De Re Metallica, 13, 2009 pp. 35-41

ISSN: 1577-9033

MINING ACADEMIES AS CENTERS OF GEOLOGICAL RESEARCH AND EDUCATION IN EUROPE BETWEEN THE 18TH AND 19TH CENTURIES[1]

Ezio Vaccari

Dipartimento di Informatica e Comunicazione, Università dell'Insubria,
via Mazzini 5, 21100 Varese (Italy)
ezio.vaccari@uninsubria.it

ABSTRACT

The importance of the early activities of the mining academies for the scientific development of the Earth sciences is generally accepted by historians of geology, mining and metallurgy, but it needs more support from new detailed researches on primary sources. The teaching programs of these centers of education, where also distinguished scientists were employed, did not include only the technical disciplines traditionally connected to mining, but also scientific courses, which included mineralogy, lithology and geology. This paper intends to offer an overview of this historiographical question within the European context.

KEY WORDS: Mining academies, history of geology, history of mineralogy, mining education, geological education, Europe, 18th century, 19th century.

RESUMEN

La importancia de las primeras actividades de las escuelas de minas para el desarrollo científico de las Ciencias de la Tierra está generalmente aceptada por los historiadores de la geología, la minería y la metalurgia, pero necesita más apoyo de nuevas investigaciones detalladas sobre las fuentes primarias. Los programas de enseñanza de estos centros, que emplearon también a distinguidos científicos, no sólo incluyeron las disciplinas técnicas tradicionalmente relacionadas con la minería, sino que también se desarrollaron cursos científicos, que contemplaron la mineralogía, la geología y la litología. El presente trabajo pretende ofrecer una visión general de esta cuestión historiográfica en el contexto europeo.

PALABRAS CLAVE: Escuelas de minas, historia de la geología, historia de la mineralogía, educación minera, educación geológica, Europa, siglo XVIII, siglo XIX.

INTRODUCTION

The aim of the 18th century mining academies was to create a completely new type of higher education at the same level of the classical universities.Most of the historians agree in stating that toward the end of the 18th century the development of new techniques, together with the increasing demand for metals and the problems of exploitation, required the formation of a new trained class of mining officers and experts. The European models of education and training in the mining industry have been studied in detail by Donata Brianta (2000; 2007).In the cases of Freiberg and Schemnitz the foundation of the mining academies was mainly the regulation and reinforcement of a local mining tradition which had already been in existence for a long time, but for example in the case of Paris, the establishment of the École des Mines was an attempt to create a completely new category of French mining experts free from foreign influences. Moreover, in the German speaking world, the mining academies compensated for the lack of teaching of mineralogy and mining within the universities. Through the teaching programs of the new Academies, the students were not simply instructed in the techniques and in the disciplines traditionally connected to mining, such as metallurgy, but were also introduced to the scientific study of mineralogy and geology. Some of the professors were distinguished scientists, who played a significant role in the development of mineralogy and in the birth of geology as a science, particularly during the last decades of the 18th century.

[1] In memory of Donata Brianta (1951-2009).

To date the mining academies have been studied mainly individually within local contexts (e.g. Aguillon, 1889; Valentiner, 1925; Wächtler *et al.*, 1965; Vlachovich, 1976; Strunz, 1979), or more recently in a comparative overview (Habashi, 2003), although an historical analysis concerning their specific role within the development of geological research and education does not yet exist especially for the late 18th and the early 19th centuries, which was the critical time of their formation. The importance of the mining academies for the history of the Earth sciences is acknowledged within the historiography (Vaccari, 1998a), but this recognition needs more support from new comparative in depth research on institutional and economic-political history, as well as on history of technology, history of science and history of mining heritage.

MINING ACADEMIES IN THE HISTORY OF GEOLOGY AND MINERALOGY

The early history of the mining academies can be significantly investigated thanks to the impressive and invaluable richness of their libraries and archives, which in some cases (e.g. Freiberg or Paris) may be considered highly specialized collections of primary sources, not only in the history of mining and metallurgy, but also in the field of the history of geology and mineralogy. Moreover, the history of mining schools and academies is important because the seventy years between 1760 and 1830, which marked the establishment and the main growth of these new specialized technical-scientific training institutions particularly in Europe, represents a crucial period for the emergence of geology as a scientific discipline (Guntau, 1978; Laudan, 1987; Vaccari, 1998b). And this new science was also strongly connected to the "knowledge of the Earth" obtained through mining practice (Vaccari & Morello, 1998; Vaccari, 2000).

It is well known that the term "geology" came to be used by several scholars to indicate a scientific discipline from the last decades of the 18th century and especially from the 1780s onward. However, many geological researches continued to be included within the wider definition of "mineralogy", as in some early 19th century works. Although the terminological framework is clearly non-homogeneous,from the 1770s and the 1780s the presence of an international scientific community devoted to what we now call 'geological sciences', often based on fieldwork on a regional basis, may be found throughout most of Europe. It was a specialized scientific community with a well organized internal system of communication: personal meetings, correspondence, publications and geo-mineralogical travels undertaken in order to collect specimens, make observations and discuss geological questions in the field. During the crucial years from 1760 to 1830 the development and diffusion of geological research, as well as the means of training (or self-training) in order to become an Earth scientist, changed significantly due also to the emergence of new institutional references. Since the middle of the 18th century the number of geological studies had increased drastically in different European countries, as had their reception within the scientific community. In the late 18th century the Earth scientists were naturalists, scientists involved in chemical, botanical or medical studies, amateurs and collectors of naturalistic specimens, but also scholars with a technical background drawn particularly from mining. These latter scholars came from German speaking countries (including Hungary, Bohemia and other central-eastern European mining districts), but also from England, Sweden and some Italian States. They were mining experts with a strong practical technical background, often self taught in mineralogy and chemistry (as well as mathematics and physics), who achieved great results in the geological study of the Earth's surface.

The teaching and study of geological subjects played only a minor role within the 18th century European universities: in Italy for example, only some professors of natural history (such as Antonio Vallisneri junior in Padua or Lazzaro Spallanzani in Pavia) gave courses on the 'mineral kingdom'. Sometimes these chairs of Natural History continued to include geology until the mid-19th century, even if new specialized chairs in botany and chemistry were established. Around the mid-18th century, the first chairs of chemistry also included mineralogy, in countries with a well established mining tradition such as Sweden, Russia or some German States (Porter T, 1981). By the end of the century the first mineralogical societies were established in Jena (1798), London (1799) and New York (1799), ten years before the Geological Society of London (1807).The first mineralogical journals such as the "Magazin für die gesamte Mineralogie" (1801-1810) or the "Taschenbuch für die gesamte Mineralogie" (1807-1824), often included geological debates (Guntau, 1991).

This fundamental relationship between the old practice of mining and the new science of geology through mineralogy has been studied by several authors during the last thirty-five years (Porter R, 1973; Guntau, 1978; Laudan, 1987; Vaccari, 1993, 2000), who emphasized the 18th century fundamental contribution given by mining expertise to the development of geological investigations and theories. However, these studies did not provide a comparative analysis of the institutions where the definition of the new geological science and the gradual professionalization of the scientist as a 'geologist' took place from the last decades of the 18th century: these institutions were not the universities nor the scientific societies (although the latter were sometimes very significant for geology, as in the case of the Royal Society of Edinburgh), nor even museums such as the Muséum d'Histoire Naturelle of Paris (although it promoted the teaching of geology), but they included the mining academies, which represented an international phenomenon with a strong impact not only on the development of technical-scientific education, but also on research and communication.

THE SCIENTIFIC ROLE OF MINING EDUCATION

The first mining academies were established for political-economical reasons by the governments of some central European States during the late 18th century and these often followed on from a previous tradition of mining schools ("bergschule") and private technical teaching. Although these new institutions were not part of an academic scientific project and did not clearly display a scientific aim, the scientists interested in geological and mineralogical matters viewed them with particular interest. In fact, these scientists believed in the importance of combining the knowledge acquired in mining with detailed geological fieldwork in order to provide new answers to the old questions raised by the rigid interpretative models of the "theories of the Earth" proposed from the middle of the 17th century. According to these scientists, observing a mining area meant studying the mineral veins inside the mine together with the surrounding lithological, geomorphological and stratigraphical features. They also knew that the valuable heritage of practical mining knowledge, which could be usefully employed within geo-mineralogical or litho-stratigraphical studies, was not usually available in printed or even written documents (Eyles, 1969).Part of this gap was gradually filled by the published works of some travelling mineralogists, such as Johann Jakob Ferber (1743-1790) and Ignatz von Born (1742-1791), who visited and described various mining districts in central-eastern Europe during the 1770s and 1780s for technical-metallurgical as well as scientific-geological puroposes. During the same years some distinguished mining officers gave significant contributions to lithological studies, as in the case of Giovanni Arduino (1714-1795) in Tuscany and the Venetian Republic, Johann Gottlob Lehmann (1719-1767) in Saxony and Prussia, Georg Christian Füchsel (1722-1773) in Thuringia and Axel Cronstedt (1722-1765) in Sweden.

Within this context the aim of the international mining society "Societät der Bergbaukunde", founded in 1786 under the direction of Ignatz von Born and Friedrich Heinrich Wilhelm von Trebra (1740-1819), can be considered as an attempt to assign an higher scientific status to mining and metallurgy, by also showing their connections to geology and mineralogy. Not by chance, the nominated 'national directors' ("directoren") of the Society included several distinguished scientists involved in geology and mineralogy, such as Giovanni Arduino for Italy, Johann Wilhelm Friedrich Charpentier (1738-1805) for Saxony, Martin Brünnich (1737-1827) for Denmark, John Hawkins (1761-1841) for England, Philipp Friedrich Baron von Dietrich (1748-1793) for France and Peter Simon Pallas (1741-1811) for Russia. Among the members from more than 15 countries, not only mining experts may be found, but more active geologists such as the Italians Alberto Fortis (1741-1803), Spirito Benedetto Nicolis di Robilant (1724-1801) and Ermenegildo Pini (1739-1825), as well as the Briton William Hamilton (1730-1803) in Naples; the German Rudolf Erich Raspe (1736-1794) in England and Richard Kirwan (1733-1812) in Ireland; the travelling geologist Horace Bénédict de Saussure (1740-1799) in Switzerland. Moreover, the link between mining and geology appears rather evident in the title page of the first volume of the journal of the society, *Bergbaukunde* (Born & Trebra, 1789), which represented a spectacular basaltic cliff probably from the Fingal Caves of the Island of Staffa in Scotland (Figure 1): a picture not devoted to a technical mining or metallurgical subject, but to a geological problem widely debated at the end of the 1780s, the origin of basalt (Den Tex, 1996).

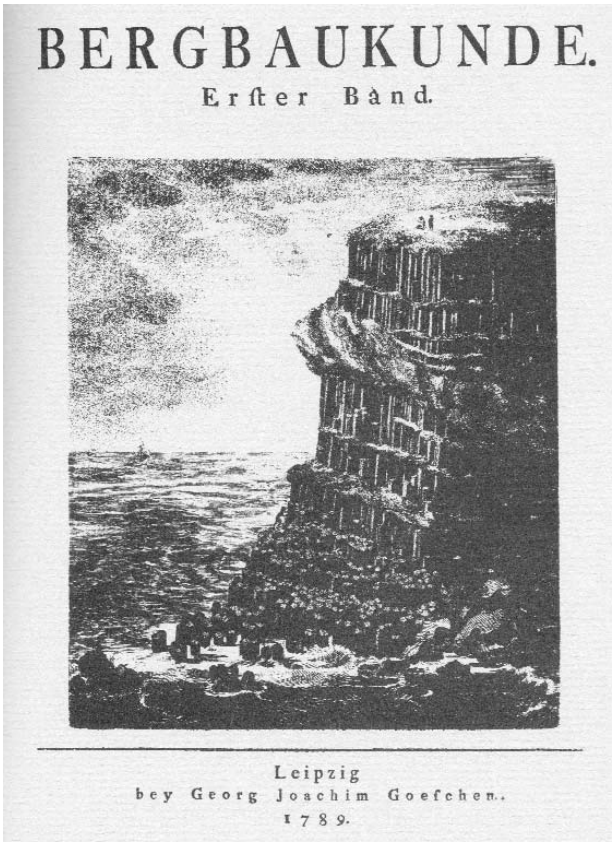

Figure 1. Title page of Bergbaukunde 1789.

In the late 1780s the mining academies in Saxony (Freiberg, est. 1765), Austro-Hungarian Empire (Schemnitz, est. 1770), Prussia (Berlin, est. 1770), Russia (St. Petersbourg, est. 1773), Harz (Clausthal, est. 1775), Spain (Almaden, est. 1777) and France (Paris, est. 1783) had already been established: they aimed to create a new category of mining officers (later called mining engineers) with a solid specific technical-scientific training, not necessarily aimed at the mining district where the academy was located. Consequently these institutions gradually offered possible alternative job opportunities to scientists who were also able to work within the universities (e.g. the Écoles Polytechniques in France), as the mining academies provided courses of chemistry, mathematics, physics, geometry, besides other technical subjects. However, new scientific cours-

es were also gradually introduced and for some European geologists this was really a new opportunity to be employed for the first time in order to teach their own research subjects particularly in mineralogy, lithology and stratigraphy.

GEOLOGY IN THE MINING ACADEMIES: FREIBERG, SCHEMNITZ, PARIS

It took some time before Geology became part of the mining academies' educational structure, as in the case of the Mining Academy (Bergakademie) of Freiberg, established in 1765: during the first decade of its activity, the number of metallurgical – technical courses far outweighed the theoretical scientific ones and the geo-mineralogical courses were introduced later (Reich, 1850: 23-35). In fact, one of the first professors of the academy, the mineralogist and lithologist Johann Wilhelm Friedrich Charpentier (Figure 2), who published a coloured lithological map of Saxony (Charpentier, 1778) gave theoretical courses of geometry, mathematics and physics, before Abraham Gottlob Werner (1749-1817) (Figure 3) started in 1775 his courses in mineralogy and mining exploitation ("Bergbaukunst"). This was followed in 1779 by the new course "Gebirgslehre" (lithology and theory of rock formation), which was later divided into "Oryctognosie" (lithology) and "Geognosie" (historical geology).

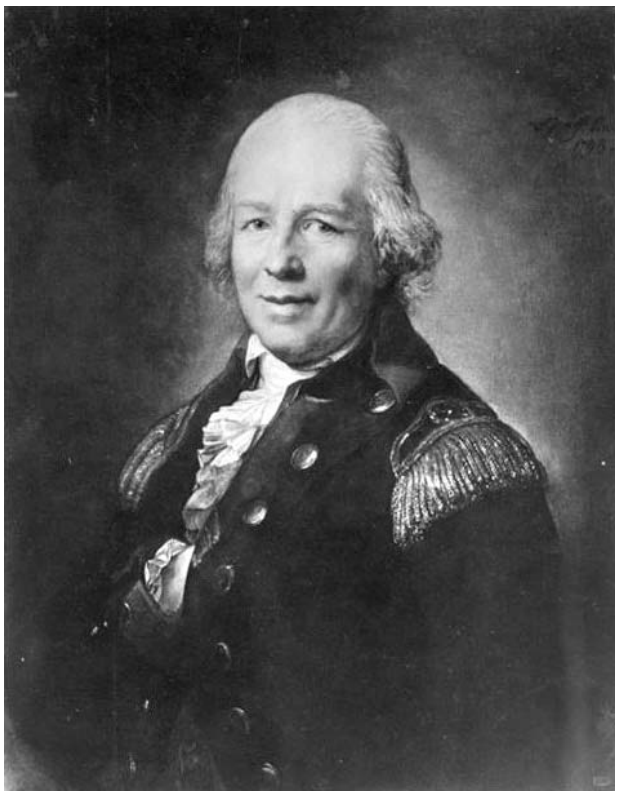

Figure 2. Johann Wilhelm Friedrich Charpentier (1738-1805).

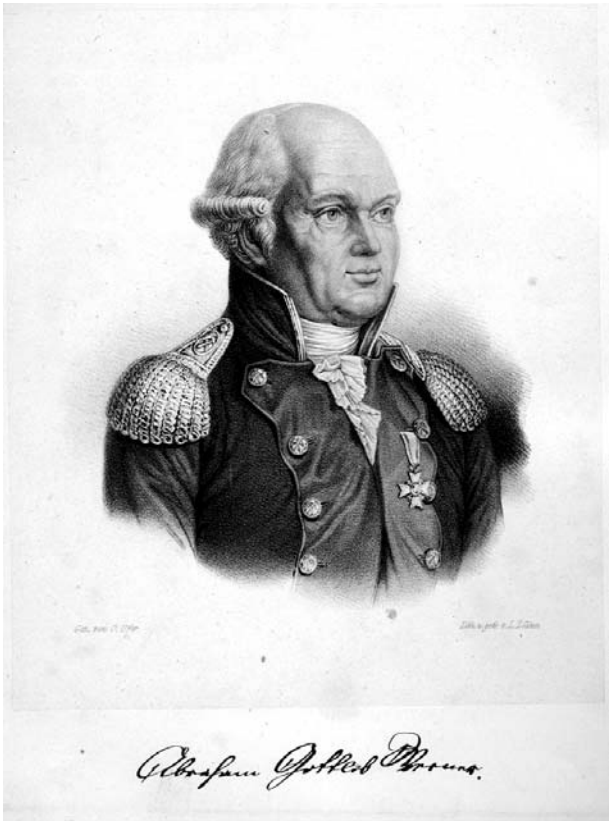

Figure 3. Abraham Gottlob Werner (1749-1817).

In Schemnitz, besides the usual teaching of "mathematics" (with applied physics and mechanics) used for surveying purposes (Figure 4), there were also courses in mineralogy, chemistry and metallurgy, as well as mining techniques, including the lithological study of mountains and rock types in relation to minerals (Zsámboki, 1996).This 'geological perspective' in teaching at Schemnitz was particularly pursued by scientists such as Giovanni Antonio Scopoli (1723-1788) (Figure 5) and Christoph Traugott Delius (1720-1799) during the 1770s.

It is well known that the Mining Academy of Freiberg attracted several students from all over Europe and sometimes from the Americas (Gottschalk, 1866), par-

Figure 4. Students of the Mining Academy of Schemnitz (from Peithner, 1780).

Figure 5.Giovanni Antonio Scopoli (1723-1788).

272 Insp. Werners kurze Klassification und Beschreibung

VII.

Kurze Klassifikation und Beschreibung
der
verschiedenen Gebirgsarten. a)
von
A. G. Werner, Berg-Inspektor zu Freyberg.

§. 1.

Von den verschiedenen Gebirgsarten überhaupt.

So äußerst mannigfaltig diejenigen Steinarten, welche die Gebirge, oder überhaupt die Masse unsers festen Erdkörpers ausmachen, (Bergarten, Gebirgsarten,) dem ersten Ansehen nach zu seyn scheinen; so findet man doch bey näherer Untersuchung, daß ihre Verschiedenheit nichts weniger, als bis ins Unendliche gehet, und daß die meisten derselben, in Ansehung ihrer Natur, sehr ausgezeichnet und bestimmbar sind. Es ist sogar wahrscheinlich, daß wir den größten Theil derselben bereits kennen: weil, nach den Beobachtungen reisender Naturforscher, die Gebirgsarten, auch der entferntesten Länder, insgemein mit unsern bekannten Gebirgsarten übereinkommen.

§. 2.

a) Gegenwärtige Abhandlung ist eigentlich eine bloße Skizze, wie denn diese wichtige Materie nächstens in einem eigenen Werke von dem gelehrten Verfasser ausführlicher behandelt werden wird. A. d. H.

Figure 6. Title page of Werner 1786.

ticularly in the period of Werner's teaching (1775-1817), which emphasized the importance of the geological knowledge integrated with mining expertise.Thanks to Werner Freiberg became not only a center of technical specialized training, but also a center of geological and mineralogical research (Albrecht & Ladwig, 2003). In his work *Kurze klassification und Beschreibung der verschiedenen Gebürgsarten* (1786) (Figure 6) Werner proposed a classification of rocks separated from the classification of minerals. His taxonomy of rocks reflected the series of the geological periods of the Earth's history. One of his aims was to find a possible link between lithology and mineralogy for associating certain rocks to specific minerals.According to Werner, the knowledge of what we now call "regional geology" would allow immediate recognition of the presence of useful minerals and consequently the pursuit of the direction of their veins. Werner tried to document and organize scientifically this way of thinking, already in existence, among mineralogists involved in mining: this attitude of mind improved significantly also the meaning of the geo-mineralogical collection organized for teaching purposes (Figure 7).

Figure 7. Mineralogical museum and library of the Mining Academy of Freiberg (from Kern, 1772)

Moreover, Werner elaborated in Freiberg a well known geological theory, later defined by his pupils as "Neptunismus", which regarded as essential the sedimentary process for the formation of most rocks of the Earth's surface. The widespread and rapid diffusion of Neptunistic ideas among the late 18th - early 19th century geologists was certainly favoured by Werner's distinguished position as professor of geological and mineralogical subjects in one of the most successful European mining academies (Wagenbreth, 1967; Vaccari, 1998c): but on the other hand the Bergakademie became more visible and renowned thanks to Werner's teaching and publications.

The mining academy of Freiberg not only exported its teaching model to other similar institutions, but also became a tool for the diffusion of a geological model of

interpreting the Earth's history: for example, the Italian Matteo Tondi (1762-1835), who was a student of Werner in 1793 and later became professor of mineralogy in Naples, published two neptunistic treatises, the *Elementi di Orittognosia* (Naples, 1817) and the *Elementi di Oreognosia* (Naples, 1824); the Spanish mineralogist Andrés Manuel del Río (1765-1849), was also a pupil of Werner in Freiberg and later became professor of mineralogy and geology (1794) at the mining academy in Mexico City ("Real Seminario de Minería"). Del Rio's main work, *Elementos de Orictognosia* (Mexico, 1795) based on the Wernerian system as a textbook for the students of the Mexican mining academy, was also significantly influential for the development of geology in Spain.

In France the École Royale des Mines, established in 1783 in Paris under the direction of Balthazar-Georges Sage (1740-1824) (Figure 8) - who also taught mineralogy - employed a number of renowned geologists and mineralogists especially after the 1794 reorganization: Déodat de Dolomieu (1750-1801), André Jean Marie Brochant de Villiers (1772-1840), René Just Haüy (1743-1822) and Jean-Baptiste-Armand-Louis-Léonce Élie de Beaumont (1798-1874). They all linked their original research work to teaching and in the case of Brochant de Villiers the influence of Werner's mineralogy and 'geognosy' was significant.

The cases of Freiberg, Paris and Schemnitz are probably the most prominent in Europe, but the role of the other academies as well as the school of mines should not be underestimated: in addition the cases of England and Sweden should be carefully considered, as the lack of mining academies during the 18th century in these countries, in spite of their long-standing mining tradition, was due to different reasons such as the predominant role of private enterprise in England and the presence of the state-controlled Bergskollegium in Sweden.

CONCLUSIONS

Between the late 18th and the early 19th century the mining academies established a new type of higher technical-scientific education which was not provided in the universities, in particular regarding geological knowledge acquired in the field, also through mining practice. Consequently the academies offered to some emerging geologists the possibility to undertake research work and teaching in the field of the Earth sciences which had not been available previously within an institutional context. One of the most significant results of the methodological approach adopted by the various scientists teaching geology or mineralogy in the mining academies was "their attention to the field as well as to the laboratory" (Laudan, 1987: 47). Moreover teachers and former students of the mining academies published geological and mineralogical textbooks especially at the beginning of the 19th century: for example the *Elementos de orictognosia* by Da Rio, the *Traité elementaire de minéralogie* (1801-01) by Brochant de Villiers, and the

Figure 8.Balthazar-Georges Sage (1740-1824).

Traité de Geognosie (1819) by Jean-François d'Aubuisson de Voisins (1762-1841), as well as the works by Matteo Tondi and the *Manuale geologico* (1809) of another Italian pupil of Werner, Giuseppe Melograni (1750-1827).

In 1831 Ami Boué (1794-1881), one of the founders of the Societè Géologique del France, published in his *Journal de Géologie* a long "Notice sur les nouvelles societés savantes qui s'occupent de géologie et sur les publications periodiques interessant pour le géologue": thus in the crucial years when Charles Lyell was publishing the *Principles of Geology* the new science was achieving a complete disciplinary status. The institutional context had significantly changed from the last decades of the 18th century: new geological societies, new university chairs, new specialized periodicals were listed by Boué and furthermore the first European geological surveys would be established in the 1840s. Henceforth the mining academies, which as centers of geological research and education had made a major contribution to the final institutional development of the new science of geology, began to loose their impact on the scientific community. Their importance as centers of technical instruction would instead increase from the second half on the 19th century.

REFERENCES

Aguillon, L. 1889. L'École des Mines de Paris. Notice Historique. *Annales des Mines*, 15, 433-686.

Albrecht, H. & Ladwig, R. (eds.) 2003. *Abraham Gottlob Werner and the Foundation of the Geological Sciences. Selected*

Papers of the International Werner-Symposium in Freiberg, 19th to 24th September 1999. Freiberger Forschungshefte D 207 - Montan und Technikgeschichte, Freiberg, 396 pp.

Born, I. von & Trebra, F.W.H. von (eds.) 1789. *Bergbaukunde*. G.J. Goeschen, Leipzig, vol. I, 408 pp.

Brianta, D. 2000. Education and Training in the Mining Industry, 1750-1860: European Models and the Italian Case. *Annals of Science*, 57, 267 - 300.

Brianta, D. 2007. *Europa mineraria. Circolazione delle élites e trasferimento tecnologico (scoli XVIII-XIX)*, Franco Angeli, Milano, 447 pp.

Charpentier, J.F.W. 1778. *Mineralogische Geographie der Chursächsischen Lande*, bey Siegfried Lebrecht Crusius, Leipzig, 434 pp.

Den Tex, E. 1996. Clinchers of the basalt controversy: Empirical and experimental evidence. *Earth Sciences History*, 15, 37-48.

Eyles, V. 1969. The extent of geological knowledge in the Eighteenth century and the method by which it was diffused. In: C.J. Schneer (ed.), *Toward a history of geology*. M.I.T. Press, Cambridge (MA) & London, 214-225.

Gottschalk, C.G. 1866, Verzeichniss Derer, welche seit Eröffnung der Bergakademie und bis Schluss des ersten Säculum's auf ihr studirt haben. In: *Festschrift hundertjährigen der Königl. Sächs. Bergakademie zu Freiberg am 30 juli 1866*. Meinhold & Söhne, Dresden, 227-249.

Guntau, M. 1978. The emergence of geology as a scientific discipline. *History of Science*, 16, 280-290.

Guntau, M. 1984.*Abraham Gottlob Werner*. Teubner, Leipzig, 120 pp.

Guntau, M. 1991. Geologische Institutionen und Staatliche initiativen in der Geschichte. In: Büttner, M. & Kohler, E. (eds.), *Geosciences/Geowissenschaften. Proceedings of the Symposium of the XVIIIth International Congress of History of Science*. III.Teil, Universitätsverlag,Bochum, 229-239.

Habashi, F. 2003. *Schools of Mines. The Beginnings of Mining and Metallurgical Education*. Métallurgie Extractive Québec, Sainte-Foy - Québec, 588 pp.

Kern, J.G. 1772. *Bericht vom Bergbau*. S.L. Crusius, Leipzig, 312 pp.

Laudan, R. 1987. *From Mineralogy to Geology. The foundations of a science 1650-1830*. Chicago University Press, Chicago, 278 pp.

Peithner, J.T.A. 1780. *Versuch über die naturliche und politische Geschichte der böhmischen und märischen Bergwerke*. M.A. Schmidt, Wien, 464 pp.

Porter, R. 1973, The Industrial Revolution and the rise of the science of geology. In: Teich, M. & Young R. (eds.) *Changing perspective in the history of science*. Heinemann, London, 320-343.

Porter, T. 1981. The promotion of mining and the advancement of science: the chemical revolution of mineralogy. *Annals of Science*, 38, 543-570.

Reich, F. [1850]. *Die Bergakademie zu Freiberg. Zur Erinnerung an die Feier des hundertjährigen Geburtstages Werner's am 25. September 1850*. J.G. Engelhardt, Freiberg, 122 pp.

Strunz, H. 1979.*Von der Bergakademie zur Technischen Universität Berlin, 1770-1970*, Glückauf, Essen, 151 pp.

Vaccari, E. 1993. *Giovanni Arduino (1714-1795). Il contributo di uno scienziato veneto al dibattito settecentesco sulle scienze della Terra*, Olschki, Firenze, 408 pp.

Vaccari, E. 1998a. Mining Academies. In: Good, G.A. (ed.), *Sciences of the Earth: An Encyclopedia of Events, People and Phenomena*. Garland, New York & London, 585-589.

Vaccari, E. 1998b. Geology: Disciplinary History. In: Good, G.A. (ed.), *Sciences of the Earth: An Encyclopedia of Events, People and Phenomena*. Garland, New York & London, 329-337.

Vaccari, E. 1998c. Mineralogy and mining in Italy between 18th and 19th centuries. The extent of Wernerian influences from Turin to Naples. In: Fritscher, B. & Henderson, F. (eds.), *Toward a History of Mineralogy, Petrology and Geochemistry*. Institut für Geschichte der Naturwissenschaften, München,107-130.

Vaccari, E. 2000. Mining and knowledge of the Earth in Eighteenth-century Italy. *Annals of Science*, 57, 163-180.

Vaccari, E. & Morello, N. 1998. Mining and knowledge of the Earth. In: Good, G.A. (ed.), *Sciences of the Earth: An Encyclopedia of Events, People and Phenomena*. Garland, New York & London, 589-593.

Valentiner, S. (ed.) 1925. *Die Preussische Bergakademie zu Clausthal 1775-1925. Festschrift zur 150-Jahrfeier*. Preussische Bergakademie, Clausthal, 512 pp.

Vlachovich, J. 1976, Die Bergakademie in Banska Stiavnica (Schemnitz) im 18.Jahrhundert. In: Amburger, E., Ciesla, M. & Sziklay, L. (eds.), *Wissenschaftspolitik in Mittel- und Osteuropa*. Verlag Ulrich Camen, Berlin, 206-220.

Wächtler, E., Wagenbreth, O., Baumgärtel, H. et al. 1965. *Bergakademie Freiberg, Festschrift zu ihrer Zweihundertjahrfeier*. Vol. 1. *Geschichte der Bergakademie*. Deutscher Verlag für Grundstoffindustrie, Leipzig, 409 pp.

Wagenbreth, O. 1967. Werner-Schüler als Geologen und Bergleute und ihre Bedeutung für die Geologie und den Bergbau des 19. Jahrhunderts. In: *Abraham Gottlob Werner. Gedenkschrift*. Deutscher Verlag für Grundstoffindustrie, Leipzig, 163-178.

Werner, A.G. 1786. Kurze Klassifikation und Beschreibung der verschiedenen Gebirgsarten. *Abhandlungen der Bömischen Gesellschaft der Wissenschaften*, 2, 272-297.

Zsámboki, L. 1996. The first hundred years of teaching geological sciences at the Selmecbánya (Schemnitz) School (later Academy) of Mining. In: Dudich, E. & Lobitzer, H. (eds.), *Austrian-Hungarian Joint Geological Research*. MÁFI, Budapest, 19-24.