because of his refusal to take the oath of allegiance to the new French regime of the *Repubblica Cisalpina*. The Jesuit community in Bologna was promised protection by Napoleon with the condition that it does not meddle in "public affairs" (Ronan 2003). In spite of this, the Jesuit school continued to play an important role in the teaching of the sciences in the city during this period. In 1798, King Charles IV decreed that the exiled Jesuits can return to Spain but at the end of 1801 only thirty one Jesuits took advantage of this permission. In 1802, Molina did make arrangements to return to America but gave up his plans upon receiving news of the sad plight of two of his Jesuit friends who had taken the opportunity to return home. Molina's cooperation with the occupying forces is evident from his actions, such as, the dedication of the second edition of *Storia Naturale* published in 1810 to Eugène de Beauharnais (1781-1824), Napoleon's viceroy in Italy.

In 1802, Molina was accepted as a member of the Bologna Academy of Sciences, that changed names several times during the Napoleonic occupation (Vai and Cavazza 2003), and later, in 1805, he received honorary membership of the Medical Society of Bologna for his "outstanding talents" particularly in the field of natural sciences.

In September 1805, he received a visit from the noted German scientist and naturalist Alexander von Humboldt (1769-1859), who desired to meet the Jesuit. Molina took genuine satisfaction from the visit and it is very indicative of his reputation as a scholar and naturalist at that time (Ronan 2002). In 1806, he travelled, together with other Jesuits, to Leghorn via Lucca, west of Florence, with a special Napoleonic permit (Ronan and Hanisch 1979).

In 1810, he published the revised second edition of *Storia naturale* that he had been working on since 1804. Comparing the 1782 with the 1810 edition, the revision embraces several new points as a result of the addition of considerable new data derived from new scientific expeditions of the 18th century and contains a new map, "drawn according to the latest astronomical observations" (Molina 1810).

In 1812, Molina received a letter from the Rector of the University of Bologna with an offer of the post of substitute lecturer of the natural history in the absence of the regular professor Camillo Ranzani (1775-1841), a former student. Ranzani, at the time was in Paris on the invitation of the noted zoologist Georges Cuvier (1769-1832) (Ronan and Hanisch 1979).

In 1814, with the restoration of the Jesuit order by Pope Pius VII, Molina ones again planned a return to Chile but several factors, including the volatile political situation in Chile and Argentina, and his advanced age, dissuaded him from the trip. In 1815, upon the collapse of Napoleon's empire and Bologna's return to papal rule, Molina was seventy five years of age. In the last years of his live his health was progressively deteriorating and on September 12, 1829, he passed away. He was buried in the Bologna cemetery and it was not until 1967 that his mortal remains were finally returned to Chile where they now rest in the church of the town of Villa Alegre.

LECTURES AND *MEMORIE*

Between 1805 and 1815, Molina gave several lectures at the Bologna's Academy

of Sciences that were published in Bologna in 1821 in two volumes with the title of *Memorie di storia naturale* -Treatises of Natural History-. The volumes consisted of fourteen lectures -*Memoria*-, addressing various topics within and without the natural sciences endowed with his most advanced thinking (Molina 1821 a, b). Living in Bologna, Molina had available to him the extensive libraries of the university and other scientific institutions, as well as a significant number of documents of the Jesuit community. From the first lectures, Molina's description method of topics in different scientific fields became evident. First, he reviewed the information from previous works then he compared it with his own data and ideas, and with those of other scholars of the epoch, concluding with an interpretation (Ronan and Hanisch 1979). Several topics addressed by his lectures were supported by his direct observations while in the Bologna countryside and during his visits in several localities of the Apennines.

From our point of view, only a few of the Memorie merit special attention, specifically those dealing with the earth sciences, while *Memoria VI* needs special explanation because, as a result of what was said in this lecture, Molina was denounced for heresy.

I - On the Porretta

This *Memoria* deals with a research study that Molina carried out as member of a scientific expedition sent to study the hot baths of the Porretta Terme (Fig. 2). The list of members with whom he travelled is reported in the second edition of *Storia Naturale* (Molina 1810: 41) and includes the physicists Giovanni Castiglioni, Giacomo Naldi, Paolo Verati, Pier-Filippo Zanelli and Antonio Baccchetti. The town of Porretta Terme (Fig. 3) is located 50 km SSW of Bologna in the Northern Apennines, at the confluence of the Maggiore and Reno Rivers, at an altitude of 350 m. The area was well known for its thermal springs and baths as far back as the Etruscan and the Roman ages, from the 4th century BC. The geology of the area is characterized by large outcrops of Upper Cretaceous-Ligurian facies- clays and shales in a chaotic rocky mass -mélange - olistrostome- (Fig. 4), pertaining to the sedimentary cover of the oceanic crust, located in the Cretaceous between the African and European plates (Pini 1999, Castellarin 2001). All the rocks are hosted in the Oligo-Miocene sediments of the Northern Apennine foredeep basin. The Porretta Terme area consists of a thin, NW-SE striking slice of subvertical Oligocene sandstone bounded by thrust faults of the NE limb of an asymmetric anticline pertaining to the Miocene Apennine foreland fold-and-thrusts belt. The NE limb of the structure, dissected by several thrust planes with an offset of a few kilometres, is subvertical and characterized by reverse bedding, while the other limb of the anticline is gently dipping to the SE.

The hot springs near the rivers are characterized by temperatures between 25-36° C with a fixed residue ranging from 2500 to 4600 mg/l, the geochemistry is dominated by Na-K, SO_4 ions and a diffuse presence of CH_4 gas. Historical gas vents are known to be still active in the area.

Molina's Porretta lecture is a very good example of a scientific paper written with an introduction followed by a discussion of previous studies and then the presentation and analysis of data. The text begins with a morphological description of the area: hills characterized by gently dipping SW slopes and steep NE flanks. Molina expressed several doubts about the interpretations of the geological origins of the mountains, citing the chaotic structures of the outcrops characterized by sparse rocky blocks, reverse bedding without any primary structures and the absence of marine fossils as reasons.

Molina doubted about the volcanic origin of the area proposed by previous researchers on the basis of the observed gas venting. Having explored the territory, especially around the thermal spring, Molina reported the discovery of a small hydrogen sulfide vent, where he tested the gas composition by utilizing candles that produced a bice -light blue- colored flame. Today we know that the gas composition of the vents is mainly CH_4 with trace amounts of sulfur that give the characteristic rotten eggs smell, especially in the Puzzola -skunk- springs.

Molina argued that this small vent cannot serve as proof of the strong volcanic activity necessary to explain the chaotic disposition of the rocks in the area. Moreover, he explained that lava and tuffs, usually associated with strong volcanic activity, a fact well familiar to him from his experiences in Chile, are absent in the area. He also excluded the possibility of an earthquake related origin because the complex structures of Porretta are too localized.

Molina tried to explain the chaotic structures of the area by relating them to the rivers and large floods resulting from raging storms that could have occurred in the past in this part of Italy. Of course, Molina's thinking was strongly influenced by Diluvialism, which was very popular among the geological scientific community in the beginning of the 19th century (Vai 2003). According to his idea the origin of the deposit was a big lake containing a large amount of organic matter which, for decomposition, would later supply the sulfur and gas vents. He found pyrites and performed chemical tests to check for the presence of sulfur and the possibility of producing iron and aluminum sulfates. Based on his own experience, Molina hypothesized the impossibility of finding ore in the Bologna region, which, he stated, is instead full of cultural and historical riches.

A description of the main rocks outcropping in the area was reported with the mineralogical composition of the sandstones that he subdivided into three categories: the first, the most compact due to the presence of quartz and a hard cement, is characterized as similar to a granite; the second and richest in feldspars is softer; the third, called *sassomorto* -dead rock- flakes easily. He describes rhombo-

Figure 3: Panoramic view looking NW of the Porretta Terme area. The smooth morphology in the foreground, around the town corresponds to the outcrops of clay and marls of Argille Scagliose. In the background the rugged landscape correspond to the outcrops of Miocene sandstone.

Figure 4: A Liguride olistostrome outcrop of the Northern Apennines. The olistostrome is characterized by shale and clay within a chaotic rocky mass.

hedral rock bodies and structures of different sizes -in this case, tectonosomes as defined by Pini (1999)-. Carbonate rocks are described and subdivided into three varieties where the first is a dark compact limestone, the second is a more friable limestone and the third is a pudding limestone. Schists covering the main outcrops are last to be described.

Molina also discussed the risk of rock falls for the houses in the area and talked about his own experience with a rock fall. Large fractures on the top of a small hill south of Porretta village attracted his curiosity. In the final section of the *Memoria* he talked about the possible relationship between volcanic activity and sea water. The relationships of fourteen Chilean volcanoes with the waters of the Pacific Ocean and the coastline, as well as with the Italian volcanoes of Vesuvio and Etna, both of which are located close to the sea, are discussed.

Next is a description of calcite, quartz, barite, gypsum and salt minerals commonly occurring in the area. The salts are present in the Pliocene diagenetic marls of several outcrops near Bologna and Imola. The last pages of the *Memoria* are dedicated to the flora of Porretta Terme and to a discussion of the origins of mineral water and the origins and presence of "albumin" in these waters. Molina suggested that this material was produced by cryptogamic plants and was transported by groundwater along underground fractures. Most likely, Molina was referring to the white organic matter present near the springs, a product of the oxidation of sulphides to elementary sulfur upon contact with air.

II - Observations on the physical constitution and the mineral products of the mountains of Bologna.

In this second *Memoria*, Molina discussed the ore resources of the areas surrounding Bologna. This lecture also appeared in the Italian journal *Opuscoli Scientifici*, in 1823. The first pages referred to the popular idea, linked to several legends, on the presence of gold, silver and copper in the region. Molina reported many cases of misinformation and findings of minerals that can easily be confused with gold, such as pyrite or mica, citing as examples his personal experience on small iron ore deposits associated with pyrites present in sedimentary successions and in a small mine close to the Porretta Terme. He definitively concluded that the ores are not present in the area, however, this lack is compensated for the rich cultural heritage of the territory. He suggested, based on historical data, that the area is well suited to olive-growing -see *Memoria III*- and viticulture, and make mention of the severe winter weather conditions of the region.

Turbidite outcrops of the Mio-Pliocene foredeep basin, characterized by prevalent pelagic marls, are present in the Bologna countryside and the surrounding Northern Apennine hills. Molina labeled these sediments as "volcano-pelagic marls" due to the similarity of their

grey color to volcanic ash. He suggested a marine origin for the sandstones, related to the oceanic retreat that was also responsible for the formation of the Apennine structures. Derived from the Alps and Dinaride mountain chains, these sediments were transported to their current locations and "agglutinated" to form rocks. Subsequent weathering produces sediments that were then transported by rivers and deposited in the large plain of northern Italy.

Molina then proceeded to describe carbonate rocks, in particular those used in building construction and as ornamental stones, and travertine deposits related to a thermal spring. Gypsum is a mineral characteristic of an important, continuous outcrop of Late Miocene euxinic sediments located in the hills surrounding Bologna (Cita and Corselli 1990). In his lecture, Molina described the different morphologies of gypsum from swallow-tail selenite crystals to those hosted in the marls, to the satin-spars. He argued that the origin of this mineral cannot be the action of sulfuric acids -derived from pyrites- on the limestone, as previously proposed by several authors. In his opinion, the iron poor nature of the gypsum deposits and their surroundings is suggestive of an origin related to the interaction with other acids produced as a result of the reactions of atmospheric gasses. At the beginning of the 19th century, chemistry was in its infancy, transitioning from alchemy to a modern science following the pioneering researches of the Antoine-Laurent de Lavoisier (1743-1794).

Molina discussed the common hypothesis of the origins of salts in the area between Bologna and Imola and described his visit to the Rio Salato -Salty River- where he found salt crusts on marls outcrops (Fig. 5). These salts, found in association with Pliocene marls, are linked by him to connate water present in the turbiditic formation of the Northern Apennine foredeep.

The following paragraphs contained a description of the clay used in the production of ceramics, the schist used as a roofing material in the mountain areas, and a description of the sandstones commonly used as building stone. Molina reported the presence of barite, a mineral notorious for its luminescence, which was named, in the 1640 study by the University of Bologna Professor Fortunius Licetus (1577-1657), the Bolognian Stone.

The last part of this *Memoria* dealt with the description of bitumen deposits and oil seeps present in the vicinity of several thermal springs and often associated with CH_4 vents in the Northern Apennines. Molina also mentioned the still active *Dragone di Sassuno* mud vent, located SW of Imola, which spews hydrocarbon-rich mud (Fig. 6). Several mineral springs including saline and sulfur springs, are reported with descriptions of their curative proprieties. Molina concluded by expressing hope for a continued exploration of Bologna's territory for ore resources that may in the future contribute to the prosperity of its people.

Figure 5: A marl outcrop along the Rio Salso, SW of Forlì (above) -location in Fig. 2-, where several salty springs are located (below).

III - On the cultivation of olives

This *Memoria* was published twice prior to being included in this volume, the first time in the *Gazzetta di Bologna* and the second time in the *Redattore del Reno.* The dates of these publications are unknown. The text is a discussion on the possibilities of olive tree cultivation in the Bologna area. It is a sort of call for the local

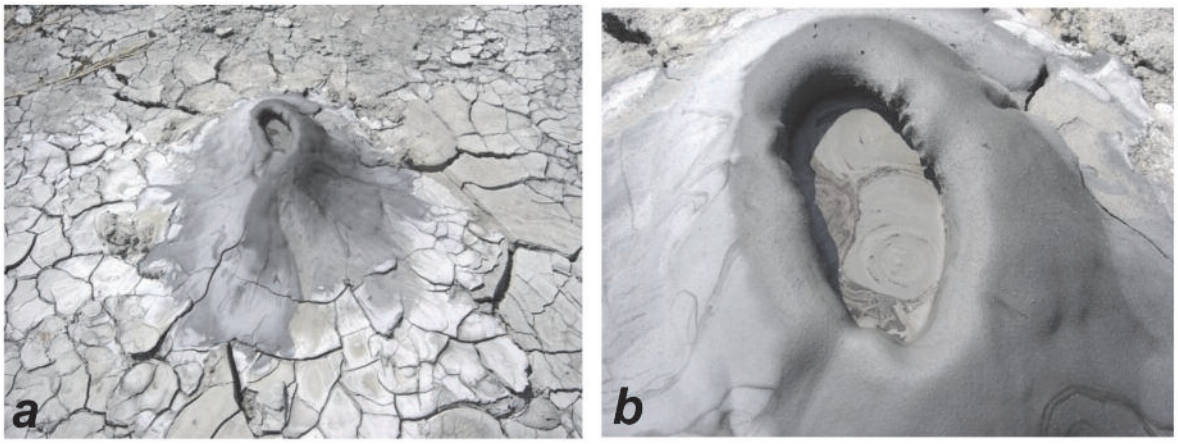

Figure 6: a) The small Dragone di Sassuno mud vent SW of Imola -location in Fig. 2-; b) the presence of hydrocarbons is visible in the small pools at the mouth of the mud cone.

farmers to plant olive trees, particularly on the south facing hillsides, where the winter weather conditions are less severe (Rondoni 2009).

IV - On marls

This lecture followed about one year behind that of *Memoria II* and deals with the possibilities of using marls as fertilizer for acidic soils. In the Bologna area, turbidite outcrops of the Miocene and Pliocene Apenninic foredeep containing thick marl beds are abundant (Pini 1999, Castellarin 2001). Molina cited the Roman naturalist Plinio -Gaius Plinius Secundus, better known as Pliny the Elder (23-79 AD)- that introduced the Gallic term *marga* from which the current name for these rocks is derived. He described the mineralogical composition of the rock, resulting from an unknown natural combination of calcium carbonate and clay, and proposed a theory for its origin. The theory states that the calcium carbonate could derive from marine organisms while the clay from animal and plant decomposition. Molina then reported several examples of the use of marls as a fertilizer in agriculture. He explained the method for the recognition of marls in the field and in the laboratory, and finally, he indicated where marls can be found in the region between Tuscany and Bologna. Molina identified two types of marls: the first, marine volcanic in origin -see above in *Memoria II*- is infertile and requires the addition of a substantial amount of manure in order to be used for agriculture; the second, outcropping in the areas surrounding Bologna, is considered the real marl. Molina did not go into detail about the characteristics of the latter but proposed to show the audience several samples of the marls at the end of his talk. He proceeded to list and discus then several other marl classifications originating in England, where the marls are extensively used in agriculture. Several simple laboratory chemical tests to distinguish the carbonate and the clay fractions of the different types of Bologna marls are reported. Molina also suggested a simple test to check the marl quality that would be accessible to farmers using vinegar, and explained how to use it as fertilizer.

This *Memoria* presented new knowledge in the field of agriculture achieved by Filippo Re (1763-1817), a professor at the University of Bologna from 1803 to 1815. Re was one of the first to apply a scientific approach to the study of agriculture by integrating his knowledge of botany, chemistry, meteorology and even equipment (Vai and Cavazza 2003). In Molina's *Memoria*, there is a considerable interest in agriculture and a social spirit that strives to popularize knowledge. In 1817 the *Academia Private dei Gergofili* invited him to become an honorary member, for his theoretical and practical knowledge in Agriculture (Ronan 2002).

V - Coffee

In this *Memoria*, after a description of the origin of the plant and its seeds, the different techniques of preparing this drink around the world are described, from the Middle East to Europe. Molina also reported the harm to one's health that can result from excessive coffee drinking citing the death of the French scientist and philosopher Voltaire -François Marie Arouet (1694-1778)- stemming from coffee abuse as an example.

VI - Less-noticed analogies in the three kingdom of nature

In 1815, Molina gave three lectures at the Academy of Sciences of the University of Bologna entitled *Analogie meno osservate dei tre regni della Natura*. During these lectures he propounded the theory that the division of nature into three kingdoms -animal, mineral and vegetable- is as exclusive as thought, but that beings in each kingdom are connected with those of the others creating a sort of a continuous queue that expands into a network of interconnections (Molina 1821a: 176), all, of course, in accordance with the Divine Design. This theory was part of the preformationism that originated in late seventeenth century and was expounded by several scientists, such as the Swiss Char-

les Bonnet (1721-1793) and the Italian Vitaliano Donati (1717-1762). One of the key aspects of preformationism was that all organisms that have ever appeared on Earth were created at the same time by God. Another aspect of this theory was the concept of the existence of a "chain of being" or, in other words, a continuous ascending scale of beings in nature.

In his lecture Molina explained these concepts by citing fluids that contribute to the growth of animals, plants and minerals. In the first part described the growth of minerals in the earth as a result of rising fluids and how these fluids can contribute to ore deposition. He cited Newton's law of universal gravitation as an explanation for the movement of the fluids and the attraction of the bodies contributing to the formation of minerals. The polarity -magnetism- of some minerals together with gravity -or the force of attraction- is interpreted as a sort of "vitality" that makes the causal aggregation of particles and molecules possible, generating the symmetric structure of crystals. Dendritic crystal growth, producing the typical multi-branching tree-like forms, is compared with shapes characteristic of the vegetable kingdom. Molina also drew an analogy between the vegetable and animal kingdom by comparing the life spans of each group, reporting data about hundred-year-olds living beings in Europe as well as in Chile. He suggests that the increasing number of centenarians could be related to the variation in the obliquity of the Earth ecliptic.

Very interesting are Molina's reports of increasing air temperatures and milder winters in the early years of the 19th century (Molina 1821a: 196). Today we know that a Little Ice Age that began in the 13th century and ended in the latter half of the 19th century or early 20th century (Matthes 1939, Man *et al.* 1999, Lamb 1972). Molina stated that this warming could be a reason for the appearance of taller trees and people but, he was aware that there was a lack of systematic observation to support this conclusion. He rejected the belief that the Patagonians, who he calls the *Puelci*, have a normal height. Molina pointed out several similarities between trees and animals, especially between animal eggs and the seeds. A detailed comparison of the characteristics and the life cycles of many plants and animals is also reported.

In this *Memoria* Molina lacked clarity in employing certain terms, such as insight and intelligence, which he used in his descriptions of plants and animals; this invited trouble. As he later explained, his intent was not to use these terms in a metaphysical sense but only as an analogy, however, traditionalist in his audience, misinterpreted him as endowing animals and plants with human attributes, and were alarmed (Ronan 2002). As a result Molina was suspected of theological heterodoxy and denounced to the Archbishop of Bologna by his former student Camillo Ranzani (1775-1841) for dangerous doctrine and heterodoxy. While the controversy was being resolved Molina experienced several difficulties, including a denial of his teaching permit. Molina was absolved, in part because he expressed opinions common to the scientist of the epoch (Ronan and Hanish 1979). In spite of this controversy the texts of all the *Memorie* were printed in Bologna in 1822 by Molina's former students, after a review and approval by several ecclesiastic censors and including the subsequent cuts and corrections (Ronan 2002).

Several authors have seen Molina's philosophy in this *Memoria* as a sort of precursor to evolutionism (Espinosa 1965), in particular where he discussed the new idea of the transmutation of species. In this text Molina clearly expressed his adhesion to the idea of The Great Chain of Being, referring to the ancient Greek Neoplatonist philosophers, particularly in vogue during the Renaissance leading into the 18th century (Lovejos 1960). This theory rejects the concept of the specie, and states that all of the creation is a continuum, from Men, at the higher levels, to the lowest organisms. This philosophy was part of the Enlightenment, in which reason and logic were advocated as the primary sources for legitimacy and authority. This philosophy contrasted with those appearing during the revolutionary Romantic movement of the end of the 18th century promoting diversity and differentiation. Jean Baptiste Lamarck (1744-1829), who was among the main proponents of these new philosophies and one of the first to introduce the concept of evolution, is not cited by Molina in his books, while Bonnet's concept of continuity is cited several times. Nowhere in his books did Molina consider the concept of species nor that of evolution. From a geological point of view, the discoveries of Georges Cuvier's (1769 -1832) fossils in the Paris basin, modified the concept of The Great Chain of Being by placing it within a temporal scale and introducing a sort of progression, where the simplest fossils were at lower levels and the most complex organisms in the upper levels.

In this *Memoria* Molina expressed the scientific philosophy of the different natural kingdoms accepted at the time, introducing only a few concepts related to the idea of species and their evolution. All this is far from the present day concept of evolution. The controversy about his orthodoxy and the dangerous doctrine denouncement stemming from the innovative vision presented in his *Memorie*, most likely served to forward the concept of The Great Chain of Being that, by 1815, was all but obsolete. Moreover, Darwin (1839) made several references to Molina's descriptions of new species in South America, suggesting that he was aware of Molina's books published in London in 1809.

VII - The English gardens

In this lecture Molina began with a historical account of the tradition of incorporating gardens into towns. He observed that it was the French Jesuit Jean Denis Attired (1702-1768), a missionary to China, who inspired the English landscaper John Kent (1694-1748) to introduce the "natural garden" to England. In the final part of the *Memoria*, he catalogued the

different species of trees present in the Bologna countryside and their main characteristics.

VIII - On whales in the South Sea

Starting with a detailed discussion of historical knowledge about whales, Molina described the Pacific Ocean species that he was familiar with in Chile, and his experiences during his voyage from Chile to Europe. He disagreed with the French naturalist Buffon -Georges-Louis Leclerc, Comte de Buffon (1707-1788)- who in his book *Epoques de la Nature* of 1780, denied their existence in the southern Ocean. In the final part of the *Memoria*, he referred to the various whale hunting methods in different regions.

IX - On the propagation of trees, especially the spruce

The first pages of this *Memoria* cover the use of wood in different countries. This is followed by a description of the large diffusion of forests in Italy. Molina then proceeded to expose the practice of deforestation, especially in the mountain areas that results in widespread erosion and landslides. In the final portion he proposed reforestation using spruce.

X - On coal

Molina began his discussion of coal and carbon by describing the various popular practices of charcoal production, from wood pile to kiln, and explained its physical and chemical proprieties. The different applications of coal are reported, including gunpowder production, water purification, and its use in metallurgy as a reducing agent. He described the different types of fossil and mineral coals, from the superficial lignite to coal of the deep mines of England, Belgium and North America. He listed the coals transported via rivers in the Bologna region and suggested that the *olio di sasso* -rock oil-, or petroleum, may derive from the distillation of coal. In the Oligo-Miocene turbidites of North Apennines small blocks of coal are present, particularly in sandstones. Small mud vents, associated with methane emissions and oil seeps, are also known (Fig. 6).

Next Molina referred to the industrial uses of mineral coal for steam engines and the production of coal gas at the beginning of 19th century for light in London and other cities. Finally, he reported the different forms of carbon from diamonds to carbon dioxide.

XI - On Potosí, Peru's mountain of silver

In Molina's time Potosí was part of the viceroyalty of Peru, however, since 1825, it has been part of Bolivia. Potosí is the capital of the region of the same name and is located at an elevation of more than 4000 m, at the foot of Cerro de Potosí, sometimes referred to as Cerro Rico -Rich Mountain-, popularly believed to be made of silver ore. The city is of great historical importance, since it was the major supplier of silver to Spain during the Spanish colonial period.

Molina began by describing the location of Potosí, the morphology of the area, the local way of the life and the legend surrounding the discovery in 1545 of silver veins. The geological characteristics of the veins and the different types of the silver ore are then explained and a list of the main mine localities along the Andean Cordillera is included. Mining methods and ore transport using llamas are also explained together with metal extraction methods using mercury -amalgamation-.

XII - On the propagation of the human race in different parts of the world

This *Memoria* focuses on the question of the settling of peoples in the Americas and how it came about. Molina treated this argument using the same methodology as his other topics. First, he rejected several theories that he considered unacceptable. Then, he presented and rejected the theory of two Italian writers who proposed that peoples of the Italian peninsula sprang spontaneously from the earth like mushrooms. Instead, Molina argued that primitive people migrated and could cross wild mountain chains, vast deserts and wide rivers. Nevertheless, he pointed out that the substantial differences in physiognomy of the human races cannot be used as proof of differentiation because it is the product of geographic and climatic variation. As an example, Molina used the differences in the skin color of the Africans and the Americans living along the same latitude, with the black Africans living in a dry climate while the American "red-skin" people, in a humid one. He discussed the common opinion that the human race originated in the eastern regions of the globe and migrated to the west. Molina shared the opinion of other writers, for which the vast continent was "improperly called the New World", that the Americas were populated by several waves of people arriving from three different directions about a century after the Noachian flood -Great Flood-. He separated the Native American populations into two groups, those of the North and those of the South regions, each having different origins and characters. Some arrived in America by crossing "Cook's Strait" -the Bering Strait-, others via the many islands of the Pacific Ocean, and still others from northern Europe via Greenland and Labrador.

Molina contended that the indigenous populations of Peru and Chile migrated from India and the Orient at a much later date than the other inhabitants of South America. He asserted that the arrival of humans in Peru and Chile coincided or shortly followed the arrival of Alexander the Great at the Indus River. According to Molina the proof that the ancestors of the Chilean indigenous peoples were influenced by contact with the ancient Indo-Greek cultures lay in their knowledge of weaving, astronomy, the game of chess, and hydraulics; their methods for fusing metals, cultivation of cereals; their military tactics, and in particular, the structure and vocabulary of the Araucanian language with a large number of words that are not only of definite Latin or Greek origin but also carry the sa-

me meanings (Molina 1787).
Molina concluded this lecture by explaining the great potential of the human race to propagate across continents and oceans. All these questions are still under debate in our own time (Irwin 1992).

XIII - On cacao, vanilla and canella
This *Memoria* discusses the cacao plant and other flavorings and spices used in food preparation of the 16th and 17th centuries. Several sweeteners, such as cacao, were considered a sort of medicine but are deleterious to one's health.

XVI - On sugar
This last *Memoria* deals with the diffuse use of the sugar in the 18-19th centuries. The effects of sugar on one's health were also explained.

CONCLUSION

Molina's writings give a portrait of a man and a scientist with encyclopedic knowledge who is perfectly integrated into the scientific thought of the 18th and 19th centuries. He made an important contribution to the study of Chile's natural history and to the South American natural sciences in general. During his stay in Italy, he applied his knowledge and experience, which certainly contributed to the developed of the scientific method, to the study of the geological phenomena of the Bologna countryside. In his studies, he considered field observations and reasoning as the foundations for understanding of the natural phenomena. This is consistent with the modern approach to the study of natural sciences: starting from field data, proceeding to laboratory tests, and finishing with an examination and discussion of observations and results. In all his writings he begins with a logical, critical review of the past knowledge.
Without doubt, Molina was one of the most noted scientists of his day, highly regarded as a historian and naturalist as well as for his teaching excellence. Serving as testimony is the sheer numbers of his devoted students, attracted to him for his open minded approach to science and the experimental method. Being a lecturer, he was aware of the relationship between research and teaching and its importance in spreading the modern eclectic thinking. He was able to reconcile the dichotomy between scientific tenets and his religious profession endowing his treatises with an important philosophic method and a critical spirit. Although Molina lived most of his life outside Chile, he continued to nourish a deep love for his country, of which he was proud. The images that emerge from his writings have contributed to a large degree in acquainting the world with a true picture of his native land and its native peoples.

ACKNOWLEDGEMENTS

I am indebted to a Chilean friend, Pancho Hervé, and the Argentinean Victor Ramos for their encouragement in my research about Abbot Molina. The Bologna Archiginnasio Library kindly granted me access to the material related to the Abbot Molina. I am particularly obliged to Dott. Maria Fokin for reviewer the English spell. Thank you to the two reviews Nicola Ciancabilla, Reynaldo Charrier and to the Editor Guillermo Ottone for helpful comments.

WORKS CITED IN THE TEXT

Agassiz, L. 1840. Étude sur glaciers. Jent et Gassman, 347 p., Neuchâtel.

Berninghausen, W.H. 1962. Tsunamis reported from the west coast of South America 1562-1960. Bulletin of the Seismological Society of America 52(4): 915-921.

Boccaletti, M. and Martelli L. 2004. Carta Sismotettonica della Regione Emilia-Romagna, scala 1:250.000. Servizio Geologico Sismico e dei Suoli, 60 p., Firenze.

Borges, J.L. 1982. Nueve ensayos dantescos. Espasa Calpe, 161 p., Madrid.

Boschi E., Guidoboni E., Ferrari G., Mariotti D., Valensise G. and Gasperini P. 2000. Catalogue of Strong Italian Earthquakes from 461 B.C. to 1997. Annali di Geofisica 43: 609-868.

Cadelo, E. 2009. Quando i Romani andavano in America. Palombi & Partener, 293 p., Roma.

Castellarin, A. 2001. Alps-Apennines and Po Plain-frontal Apenines realtions. In Vai, G.B. and Martini, I.P. (eds.) Anatomy of an Orogen: the Apennines and adjacent Mediterranean Basin. Kluwer Academic Publisher: 177-196, Dordrecht.

Cavazza M. 1990. Settecento Inquieto. Alle origini dell'Istituto delle Scienze di Bologna. Il Mulino, 281 p., Bologna.

Cavazza, M. 2002. Society in the eighteenth century. The Institute of Science of Bologna and the Royal Society in the eighteenth century. Notes and Records of the Royal Society of London 56: 3-25.

Cita M.B. and Corselli, C. 1990. Messinian paleogeography and erosional surfaces in Italy: an overview. Palaeogeogeography, Palaeoclimatology, Palaeoecology 77(1): 67-82.

Darwin, C.R. 1839. Narrative of the surveying voyages of His Majesty's Ships Adventure and Beagle between the years 1826 and 1836, describing their examination of the southern shores of South America, and the Beagle's circumnavigation of the globe. Journal and remarks. Volume III. Henry Colburn, 615 p., London.

de Olivares, M. 2005. Los Jesuitas en la Patagonia: Las misiones en la Araucanìa y el Nahuelhuapi (1593-1736). Continente, 224 p., Buenos Aires

Espinosa, J. 1946. El Abate Molina, uno de los precursores de Darwin. Zig-Zag: 65-191, Santiago.

Falkner, T. 1774. A Description of Patagonia, and the Adjoining Parts of South America; containing an account of the soil, produce, animals, vales, mountains, rivers, lakes, &c. of those countries; the religion, government, policy, customs, dress, arms, and language of the Indian inhabitants; and some particulars relating to Falkland's Islands. C. Pugh, T. Lewis, 144 p., London, Hereford.

Galeano, E. 1984. Las venas abiertas de América Latina. Catalogos, 379 p., Buenos Aires.

González de Agüeros, P. 1791. Description historial de la provincia y archipiélago de Chiloé, en el Reyno de Chile y Obispado de ka Concepción. Don Benito Cano, 318 p., Madrid.

Grasso Ibarra, D.E. 1994. Sud America Indigena. TEA, 715 p., Buenos Aires.

Hallam, A. 1989. Great geological controversies. Oxford University Press, 244 p., New York

Irwin G. 1992. The prehistoric exploration and

coloniasation of the Pacific. Cambridge University Press, 240 p., Cambridge.

Jaramillo, B.R. 1967. *Memoria*s de historia natural, segunda fase de la obra escita de Molina (1812 -1822). Revista Universitaria 52: 85-99.

Jiménez J. 1974. El abate Molina: humanista clásico y sabio cristiano. Universidad Católica de Chile, Anales de la Facultad de Teología 24, 284 p., Santiago.

Lamb, H.H. 1972. Climate: Present, Past and Future. Vol. 1: Fundamentals and Climate Now. Methuen, 613 p., London.

López Gamundi, O.R. 1983. Modelo de sedimentacion glacimarina para la Formacion Hoyada Verde, Paleozoico superior de la provincia de San Juan. Revista de la Asociación Geológica Argentina 38(1): 60-72.

Lovejos, A.O. 1960. Great chain of being. Harvard University Press, 382 p., Massachuset.

Lyell, C. 1830. Principles of Geology, being an attempt to explain the former changes of the Earth's surface, by reference to causes now in operation. Vol. I. John Murray, xv, 511 p., London.

Mann, M.E., Bradley, R.S. and Hughes, M.K. 1999. Northern Hemisphere temperatures during the past millennium: inferences, uncertainties, and limitations. Geophysical Research Letters 26: 759-762.

Matthes, F. 1939. Report of Committee on Glaciers. Transactions of the American Geophysical Union 20: 518-535.

Molina, J.I. 1776. Compendio della storia geografica naturale e civile del regno del Chili. Stamperia di S.Tommaso d'Aquino, 367p., Bologna.

Molina, J.I. 1782. Saggio sulla storia naturale del Chile del signor Abate Giovanni Ignazio Molina. Stamperia di S.Tommaso d'Aquino, 367p., Bologna.

Molina, J.I. 1787. Saggio sulla storia civile del Chili. Stamperia di S. Tomasso d'Aquino, 333 p., Bologna.

Molina, J.I. 1810. Saggio sulla storia naturale del Chili. Tipografia De' Fratelli Masi e Comp., 306 p., Bologna.

Molina, J.I. 1821a. Memorie di storia naturale, lette in Bologna, nelle adunaze dell'istituto, dall'abate Gion-Ignazio Molina, Americano, miembro dell'istituto pontificio. Tipografía Marsigli, Prima Parte, 283 p. Bologna.

Molina, J.I. 1821b. Memorie di storia naturale, lette in Bologna, nelle adunaze dell'istituto, dall'abate Gion-Ignazio Molina, Americano, miembro dell'istituto pontificio. Tipografía Marsigli, Prima Parte, 283 p., Seconda Parte, 251 p. Bologna.

Parrot, M. 1994. Statistical study of ELF/VLF emissions recorded by a low altitude satellite during seismic events. Journal of Geophysical Research 99: 23, 339-23, 347.

Pedretti, C. 1985. Leonardo: il Codice Hammer e la Mappa di Imola. Giunti Barbera, 205 p., Firenze.

Pini, G.A. 1999. Tectonosomes and olistostromes in the Argille Scagliose of the Northern Apennines, Italy. Geological Society of America, Special Paper 335, 70 p.

Ramos, V. 2009. Darwin at Puente del Inca: observations on the formation of the Inca's bridge and mountain building. Revista de la Asociación Geológica Argentina 64(1): 170-179.

Ronan, C.E. 2002. Juan Ignacio Molina. The world's window on Chile. P. Lang, 318 p., New York.

Ronan, C.E. and Hanisch, E.W. 1979. Epistolario de Juan Ignacio Molina S.J. Editorial Universitaria, 257 p., Santiago.

Rondoni, E. 2009. Gli olivi nella collina di Bologna (http://olivisecolari.ibimet.cnr.it/index.php?id=259)

Ryan, W.B. 2007. Status of the Black Sea flood hypothesis. In Yanko-Hombach, V., Gilbert A.S., Panin, N. and Dolukhanov, P.M. (eds.) The Black Sea flood question. Springer: 63-88, Dordrecht.

Ryan,W.B. and Pitman, W. 1998. Noah's Flood. The new scientific discoveries about the event that changes history. Simon & Schuster, 319 p., New York.

Salinas, A. 1998. El Abate Molina y la ciencia de su época. Universum 13: 211-225.

Santágata, A. 1845. De vita et doctrina. Io. Ignatii Molinae, chilensis, Bolonia; traducción de Barrios Casamayor, Pedro, 1860. Anales de la Universidad de Chile 17: 613-630.

Sarti, C. 2003. The Istituto delle Scienze in Bologna and its geological and palaeontological collections in the 18th century. In Vai, G.B. and Cavazza, W. (eds.) Four centuries of the word geology: Ulisse Aldrovandi 1603 in Bologna. Minerva: 204-219, Bologna.

Sartori, R. 2003. Luigi Ferdinando Marsili, founding father of oceanography. In Vai, G.B. and Cavazza, W. (eds.) Four centuries of the word geology: Ulisse Aldrovandi 1603 in Bologna. Minerva: 169-177, Bologna.

Vai, G.B. 2009. The scientific revolution and Nicholas Steno's twofold conversion. In Rosenberg, G.D. (ed.) The Revolution in Geology from the Renaissance to the Enlightenment. Geological Society of America, Memoir 203: 187-208.

Vai, G.B. and Cavazza, W. 2003. Four centuries of the word geology. Ulisse Aldrovandi 1603 in Bologna. Minerav, 326 p., Bologna.

Vai, G.B. and Cavazza, W. 2006. Ulisse Aldrovandi and the origin of geology and science. In Vai, G.B. and Caldwell, W.G.E. (eds.) The origin of Geology in Italy. Geological Society of America, Special Publication 411: 43-63.

Zunino, M. 2007. LatinoAmérica ante las ciencias de la naturaleza y del medio ambiente. Materiales para una reflexion historica. Acta Zoologica Mexicana, nueva serie, 23(3): 181-190.

Recibido: 2 de marzo, 2011.
Aceptado: 29 de junio.