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THEMATIC ISSUE

Geochemistry in Argentina: from pioneers to the present

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Abstract Argentine geochemistry evolved during the nineteenth century hand in hand with other sciences. The Scotsman John J. Kyle was the first chemist to arrive in Argentina in 1862, contributing during his lifetime reports that expanded the geochemical knowledge of local natural resources. After visiting the USA and Europe (1868), Argentina's President Sarmiento requested Hermann Burmeister (a prestigious biologist) to engage European scientists to foster the teaching and research of Natural Sciences (*sensulato*) in Argentina. The first to arrive, in August 1871 at the National Academy of Sciences and the university in Córdoba, was Max Siewert, a chemist from the German Martin Luther University. Siewert set up a state-of-the-art laboratory and analyzed, as Kyle had a few years before, a range of materials from waters and minerals to natural salts and biological materials. Some years later, Adolf Döring replaced Siewert. In the twentieth century, Gustavo Fester is the personality to highlight as a chemist/geochemist because he accomplished a vast task as teacher and researcher at the *Universidad Nacional del Litoral* and other institutions. During the 1950s and 1960s Argentine Geochemistry experienced slow but sustained growth, promoted by competent university professors such as Félix González Bonorino, José Catoggio, Mario Teruggi and Carlos Gordillo. The first Geochemistry curriculum was initiated in 1958 at the *Universidad Nacional de La Plata* as a result of the bold initiative of Catoggio and Teruggi. Nowadays, Geochemistry is solidly established in Earth Sciences curricula and Argentine geochemical papers are found in all the international journals of the specialty.

Keywords Earth Sciences · Chemistry · Geology · Natural Sciences · Academia Nacional de Ciencias · Academia Nacional de Ciencias Exactas, Físicas y Naturales · Sociedad Científica Argentina

Introduction

The historical trajectory of geochemical knowledge developed in Argentina, as a significant branch of the Earth Sciences, is similar to those followed by other scientific disciplines such as Biology, Physics and Chemistry. It was, however, somewhat different from its evolution in other South American countries during the last decades of the nineteenth century. This difference is related to the political history which, after a turbulent beginning that lasted several decades (Argentina became an independent nation in 1816), gradually evolved towards a modern model of government (a republican Constitution was adopted in 1853), driven by principles of economic and social progress and sustained advancement in education, culture and incipient science.

Cosme M. Argerich (1758–1820) was born in Buenos Aires and completed his medical studies at the *Real y*

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Pontificia Universidad de Cervera, in Spain. Herrero Ducloux (1912) points out that, as the initiator of the teaching of Chemistry in what was then the seat of the Viceroyalty of the Río de la Plata, he should be recognized as the father of Argentine Chemistry. The University of Buenos Aires was established in 1821 and was an appropriate platform to continue Argerich's quest, mostly from a pharmaceutical point of view. Nevertheless, Geochemistry, as will be shown here, would develop strong roots elsewhere. It must be stressed at this point, that this review is not about the history of Chemistry in Argentina, but that of Geochemistry (or, in the beginning, of geologically-oriented Chemistry), whose pioneers in the nineteenth century were outstanding naturalists or chemists who provided early chemical analyses of natural materials, of surface- and ground-waters, soils, minerals and rocks.

During the second half of the nineteenth century, Domingo F. Sarmiento (1811–1888) was a major Argentine public figure (i.e., statesman, educator, writer, and soldier) of strong character who, starting in 1865, travelled extensively through the Eastern United States as a special Ambassador. At the time, he interacted with intellectuals like Ralph Waldo Emerson, Henry Longfellow, Thomas Hill (mathematician, physicist and astronomer, also President of Harvard University), and Alexander Agassiz (son of the famous Swiss geologist, Louis Agassiz), among many others. The views of Horace Mann (whom he had met on a previous trip), Elizabeth Peabody and Mary (her sister and also Mann's widow) strongly influenced Sarmiento's ensuing program in Education. Sarmiento (Fig. 1) went on to Europe to visit the Universal Exposition in Paris (1867). When he returned to Argentina the following year, he had just been elected as Argentina's seventh President for the period 1868–1874 (García Castellanos 2004).

The fruitful period that followed was characterized by massive European immigration and the foundation of scientific institutions such as the National Academy of Sciences (*Academia Nacional de Ciencias*, ANC, www.anc-argentina.org.ar), the Astronomical Observatory (*Observatorio Astronómico*, www.oac.uncor.edu), both in Córdoba, and the Scientific Society of Argentina (*Sociedad Científica Argentina,* es.wikipedia.org/wiki/Sociedad_Cient%C3%ADfica_Argentina), the National Academy of Exact, Physical and Natural Sciences (*Academia Nacional de Ciencias Exactas, Físicas y Naturales,* ANCEFN, www.ancefn.org.ar) and the National College of Buenos Aires (*Colegio National de Buenos Aires*, www.cnba.uba.ar) in Buenos Aires, and others. Although he was not the only supporter of this line of thought, President Sarmiento was its most enthusiastic advocate, well aware that this entire revolutionary project would not prosper if the institutions being created were not initially supplied with expert scientists, mostly from Europe and the USA. Although

Fig. 1 Bronze statue of Domingo F. Sarmiento signed by Yvette Companion, offered in 1913 by the Argentine government as a gift to the City of Boston. It was finally dedicated in 1973 and it is located on the Mall, between Gloucester and Hereford Streets (Wikipedia Commons)

Argentina had one of the oldest universities in the Americas (the University of Córdoba was initiated by the Jesuits about 400 years ago), teaching was basically limited to Philosophy, Theology, and Law. The University of Córdoba, named *Real Universidad de San Carlos y de Nuestra Señora de Monserrat* in 1800, was nationalized in 1856. By the 1870s young scientists from various European countries started to arrive in Argentina and settle in different institutions, setting the cornerstones of the Argentine scientific edifice. Although some of them returned to Europe a few years after their arrival in Córdoba, many remained in the country, undertook pioneering studies in several scientific disciplines and contributed to the formation of the first generation of Argentine scientists: their names are remembered today in important awards now bestowed upon outstanding scientists by different scientific institutions.

There is no doubt that a nation's blueprint in which education and science teaching had a leading role resulted in the embryonic but dynamic middle class that characterized Argentina at the beginning of the twentieth century. Despite the political turmoil that periodically affected Argentina during most of last century, the seeds dispersed almost a 100 years ago flourished in many scientific disciplines. Success was particularly remarkable in Medicine

and Biochemistry, and resulted in three scientific Nobel Prize winners during the second half of the twentieth century.

The scenario described above regarding the beginnings of some disciplines applies to almost the full Argentine scientific spectrum. The task here, however, is to track scientists and institutions that made important contributions to the development of Geochemistry, as an important branch of the Earth Sciences. Argentine chemists, geologists and paleontologists have already made important contributions to the progress of their respective disciplines. Geologists and paleontologists, for example, have organized and still sustain periodical meetings and permanent symposia to report on the scientific activity of pioneers, the development of geological ideas, and the role carried out in the past by different academic institutions (e.g., Alonso 2013).

This paper seeks to fill this gap as completely as possible for the geochemical discipline, of which very little has been written before. During the recent III RAGSU meeting (*III Reunión Argentina de Geoquímica de la Superficie* (3rd Argentine Reunion on Surface Geochemistry, Mar del Plata, Argentina, 12/2-6/2014), the enthusiastic meeting organizers and Dr. James LaMoreaux (Editor-in-Chief of EES) encouraged the authors, as senior researchers in hard rock (CWR) and surface (PJD) geochemistry, to prepare this initial historical outline for this discipline in Argentina. This paper must be seen as a first attempt to cover over 150 years of a discontinuous history and a summary of landmark events, and also as a tribute to remarkable scientists and teachers that contributed to build this pathway that extends through time up to today. Future workers will have to complete this already long history. Although some might not be mentioned in this overview, all the early scientists named here have played a significant role developing the science of Geochemistry in Argentina by studying the chemical nature of rocks, minerals, sediments, soils, and waters and, above all, by being our teachers' teachers. This story is dedicated to them all.

Pioneer geochemists, studies and institutions

Nineteenth century

Although the term *Geochemistry* was first coined by the Swiss-German chemist Christian Friedrich Schönbein in 1838 (Reinhardt 2008), there was very little interaction between Geology and Chemistry in the nineteenth century. Most of the knowledge on the chemistry of natural substances, such as fresh and marine water, brines, soils, minerals and rocks was supplied by chemists and expert mineralogists. Therefore, the European scientists who came to Argentina during the nineteenth century and produced the first chemical analyses of natural materials were, in most cases, outstanding chemists. Nevertheless, it is surprising to find in those early articles that their writers were not specialists, restricted to one specific field, as is common today. In a broad sense they were, instead, fully-fledged naturalists with intense curiosity and ample expertise in other related fields, which went far beyond simply performing analysis. In simple words, the naturalists of the nineteenth century were, by and large, "jacks of all trades".

A good example is that of John Joseph Jolly Kyle (Fig. 2) (1838–1922), born in Stirling, Scotland, and educated at the universities of Edinburgh and Glasgow. He travelled to Argentina in 1862 and on the outbreak of the War of the Triple Alliance served as a pharmacist in the Argentine Army medical corps. Kyle became an Argentine citizen in 1873 and is clearly the first chemist/geochemist in the list of scientists that initiated research and education in the broad chemical field.

J.J.J. Kyle was a high school Chemistry teacher at the *Colegio Nacional de Buenos Aires*, but his more relevant activity was as Chair of both Organic and Inorganic Chemistry at the *Facultad de Ciencias Exactas, Físicas y Naturales* of the University of Buenos Aires, which also conferred the *honoris causa* doctorate as a way of honoring him for his contributions to the field of Chemistry. He also

Fig. 2 Photograph (ca 1881) of John Joseph Jolly Kyle, the pioneering Argentine chemist/geochemist (Wikipedia Commons)

supervised in 1901 the first doctoral thesis in Chemistry in Argentina (Enrique Herrero Ducloux). He was President of the *Sociedad Científica Argentina* (1874–1875 and 1892–1893) and Member of the National Academy of Sciences. Since 1927 the *Asociación Química Argentina* has bestowed the *"Dr. Juan J.J. Kyle"* award as its maximum honorary distinction.

When he retired in 1906 Kyle had published sixty-five scientific papers on very different topics, mostly written in Spanish. The most relevant are those related to the characteristics and composition of ground waters in the province of Buenos Aires. Along with studies on the best location for groundwater wells, he advised on the collection of freshwater from rivers to supply the city of Buenos Aires. Subjects as diverse as the caffeine content of *yerba mate* or the chemical composition of meteorite falls near Buenos Aires, among many others, did not escape Kyle's scrutiny.

It must be emphasized that Kyle produced the first report on the chemical composition of the Río de la Plata, with samples collected onboard, looking for the transitional zone that divides the huge mass of river freshwaters from the saline waters of the Atlantic Ocean (Kyle 1874). What is remarkable in this paper is the critical view he had of his own research, being aware of the limitations of his data. Clearly, it was difficult at the time, or downright impossible, to sample a large river at different depths. Another problem was the lack of information on water currents or on the relative discharges of incoming tributaries. Nevertheless, the value of Kyle's data was recognized by Frank Wigglesworth Clarke and his widely-cited *Data of Geochemistry* (Clarke 1908). John Joseph J. Kyle died in Buenos Aires as Juan José J. Kyle in 1922.

Early in Sarmiento's Presidency, Congress passed a law (No 322, of September 11, 1869) that allowed the Argentine President to hire a group of foreign scientists who would become researchers and professors at Córdoba University. This date is nowadays taken as the founding date of the National Academy of Sciences of Argentina, also located in the city of Córdoba, where it was originally a part of the university. The *Facultad de Ciencias Físico-Matemáticas* was founded in 1873 alongside the Academy, which the following year became an autonomous institution. To start his project of science promotion, President Sarmiento asked the German physician Hermann Burmeister (1807–1892) (Fig. 3), at the time Director of the Natural Sciences Museum in Buenos Aires, to search among the professors in his *alma matter* (Martin Luther University of Halle-Wittenberg, Germany) for natural scientists (*latosensu*) who might be interested in becoming researchers and professors in Argentina. The salaries were generous, more than commensurate with the offered positions, but the possibility of traveling to the Southern

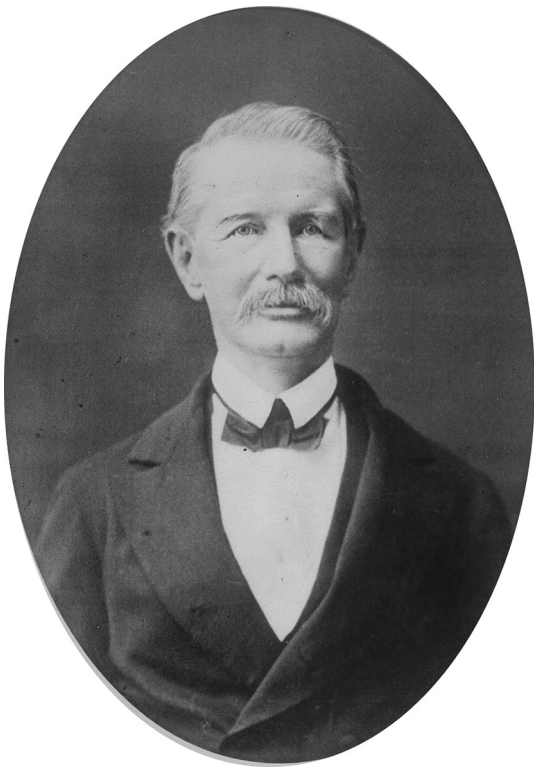

Fig. 3 Karl Hermann Konrad Burmeister, a German natural scientist who came to live in Argentina in 1861. He was asked by President Sarmiento to hire a group of foreign scientists that would form the scientific core of Argentina's *Academia Nacional de Ciencias* (photograph ANC archives)

Hemisphere and studying Nature in a territory almost unknown to European scholars was probably the most tempting factor. Early travelers, like Humboldt, Darwin, and D'Orbigny, reached fame and fortune after publishing their scientific findings in South America. Moreover, Burmeister was a prominent zoologist/paleontologist, entomologist, herpetologist, and botanist, whose prestige added significance to the offer. Burmeister was successful in his endeavor and in August 1871, the first scientist, Max Siewert, arrived in Córdoba (e.g., Tognetti and Page 2000; Tognetti 2004).

Max Hermann Siewert (1843–1877) (Fig. 4) had been born in Marienwerder (Eastern Prussia, Germany). Like Burmeister, he had studied at Martin Luther University of Halle-Wittenberg, where he obtained a Doctor's degree in Chemistry in 1859. He spent some time at the University of Göttingen and returned to Halle-Wittenberg where he received Burmeister's work offer which he immediately accepted. He and his newlywed wife boarded the ship that would take them first to Buenos Aires (hit at the time by a yellow fever epidemic) and then, probably by train, to Córdoba, in August 1871. In Germany, Siewert had published extensively, covering a wide spectrum of inorganic and organic chemistry, and biochemistry. Once in Córdoba,

Fig. 4 Max Hermann Siewert, a German chemist, was the first of the hired scientists who arrived in Córdoba, Argentina, in August 1971. He and J.J. Kyle are together considered to be "the forefathers of Argentine Geochemistry" (photograph ANC archives)

Siewert organized a state-of-the-art laboratory that tackled the investigation of every conceivable chemical field: fibers, tissues, organic and inorganic acids, salts, etc. The Academy's geologists supplied him with abundant samples of fluorite, apatite, columbite, and other minerals that he dutifully analyzed, thus expanding geological knowledge. He even dedicated considerable effort to applied projects, such as studying the suitability of diverse vegetable fibres to produce paper. This is why he is nowadays considered the forerunner of Chemistry in the University of Córdoba. With wide-ranging scientific interest he analyzed minerals, waters, bitumen and other natural substances that now lead us to see him, together with Kyle, as one of the "fathers of Argentine geochemistry". An example of his interesting scientific production is his paper on the chemical characteristics of ground waters, originally published in 1874 in the *Anales de Agricultura de la República Argentina* (Siewert 1973).

Several other Europeans scientists in the group hired by Burmeister were reluctant to take up their teaching responsibilities and preferred to devote most of their available time to research, partly because it was their main interest and probably because they also had difficulties with the Spanish language. This situation led to conflict with Burmeister who eventually fired several scientists, Siewert among them. However, the central Government did not want to lose the valuable contribution of the hired scientists but tried to avoid a direct confrontation with Burmeister. Therefore, in 1874, Siewert moved to the city of Salta (in NW Argentina) with appointments at the Agronomy School of Salta and at Salta's National College. By that time, Siewert and his wife had four children, all of them born in Argentina. In Salta, Siewert worked extensively in the chemistry of natural waters (rivers and streams, and ground waters). He was particularly interested in the composition of hydrothermal manifestations like those of *Rosario de la Frontera* and *El Bordo* in the Province of Salta and *Termas de Reyes* in Jujuy.

Max Siewert returned to Germany by the end of 1876 and soon afterwards was appointed Director of the Institute of Agricultural Experimentation in Danzig, where he worked until his death in 1890, when he was 59 years old.

In April 1872, about eight months after Siewert, Alfred Wilhelm Stelzner (1840–1895) arrived in Córdoba. He was born in the German city of Dresden and studied Geology and Mineralogy at the *Bergsakademie Freiberg* between 1859 and 1864, under the guidance of the famous mineralogist and geologist Carl Bernhard von Cotta (Sureda 2008). In 1871, he received and accepted the job offer from Burmeister and traveled to Argentina, where he stayed at the *Academia Nacional de Ciencias* until 1874. In Córdoba, Stelzner met Siewert and other members of the newly established Academy (Fig. 5). A marked personal disagreement with Burmeister and also the death of von Cotta determined his return to Freiberg in 1874 to occupy the vacant Chair of *Geologie und Lagerstättenlehre* (Toselli and Rossi 2008). Stelzner was a skilled mineralogist who worked in close association with Siewert, who probably assisted him in the discovery of two new minerals: famatinite (Cu_3SbS_4) and franckeite ($Pb_5Sn_3Sb_2S_{14}$). Stelzner died in Freiberg in 1895.

Adolf Döring (also known as Adolfo Doering) (1848–1925) was born in Hannover, Germany (Fig. 6). He was hired, together with his brother Oskar, by Burmeister. They both belong to what is known in the academy as "the second generation". Adolf arrived in Córdoba in 1872 and was initially an assistant to Max Siewert, teaching Chemistry, while Oskar arrived 3 years later and taught Mathematics. Adolf Döring left his doctorate in Natural Sciences at the University of Göttingen unfinished to accept the position offered at the Academy and the University of Córdoba. When Siewert moved on to Salta, he took over the Chemistry Chair. Adolf Döring remained in Argentina until his death and during 50 years made important contributions to Argentine science in Chemistry, Zoology, and Geology, particularly on the chemical and physical composition of soils from the extensive pampean region of central Argentina (e.g., Döring 1874). He also analyzed

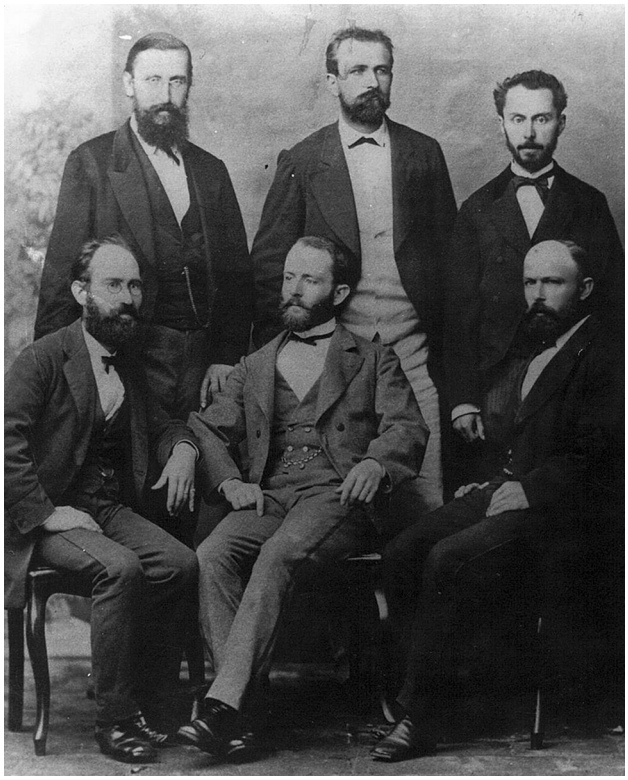

Fig. 5 Photograph of a group of the early members of the *Academia Nacional de Ciencias*. Sitting, from *left* to *right*: M. Siewert (chemist), K.A. Vogler (mathematician), A. Stelzner (mineralogist/geologist). Standing, from *left* to *right*: P.G. Lorentz (botanist), K. Schulz-Sellack (physicist), and H. Weyenbergh (zoologist) (photograph ANC archives)

water for human consumption (Döring 1879), mineralized waters and brines. He also maintained records of meteorological and geophysical observations. Adolf Döring was President of the *Academia Nacional de Ciencias* between 1914 and 1923 and published over twenty scientific articles in the *Boletin de la Academia Nacional de Ciencias*, which he helped to create and sustain. Adolf Döring died in *Capilla del Monte*, Córdoba, the mountainous town that he had helped to establish.

Although not directly associated with Chemistry or Geochemistry, it is impossible not to mention in this overview the monumental work accomplished by Ludwig Brackebusch (1849–1906, Fig. 6), also a member of the *Academia Nacional de Ciencias* and a contemporary of Adolf Döring. Brackebusch, born in Northeim, Germany, accomplished a vast geological work which was very useful to the geochemical investigations that followed. He studied in the German University of Göttingen (*Königlich-Preußische Georg-Augustus Universität*) and, before accepting Burmesiter's offer, worked at the Geological Institute of Prussia (*Königlich-Preußische Geologische Landesanstalt*) in the Harz region.

Brackebusch arrived in Córdoba in 1875 to take over the Mineralogy Chair and, as well, the Direction of the Mineralogical Museum, expanding significantly to more than 8000 specimens its mineral and rock collection, originally initiated by Stelzner. Outstanding in his scientific production is a magnificent map of NW Argentina (*Mapa Geológico de la Argentina*) published in 1891 (Pastore 1925) (Fig. 7). In 1888 Ludwig Brackebusch returned to Germany, continuing with his studies and publications on the geology of Argentina. He died in Hannover, Germany, at the age of 57.

Enrique Herrero Ducloux (1877–1962) was the chemist who was central in the passage to twentieth century geochemistry. He was born in Navarra (Spain) and early in his life moved abroad with his family, to Argentina. In 1901 he obtained the first doctoral degree in Chemistry granted in Argentina (supervised by Kyle). He was a professor at the universities of La Plata and Buenos Aires, and Secretary of the *Sociedad Científica Argentina*, prominent for the books and didactical material that he produced during his long life. He was a distinguished member of several academies and received distinctions from numerous institutions. As an expert analytical chemist he analyzed the meteorite known as *El Toba*, determining iridium and, for the first time in a meteorite, ruthenium and osmium. Furthermore, he produced the first petroleum analyses from several oils seeps, and was member of a research team that, between 1936 and 1948, produced fourteen volumes on *Aguas Minerales de la República Argentina* (Sussini et al. 1936–1940). This outstanding work collated all the available knowledge on all sorts of Argentine mineralized waters. Herrero Ducloux died in La Plata (Argentina) when he was 85 years old.

Twentieth century

The beginning of the twentieth century brought huge progress in the knowledge of physical–chemical equilibrium in silicate systems and the quantitative relations between the whole-rock chemistry of igneous rocks and their mineral composition (e.g., Bowen 1928; Cross et al. 1902). Nevertheless, the scientist who is universally considered the "father of modern geochemistry" is Victor Moritz Goldschmidt (1888–1947) as he precisely established the twofold purpose of the subject: (a) the determination of the absolute and relative abundance of chemical elements and isotopes on Earth, and (b) the study of the distribution and migration of these elements in the different parts of the Earth (atmosphere, hydrosphere, crust, mantle, etc.), as well as in minerals and rocks, to identify the processes that control such distributions and migrations (Mason 1992). In a similar way, the Russian geochemist Vladimir Ivanovich Vernadsky (1863–1945) was the founder of biogeochemistry.

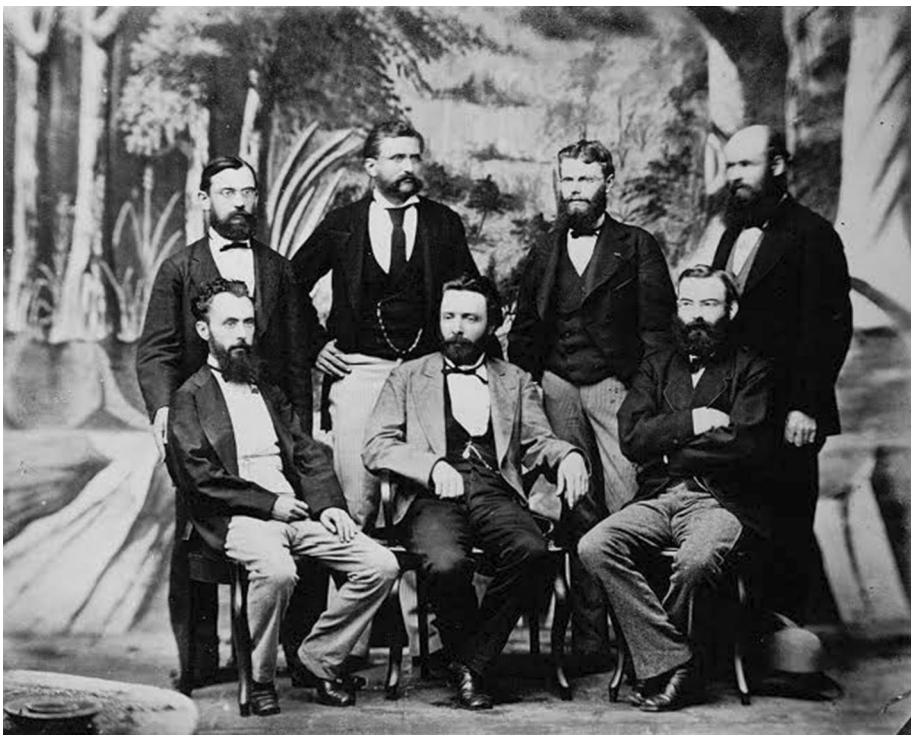

Fig. 6 Photograph of the second generation of members of the *Academia Nacional de Ciencias*. Sitting, from *left* to *right*: H. Weyenbergh (zoologist), F. Latzina (mathematician), O. Döring (mathematician). Standing, from *left* to *right*: G. Hieronymus (botanist), L. Brackebusch (geologist), A Döring (chemist), and F Schultz (botanist) (photograph ANC archives)

In Argentina, one scientist who was well aware of Goldschmidt's studies, and exchanged letters with him, was Gustavo A. Fester (1886–1963) (Fig. 8). Born in Frankfurt, Germany, he studied at the University of Leeds (U.K.) and obtained a doctoral degree in Chemistry at the University of Munich (1910). He taught Industrial Chemistry at the University of Istanbul (1915–1918) and, later, at Frankfurt University. In 1924, he accepted a position at the *Universidad Nacional del Litoral*, in the Argentine city of Santa Fe. There he pursued an amazing career as an organic and industrial chemist. For this he received the J.J. Kyle Award of the *Asociación Química Argentina* in 1952. Later, he became a member of the National Academy of Sciences (1958). From the beginning of his career he was keenly interested in and worked extensively in Geochemistry. Good examples are his chapters on vanadium, uranium, and thallium in the Musspratt Industrial Chemistry Encyclopedia. He was particularly interested in the geochemistry of solid hydrocarbon (asphaltite) (Fester and Cruellas 1935), and the processes that result in concentrations of vanadium up to several thousand parts per million (ppm) in such rocks, whereas in the continental crust it averages only about 140 ppm. This was probably the first paper of modern Geochemistry written in South America. It is worth pointing out here that while Fester was a well known organic chemist who published in recognized journals, he worked in a university where research and/or teaching in Geology were nonexistent. Therefore, his papers in Geology and Geochemistry were published in local journals with a limited distribution. Moreover, between 1934 and 1941 he taught Physical Geology and Geology to Geography students, at the *Instituto Nacional del Profesorado* in the city of Paraná, Entre Rios, Argentina. For these reasons his contributions were poorly known in the community of Argentine Earth Scientists, and this biographical review is the first account of his remarkable activity in this field and could be considered as homage to him.

There is a colorful side in Fester's career in the Earth Sciences, as he made reconnaissance studies all along the Andean chain, from Peru to *Tierra del Fuego* and the *Orcadas del Sur* islands, in his search for asphaltites. He described the geology and geomorphology in the area of the Beagle channel (Fester 1934) and he was the first one to climb the highest peaks in Tierra del Fuego and make structural and lithological cross-sections of the mountains to the northeast of Ushuaia (Fester 1937). He maintained fluid contacts with other German geologists who had migrated to Argentina, particularly with Juan Keidel (1877–1954). Keidel had made the pioneering correlation of the *Sierra de la Ventana* in southern Buenos Aires Province with those of the Cape Fold Belt in South Africa (Keidel 1916), both deformed by the Gondwanide orogeny (Keidel 1922). Keidel's observations supported the theory of continental drift postulated by Alfred L. Wegener (1880–1930) and embraced by Alexander Du Toit (1878–1948) in South Africa. The extraordinary history of Keidel's achievements explains why a small geological

Fig. 7 Geological map by L. Brackebusch, published in 1891, of a sector of NW and central Argentina. The field work was performed between 1875 and 1888. The SW sector remained unfinished (ANC Library)

community, which included Fester, continued to accept and teach continental drift, while most of the northern hemisphere researchers remained very skeptical and attached to non-mobilistic views until the explosion of plate tectonics in the 1960's. Ramos (2013) supplied a detailed chronicle of these events. In connection with the early teaching of continental drift in Argentina, there is an illustrative anecdote worth retelling. When the mother of one of the authors (CWR), who had been a former student of Fester at the Institute in Paraná, heard about plate tectonics from her

Fig. 8 Photograph of Gustavo A. Fester. He was the first scientist to tackle geochemical research in Argentina using modern methodologies

Fig. 9 Photograph of Félix González Bonorino. He was a major promoter of Argentine science, collaborating with Bernardo Houssay (Nobel Prizewinner) in the creation of Argentina's *CONICET* (Teruggi and Llambías 2000)

son, at the time a doctoral student at the University of La Plata, at the beginning of 1970s, she asked him with a curious and condescending smile "Are you telling me that this paradigmatic new theory recognizes that continents drifted apart thousands of kilometers?; that Africa and South America were once together as part of the Gondwana supercontinent?; and that the *Sierra de la Ventana* System has a counterpart in South Africa? We were already taught this by Professor Fester back in 1939!"

The history of Argentine Geochemistry during the 1950s and 1960s was partly coeval with the undergraduate studies of both authors of this paper in the 1960s, since they personally met most scientists associated with Geochemistry at the time, either as their professors or as relevant scientific personalities; in some cases even sharing co-authorship in early publications.

A relevant scientist during the period spanning between 1940 and 1980 was Félix González Bonorino (1918–1998) (Fig. 9). A regional geologist, petrologist and sedimentologist, González Bonorino is widely recognized for his classic works in the *Sierras Pampeanas* of Argentina and the paired metamorphic belts of southern Chile (e.g., González Bonorino 1946, 1950a, b, 1960, 1970, 1971). He was a professor at the universities of La Plata (1946–1950) and Buenos Aires (1953–1966). As a fine petrologist who combined detailed field observations and mapping with laboratory expertise, he acknowledged the urgent need of having modern geochemical facilities in the universities. In accord with this conviction he set up a geochemical lab at the University of Buenos Aires that functioned between 1958 and 1966. The project was sadly aborted as a result of the 1966 military coup. Hundreds of well-known professors and researchers resigned their positions at the University of Buenos Aires and other Argentine universities during 1966 and 1967; many eventually left Argentina to carry on their careers at universities and institutions in foreign countries. To this day this is considered a scientific tragedy and setback. While living abroad, González Bonorino made fundamental contributions to the geology of the basement in southern Chile (González Bonorino 1970, 1971) and wrote the book *Introducción a la Geoquímica* (González Bonorino 1972), in which he described the chemical principles of igneous and surface geochemistry. This is the only book on general Geochemistry written by an Argentine author. He was also deeply involved, in general, with the development of Argentine science. Obviously, he was particularly concerned about the growth of Argentine Geosciences: in 1945 he was one of the founding members of the Argentine Geological Association (*Asociación Geológica Argentina,* AGA, www.geologica.org.ar). He presided over this institution between 1952 and 1954. In 1958, he was a founding member of Argentina's National Council of Scientific and Technological Research (*Consejo*

Nacional de Investigaciones Científicas y Técnicas or *CONICET*, as well, www.conicet.gov.ar). A few years later *CONICET* became the main scientific institution of Argentina, with Bernardo Houssay (1887–1971)—1947 Medicine Nobel Prize winner—as its first President and González Bonorino as the first Vice-President. He was also a Member of UNESCO's Advisory Committee on Natural Sciences, and Vice-President for Latin America of the International Union of Geological Sciences (IUGS, 1964–1972). After Argentine democracy was re-established in 1983, González Bonorino was appointed Emeritus Professor at the University of Buenos Aires and reached the topmost level in *CONICET*'s scientific hierarchy (*Investigador Superior*).

It would be impossible to describe the history of the hard-rock Geochemistry and igneous and metamorphic Petrology in Argentina without mentioning Carlos Ernesto Gordillo (1925–1984). He was born in Villa Ascasubi (Córdoba Province, Argentina) but spent most of his childhood in La Rioja, where the seed of his passion for minerals and rocks was most likely planted. Gordillo studied at the University of Córdoba and obtained a doctorate in Natural Sciences in 1953 (e.g., Sureda 2008). While working (1952–1965) at the laboratories of Argentina's National Atomic Energy Commission (*Comisión Nacional de Energía Atómica*) in Córdoba, he was awarded the *Alexander Von Humboldt Stiftung* post-doctoral fellowship, which focused on Petrology (with Gerald Rein) and Geochemistry (with Paula Hahn-Weinheimer) at the *Johann Wolfgang Goethe Universität Frankfurt*. He spent most of his academic life (between 1962 and 1984) as Full Professor of Petrology at the University of Córdoba (*Profesor Titular de Petrología de la Universidad Nacional de Córdoba*). At the university, he set up a chemical laboratory in spite of counting on very limited funding, where he personally performed most of the geochemical analyses that are now found in his many papers on the igneous and metamorphic petrology of the *Sierras Pampeanas de Córdoba*. A hard worker and a rigorous chemical analyst, he was happy in his small, humble laboratory (Fig. 10, see also Caminos 1985). Although he was not a flamboyant speaker, he managed to share his contagious enthusiasm with a large number of students, who later on formed the basis of a well-known school of Petrology and Geochemistry at the University of Córdoba. In a number of studies, he demonstrated the Cretaceous age and the alkaline nature of several igneous centers emplaced in the geological basement of Córdoba (Gordillo and Lencinas 1967, 1969), as well as the characteristics of the subalkaline Cenozoic volcanism (Gordillo and Linares 1981), associated with the flat segment of the subducted Andean Nazca plate (Kay and Gordillo 1994). He also co-authored several important mineralogy papers (e.g., Gordillo et al. 1966; Schreyer et al. 1979; Angelelli et al. 1983). However, Gordillo's main contributions to Argentine geology were his many papers on the petrology of the basement of the *Sierras de Córdoba* y *San Luis*, initially summarized in Gordillo and Lencinas (1972). The pressure and temperature conditions of the extensive cordierite (magnesium iron aluminium cyclosilicate) migmatite massifs of the Sierra de Córdoba were established using chemical analyses of cordierite-garnet pairs (e.g., Gordillo 1979, 1984), which were subsequently used to measure partition coefficients of trace elements during the partial melting of crustal protoliths containing the cordierite and garnet mineral association (Rapela and Gordillo 1981). In this cordierite-bearing high-grade terrain, Gordillo reported the finding of a unique rock, with up to 90 % cordierite, with massive and orbicular varieties, which he named "cordieritite" (Gordillo 1974). The outcrops of cordieritite are large enough to be exploited as ornamental stones, exported to Europe, and used to decorate some of the most elegant shopping centers in Buenos Aires. These outcrops represent the largest cordierite accumulation reported on Earth: its age, geochemistry and petrogenesis have been described in a paper dedicated to Gordillo's memory (Rapela et al. 2002).

Fig. 10 Photograph of Carlos E. Gordillo working in his geochemical laboratory at the *Universidad Nacional de Córdoba*. He was the most prominent Earth scientist in Argentina when he died of cancer, at 59 years of age

In 1968 Carlos Gordillo became a Member of Argentina's National Academy of Sciences and, later on, he was elected a member of its steering board. He became a member of *CONICET*'s *Carrera del Investigador Científico y Tecnológico* (1978) and was appointed Honorary Member of the Geological Association of Argentina

(*Asociación Geológica Argentina*, in 1980). Gordillo died prematurely in December 1984. In a meeting at *CONICET*, a few months earlier, he had said to one of the authors (CWR): "…in the future somebody should recognize the pioneering work of Gustavo Fester in Geochemistry, a man who exchanged several letters with Goldschmidt about his geochemical work in the Andes and is almost ignored by Argentina's geological community…". Gordillo knew already that he was ill, and that he would not return to *CONICET*'s headquarters in Buenos Aires. We would like to take his words as a worthwhile reminder of a mission that we hope to have fulfilled in these pages, 30 years later.

The year 1958 was a turning point for Argentine science. A two-pronged government policy proved crucial in generating scientific growth. Firstly, through substantial funding to hire full-time university professors for the system of federal universities; secondly, for the creation of *CONICET*, as a national agency, with the primary role of funding scientific research, creating scientific institutes and hiring researchers in all branches. It was a period of fast growth and enthusiasm in the development of knowledge. New and interdisciplinary research was encouraged. Hence, and not surprisingly, undergraduate and graduate degrees in Geochemistry were created in 1958 at the *Universidad Nacional de La Plata*, sponsored by two prominent professors: José A. Catoggio (1923–1994), professor of Analytical Chemistry (Fig. 11) and Mario E. Teruggi (1919–2002), professor of Petrology and Sedimentology (Fig. 12). The origin of this ambitious academic project was most likely connected with a visit that Catoggio had paid to the Massachusetts Institute of Technology. In that prestigious academic institution he became acquainted with J.W. Winchester and his geochemical work. Winchester was subsequently invited by Professor Catoggio for a long visit to the Department of Analytical Chemistry of the University of La Plata (Fig. 11). Simultaneously, a brilliant undergraduate student, Verónica Gómez de Posadas (1939–1997) (Fig. 13), who at the time was studying both Chemistry and Geology, played a crucial role connecting these two sciences. Between 1964 and 1966 she lived in the USA where she got a master's degree at MIT under the supervision of P.M. Hurley. This work was focused on Rb–Sr geochronology of igneous complexes in Venezuela (Posadas 1966). The chosen subject was related to the search for links connecting the basement of NE South America with that of the western African Shield, as evidence of continental breakup and plate tectonics mechanisms (Posadas and Kalliokoski 1967). Posadas continued working with Hurley at MIT, as a laboratory assistant until 1970, helping to set up the laboratory for the analysis of lunar samples brought back by the Apollo 11 mission in 1969. She returned to Argentina in 1971, where she obtained an Adjunct Professorship (in Geochemistry) at the University of La Plata. She remained in this position until her premature death, at the age of 58, leaving behind many unfulfilled prospects.

Although chemical and geological curricula in Argentine universities were solidly established as markedly separate disciplines in the 1960s and 1970s, it was clear

Fig. 11 Photograph of José A. Catoggio (*right*) introducing the American geochemist J.W. Winchester (*left*) during a seminar at the University of La Plata (c. 1967). During his last years of academic activity, Catoggio became strongly involved in environmental chemistry and geochemistry topics (e.g., Catoggio et al. 1989). He created the *Centro de Investigaciones en Medio Ambiente* (CIMA) and together with Mario Teruggi, they launched geochemistry as an undergraduate curriculum at the University of La Plata, in 1958

Fig. 12 Photograph of Mario E. Teruggi who was author or co-author of more than 100 publications in Petrology, Sedimentology and Quaternary Geology, some of them genuine classics (e.g., Teruggi 1957). He also authored books widely used in South American universities (e.g., Teruggi 1960)

Fig. 13 Photograph of Verónica Gómez de Posadas. Verónica Posadas was the first undergraduate student of Geochemistry at the University of La Plata. She was married before finishing her studies, and then moved on to Boston where she obtained an MSc at MIT, under the supervision of P.M. Hurley. She returned to Argentina and was Adjunct Professor of Geochemistry at the University of La Plata until her death in 1997

that the lack of basic education and geochemical research was an important breach that had to be filled if future developments were to be expected in this field. The promotion of doctoral and post-doctoral studies in renowned European or American universities was, therefore, the obvious solution to this educational gap. Some young Argentine geologists started to look to the Northern Hemisphere to expand their geochemical knowledge. This was the case of one of authors (PJD) who, after obtaining a degree in Geological Sciences at the University of Córdoba, moved on to the University of California, San Diego at La Jolla, with the aid of a Fulbright grant. There he joined a group led by the renowned marine geochemist Edward D. Goldberg (1921–2008) at the Scripps Institution of Oceanography (SIO).

At the time, the situation at the University of La Plata was encouraging, mainly due to the already described establishment of the geochemical curriculum at the doctoral level. The first geochemical theses in Argentina were carried out under the supervision of Professors Catoggio (Ronco 1974, Biogeochemistry) and Teruggi (Rapela 1975, Igneous Geochemistry). During those years the background provided in Chemistry, Mathematics and Physics was sound, but there was a lack of geochemical expertise, which resulted in a significant set-back. Clearly, post-doctoral training was needed and, therefore, promoted, mainly by Argentina's *CONICET*. One of the authors (CWR), for example, spent 2 years with a *CONICET* fellowship, working at Denis M. Shaw's (1923–2003) laboratory, in the Department of Geology of McMaster University, Canada. This experience led to the first use of trace element models in South American igneous rocks (Rapela and Shaw 1979). Later, it was possible to lecture on these topics in post-doctoral seminars and short courses given by the author (CWR) in several Argentine universities and at the *Asociación Geológica Argentina*.

The birth of Geochemistry as an independent subject at the University of La Plata was marked in 1969 by its introduction as a 1-year course in the undergraduate Geology curriculum. The first professor of this General Geochemistry course for geologists was Julio C. Merodio (1929), an outstanding analytical chemist and lecturer, who retired in 2010 (Fig. 14). He also taught Analytical Geochemistry and Statistics in the Geochemistry curriculum, also giving many short courses on these topics at other universities. Although he published papers in different geochemical fields, he was particularly fond of shale geochemistry, e.g., for the discrimination of sedimentary and

Fig. 14 Photograph of Julio César Merodio. He was the first Professor of Geochemistry in an Argentine university (1969)

tectonic environments (Merodio and Spalletti 1990),which led to development of a norm for fine-grained sedimentary rocks (Merodio et al. 1992), an unfortunately poorly known but a very useful paper. Geochemistry was progressively introduced after 1969 as a formal course for Geology undergraduates in most Argentine national universities and in those created since (seventeen universities in all).

As the critical mass of geochemists started growing, interdisciplinary research with other related geological disciplines stimulated an appropriate environment for the creation of research institutes. In the *Facultad de Ciencias Naturales y Museo* of the University of La Plata, a group of hard-rock geologists that included geochemists (J.C. Merodio and C.W. Rapela) founded in 1976 the *Instituto de Mineralogía, Petrología, Sedimentología y Geoquímica (IMPSEG)*. Four years later, the IMPSEG evolved into a larger institution, the *Centro de Investigaciones Geológicas(CIG)*, and in 1981 began to be co-sponsored by the University and *CONICET,* being CWR its current Director. In the *Facultad de Ciencias Exactas* of the same university, José Catoggio created in 1978 the *Centro de Investigaciones en Medio Ambiente(CIMA)*, focused on basic and applied environmental Chemistry and Geochemistry, currently directed by Alicia Ronco, the first of Catoggio's disciples in this field. Without the explicit cooperation of leading Geology professors, as has happened in La Plata, the task of developing institutions for geochemical research in other universities was more difficult. One of us (PJD) cooperated in establishing in 1999 the *Centro de Investigaciones Geoquímicas y de Procesos de la Superficie (CIGeS)*, at the University of Córdoba, being its first director. The framework provided by this small research centre was fundamental in the organization of *I Reunión Argentina de Geoquímica de la Superficie (I RAGSU)*, held in Córdoba in 2009. This initial meeting, and subsequent *RAGSUs,* proved to be a significant boost in promoting the awareness of exogenous processes. In 2007, *CIGeS* became one of the building blocks of a larger institute, also co-sponsored by *CONICET* and Córdoba National University: the *Centro de Investigaciones en Ciencias de la Tierra (CICTERRA)* of which PJD was the first appointed Director. As of 2015, it is directed by E.G. Baldo. This centre is now a leading Argentine institution in several branches of Earth Science, particularly, in surface Geochemistry and Hydrochemistry.

The twenty-first century

One of the worst, if not the worst ever, economical and political crises in the history of Argentina occurred at the beginning of the twenty first century. Science and technology were not considered priority issues by the Argentine administrations that ruled during the 1990s, and the funding of scientific institutions, universities, together with the salaries of scientists and professors, reached historical lows. For many young, and not so young, scientists it was a decade of emigration; it was the time for writing letters to our friends and colleagues abroad, recommending young doctoral students, eager to find elsewhere more propitious conditions for academic growth. We, the writers of the letters, were past the age to do this!

A very fortuitous combination of rapid economic recovery, due to the huge international increase in the price of commodities, and a significant change in science policy of the new administration, brought about an unsuspected improvement to Argentine scientific life. *CONICET*, being the leading national institution in the promotion of science, started in 2003 an aggressive policy to heal the wounds inflicted during the previous decade. This was accomplished by increasing the number of fellowships yearly granted for graduate studies, by developing a program for the return of emigrant scientists (more than 1000 have done so at this point in time) and by increasing the salaries of scientists working in research institutions and universities. The second step has been the creation of many new research institutes, mostly co-sponsored between *CONICET* and Argentine universities. Also important was the increase, in both number and value, of research grants; the organization of special programs for the acquisition of scientific instrumentation, and finally, the renovation of existing building facilities and the construction of new research laboratories and infrastructure. A third issue, now fully under way, is the promotion of technological transfer to the productive domain, and the creation of structures that facilitate the connection between basic and applied science with technology and innovation.

Within the wide framework of Geological Sciences, where Geochemistry is now a recognized subject, several important institutions have been created during this period:

2006, *INGEOSUR (Instituto Geológico del Sur*, Bahía Blanca);
2007, *CICTERRA (Centro de Investigaciones en Ciencias de la Tierra*, Córdoba, with new building facilities in 2012);
2008, *INCITAP (Instituto de Ciencias de la Tierra y Ambientales de La Pampa*, Santa Rosa, La Pampa, with new building facilities in 2014);
2010, *IDEAN (Instituto de Estudios Andinos "Don Pablo Groeber"*, Buenos Aires);
2012, *IGEBA (Instituto Geológico de Buenos Aires*, Buenos Aires).

New building facilities for the *Centro de Investigaciones Geológicas* (CIG), at La Plata, are being finished as this paper is written and will be inaugurated in September 2015. New geochemical instrumentation, such as ICP-MS,

mass spectrometers, scanning electron microscopes and electron microprobes, are now, or will soon be, available in several universities or institutes.

Geochemistry in Argentina has undergone the same oscillatory behavior experienced by all Argentine science during the last 150 years, mainly as a result of successive political and economic crises, which usually interrupted periods of comparative stability and growth. Argentina's socio-economic structure still allows for relatively rapid recovery when appropriate policies for scientific development are implemented. In our view, however, this advantage will not last another century unless careful attention is paid to the fostering and supervision of all levels of education and to the permanent promotion of science and technology. An almost dream-like wish, shared by most Argentine scientists, is the adoption of a state policy, by all sectors concerned, of long-lasting science sponsorship, thus realizing that scientific and technological growth is a major cornerstone in any country's future.

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