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HOMAGE TO IGNACY DOMEYKO (1802–1889) AT THE 200th ANNIVERSARY OF HIS BIRTH

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Abstract: Ignacy Domeyko was born on July 31, 1802 in Niedźwiadka, Novogrodek district. After attending the Piarist College in Szczuczyn he studied at the Vilna University and got the M. Sc. degree in 1822. As a member of the illegal Philomat Society was interned till 1829. In 1831, as participant of anti-Russian insurrection had to escape to Prussia, from where moved to Saxony and France. In the years 1832–1838 Domeyko was studying exact and geosciences at Sorbonne and École des Mines. Invited by the Government of Chile was teaching physico-chemical and geo-sciences in the Coquimbo College in La Serena in the years 1838–1846, carrying out large-scale geological and ethnographic field studies as well as chemical-mineralogical investigations. In the years 1846–1884 Domeyko was very active as academic teacher and in the period 1867–1883 as rector of the Chile University in Santiago, continuing research works and reforming local education system. His many-sided activity contributed significantly to economic and educational progress of Chile. At the final stage of his life (1884–1888) Domeyko, as already world-wide known scientist, could visit his homeland and other European countries, as well as Holy Land, but on the way back felt ill and on January 23, 1889 died in Santiago, admired and venerated by Chileans as their apostle of science and education.

The present paper deals with essential Domeyko's achievements in geosciences. Already during his stay in Paris the results of his observations on sinking of the area of East Prussia in historic times were published and Domeyko has prepared the geographic atlas of the territory of the native Polish-Lithuanian Commonwealth, but only a part of it could be printed.

In Chile, apart from didactic activity, accenated by edition of handbooks on mineralogy and assaying, Domeyko was carrying out large-scale geological, mining and mineralogical investigations of the Andes showing predilection to chemical analyses of collected materials. As follows from the inspection of archival materials, he is the author of at least 160 analyses of various, often chemically very complicated, minerals (including meteorites) and about 60 analyses of waters. This resulted in the discovery of several new minerals which were announced in renowned European periodicals. One of them – copper arsenide – was named by W. Haidinger domeykite. Besides, several Andean fossils sent by Domeyko to France were by A. d'Orbigny and other French palaeontologists named after their discoverer. Following several minor papers on regional geology, including detailed studies of volcanic phenomena, he published in 1878 in Polish a monograph on Chilean Cordilleras and ore deposits, comparing some their fragments with similar horizons in the Polish Carpathians. These and other problems treated by Domeyko in numerous publications are discussed in the present paper.

Domeyko's achievements were highly appreciated by several European and American scientific societies and universities by conferring him memberships and honorary doctorates.

Moreover, due to his exceptional personality and spirituality, expressed in deeply Christian virtues realized in private and social life, Domeyko is a candidate for beatification. Geoscientists of Poland, Lithuania, Chile, Belorussia, France and other countries are celebrating the 200th anniversary of his birth, paying homage to this eminent citizen of the world.

Key words: Domeyko, Philomat, Poland, Lithuania, Belorussia, France, Chile, geosciences, ores, Andes, chemical mineralogy.

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INTRODUCTION

In every significant encyclopedia we can find such entries as mineral domeykite and Cordillera Domeyko Mts. in Chile. However, there are, in general, no data that they refer to Ignacy Domeyko (1802–1889), geologist, mineralogist and mining engineer, educated in Europe who in the years 1838–1889 was very active in South America. We cannot

Fig. 1. Ignacy Domeyko (1802–1889) – a photograph made during his stay in Warsaw in 1886 (from W. Żabiński collection)

find his biography even in numerous specialistic lexicons, such as renown Dictionary of Scientific Biography, containing the data on even less known scientists of the 19th century. It seems, therefore, astonishing that UNESCO has declared the year 2002 as devoted to Domeyko. Consequently, in many countries, related with his many-sided activity, i.e. in Belorussia, Chile, France, Lithuania and Poland, numerous international sessions and exhibitions were organized, do- cumented by nicely edited materials and books, containing the presented lectures. For Domeyko was, unquestionably, not only an eminent scientist, publishing his papers in European and American specialistic periodicals, but also an advocate of propagation of education and of rapprochement of nations. Therefore, in Chile he was named the apostle of science and education. These elements of his biography have created a legend of his name not only in South America but also in the countries of his longer stay, first of all in Belorussia, Lithuania and Poland, forming for several centuries fraternal Commonwealth.

GENERAL BIOGRAPHY

Ignacy Domeyko (Fig. 1), son of Antoni Hipolit and Karolina née Ancuta, was born on July 31, 1802 in Niedźwiadka, Novogrodek district, i.e. in the area occupied after Poland's partition by Russia and named officially "Polish provinces of the Russian Empire". Till 1795 this district was a part of the Great Duchy of Lithuania, inhabited by Polish-speaking Lithuanian nobility, Samogitian, Belorussian, Jewish and Polish people and national minorities – mainly Tartars, Germans, Karaits, etc. The conception of nationality did not exist yet in Domeyko's times. As the citizens of Polish-Lithuanian Commonwealth they were declaring themselves as Poles but, taking into account their territorial radices, also as Lithuanians. Consequently, they were using the words Pole and Lithuanian commutably. This results clearly from Adam Mickiewicz's poems and Domeyko's autobiographies. So, e.g. his, most probably, oldest autobiography begins with the following words: "Ignace Domeyko née en Pologne á Niedźwiadka, district á Novogrodek…" (see Bator, 2002), The independent Lithuania, originated in 1918, has accepted as the national language one of Samogitian dialects. However, the Lithuanian nobility was, in general, not using it in the first half of the 19th century since Samogitians knew Polish language, similarly as people of other nationalities living in eastern and southern parts of the former Great Duchy of Lithuania, first of all Belorussians.

Ignacy Domeyko has inherited from his home – apart from native Polish language – the knowledge of Belorussian, French and German. In secondary school he has perfectioned Russian and has learned basic Latin. The knowledge of several languages was a norm for the nobility of that period, preparing thoroughly young people for specialistic university studies. In the years 1812–1816 Domeyko was attending, inspired by his uncle Józef – graduated from the Mining School in Freiberg, the Piarist College in Szczuczyn, showing special interest in the history of Poland and chemistry. Consequently, he decided to study at the Faculty of Physical and Mathematical Sciences of the Vilna University. At that time it was the only university within Polish provinces of the Russian Empire and administrative center of the Vilna Educational Region. Among his university friends we have to mention Adam Mickiewicz, Tomasz Zan (later merited in the study of geology of South Ural Mts.), and Józef Kowalewski (orientalist, later university professor in Kazan and Warsaw). Since 1817 they have formed a self-educating circle, called the Philomat Society, known from 1820 as the Philaret one. Domeyko was attending the Vilna University in the years 1816–1822 when the teaching language was Polish. He has obtained the M.Sc. degree on the ground of a dissertation on higher mathematics and was planning to specialize later in architecture. These plans were stopped by political events. The secret Philaret Society was detected by Russian authorities. Some of its members (e.g., T. Zan) were imprisoned, others deported into Russian interiors (e.g., A. Mickiewicz). Domeyko was interned under police control in his uncle's Ignacy estate Zapole near Lida, where in the years 1824–1829 was administrating successfully agricultural production. Russian authorities did not allow him to be employed in any state or regional offices. Nevertheless, he was still active in illegal self-educating organizations, helping his friends philomats and philarets deported to Russia, first of all to Mickiewicz. Domeyko's at-

tempts to get in a specialistic employment in Warsaw, the capital of Polish Kingdom within the Russian tsar Nicolaus I empire, were unsuccessful. In 1831, after the outbreak of anti-Russian insurrection, Domeyko has joined the partisan armed forces in the territory of the Great Duchy of Lithuania. After their defeat they have to cross the Russian-Prussian frontier and were interned near Königsberg (Królewiec) till the beginning of 1832. Liberated by Prussian authorities Domeyko emigrated first to Dresden and, subsequently, to Paris.

When living in French capital in the years 1832–1838 Domeyko was studying mainly exact and technical sciences at Sorbonne and College de France. Stimulated by J.B. Élie de Beaumont he studied practical geology at the École des Mines. Graduated in 1837 as mining engineer he was at once employed in the prospection for iron ores in Alsace, but soon has received the proposal of a six-year contract for teaching in Coquimbo – La Serena in Chile.

Domeyko has accepted this chance to visit such a distant country over the ocean.

Worth emphasizing is Domeyko's stability in professional and research interests. As a boy he was showing already distinct predilection to chemistry and his knowledge in this branch during college and university studies was exceptional. In France he intended to be employed in a chemical factory but it was impossible for a foreigner. When studying at the mining school Domeyko was paying particular attention to analytical chemistry of mineral raw materials. Therefore, the directory of this school has recommended just him to Chilean authorities, since there was an urgent need in this young South American republic to form modern industrial chemical laboratories. On the other side of the ocean Domeyko was active both in science and administration. But, first of all, he was teaching chemistry and mineralogy. Consequently, he and his pupils have contributed significantly to economic progress of Chile, since financial output of this country was based mainly on mining and metallurgic industry.

In the years 1838–1846 Domeyko was teaching at the Coquimbo College in La Serena where he has educated first Chilean specialists in mineralogy and assaying, sending three of them as his successors for supplementary mining studies to France. Simultaneously, he considered as necessary a reorganization of the Chilean education system by accepting that checked in the Vilna Educational District. In 1846 he was invited to Santiago as professor of Chilean University, lecturing chemistry, mineralogy and assaying. In 1852 the Chilean government has entrusted him the reorganization of this University, and in 1867 Domeyko was elected its rector, remaining on this duty till 1883 due to three reelections.

In the years 1884–1888 he visited Europe, mainly his native Lithuania and Poland, as well as Holy Land. Domeyko died in Santiago de Chile on January 23, 1889. His funeral was an enormous manifestation of Chilean population, paying tribute to their arrived from Europe apostle of science and education (see Wójcik, 1995; Ryn, 2002a).

SCIENTIFIC PUBLICATIONS IN EUROPE

The publications presented in this chapter refer mainly to Domeyko's native country, i.e. the former Polish-Lithuanian, Commonwealth whereas those elaborated in Chile but published in France and Germany will be discussed in the next chapter.

There are some indirect pieces of information on rather minor papers published during his studies in Vilna and internment in Zapole (see Wójcik, 1995) but they were, certainly, not geologic in character. His interest in geoscientific problems appeared first during Domeyko's internment in East Prussia in 1831. The results of his observations in this country were published in 1837 in Paris in the paper "Notice sur les changements qu'a subis la côte prussiene de la mer Baltique depuis les temps historiques" (Domeyko, 1837). Taking into account the available publications, he pointed attention to the sinking of the area of East Pomerania and Lithuanian coastal zone in historical period. This paper, though based on field observations, was referring to Domeyko's studies in preparing the edition of geographic atlas of the territory of the former Polish-Lithuanian Commonwealth within its frontiers before the first partition in 1772. According to his intention this atlas had to be composed of introductory text and four maps: hydrographic, geologic, economic and political (administrative) ones. Domeyko was working on this atlas during his studies at the Mining School in Paris. Before his departure to Chile he was able to publish merely its first map. The remaining materials Domeyko has left to A. Mickiewicz who, unfortunately, did not fulfill his friend's instructions. They were, merely, saved as manuscripts in the Libraries of the Academy of Arts and Sciences (Fig. 2) and of the Jagellonian University in Cracow, and in the Polish Library in Paris. The geological map, preserved in three versions (including two provisional) is documenting Domeyko's methodical workshop, based on compilation of his own observations and the data reported by other geoscientists from various parts of the country (Domeyko, 1838). Most probably, he was in contact with Ludwik Zejszner, professor of geology of the Jagellonian University. However, Domeyko has, first of all, used G. G. Pusch's map published in 1837 in the work "Geognostischer Atlas von Polen" but his map contains, of course, more data. Besides, it comprises a wider territory, up to the Finnish Bay in the north and to Dniepr river basin in the east. In the introductory text Do- meyko is paying particular attention to the peculiarities of this area as a geographic individuality. In his opinion, individual river basins should be treated as superior units, very important in investigating ethnic, economic and administrative problems.

During his long stay in Chile Domeyko attempted to publish this atlas. However, since his maps were already used by other authors, he decided not to print it. Nevertheless, he tried to popularize his statements, e.g. by suggesting the need of foundation of the Polish natural museum in Cracow (with a rich geological section), based on subdivision resulting from regional river basins. This problem was once more presented by him during Domeyko's stay in homeland at the end of the 19th century. Before his return to Chile, at a meeting of the Academy of Arts and Sciences in Cracow in

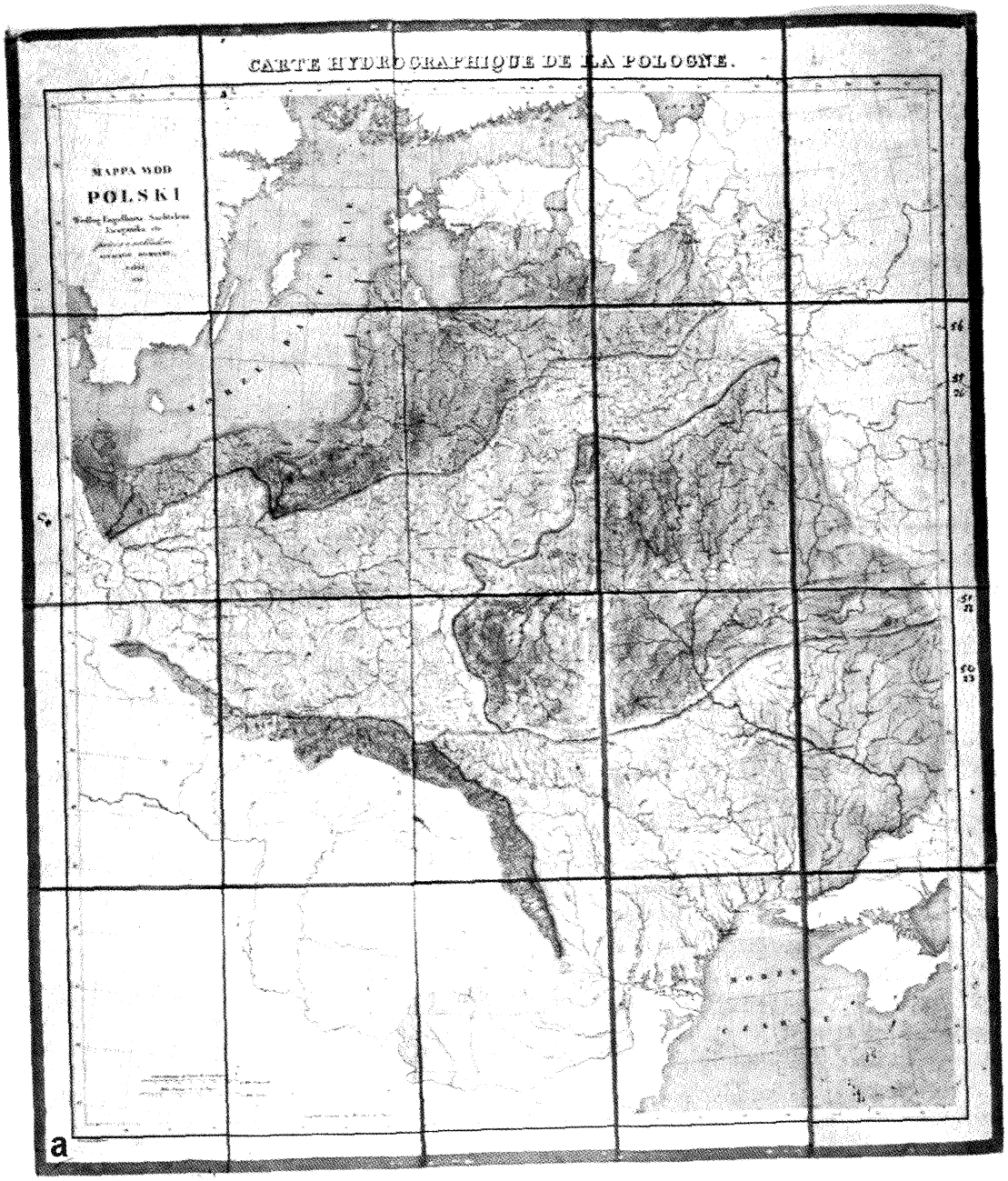

Fig. 2. Hydrographic and geologic maps of Poland and adjacent countries hand-drawn by I. Domeyko in Paris (from the collections of the Scientific Library of the Polish Academy of Arts and Sciences in Cracow). The pictures are scanned from slides made by Zbigniew Kos in the Reprographic Laboratory of this Library. **a** – Sign. 3772 C III: Hydrographic map of Poland after Engelhart, Suchtelen, Liesganik etc. drawn and edited by Ignacy Domeyko. Paris, 1838; **b** – Sign. 3776 C III: Carte géologique de la Pologne d'après de Buch, de Lilienbach, Strangways, Pusch, Eichwald etc. (Ignacy Domeyko). Paris, 1838

May 1888, he delivered a lecture "On the method which should be introduced in teaching and learning physical geography of Polish territory" (Domeyko, 1888). It should be emphasized that Domeyko's paper is based on perfect knowledge of Polish publications, traced by him also during his stay in Chile.

GEOLOGY OF CHILE IN DOMEYKO'S PAPERS

Domeyko has crossed the Argentinian-Chilean frontier over the Uspallata pass in the Andes as a 36 year old man on May 17, 1838. When going to South America he could know merely basic Spanish language. During this long travel he was feeling well on horseback due to experience in his youth. Besides, Domeyko was a trained field geologist.

The lecturing in Coquimbo College were initiated in September and later, during summer vacations (January–February) he was arranging the chemical laboratory for analyzing local ore minerals. Nevertheless, in May, June, July and August 1838 Domeyko could already make acquaintance with some elements of geology of central Chile. The first longer field works to the environs of Coquimbo he has organized in 1839 and during the following holidays was systematically continuing them, being usually accompanied by his pupils. Detailed geology of mines was usually examined by Domeyko when acting as mediator in contestations

of mining entrepreneurs. Some exploration works were ordered by private business or local authorities. They were concerning mainly the supply of Chilean capital in water (Domeyko, 1847; Fig. 3). During his long stay in Chile Domeyko was working, first of all, as mineralogist, analyzing personally local ores. The results of these chemical studies were published first in France (mainly in "Annales des Mines") and later also in specialistic German and Chilean periodicals of international importance.

Domeyko's bibliography, presented by Ryn (2002a), consists of three sections: subjective (his publications and manuscripts), objective (publications devoted to Domeyko), and epistolographic. In the first one there are 66 books and 354 publications which appeared or were reprinted in the years 1832–1998, as well as 23 manuscripts or inventory data on them in various libraries from the years 1832–1988. The second section comprises 24 books published in the years 1867–2000, and 2205 data on dissertations, papers and references which appeared in the years 1838–2001. In the third part there are 82 published and 57 unpublished Domeyko's letters. Moreover, this bibliography includes the information on other subjects as, e.g. iconographic data. Altogether, it contains 4500 positions. However, the resulting general picture is not quite clear, mainly because numerous data are presented by the Author from the second hand. Nevertheless, the essential problem was not obfuscated. As follows from these data, Domeyko was undoubtedly the man of action both as geoscientist and as administrative worker and pedagogue. As geologist he was publishing regularly several papers yearly. Besides, he elaborated

Do Bibliotheki Academii Krakowskiej
autor I. Domeyko

MEMORIA SOBRE LAS AGUAS DE SANTIAGO

I DE SUS INMEDIACIONES.

Resultado de las investigaciones hechas en los meses de Enero i Febrero de 1847 en la capital de Chile, acerca de la naturaleza de las aguas que surten la ciudad i sus inmediaciones.

	Agua de Ramon.	Agua de Peñalolen.	Agua de Mapocho	Agua de Velasco.	Agua del Pozo.	Agua de la pila.	Agua de Maipo. en Sant.°	Agua de Maipo. a 5 leguas de Sant.°
En un cuartillo de agua, lo que equivale a 1265 gramos en peso.								
Materias disueltas.								
	gr.	gr.	gr.	gr.	gr.	gr.	gr.	gr.
Cloruro de sodio. (n)	0,007	0,006	0,058	0,068	0,096	0,042	0,193	0,170
Sulfato de cal (yeso)	indicio	indicio	0,139	0,125	0,204	0,275	0,474	0,623
Carbonato de sosa.	0,018	0,005						
de cal.	0,068	0,170	0,090	0,135	0,103	0,129	0,115	0,054
de magnesia.	0,010	0,012	0,029	0,029	0,013	0,020	0,048	0,060
Hierro con un poco de alumina.	0,008	0,017	0,052	0,052	0,007	0,015	0,010	0,014
Sílice.	0,022	0,017	0,013	0,013	0,017	0,035	0,033	0,118
	gr.	gr.	gr.	gr.	gr.	gr.	gr.	gr.
Total de materias disueltas.	0,133	0,257	0,381	0,412	0,410	0,516	0,873	1,039
			gr.			gr.	gr.	gr.
Materias que enturbian el agua.	"	"	0,508	"	"	0,040	1,100	1,545
En cada cien mil partes de agua hai								
Materias disueltas.								
Cloruro de sodio.	0,6	0,5	4,6	4,6	7,5	3,3	15,3	13,5
Sulfato de cal.			11,0	9,9	16,1	21,8	37,5	49,3
Carbonato de sosa.	1,4	0,4						
de cal.	5,4	13,5	7,1	10,6	8,2	10,2	9,1	4,3
de magnesia.	0,7	1,0	2,3	2,3	1,0	1,6	3,8	4,7
Hierro con alumina.	0,7	1,4	4,1	4,1	0,6	1,2	0,8	1,1
Sílice.	1,7	3,9	1,0	1,0	1,4	2,8	2,6	9,3
Total.	10,5	20,7	30,1	32,5	34,8	40,9	69,1	82,2
Materias en suspension.	"	"	40,0	"	"	3,2	87,0	122,1

(Nota) En todas las aguas he encontrado algun indicio de cloruro de potasio que no pasa de dos miligramos por cada cuartillo i algun indicio de cloruro de magnesio.

Fig. 3. Chemical composition of potable waters of Santiago and its environs analyzed by I. Domeyko. Tabular presentation in his book "Memoria sobre las aguas de Santiago i de sus immediaciones". Santiago, 1847, dedicated to the Library of the Jagellonian University

handbooks on mineralogy, chemistry and assaying, and, as a polyglot, he was appreciated as translator. Some of his papers are devoted to mining, metallurgy, meteorology, geophysics (e.g. earthquakes, tectonic events), volcanology, hydrogeology, etc. Moreover, Domeyko was writing his excellent memoirs in very beautiful Polish, sometimes nicely illustrated by himself.

As a member of the Academy of Arts and Sciences in Cracow he was obliged to enrich its library in his publications. In the Transactions and Reports of the Section of

ROZPRAWY

i

SPRAWOZDANIA Z POSIEDZEŃ

WYDZIAŁU

MATEMATYCZNO-PRZYRODNICZEGO

Akademii Umiejętności.

Tom V.

(Z 8 tablicami litografowanemi).

W KRAKOWIE.

NAKŁADEM AKADEMII.
W DRUKARNI UNIWERSYTETU JAGIELLOŃSKIEGO,
pod zarządem Ign. Stelcla.

1878.

Rzut oka

na Kordylijery Chilijskie

i zawarte w ich łonie pokłady metaliczne.

Przez

Ignacego Domeykę,
Członka czynnego Akademii.

Część pierwsza.

Położony między brzegiem oceanowym od zachodu, a linią rozdziału wód na grzbiecie Andów od wschodu, kraj Chilijski, trzydzieści stopni szérokości a zaledwo dwa długości geograficznéj obejmuje na całym swym obszarze. Jest to pas lądu nadmorskiego, stosunkowo wązki a długi, cały poryty, najeżony górami, które się we dwa główne łańcuchy równoległe wiążą: z nich jeden, niższy, nadbrzeżny, zachodni, zowie się Kordylijerą Nadmorską *(Cordillera marítima, Cordillera de la Costa)*, drugi, a trzykroć wyższy, wschodni, stanowi właściwe Andy *(Andes, Cordillera de los Andes)*.

Podróżny, który od zachodu do brzegów chilijskich przypływa, gdyby jednym rzutem oka mógł ogar-

Fig. 4. Title pages of Transactions and Reports of the Section of Mathematical and Natural Sciences of the Academy of Arts and Sciences, vol. V, 1878, containing I. Domeyko's monograph (written in Polish) "General view on the Chilean Andes and metallic deposits contained in them"

Mathematical and Natural Sciences of this Academy, vol. 5, 1878 (Fig. 4) there appeared written in Polish his exhaustive treatise "General view on the Chilean Cordilleras and metallic deposits contained in them" (Domeyko, 1878a). This is, probably, the last monographic paper on this subject published by the already 76 years old geologist. Domeyko refers in it to his earlier works, mainly those published in 1846 in "Annales des Mines", entitled "Memoire sur la constitution géologique du Chili"and "Récherches sur la géologie du Chili" (Domeyko, 1846a, b). The former is supplied with geological map representing a pioneer presentation of the area studied by him. The investigations of later authors, cited by Domeyko, particularly of Aimé Pissis (1812–1889), have introduced some important stratigraphic elements. However, poor palaeontologic documentation often renders these data rather doubtful. The discussed Domeyko's synthetic monograph is very interesting from geologic, mineralogic and mining viewpoint. All these branches, similarly as physical geography, were treated by Domeyko as an integral unity. As far as geology is concerned he had, in fact, no predecessors, since Ch. R. Darwin (1809–1882) had studied merely pericoastal zone consisting of younger, predominantly Tertiary, formations, whilst J. D. Dana (1813–1895) and A. d'Orbigny (1802–1857) studied only granites near Valparaiso. Besides, Pissis in the years 1848–1849 performed geodetic measurements of Chilean territory from Copiapo to Bio-Bio river (i.e. between 27 and 37° of the southern latitude). During successive 20 years this author was working on geological map of Chile and distinguished some stratigraphic members which, however, were insufficiently palaeontologically documented.

Domeyko, since his first geologic publications in 1845–1846, was looking after more distinct features, differentiating two main Cordillera ranges in Chile. In the map of his travel published in the paper of 1846 he traced the demarcation line between these two chains, i.e. the western Coastal Cordillera and the eastern one of the proper Andes. This allowed him to point the location of the main ore deposits relative to this contact line of two different formations. As far as relative ages of these formations, showing rather complicated composition, are concerned, Domeyko has chosen as key horizon the only calcareous-clayey member containing rich characteristic fossils. This allowed him to subdivide the whole stratified complex into the pre-Liassic and the post-Liassic (Domeyko, 1878a). In the discussed synthetic treatise Domeyko also presented characteristic geomorphologic features of Chilean territory, consisting in the occurrence of two parallel mountain ranges: the lower Coastal Cordillera and proper higher Andes, separated by the Median Plane. These both ranges are distinctly lowering southwards, whereby the western one passes into an archipelago. Varying climatic conditions have caused

distinct geographic diversity of Chilean territory. The marginal northern zone is a desert, the central one – interesting from mining viewpoint, the southern central – favouring for agriculture, and the marginal-southern one is insular in character. All these zones are described in detail. In the successive chapter, the subdivision of Coastal Cordillera into: A – crystalline rocks, B – undetermined sedimentary older (probably Palaeozoic) rocks, C – stratified Tertiary rocks containing brown coal, and D – alluvial deposits, dunes, guano etc., is presented

This subdivision is followed by megascopic characteristics of the above complexes. In 1876 trilobites were found to occur in older sedimentary rocks. As far as Cainozoic rock complex is concerned, Domeyko informs, that approximately the same number of old oceanic and continental horizons occur in glacial deposits of very distant Scandinavian coasts.

The next chapter is devoted to detailed description of the formations distinguished in the Cordillera of the proper Andes. On its western slopes there occurs the above mentioned Liassic horizon, documented palaeontologically. In relation to this key horizon, Domeyko distinguished the following lithostratigraphic members:

I. Sub-Liassic formation, subdivided into metamorphic and Red Sandstone, both stratified;

II. Liassic and supra-Liassic (Jurassic and Cretaceous) – sedimentary;

III. Crystalline masses, not stratified; some are lifting up the whole stratified complex (dome-shaped granitic and porphyric rocks); other are effusive (former trachites and recent volcanic forms).

In Pissis' opinion, the above red sandstones are Permian and Triassic in age, since similarly dated rocks occur in Bolivian Andes. The underlying metamorphic rocks are older but some zeolitic porphyries and amygdaloidal volcanics interfinger with conglomerates and red sandstones. The Liassic horizon is represented mainly by oolitic limestones which are locally covered by Neocomian carbonate rocks. The overlying volcanic rocks are younger.

Summing up the above presentation, Domeyko attempted to make a comparison of the Andean geology with that of the Tatra Mts. in the Carpathians, basing on available L. Zejszner's data.

He used the following words: "...The composition of this giant Andean chain is similar in many respects to that of our Tatra Mts., where often my spirit was floating when I was traveling along the Chilean Cordillera. In the Andes, as in the Tatras, Liassic limestones represent the most distinct geological horizon. They are underlain by red sandstones containing no organic remnants and in bottom parts by metamorphic rocks. They are always overlain by younger beds up to the Cretaceous, locally Tertiary in age..." (Domeyko, 1878a, pp. 194–195). The second part of this Domeyko's monograph is devoted to the relation of ore-bearing beds and of other formations of the Coastal Cordillera and Andes. In his remarks on the diversity of ore deposits the following sentence is contained: "...In Chile there are no zinc deposits and the mines of this metal similar to those exploiting galmei in Poland and Silesia but zinc blende is often associated with copper and lead sulphides, as well as with pyrites..." (Domeyko, 1878a, p. 203).This statement is followed by detailed description of the mode of occurrence of ores and the data on the composition of ore veins of different generations. This problem will not be dealt with in this paper since, it is discussed in detail by specialists in ore geology (Motuza, 2002; Paulo, 2002). It should be mentioned that Domeyko is often emphasizing the significance of the experience of miners in exploration works, expressing deep sympathy to people employed in underground mines.

The last chapter deals with detailed characteristics of the most important regions of ore exploitation with tabular presentation of statistical data, showing the annual production of Chilean mines in the years 1874–1875.

It should be remembered that in the 19th century the idea of important role of Liassic beds was also valid for the European Alpides, including the Tatra Mts. (L. Zejszner). Nearly everywhere they abound in well- preserved marine invertebrates. On the other side, older and younger sedimentary rocks (except Tertiary deposits) were not palaeontologically documented. Domeyko, being not particularly interested in palaeontology, was sending occasionally the collected fossils to French specialists. These were studied mainly by A. d'Orbigny who, in honour of their discoverer, has named some of them *Terebratula ignaciana* d'Orb and *Nautilus domeykus* d'Orb. (Fig. 5). They are actually exposed at the Museum of Natural History in Paris together with preserved remarks of this distinguished French paleaontologist: "M. Domeyko, ingénieur polonais, a dernierment envoyé a M. Dufrenoy das coquilles fossiles recueilles aux environs de Coquimbo (Chili). Palmi ces coquilles se trouvai un bloc de calcaire compact jaune, contenant beaucoup de térébratules et des individus séparés de deux espèce de ce genre. D'apres l'examen que j'ai fait de ces coquilles, M. Dufrenoy croit d'avoir la roche aux terrains jurassiques." In 1851 C. E. Bayle and H. Coquand have examined the Domeyko's Chilean collection from École des Mines in Paris (Fig. 6) and have named two species *Ammonites domeykanus* Nob. and *Terebratula domeykana* Nob. (Grigelis, 2002).

As follows from these data, the beds called by Domeyko to be the Liassic could also, as in the Tatra Mts., represent Alpine Triassic carbonates and a part of Jurassic series. The latter age can correspond to Domeyko's statement on the occurrence of Neocomian beds. It should be emphasized that our eminent compatriot was prudent in drawing conclusions without proper documentation what is characteristic for specialists in exact sciences.

DOMEYKO – PIONEER OF CHEMICAL MINERALOGY

Domeyko was, unquestionably, an outstanding geologist and an eminent specialist in the study of ore deposits. It should be, however, emphasized that his world-wide reputation and significant scientific achievements were strictly connected with Domeyko's liking and mastery of chemical examination of minerals. His predilection for natural sciences and chemistry was arisen already when he was attend-

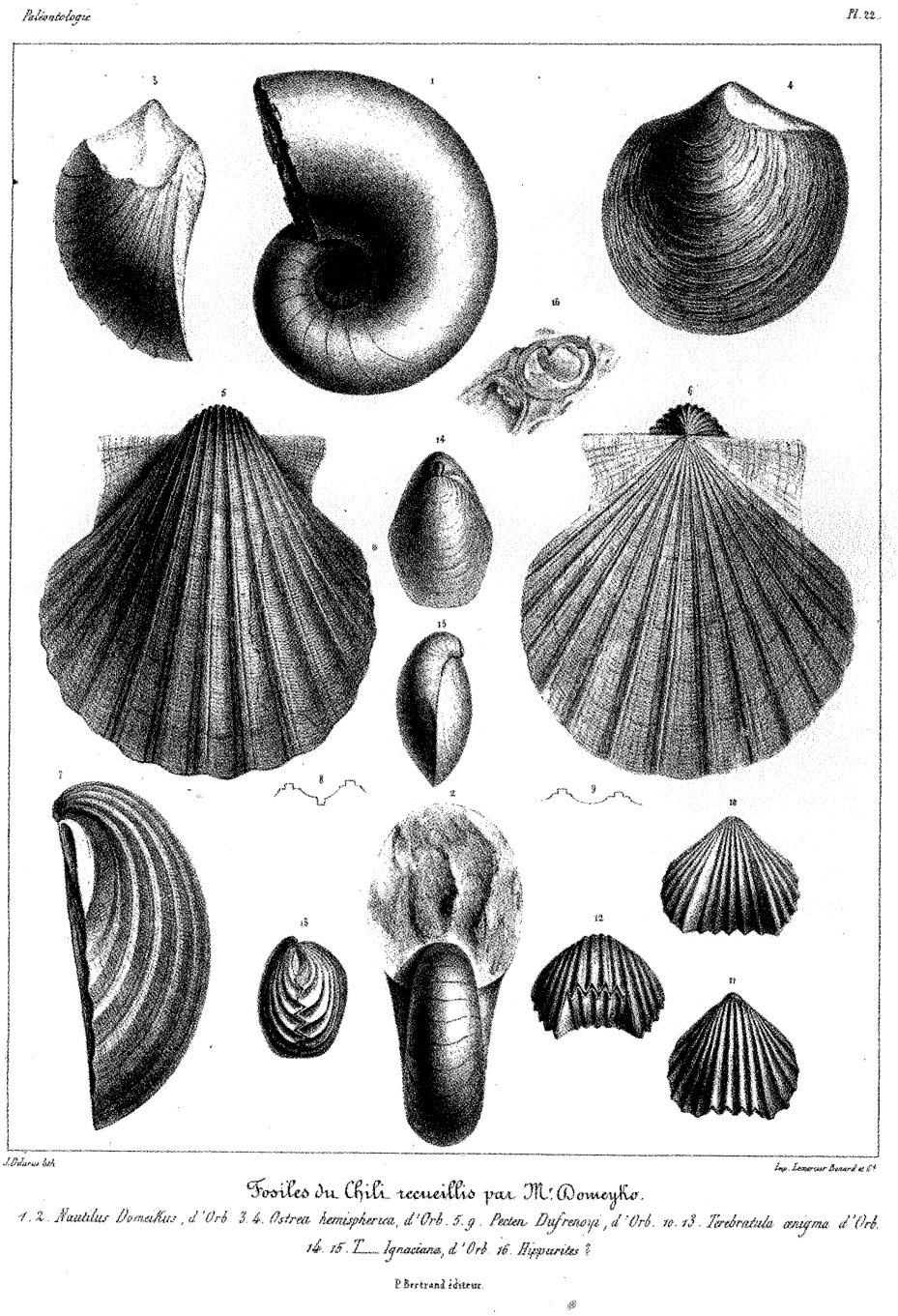

Fig. 5. Jurassic fossils collected by I. Domeyko in the Chilean Andes and determined in Paris by A. d'Orbigny: 1, 2 – *Nautilus domeykus* d'Orb.; 14, 15 – *Terebratula ignaciana,* d'Orb. (after Grigelis, 2002)

ing the Piarist's College in Szczuczyn and studying at the Vilna University, stimulated by his uncle Józef, A. G. Werner's pupil at the Mining Academy in Freiberg. Very important in this respect were excellent lectures of outstanding chemist Jędrzej Śniadecki (1768–1838) and of author of the first Polish academic handbook of mineralogy Feliks Drzewiński (1788–1850). It should be emphasized that at the beginning of the 19th century this university was a leading academic school in the former Polish-Lithuanian Commonwealth.

Domeyko was also very fortunate in Paris where he could participate in lessons of such eminent chemists and physicists, as P. L. Dulong (1785–1838), initiator of quantitative volumetric analysis, J. G. Gay-Lussac (1778–1859), distinguished specialist in analysis of minerals and discoverer of chromium and beryllium, N. L. Vauquelin (1763–1857), and J. B. A. Dumas (1800–1884). The latter, as follows from Domeyko's memoirs (Domeyko, 1962–63), "has inoculated the will and taste of chemical analysis" in his Polish student. However, as already mentioned, the deciding role in the choice of his future profession has played Domeyko's meeting with J. B. Élie de Beaumont (1798–1874), and the resulting studies at the École des Mines in Paris.

Fig. 6. Jurassic fosssils collected by I. Domeyko in Chilean Andes and estimated in Paris by C. E. Bayle and H. Coquand. 4, 5 – *Ammonites Domeykanus* Nob. (after Grigelis, 2002)

Already during his first employment as investigator of iron ores in Alsace he has performed chemical analyses of these raw materials, but their results are not available.

As one of the best graduates of this mining school and talented chemist, Domeyko was proposed by its directory to C. Lambert, representing the Chilean government, as a candidate for six-year contract of a teacher of physico-chemical and geological sciences in the Coquimbo College and organizer of research works on ore deposits in this young South American Republic. Soon after his arrival to Chile built in La Serena and equipped with instruments and reagents supplied from France a modern chemical laboratory and started to analyze local ores and minerals, collected by him and his pupils during field works. It should be emphasized that already his first contacts with very rich and diversified Chilean mineral kingdom have shown that chemical methods are of essential importance in identification of individual minerals, since the majority of them is not crystalline, but amorphous. Therefore, his didactic activity was initiated by lectures on experimental physics and chemistry, followed by teaching mineralogy and practical geology. Taking into account the lack of proper manuals in Spanish, Domeyko has published already in 1841 and in 1844 his lectures in local periodical "El Araucano" (see Ryn, 2002a, pp. 383, 384) and prepared two handbooks: on assaying of raw materials "Tratado de Ensayes" (1844) and "Elementos de Mineralogia" (1845), edited by Coquimbo College, whereby the author is presented as professor of chemistry and mineralogy, respectively. In fact, the former is essentially chemical in character, whereas in the latter manual the

6 NOUVELLES ESPÈCES MINÉRALES

contraire, est assez commun dans les autres minerais de cuivre.

Analyse. Après avoir reconnu les éléments qui composent ce minéral, dans une analyse qualitative par l'eau régale, on a déterminé leurs proportions dans une analyse par le nitre. Pour cela, on a commencé par séparer, au moyen d'un triage, la partie métallique la plus pure possible, et, après l'avoir broyée et porphyrisée, on l'a fait digérer dans l'acide muriatique pur au contact de l'air, et on a lavé le résidu avec de l'eau acidulée d'acide muriatique, puis avec de l'eau pure, afin d'enlever tout l'oxydule.

On a fondu dans un creuset d'argent un mélange de :

2 gr. de minéral ainsi purifié,
4 gr. de nitre, et
10 gr. de carbonate de potasse pur.

La matière étant reprise par l'eau filtrée et lavée, on a sursaturé la dissolution alcaline avec de l'acide muriatique et on l'a fait bouillir. Il ne s'est formé aucun précipité au moment de la saturation, ni en ajoutant un sel de baryte à la liqueur bouillie. On a dosé l'acide arsénique à l'état d'arséniate de fer par la méthode de M. Berthier; et, quant au résidu qui provenait de la filtration de la liqueur précédente, on l'a repris par l'acide muriatique, on a précipité le cuivre par l'hydrogène sulfuré, et on a recherché l'oxyde de fer et les éléments de la gangue dans la liqueur et dans la partie insoluble dans l'acide, etc.

Composition. Par ce moyen, on est parvenu à obtenir pour la composition du minéral :

TROUVÉES AU CHILI. 7

Cuivre. . . .	0,7073	
Arsenic. . . .	0,2662	
Gangue. . . .	0,0255	
	0,9990	

Analyse (1).

Pour la partie pure :

Cuivre. . . .	0,7164	(3)
Arsenic. . . .	0,2836	(1)
	1,0000	

On voit, par conséquent, que c'est un sous-arséniure de cuivre dont la formule est :

Cu^3Ar.

Minerais arsénié de San Antonio. La même espèce minérale se rencontre en quantité considérable dans les mines d'argent de San Antonio du département de Copiapo. Ces mines se trouvent à peu près à la même distance du centre des Cordillières que la montagne de Calabazo, et à plus de 180 lieues au nord de cette dernière; elles sont à 7 ou 8 lieues plus près de la Cordillière que les mines de chlorure d'argent de Chanarcillo, et leur gisement se rapporte au même terrain secondaire stratifié que celui de Calabazo. Elles se trouvent, d'après les observations de M. Gay, à 1.260 mètres de hauteur au-dessus du niveau de la mer.

L'arséniure de cuivre de San Antonio accompagne les minerais riches d'argent métallique et de sulfures doubles de cuivre et d'argent. Sa gangue ressemble à celle du minerai précédent, mais il se trouve mélangé d'une petite proportion de cuivre panaché qui le rend encore plus ressemblant à ce dernier. Du reste, les caractères sont toujours les mêmes, et il est toujours facile de reconnaître ce minéral par l'éclat argenté qu'il prend dans sa cassure fraîche.

Fig. 7. I. Domeyko's report on the discovery and chemical analysis of a new mineral – copper arsenide Cu_3As – named in 1845 by W. Haidinger "domeykite" (Annales des Mines, 4 s., III, 1843, 3–18).It should be noted that in the middle of the19th century the chemical symbol of arsenic was not "As" but "Ar"

minerals are arranged according to the Berzelius' chemical classification and the description of each one contains the recommended methods of their analysis using dry and wet procedures.

As follows from Domeyko's letters to A. Mickiewicz, the analysis of minerals was, certainly, his favorite occupation. In one of them he stated: "...I am living in my laboratory where also during many nights I am backing in crucibles and retorts these strange local ores...". The results of his analyses, as well as samples of rare Chilean minerals, Domeyko was sending to his European, mainly French, friends. Numerous papers published in "Annales des Mines", "Comptes Rendus Hebdomadaires des Séances de l'Academie des Sciences" and "Jahrbuch für Mineralogie, Geognosie, Geologie und Petrefakten-Kunde" were informing European mineralogists and geologists about his achievements. Consequently, one of new substances discovered and analyzed by him in, 1843 – copper arsenide Cu_3As (Fig. 7) – was in 1845 named domeykite by an Austrian mineralogist W. Haidinger (Domeyko, 1843). Later, he was also publishing his papers in local "Anales de la Universidad de Chile" but the most interesting of them were often translated and published or abstracted in the above European periodicals. Considerable variation of climatic conditions in meridionally elongated country results in exceptional variability of mineral associations in Chile. Particularly interesting are assemblages of usually unstable products of alteration of primary ores and of thick beds of bird's excrements, guano. Among these minerals, worth mentioning are: lead oxy-chlorohydroxy-iodate schwartzembergite $Pb_3[IO_3/Cl_2O\ (OH)]$ discovered in Atacama desert and analysed by Domeyko (Domeyko, 1862), bismuth oxychloride BiO(Cl,OH), described and called by him in 1876 daubréeite in honour of his French friend, (Domeyko, 1876), as well as sodium-calcium hydroxy-borate ulexite $NaCa[B_5O_6(OH)_6]\cdot 5H_2O$ (Domeyko, 1853), hydrated copper sodium sulphate kröhnkite $Na_2Cu[SO_4]_2\cdot 2H_2O$ (Domeyko, 1879), and a series of silver and mercury halides. Moreover, he was paying attention to natural silver amalgam, called by him arquerite, evidencing different contents of mercury in it. In 1880, when our eminent mineralogist was already 78 years old, there appeared his report on the discovery in the Mejillones guano deposit, analysed by his coworker and pupil Dr. G. Krull, a rare phosphate minerals bobierrite $Mg_3[PO_4]_2\cdot 8H_2O$ and newberyite $MgH[PO_4]\cdot 3H_2O$, and a complex boro-phosphate – most probably lüneburgite $Mg_3[(PO_4)_2/B_2O(OH)_4]\cdot 6H_2O$ (Domeyko, 1880). Detailed inspection of the first author of available original

COMPOSICION QUÍMICA DE LAS AGUAS POR CADA 10,000 PARTES (EN CADA DIEZ LITROS).

Número.	LOCALIDAD.	Azufre.	Sulfato de sosa.	Sulfato de cal.	Sulfato de magnesia.	Cloruro de sodio.	Cloruro de potasio.	Cloruro de calcio.	Cloruro de magnesio.	Carbonato de cal.	Óxido de hierro i alumina.	Silice.	LOS DEMÁS ELEMENTOS	Totales 10,000.
	Aguas sulfurosas.													
	Chillan													
1	A. de azufre	0.201	0.90	.....	.....	0.12	....	.....	0.06	2.50	0.24	...	Carbonato de sosa 0.44	4.96
2	Id.	0.041	0.61	.....	.....	0.02	....	.....	0.03	1.78	0.12	0.44	Id. id. 0.41	3 44
3	Id. de potasa	0.260	0.82	0.24	0.24	0.12	....	.....	.. ..	0.20	0.02	0.66	Súlfuro de sodio (!) 0.46, por Claessen	2.72
4	Sotomó, San Luis	0.0378	....	.....	.....	10.68	....	.....	.....	.....	.....	....	Carbonato de sosa 1.37, por Claessen	29.2
5	Cochamó	0.1323	....	.. ...	.....	25.38	....	.....	... .	. ....	.....	...		
	Aguas cloruradas.													
6	Cauquenes	.....	0.32	0.60	.....	10.31	....	21.68	indic.	.....	0.02	0.10	.....	33.03
7	El pelambre	.....	0.63	0.41	... ..	11.01	....	21.75	.....	.....	....	0.12	Por Smith	39.92
8	Id.	.....	... ..	0.07	.....	12.08	...	21.22	0.55	.....	....	....	Bromo, litio, stroncio, potasio, por Jacobson	33.92
9	Id.	.....	.....	1.25	.....	12.52	ind.	23.56	indic.	.....	.....	....	Iodo, litio, silicio, por Boussingault	35.33
	Apequindo													
10	Piedra	.....	.....	0.22	.....	3.86	0.04	10.18	0.01	0.42	0.32	0.06	Ácido fosfórico 0.04	15.15
11	Litre	.....	.....	0.53	.....	6.95	0.04	16.80	indic.	.....	0.34	0.23	Id. 0.10	21.99
12	Cañita	.....	.....	0.52	.....	11.77	....	21.65	0.31	.....	0.20	0.35	Iodo	31.33
13	Tinguiririca	.....	.....	1.98	.....	22.73	0.63	1.11	0.23	.....	F. 0.05--Al. 0.10	1.00		27.86
14	Laguna de Maule	... ..	... ..	1.98	.....	166.28	0.06	55.12	1.00	.....	0.32	0.40		225.16
15	Mejillones	.....	.....	26.60	21.16	365.31	...	.....	27.80	4.02	0.15	0.10	Carbonato de magnesia 6.61	157.75
16	El Toro (*Coquimbo*)	.....	.....	11.80	.....	21.38	....	4.33	.....	5.48	1.87	0.04	0.29	48.19
17	Mondaca	.....	.....	.....	2.20	4.96	....	. ....	0.09	2.07	.....	0.79	Carbonato de sosa 0.32	10.43
18	Vilicura	.....	.....	0.05	.....	3.33	...	9.96	0.18	.....	0.10	.. ..		4.62
19	Peterohue	.....	.....	3.76	.....	13.34	ind.	12.24	0 06	0.20	0.06	0.50		30.16
20	Nahuelhuapi	... ..	.....	0.09	. ....	7.30	ind.	5.76	0.06	0.28	indicio	0.06		13.55
21	Cochamó	... ..	.....	1.22	.....	5.04	0.06	.....	0.62	0.50	0.44	0.32		8.20
22	Sotomó	.....	.....	1.06	.....	1.85	....	2.18	.....	0.25	indicio	0.15		5.19
	Aguas sulfatadas.													
23	Chillan (de fierro)	.....	2.92	4.08	1.88	.....	....	.. . ..	.....	.....	Alumina. 0.40.	1.00	Sulfato de hierro 1.36	11.64
24	Id. id.	.....	2.09	7.22	8.92	.....	....	.....	.....	.....	2.00	....	Ácido fosfórico 0.10 !	20.23
25	Trapa-Trapa	.....	1.14	0.96	0.51	... ..	....	.....	.....	.....	0.32	0.83		3.89
26	Los volcan' (*Descabezado*)	.....	0.37	.....	0.45	.....	....	.....	.....	0.83	0.11	0.41		2.17
27	Cajon de Ibañez (*Longavi*)	.....	5.80	2.78	.... .	2.17	....	.....	.....	0.13	0.03	....		10.93
28	Juhuel (*Aconcagua*)	.....	0.72	0.47	0.71	0.11	0.01	.....	.....	1.01	0.17	0.20		3.40
29	Catapilco	.....	0.97	2.07	.....	0.05	....	.....	0.09	0.65	0.03	0.10		3.96
	Aguas cloro-sulfatadas.													
30	Colina	.....	0.78	0.20	.....	1.47	....	.....	0.09	0.67	0.07	0 16		3.41
31	Id.	.. ...	0.89	1.20	.....	1.42	....	0.77	.....	.....	.....	....	Por Smith	4.28
32	Id.	.....	0.94	1.18	.....	0.87	....	1.36	.....	.....	.....	....	Por id.	4.25
33	Paninávida	.....	1.01	0.91	.....	1.14	....	.....	0.03	.. ...	0.14	0.44		3.70
34	Catillo	indic.	1.69	0.07	.....	1.03	....	....	0.02	0.08	0.05	0.61		3.55
35	Hueiquimilla (*Maule*)	.....	1.38	0.39	.... .	1.70	....	.....	.....	.....	.....	....		
	Aguas vitriólicas.													
36	Agua de la Vida	.....	0.50	0.81	.....	.....	....	.....	.....	.. ..	.....	0.50	Sulfato de sesquióxido de hierro 0.90, sulfato de alumina 0.60, con pequeño exceso de ácido	.....
	Aguas carbonatadas calizas.													
37	Agua de Inca	.....	0.90	.....	.....	50.80	...	.....	....	18.00	.....	....	Carbonato de magnesia 0.70 ácido carbónico en exceso	70.40
	Aguas ferrujinosas.													
	Son las de los núms. 16, 23, 24 i 37													

Fig. 8. Chemical composition of Chilean mineral waters, analyzed by I. Domeyko. Tabular presentation in his book "Estudio sobre las aguas minerales de Chile", Santiago, 1871

Domeyko's papers and of C. Doelter's monumental monograph "Handbuch der Mineralchemie" have shown him to be the author of at least 160 analyses of minerals (Narębski, 2003), representing all their possible classes and often showing very complicated composition (Appendix 1). Moreover, he has also published the results of analyses of several Chilean igneous rocks (Appendix 2) and at least 58 chemical data on potable and mineral Chilean waters (Domeyko, 1847,1871; Figs 3, 8). Though the majority of these data refers to ore minerals, represented mainly by sul-

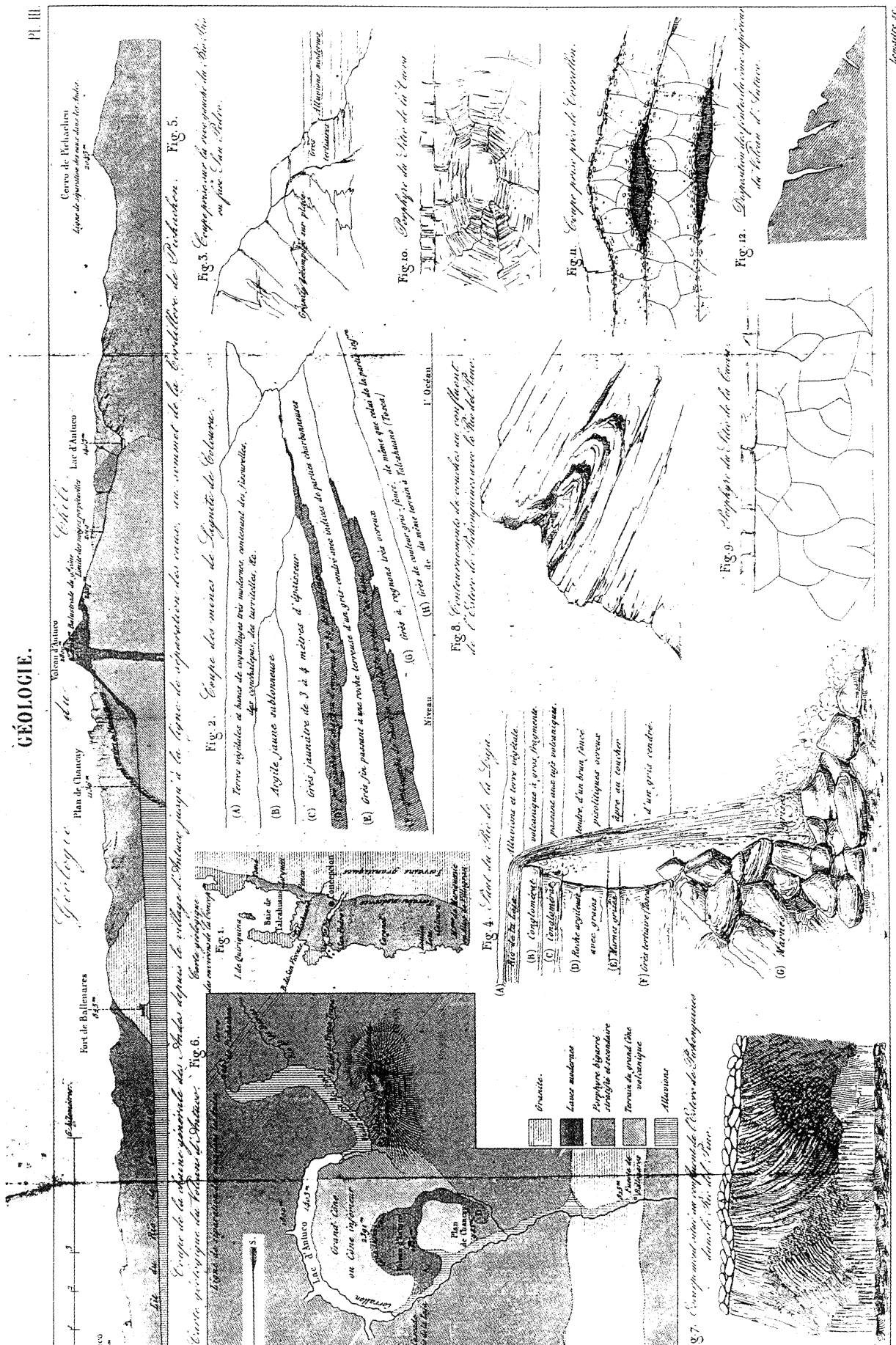

Fig. 9. Geologic map and cross-section of the Antuco volcano and its environs with detailed sketches of lithology of more interesting outcrops in this area, hand-drawn by I. Domeyko and enclosed to his paper "Description du Volcan d'Antuco" (Annales des Mines ser. 4, XIV, 1848, 187–231)

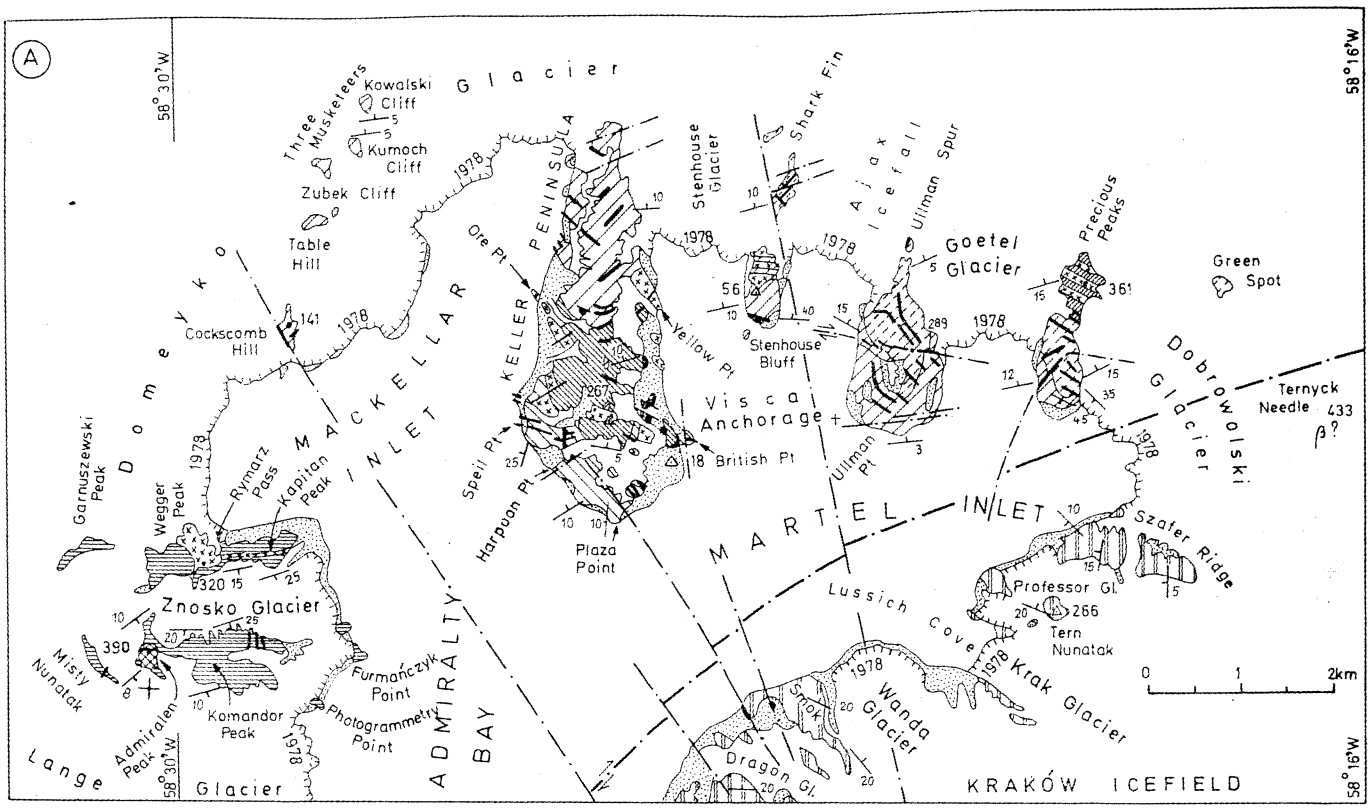

Fig. 10. Geologic map of northern part of Admiralty Bay, King George Island (South Shetland Islands, Antarctica), showing the location of Domeyko Glacier (Birkenmajer, 1982)

phides, sulphosalts, arsenides, antimonides, selenides and tellurides, as well as native elements and alloys, there is also a fairly large number of silicates. This is due to Domeyko's interest in volcanic rocks, often embedding the investigated ore deposits. This is also evidenced by his detailed study of active volcanoes Antuco (Domeyko, 1848; Fig. 9) and Descabezado, as well as of solfataric phenomena in adjacent Cerro Azul (Domeyko, 1852). One of the effects of these studies are chemical analyses of their volcanics and of rock-forming minerals – feldspars and olivine – contained in them, whereby Domeyko has emphasized some similarity of composition of the latter with that of olivine from meteorite found by him in the Atacama desert (Domeyko, 1864, Appendix 1). A fragment of this cosmic stone, nearly 23 kg in weight, belongs to the collection donated by our eminent geoscientist to the Museum of the Academy of Arts and Sciences in Cracow in 1878 and 1884, as its member since 1873 (Koszowska *et al.*, 2002). Other valuable collections of rare South American minerals were donated by Domeyko three times – in 1853, 1871 and 1887 to the Geological Museum of the Jagellonian University, as the expression of gratitude for the proposal of professorship in 1850 and his nomination to honorary doctor of this oldest Polish "Alma Matris" in 1887 (Koszowska & Wolska, 2002). Turning back to Domeyko's dangerous alpinistic excursions to Andean active volcanoes, worth remembering and republishing are his very nice drawings of some important details of geology and a sketch map of the Antuco volcano and its environs, enclosed to the paper reporting in detail the course and results of these studies (Domeyko, 1848; Fig. 9).

All the above data clearly indicate that Ignacy Domeyko should be, unquestionably, placed among pioneers of chemical mineralogy, since both the number and quality of his analytical data, often concerning new minerals, should be considered as a significant contribution to the early stage of development of this, at that time, new branch of mineralogical sciences, initiated by Sweedish analysts A. F. Cronstedt (1722–1765), T. O. Bergman (1735–1784), and J. J. Berzelius (1779–1848), German chemist M. H. Klaproth (1743–1817), and French Domeyko's teachers L. Vauquelin (1763–1857) and J. L. Thenard (1777–1857).

FINAL REMARKS

The present paper, devoted essentially to Domeyko's most significant achievements in different branches of geosciences cannot be closed without at least general remarks on his exceptional personality and spirituality, following the best connoisseur of this problem, Ryn (2002a, b). His patriotism, altruism, conscientiousness and love of knowledge and freedom were the effect of idealistic, emotional and religious atmosphere at home, as well as of his activity in the Philomat and Philaret Societies at the Vilna University, propagating the ideals of brotherhood, learning and virtue. No, wonder that on the ground of such moral standards Ignacy Domeyko was not only an eminent scientist, but also a very appreciated academic teacher, caring for his pupils, defender of local Indian population in Araucania (southern Chile), as well as a loving man and father, deeply moved

when his son Hernan in 1888 was celebrating the Easter Holy Mass in the royal Wawel Cathedral. Domeyko was often declaring his love of Cracow as of his native Vilna, considering them both to be equally important capitals of the Polish-Lithuanian Commonwealth, uniting all the nations of this Republic.

There is a general opinion that thanks to his virtues and merits Domeyko belongs, unquestionably, to the pantheon of intellectual and moral authorities not only of Poland,but and so Lithuania, Belorussia and Chile. It is, therefore comprehensible that in 1996 a group of postulators (including former Polish ambassador in Chile, Prof. Z. J. Ryn), in recognition of his heroic Christian life and activity, expressed in such transcendental values as love of neighbours, justice, solidarity and international brotherhood, has initiated the process of Domeyko's beatification, strongly supported by the local Church authorities.

The Polish geoscientists are remembering Domeyko's contribution to the Andean and Polish geology and patriotism. In 1980, K. Birkenmajer gave his name to the largest glacier at Mackellar Inlet, Admiralty Bay, King George Island (South Shetland Islands, Antarctica), and in 1982 distinguished the Domeyko Glacier Formation (Fig. 10), consisting of volcanites which have been studied in detail by a team of Polish specialists, including the first author of this paper (Birkenmajer, 1980, 1982; Birkenmajer *et al.*, 1985).

The Division of Earth and Mining Sciences of the Polish Academy of Sciences, following the proposal of its Commission on Mineralogical Sciences and of the Mineralogical Society of Poland established in 1989 the annual Domeyko Prize to commemorate the 100th anniversary of death of this exceptional personage, being the common pride of Poland, Lithuania, Belorussia and Chile, justly considered to be the citizen of the world.

Appendix 1
Chemical composition of minerals analyzed by Ignacy Domeyko
(compiled by Wojciech Narębski)

Native elements (13)
Native gold (7)

Locality (Chile)	Andacollo			Casuto		Punitaqui	Gualcu
Au	91.80	96.00	93.15	84.04	86.60	91.62	85.69
Ag	7.85	3.10	6.72	15.39	13.20	7.79	13.75
Fe+Cu	0.35	0.90	0.18	0.19	0.22	0.59	0.24
Total	100.00	100.00	100.05	99.62	100.02	100.00	99.68
Sources	Annales des Mines, 4 ser. t. VI (1844), 167						

Native silver alloys (3) and amalgams (3)

Locality (Chile)	Andacollo	San Antonio, Copiapo			Cordillera Huasco	La Rosilla	Arqueros
Ag	74.4	85.61	84.7	Ag	79.4	65.1	86.5
Bi	12.5	14.39	15.3	Hg	20.6	34.9	13.5
Cu	9.6	"chilenite"					
As	3.5						
Total	100.0	100.0	100.0		100.0	100.0	100.0
Sources	Ann. Min. 4 ser. t. VI (1844), 165-6 Ann. Min. 6 ser. t. V (1864), 456				Ann. Mines 6 ser. II (1862), 123		N. Jb. Min. (1843), 103

Meteorites and their minerals (10)

Locality	Atacama desert				
	Taltal	Imilac	Cachiyuyal	Mejillones	Dehesa
Fe	88.6	88.01	93.92	95.4	86.20
Ni	11.4	10.25	4.93	3.8	14.20
Co	-	0.70	0.39	0.1	
(Fe, Ni, Co) P	-	0.33	0.40	0.9	
Insoluble	-	0.56	0.50	-	
Total	100.0	99.85	100.14	100.2	100.40
Sources	C.R. 58 (1864), 553		C.R. 81 (1875), 597		Miner. (1979)

Silicate component of Taltal meteorite	
SiO_2	43.22
Al_2O_3	7.60
MgO	6.60
FeO	26.52
CaO	4.27
Na_2O	0.40
FeS	11.84
Total	100.45
C.R. 4 s. XIV (1848), 199	

Locality	Schreibersite		
	Juncal	Mejillones	Sierra di Dehesa
Fe	49.38	36.0	65.0
Ni	29.63	44.0	26.3
P	20.99	18.0	8.7
Total	100.00	98.0	100.0
Sources	C.R. 81 (1875), 592, 597		C.R. 66 (1868), 572

Olivine	
Atacama desert	
SiO_2	40.0
FeO	13.3
MgO	46.7
Total	100.0
Ann. Min. 4 s. XIV (1848), 199	

Oxides and hydrated oxides (7)

	Titanomagnetite		Gibbsite	Lepidocrocite (2)		Psilomelane (2)		
Locality	S. Juan Huerto	Tupungato	Juan Fernandez	La Higuera	Coquimbo		Atacama	Cerro de Catemu
Al_2O_3			63.5			MnO_2	84.0	72.1
TiO_2	15.60	6.07	-			Fe_2O_3	0.4	1.1
Fe_2O_3	70.15	63.30	-	85.30	84.90	CuO	2.0	-
FeO	10.50	31.02	-	0.20		BaO	-	10.3
CaO	0.20	-	3.7	-		MgO	0.6	0.6
MgO	0.30	-	trace	-		CaO	-	4.8
H_2O	-	-	33.2	11.15	11.80	H_2O	3.0	6.8
Insol	2.55	-	-	3.35	3.30	Insol.	8.6	4.1
Total	99.3	100.39	100.4	100.0	100.0	Total	98.6	99.2
Sources	Mineralojia (1879), 105		Mineralojia (1879), 143, 144			Mineralojia (1879), 117		

Silicates (24)

Fedspars (12)

Locality	Descabezado volcano			Coquimbo	Penon	Rio de Laguna	Juan Fernandez	Valparaiso		Papudo		Carrisal Rio Turbo
Rock	Trachyte, Lower cone		Lava, summit	Pegmatite	Granite	Granite	Trachyte	Granite		Granite		Granite
SiO_2	59.06	55.3	61.2	67.35	64.15	57.05	48.70	65.96	50.50	61.34	66.87	65.37
Al_2O_3	25.00	26.5	23.7	20.50	21.65	26.20	28.86	19.68	25.40	21.20	19.15	20.47
FeO	2.05	4.3	1.5	-	1.30	3.05	1.27	-	2.10	0.80	0.75	-
MgO	-	0.6	0.8	0.42	1.55	0.32	0.49	-	-	-	0.12	trace
CaO	5.04	6.2	4.2	0.70	1.90	8.60	12.80	0.63	12.25	7.20	2.20	2.60
Na_2O	7.40	6.7	5.6	4.00	6.90	4.15	8.10	4.99	7.30	7.30	1.20	4.00
K_2O	0.80	-	0.2	6.61	0.80	0.15	-	8.31	0.35	-	8.43	6.30
Total	99.3	99.6	97.2	99.58	99.35	99.52	100.22	99.57	97.90	97.84	98.72	98.74
Sources	Mineralojia (1879), 552, 561, 562, 724											

	Olivine	Amphiboles (2)		Pyroxenes (2)		Garnet
Locality	Antuco volcano	Canion Rio Pulido, Copiapo	Playa Ancha Valparaiso	Peñon, Andacollo	Descabezado volcano	Rio Cautin Araucania
Rock	Lava	Porphyric volcanies			Andesite	Sandy river load
SiO_2	40.7	41.9	50.06	51.1	53.3	37.0
Al_2O_3	-	16.6	13.39	1.0	5.0	10.3
Fe_2O_3	-	11.7	21.08	8.2	32.8	14.7
FeO	19.6	nd	nd	nd	nd	15.8
MnO	-	1.6	0.07	2.5	-	19.7
MgO	39.7	15.4	0.48	14.5	tr	-
CaO	-	11.6	14.26	20.6	10.1	3.0
H_2O	-	1.2	1.00	-	-	-
Total	100.0	100.0	100.34	97.9	101.2	100.5
Sources	Ann. Min. 3 s. IX, (1846), 3	Mineralojia (1879), 601			Ibidem, analyst E. Wilimas	Mineralojia (1879), 666

	Beryl	Prehnite	Laumontite (2)		Scolecite	Chrysocolla
Locality	Valparaiso	Rio de los Cipreses, Peru	Cordillera Peuco, Juncos	Tamaya mine	Cachapueltales	Andacollo
Rock	Pegmatite	Various magmatic rocks				No data
SiO_2	65.6	43.6	50.1	52.10	46.3	52.2
Al_2O_3	17.3	21.6	19.9	18.94	29.9	1.2
FeO	0.9	4.2	-	-	-	Cu O 29.5
CaO	0.4	25.0	14.1	10.26	13.4	-
BeO	13.1	-	-	-	-	-
H_2O	-	5.3	16.0	17.33	14.0	16.7
Total	98.1	98.7	100.1	98.63	100.6	99.6
Sources	Mineralojia (1879), 666	N. Jahrb. Min. (1849), 473	Neues Jahrbuch f. Mineralogie (1849), 200, 556			Mineralojia (1879), 262

Sulphides and sulphosalts (50)

	Sphalerite (5)					Stannite	Pyrrhotite	
Locality	Chibato	Rancagua - Abogado mine			Las Vacas	Guanaani (Bolivia)	Panulcillo	
Pb	1.90	-	-	-	-	-		
Cu	-	0.30	10.10	31.90	-	22.9		
Sn	-	-	-	-	-	28.2		
Fe	7.50	0.20	2.40	2.00	4.8	23.3	Fe	57.55
Zn	54.50	64.60	52.90	33.70	60.1	-	S	39.50
S	33.60	33.50	35.20	24.20	35.1	27.5	Insoluble	1.50
Insoluble	-	1.50	-	5.30	-	-	Total	98.55
Total	97.50	100.30	100.60	97.10	100.0	101.9		
Sources	Mineralojia (1879), 289			Ann. Min. 4, VI (1844), 178		Mineralojia (1879), 24	Mineralojia (1879), 153	

	Stromeyerite (5)					Stephanite (2)		
Locality	Catemo	Aconcagua		Santa Rosa	S. Pedro Nolasco		Chañarcillo	
Ag	12.08	16.58	24.04	50.10	28.8	Ag	65.10	70.07
Cu	63.98	60.58	53.94	31.00	53.4	Sb	18.80	15.70
Fe	2.53	2.31	2.09	-	-	S	15.40	14.41
S	21.41	20.53	19.93	15.80	17.8	Total	99.30	99.91
Total	100.00	100.00	100.00	96.60	100.0			
Sources	Ann. Mines, 3, IX (1843)			Mineralojia (1879), 372		Mineralojia (1879), 383		

	Bismuthinite (4)				Emplectite	Polybasite (2)	
Locality	Chorolque, Bolivia		Cerro de Tazna Constanzia, Bolivia		Cerro Blanco, Copiapo	Tres Puntas, Chile	
Cu	-	-	0.70	0.98	20.60	9.0	6.0
Fe	1.33	5.83	0.40	0.50	4.10	0.7	1.1
As	-	-	1.31	1.22	-	4.1	-
Sb	1.15	1.39	-	-	-	4.2	9.5
Bi	77.42	75.22	87.27	84.66	52.70	Ag 64.3	Ag 62.1
S	18.90	17.56	10.30	11.03	22.40	16.1	15.3
Insoluble	-	-	-	-	-	1.6	6.0
Total	98.80	100.00	99.98	98.39	99.80	100.0	100.0
Sources	Mineralojia (1879), 302-304				Ann. Min. 5 (1865), 459	Mineralojia (1879), 391	

	Chalcopyrite (3)			Bornite (4)				Pyrargyrite (2)		
Locality	Higuera-Brillador			Tamaya		Sapos	Higuera		Potosi, Bolivia	Tres Puntas
Cu	37.10	36.70	28.30	66.70	49.3	56.10	59.50	Zn	2.80	0.40
Fe	32.10	26.00	26.40	8.00	15.5	17.70	18.20	Fe	1.70	0.67
S	30.60	33.80	29.00	22.80	20.8	23.10	20.50	Ag	52.70	53.54
Insoluble	1.10	2.60	16.00	1.60	11.1	3.10	1.80	Sb	23.00	21.24
Total	100.90	99.10	99.70	99.10	96.7	100.00	100.00	S	14.90	16.92
Sources	Annales des Mines 18 (1840), 82			N. Jahrb. Min. (1842), 325		Mineralojia (1879), 220		Insol.	4.50	7.53
								Total	99.60	100.00
								N. Jahrb. Mineral. 1879, 380		

	Enargite (2)		Proustite (3)			Pearceite	Freieslebenite (2)	
Locality	Morococha, Peru	S. Pedro Nolasco	Carrizo, Huasco	Ladrillos, Copiapo	Vallenar	Arqueros	Huanchaco, Bolivia	Carrizo Huasco
Fe	3.50	4.80	0.96	-	1.20	0.60	1.00	1.2
Cu	44.20	48.50	0.19	-	-	10.70	Pb 29.10	39.3
Ag	-	0.30	63.85	66.33	62.44	63.54	21.40	6.2
Zn	0.40	2.30	-	-	-	-	0.80	1.1
Sb	2.60	6.40	0.70	-	-	0.43	26.70	27.5
As	13.40	11.40	13.85	20.18	17.45	7.29	-	Cu 3.3
S	33.40	21.10	18.00	13.11	18.00	17.07	21.10	19.0
Insoluble	-	-	1.60	0.40	-	-	-	-
Total	97.50	94.80	99.15	100.02	99.09	99.63	100.10	97.6
Sources	Mineralojia (1845), 226	Mineralojia (1879), 226, 389, 393, 398, 399						

Tetrahedrites (8)								
Locality	De Lagueda, Libertad, Peru	Machetillo, Chile	Manto di Valvidia, Punitaqui	Lajarilla Antocollo, Chile	Fortunata Talca	Vallenar, Huasco	Tres Puntas	
Fe	7.70	1.20	1.50	1.30	0.17	1.19	1.1	0.60
Cu	8.90	36.70	33.60	39.00	32.37	52.89	6.0	10.70
Zn	-	6.90	trace	-	-	-	-	-
Ag	70.55	2.90	-	-	-	-	62.1	63.54
Hg	-	-	24.00	11.00	3.80	3.83	-	-
As	7.25	6.50	-	4.00	-	-	-	7.29
Sb	18.40	20.70	20.70	20.40	34.90	12.83	9.5	-
S	26.20	25.30	20.20	24.30	27.85	18.30	15.3	17.07
Total	99.00	100.20	100.00	100.00	98.99	98.87	94.0	99.63
Sources	Mineralojia (1879), 229		Ann. Min. 6 (1844), 183	Ann. Min. 5 (1864), 472	Mineralojia (1879), 238, 239, 391, 393			

Tetrahedrites (4)				
Locality	Aullugas, Bolivia	Oruro, Peru	Hualguayoc, Peru	Tres Puntas, Chile
Cu	23.8	27.1	10.80	18.0
Ag	8.0	14.3	23.95	36.9
Fe	4.7	6.6	3.55	3.7
Zn	10.0	0.6	-	5.2 + 2.4 Pb
Sb	30.5	28.3	37.07	6.9
As	-	-	0.97	6.2
S	22.6	21.0	23.37	20.7
Total	99.6	97.9	99.71	100.0
Sources	Mineralojia (1879), 393, 394			

Arsenides, antimonides, selenides and tellurides (26)

	Löllingite (3)			Smaltite (4)				Domeykite (2)	
Locality	Descubridora, Huasco		Loreto, Chañarcillo	Copiapo, Punta Brava		Bandurrias	Cabeza Vaca	S. Antonio, Copiapo	Illapel, Coquimbo
Fe	27.60	27.60	27.35	1.19	6.20	2.61	7.16	0.52	-
Ag	-	0.20	-	4.60	3.20	2.06	-	-	-
Cu	-	-	-	-	-	-	-	70.70	71.64
As	66.20	70.30	71.58	71.60	60.30	73.82	65.81	23.29	28.36
Sb	-	-		-	-	-	-	-	-
Ni	-	-	-	-	11.40	5.16	2.62	-	-
Co	-	-	-	4.93	15.80	15.90	15.16	-	-
Pb	-	-	-	17.64	-	-	-	-	-
S	1.10	1.10	0.87	0.60	-	0.20	0.70	3.87	-
Insoluble	5.10	-	-	-	-	-	-	-	-
Total	100.00	99.20	99.80	100.56	96.90	99.75	94.75	98.38	100.00
Sources	Ann. Min. 3, IX, (1849), 467		Mineral. (1879), 162	Mineralojia (1879), 178, 179				Ann. Mines, 4 ser. III (1843), 6-7	

	Arsenopyrite (2)		Cobaltite (2)		Nickeline	Rammels-bergite	As-Argentite (2)		
Locality	S. Francesco-San Simon		Tambiello, Coquimbo	Mine d. Buitre	Chañarcillo	Morado, Huasco		Bandurias	
Fe	23.20	26.50	14.30	11.50	1.4	1.4		0.3	13.8
Ni	-	-	-	-	47.9	35.1		-	0.6
Co	2.10	7.80	16.57	27.50	0.6	-		0.6	8.3
As	49.95	42.80	52.35	42.70	47.5	56.4		10.1	27.1
S	19.40	20.10	16.64	18.60	Sb 2.6	S 2.3	Sb	0.8	1.0
Insoluble	4.70	-	-	-	-	4.7	Ag	82.5	39.8
Total	98.85	97.20	99.86	10 0.30	10 0.0	99.0	Hg	5.6	-
Sources	Mineralojia (1879), 164, 180, 185				Mineralojia (1879), 186		Insoluble	-	8.2
							Total	99.9	98.8
							Source	Mineralojia (1879), 411	

	Dyscrasite (3)			Naumannite (2)		Clausthalite	Eucairite	Hessite (2)	
Locality	Carizzo Mine	Romer Copiapo	Cachueta, Argentina				Aguas Blancas	Condoriaco, Coquimbo	
Ag	76.08	77.72	77.12	21.0	9.8	-	39.8	58.0	56.6
Co	-	-	-	0.70	2.8	-	-	-	-
Sb	23.92	22.28	22.10	-	-	-	-	-	-
Se (Te)	-	-	-	30.0	30.8	27.6	32.2	(37.3)	(38.0)
Pb	-	-	-	43.5	37.1	69.9	-	4.7	5.4
Cu	-	-	-	1.8	10.2	-	28.0	-	-
Fe	-	-	-	2.2	1.2	1.0	-	-	-
Losses	-	-	-	-	6.5	-	-	-	-
Total	100.00	100.00	99.22	99.2	98.4	98.5	100.0	100.0	100.0
Sources	Mineralojia (1879), 364			C.R. 63 (1866), 1064			Min. (1879), 401	C.R. 81 (1875), 81	

Salts of oxyacids (36)

Sulphates (8)

	Aluminite	Tamarugite	Brochantite	Langite	Coquimbite	Kröhnkite (2)		Philippite
Locality	Cerros Pintados	Miraflores mine	Paposo	El Cobre	Atacama desert		Calama, Bolivia	Cordillera Condas
Na_2O	0.7	10.70	68.5	-	-	18.80	18.04	-
CuO	-	-	-	68.5	-	23.05	23.20	14.39
CaO	0.6	0.89	-	-	0.14	-	-	-
MgO	-	-	-	-	-	-	-	0.85
Fe_2O_3	-	-	-	-	23.83	-	-	9.80
Al_2O_3	15.7	15.10	-	-	3.06	-	0.22	15.10
SO_3	31.8	41.94	15.7	16.8	41.62	47.30	45.56	28.96
H_2O	41.1	31.37	13.5	13.5	31.14	10.77	11.08	43.72
Insoluble	9.5	-	2.4	-	0.21	-	-	-
Total	99.4	100.10	100.1	98.8	100.00	100.00	100.00	100.00
Sources	2. Apend. Mineralojia (1883), 30, 31		Museum Jag. Univ.	Ann. Min. 5 (1864), 453	Mineralojia (1879), 247, 248, 250			

	Arsenates (4)				Vanadates (2)	
	Taznite (atelestite)	Mimetesite (3)			"Chileite" (Mottramite) (2)	
Locality	Tazna, Bolivia	Mina Grande, Marqueza, Arqueros, Chile				
CaO	-	-	8.31	11.06	0.5	0.58
CuO	-	-	0.96	0.92	14.6	16.97
PbO	-	63.1	68.46	58.31	54.9	51.97
$PbCl_2$	-	10.2	-	9.05	1.0	1.52
Bi_2O_5	71.50	-	-	-	-	-
As_2O_5	12.28	24.1	12.06	11.55	4.6	4.68
Sb_2O_5	5.25	-	-	-	-	-
V_2O_5	-	-	1.94	1.86	13.5	13.33
P_2O_5	-	-	5.35	5.13	0.6	0.68
R_2O_3	6.00	-	-	-	3.5	3.52
Cl	-	-	2.41	-	-	-
H_2O	4.90	-	-	1.22	2.7	2.70
Insoluble	1.00	0.2	-	-	2.0	2.85
Total	100.93	99.6	99.49	99.10	97.2	97.55
Sorces	6° Ap. Reino Min. Chile (1878), 14, 21		Annales des Mines, 4 ser. XIV (1848), 149, 150			

* taznite = slightly impure atelesite

	Phosphates (4)				Borophosphate	Borates (2)	
	Dufrenite	Turquoise	Bobierrite	Newberyite	Lüneburgite	Ulexite	
Locality	Atacama desert	San Lorenzo	Guano deposit Mejilones, Chile			La Ola, Chile	Tarapaca, Peru
Al_2O_3	2.0	46.3	-	-	-	-	-
Fe_2O_3	50.19	3.3	-	-	2.30	-	-
CuO	-	6.3	-	-	-	-	-
MgO	-	-	18.53	22.8	24.38	0.21	4.4
CaO	-	-	5.80	-	0.14	13.83	6.0
Na_2O	-	-	-	-	-	13.23	7.9
P_2O_5	21.26	17.7	40.13	42.2	27.60	K_2O 0.68	-
B_2O_3	-	-	-	-	6.80	36.74	45.9
H2O	22.08	18.8	36.00	35.0	38.30	32.35	35.4
Insoluble	3.37	7.6	-	-	-	-	-
Total	98.90	100.0	100.46	100.0	99.52	97.04	99.6
Sources	Mineralojia (1879), 161	Ibidem, 259	N. Jahrb. Mineral (1880), II, 304 (analyzed by Dr. Krull)			Mineralojia (1879), 512	An. Univ. Chile (1853), 66

	Carbonates (3)			Iodates (2)		
	Oligonite	Malachite	Azurite	Schwartzembergite		
Locality	San Pedro Nolasco	Andacollo			Atacama desert, Chile	
FeO	32.10	-	-	$PbCl_2$	11.40	22.8
MnO	30.52	-	-	PbI_2	30.89	18.7
CaO	2.75	-	-	PbO	48.92	47.1
CuO	-	71.84	69.12	$PbSO_4$	5.51	-
CO_2	32.80	19.95	25.60	$PbCO_3$	1.88	2.5
H_2O	-	18.21	5.28	$CaCO_3$	-	1.7
Insoluble	0.35	-	-	Sb_2O_3	0.91	-
Total	98.52	100.00	100.0	Insoluble	0.91	-
Sources	Mineralojia (1879), 170	Mineralojia (1879), 265		Total	99.51	98.1
				Source	Annales des Mines, 5 (1864), 543	

	Tungstates (5)					Molybdate	
	Cupro-scheelite (3)			Scheelite (2)		Wulfenite + Powellite	
Locality	Llamuco mine, Atacama desert			Talca, Coquimbo	Peralillo, Cobre		No data
CaO	18.20	18.05	15.25	18.60	18.50		6.88
CuO	3.31	3.30	5.10	-	0.30	PbO	47.00
Fe_2O_3	-	-	1.55	0.45	-		-
WO_3	76.32	75.75	76.00	68.75	79.26	MoO_2	46.12
Insoluble	-	0.75	0.40	12.15	1.94		-
Total	97.83	97.85	98.30	99.95	100.00		100.00
Sources	Ann. Mines 3, IV (1843), 15			Mineralojia (1879), 90		Ann. Min. 3, IV (1843), 15	

	Antimonates (2)		Sulphate	Complex nitrate-sulphate	
	"Ammiolite" (Partzite* + Cinnabar)		Carphosiderite**	Darapskite	
Locality	Various Chilean deposits		Inca mine	Atacama desert	
Hg	19.9	23.6	-	$NaNO_3$	60.41
S	3.3	3.3	-	Na_2SO_4	33.66
CuO	16.9	15.6	SO_3 33.8	H_2O	10.77
Fe_2O_3	2.2	3.1	48.3	Total	100.00
Sb_2O_3	24.1	29.5	Al_2O_3 0.1		
SiO_2	24.8	8.1	3.5		
H_2O	8.8	16.9	13.0		
Total	100.0	100.1	98.7		
Sources	Annales des Mines, 4 ser., VI (1844), 183		2° Apend. Min. (1883), 20 anal. Casimiro Domeyko!	Anales Universidad Chile, 11 (1854), 262	

* – complex Cu-antimonate
** – hydronium jarosite (J. Kubisz, 1960)

Haloids (7)

	Chlorides, bromides, iodides (5)					Oxychlorides (2)		
	Bordosite	Bromargyrite	Embolite	Iodargyrite	Tocornalite*		Atacamite	Daubréeite
Locality	Julia mine	Corrida Colorada	Quillota	Arqueros	Chañarcillo		Atacama desert	Tezna, Bolivia
Ag	66.98	57.1	69.3	46.2	33.8	CuO	74.7	-
Hg	2.20	-	-	-	3.9	Bi_2O_3	-	89.60
Cl, Br^1, I^2	22.64	42.9[1]	16.4, 14.3[1]	53.8[2]	41.8[2]	Cl	11.2	7.50
NaCl	1.75	-	-	-	-		-	-
Fe_2O_3	1.60	-	-	-	-		-	0.72
$CaCO_3$	4.06	-	-	-	-	H_2O	14.4	3.84
Insoluble	1.07	-	-	-	20.5		-	-
Total	100.00	100.0	100.0	100.0	100.0		100.3	101.66
Sources	Ann. Mines X (1876), 15	Mineralojia (1879), 428	Mineralojia (1845), 202	Mineralojia (1879), 429		Miner. Chile App. III, (1871)		C.R. 82 (1876), 922

* – a mixture of AgI and HgI_2

Appendix 2

Chemical composition of Chilean volcanic rocks analyzed at the chemical laboratory of the Santiago University by Ignacy Domeyko and his co-workers (compiled by W. Narębski)

Locality, volcano	Tinguiririca	Antuco	Descabezado Grande			
Rock	Andesite	Basalt	Andesites		Dacites	
SiO_2	58.43	52.5	59.50	62.86	68.50	69.72
Al_2O_3	16.75	18.0	16.90	25.08	20.03	16.33
Fe_2O_3	11.00	14.5	7.32	nd	5.50	4.63
FeO	nd	nd	nd	nd	nd	nd
MnO	nd	nd	nd	nd	nd	nd
MgO	3.27	3.7	3.01	1.40	nd	0.20
CaO	4.94	8.8	6.00	3.35	5.65	1.73
Na_2O	2.94	1.3	4.21	4.06	0.90	3.00
K_2O	0.05	0.2	0.04	0.55	nd	1.30
Losses	1.00	-	2.70	1.55	-	1.13
Total	98.48	99.0	99.68	98.85	100.58	98.04
Sources	Mineralojia, 3a edicion (1879), 577					

nd – not determined

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Streszczenie

HOŁD IGNACEMU DOMEYCE (1802–1889) W DWUSETNĄ ROCZNICĘ URODZIN

Wojciech Narębski & Zbigniew Wójcik

Wprowadzenie

Dwusetna rocznica urodzin Ignacego Domeyki, obchodzona uroczyście pod auspicjami UNESCO w krajach, związanych z jego życiem i działalnością, jest okazją do przypomnienia zasług i osiągnięć tego wybitnego badacza, pedagoga i działacza społecznego o niezwykłej osobowości. Uroczyste konferencje naukowe w Krakowie i Paryżu oraz w miastach dawnego Wielkiego Księstwa Litewskiego Wilnie; Mińsku i Brześciu, połączone z odwiedzinami stron rodzinnych Domeyków, przebiegły z udziałem przedstawicieli tego zasłużonego rodu, rozproszonych dziś po całej Ziemi od obu Ameryk, przez Europę do Australii.

Celem niniejszej pracy jest przypomnienie na łamach czołowego polskiego czasopisma geologicznego niezwykłej postaci i podstawowego dorobku naukowego Ignacego Domeyki w zakresie nauk o Ziemi.

Zarys życiorysu

Ignacy Domeyko, syn Antoniego Hipolita i Karoliny z Ancutów, urodził się 31 lipca 1802 r. w majątku rodzinnym Niedźwiadka w Nowogródzkim, na terenie b. Wielkiego Księstwa Litewskiego. W tej polskojęzycznej rodzinie wychowany został w duchu głębokiej religijności i patriotyzmu. Średnie wykształcenie uzyskał w znanym z wysokiego poziomu nauczania nauk przyrodniczych Kolegium Pijarów w Szczuczynie. W latach 1816–1822 studiował na Wydziale Nauk Fizycznych i Matematycznych Uniwersytetu Wileńskiego, słuchając wykładów tak wybitnych profesorów, jak przyrodnicy Jędrzej i Jan Śniadeccy, historyk Joachim Lelewel oraz fizyk i autor pierwszego polskiego podręcznika akademickiego mineralogii Feliks Drzewiński. Tytuł magistra uzyskał na podstawie rozprawy z wyższej matematyki, mając początkowo zamiar obrania zawodu inżynierskiego. Realizację tych zamierzeń udaremniło aresztowanie i internowanie w majątku jego stryja Ignacego Zapole koło Lidy w wyniku procesu Filomatów i Filare- tów, w którym działał wraz z A. Mickiewiczem, T. Zanem, J. Cze- czotem, A. Chodźką i innymi. Wszelkie plany pracy i działalności na ojczystej ziemi zniweczył ostatecznie udział Domeyki w powstaniu listopadowym 1831 roku. Po jego upadku bowiem musiał przekroczyć wraz z oddziałem granicę pruską, skąd udał się do Drezna, a następnie do Francji. W Paryżu miał możność kontynuowania studiów w zakresie nauk ścisłych i przyrodniczych w Sorbonie i Collége de France, ale decydujący wpływ na jego dalszy los miało uzyskanie dyplomu inżyniera górniczego po ukończeniu École des Mines. Jako jej wyróżniający się absolwent, wyspecjalizowany w umiłowanej dziedzinie analizy chemicznej surowców mineralnych, skorzystał Domeyko z propozycji przedstawiciela rządu chilijskiego i zawarł sześcioletni kontrakt, obejmując posadę nauczyciela przedmiotów ścisłych i geologiczno-górniczych w stolicy prowincji Coquimbo La Serena. Dzięki wybudowaniu wyposażonego w przywieziony z Francji sprzęt i odczynniki laboratorium, mógł nie tylko prowadzić opartą na doświadczeniach działalność dydaktyczną, ale i rozwinąć na szeroką skalę badania chemiczne miejscowych kruszców, wykrywając przy tym szereg nieznanych dotąd minerałów. Było to jednym z efektów równolegle prowadzonych prac terenowych, mających na celu rozpoznanie geologiczne i złożowe okolicznych, niezwykle urozmaiconych utworów, które to prace zaowocowały szeregiem cennych publikacji.

Osiągnięte sukcesy naukowe, dydaktyczne i organizacyjne Domeyki w Coquimbo spowodowały zaproponowanie mu stanowiska profesora Uniwersytetu w stolicy Chile Santiago. W związku z brakiem poprawy trudnej sytuacji politycznej rodzinnego kraju, Domeyko przyjął tę propozycję i w 1846 r. rozpoczął wykłady z fizyki, chemii, mineralogii i probierstwa. Niebawem wsławił się udaną reformą szkolnictwa chilijskiego na wzór sprawdzonego w okręgu wileńskim systemu oświaty.

Nieoczekiwane ale bardzo udane małżeństwo z 15-letnią Enriquettą Sotomayor w 1850 r. związało go jeszcze bardziej z adoptowaną drugą ojczyzną, ale nie osłabiło przywiązania do kraju nad Niemnem i Wisłą. Ożywiona korespondencja z krewnymi i przyjaciółmi w kraju rodzinnym oraz to, że jak sam pisał, „...zawsze modlił się i myślał po polsku..." sprawiły, że do końca życia zachował doskonałą znajomość języka ojczystego.

Wybrany w 1867 r. na rektora Uniwersytetu w Santiago pełnił tę funkcję, w wyniku trzykrotnej reelekcji, nieprzerwanie do 1883 r., zyskując opinię kryształowego człowieka oraz sławę wybitnego badacza, dydaktyka i organizatora.

W latach 1884–1888 Domeyko mógł wreszcie udać się do Europy i odwiedzić wraz z synami Kazimierzem i Hernanem kraj

rodzinny, gdzie w jednym z rodowych majątków Zyburtowszczyźnie gospodarowała od 1878 r. jego córka Anna z zięciem, a jej kuzynem Leonem Domeyką. Podczas tej podróży został on przyjęty wraz z synem księdzem Hernanem przez Papieża i odwiedził Ziemię Świętą. Domeyko gościł też z rodziną w umiłowanym przez niego, podobnie jak Wilno, i podziwianym królewskim Krakowie, gdzie otrzymał doktorat honorowy Uniwersytetu Jagiellońskiego, którego – gdyby nie nieco wcześniejsze założenie rodziny w Chile – mógłby zostać profesorem już w 1850 r. Przy tej okazji ofiarował krakowskiej uczelni, jak również Akademii Umiejętności, której był członkiem od 1874 r., kolekcje cennych minerałów i szereg wartościowych publikacji. Wielkim przeżyciem rodzinnym było odprawienie przez Hernana wielkanocnej Mszy św. w Katedrze Wawelskiej. W drodze powrotnej do Chile Domeyko zachorował i niebawem zmarł w Santiago 23 stycznia 1889 r., żegnany manifestacyjnie przez władze i ludność adoptowanej drugiej ojczyzny jako przybyły z Europy apostoł nauki i oświaty.

Prace naukowe w Europie

Podczas pobytu w Paryżu opublikował Domeyko w 1837 r. wyniki dokonanych przez niego w Prusach obserwacji obniżania się obszaru Wschodniego Pomorza i litewskiego pobrzeża Bałtyku w czasach historycznych. Głównym jednak jego zamierzeniem było wydanie atlasu geograficznego przedrozbiorowego terytorium ziem Rzeczypospolitej Obojga Narodów. Miał się on składać z tekstu wprowadzającego i czterech map: hydrograficznej, geologicznej, gospodarczej i politycznej (administracyjnej). Przed wyjazdem do Chile zdołał wydać tylko pierwszą z nich. Rękopisy pozostałych zachowały się w bibliotekach krakowskich i paryskich. Trzy egzemplarze mapy geologicznej Domeyki stanowią twórczą kompilację, opartą na danych innych autorów – głównie G. G. Puscha – ale obejmują większy obszar kraju. W objaśnieniach do atlasu zwrócił on uwagę na znaczenie dorzeczy jako jednostek nadrzędnych, ważnych przy rozpatrywaniu problemów etnicznych, gospodarczych i administracyjnych. Domeyko nawiązał do tego postulatu podczas wykładu wygłoszonego i opublikowanego w Krakowie w 1888 r.

Geologia Chile w pracach Domeyki

Po zorganizowaniu warsztatu pracy twórczej i dydaktycznej w La Serena rozpoczął Domeyko systematyczne badania geologiczne środkowej części Chile, które łączył z rozpoznaniem i studiami mineralogicznymi złóż rud, opartymi na własnych analizach chemicznych zebranych próbek w zbudowanym przez siebie i dobrze wyposażonym laboratorium. Wyniki tych badań publikował w znanych czasopismach francuskich i niemieckich. Dotyczyły one niemal wszystkich nauk o Ziemi, jak również górnictwa, metalurgii, meteorologii czy zjawisk geofizycznych, np. częstych w Chile trzęsień Ziemi. Prowadząc badania geologiczne interesował się on również problemami etnograficznymi, czego dowodem jest cenna monografia „Araukania i jej mieszkańcy", która przyczyniła się do pokojowego włączenia tego zamieszkałego przez indiańskich Araukanów obszaru w skład młodej Republiki.

Pierwsze publikacje dotyczące geologii Chile ukazały się już w 1846 roku. Domeyko starał się w nich wyznaczyć linię demarkacyjną między Kordylierą Nadmorską a Wschodnią – właściwymi Andami, załączając pionierską mapę geologiczną tego obszaru. Równocześnie przekazał kolegom do Francji znalezione w 1839 r. skamieniałości. Ich oznaczeniami zajął się znany paleontolog A. d'Orbigny, który w 1842 r. dwa z opisanych przez siebie gatunków nazwał *Terebratula ignaciana* d'Orb i *Nautilus domeykus* d'Orb. W 1851 r. badacze francuscy C. E. Bayle i H. Coquand dwa inne gatunki fauny mezozoicznej z kolekcji Domeyki nazwali *Ammonites domeykanus* Nob. i *Telebratula domeykana* Nob. Pozwoliło mu to na wyznaczenie wspomnianego liasowego poziomu przewodniego w Andach i opracowanie podziału litostratygraficznego tych gór, który przedstawił szczegółowo w opublikowanej w 1878 r. w Krakowie monografii „Rzut oka na Kordylijery Chilijskie i zawarte w ich łonie pokłady metaliczne".

Po omówieniu geomorfologii Chile i podziału tego kraju na różniące się istotnie strefy klimatyczne, od pustynnej północnej przez środkowe górniczą i rolniczą, po południową wyspiarską, przedstawił Domeyko profile litostratygraficzne obu Kordylier. W nadmorskiej wyróżnił od dołu: skały krystaliczne, paleozoiczne skały osadowe (w których w 1876 r. znaleziono trylobity), warstwowany trzeciorzęd z wkładkami węgla i aluwia. Natomiast właściwe Andy podzielił on względem wspomnianego datowanego paleontologicznie poziomu liasowego na formację podliasową, zawierającą skały metamorficzne i czerwone piaskowce oraz formację nadliasową (jurajsko-kredową). Ponadto wyróżnił on „masy krystaliczne wybuchowe" wśród których opisał skały głębinowe (granity) i wylewne (porfiry, trachity), tworzące zazwyczaj kopuły, dźwigające nadległe utwory warstwowane. Godna przypomnienia jest próba Domeyki porównania pewnych cech geologii Andów i Tatr, wyrażona m.in. słowami: „...skład tego olbrzymiego łańcucha Andów podobny jest pod wieloma względami do naszych ojczystych Tatrów, do których często duch mnie unosił, gdym przebiegał wzdłuż i w wielu punktach wszerz Kordylijery Chilijskie. W Andach jak w Tatrach lijasowe wapienie stanowią wydatniejszy horyzont geologiczny; pod niemi piaskowiec czerwony baz żadnych szczątków istot organicznych, a w spodnich ogniwach – skały metamorficzne.... Główniejsze różnice zachodzą w tem, że metamorficzne skały andyjskie są pospolicie porfiowej budowy, lub zbite, drobnoziarniste – kiedy w Tatrach według Zeisznera są łupki granitowe, gneiz, łupek mikowy i talkowy...". Natomiast w drugiej części monografii, poświęconej chilijskim złożom kruszców znajdujemy uwagę: „... nie masz tu pokładów cynku i kopalni tego metalu podobnych do kopalni galmanu w Polsce i na Szląsku..." Są to dowody, że Domeyko, badając Andy, nie zaniedbywał studiowania bieżących prac, dotyczących geologii Polski.

Domeyko pionierem mineralogii chemicznej

Niezwykłą, jak napisał w swych pamiętnikach Domeyko (1962–63), „ochotę i gust do chemii analitycznej" zaszczepiły w nim podczas studiów w Paryżu wykłady i demonstracje wybitnego chemika J. B. A. Dumas'a. Jednak już w młodości istotny wpływ na jego zainteresowania naukami ścisłymi i przyrodniczymi miał absolwent Akademii Górniczej we Freibergu stryj Józef, a następnie uczestnictwo w zajęciach na Uniwersytecie Wileńskim, prowadzonych przed tak wybitnych profesorów jak Jędrzej Śniadecki i Feliks Drzewiński.

Pełny jednak rozwój jego niezwykłych uzdolnień w tym zakresie, jak i zamiłowanie do pracy laboratoryjnej, przejawiły się podczas pobytu w Chile. Specyficzną cechą świata minerałów w tym kraju jest bowiem ogromna przewaga substancji bezpostaciowych nad krystalicznymi. W związku z tym jedyną w owych czasach metodą, pozwalającą na identyfikację badanych substancji mineralnych, była analiza chemiczna na drodze mokrej. O pasji analitycznej Domeyki może świadczyć fragment listu z Coquimbo do A. Mickiewicza: „...mieszkam w moim laboratorium gdzie niejedna północ zastaje mnie przy tyglu lub w retorcie smażącego dziwne ciekawe kruszce tutejsze..." A kilkanaście lat później z Santiago pisał: „...kiedy co zasmuciło..., to na pocieszenie siebie i ulgę w przykrości uciekałem do moich analiz i dociekań chemicznych.". Niebawem Domeyko stał się prawdziwym mistrzem analizy chemicznej wszelkiego rodzaju minerałów. Świadczą o tym liczne dokładne przepisy analityczne w wydanych w latach 1844–1845 podręcznikach probierstwa i mineralogii, których autor jest przedstawiony odpowiednio jako profesor chemii i mi-

neralogii. Zasadniczym jednak dowodem jego niezwykłych umiejętności i osiągnięć, jak również pracowitości, jest załączony do niniejszej pracy wykaz wykonanych przez Domeykę analiz chemicznych, obejmujący ponad 160 danych, dotyczących wszelkiego rodzaju minerałów o bardzo niekiedy skomplikowanym składzie (Appendix 1). Wykaz ten jest efektem szczegółowego przeglądu przez pierwszego z autorów wszystkich dostępnych w kraju publikacji naszego wielkiego Rodaka oraz wielotomowego dzieła C. Doelter' a „Handbuch der Mineralchemie". Większość tych danych analitycznych dotyczy, co zrozumiałe, minerałów kruszcowych, reprezentowanych przez siarczki, siarkosole, arsenki, antymonki, selenki i tellurki oraz pierwiastki rodzime, stopy i amalgamaty. Widnieją jednak w tym wykazie również rzadkie minerały stref utlenienia, powstałe w specyficznych warunkach klimatycznych tego kraju (halogenki), a ponadto meteoryty i ich minerały oraz krzemiany. Te ostatnie pochodzą głównie ze zanalizowanych przez Domeykę skał wylewnych, budujących zbadane przez niego wulkany Antuco, Descabezado i Cerro Azul (Appendix 2). Godne uwagi są ponadto dane o składzie chemicznym znalezionych przez niego na pustyni Atacama meteorytów i ich minerałów (Narębski, 2003). Ze wspomnianych rzadkich, a odkrytych i zanalizowanych przez Domeykę minerałów warto wymienić przynajmniej cztery, związane z jego działalnością i przyjacielską współpracą z innymi badaczami. Są to: arsenek miedzi domeykit (nazwa wprowadzona przez W. Haidinger'a w 1845 r.), tleno-chloro-hydroksy-jodan ołowiu schwartzembergit (J. D. Dana, 1868), tleno-hydroksy-chlorek bizmutu daubréeit (Domeyko, 1876) i siarczan sodowo-miedziowy kröhnkit (Domeyko, 1879). Ponadto Domeyko jest autorem conajmniej 58 analiz chemicznych wód pitnych i mineralnych (Domeyko, 1847, 1871; Fig. 3, 8).

Omówiony skrótowo niezwykle bogaty i wszechstronny dorobek Domeyki w zakresie poznania składu chemicznego wielu, w tym kilku nowych, minerałów uzasadnia w pełni zaliczenie go do pionierów rozwijającej się podówczas mineralogii chemicznej.

Rozważania końcowe

Ignacy Domeyko był nie tylko wybitnym i wszechstronnym uczonym, cenionym i ogromnie lubianym nauczycielem akademickim oraz skutecznym reformatorem i organizatorem oświaty i przemysłu górniczo-metalurgicznego w Chile. Najwyższe wartości moralne, wyniesione z rodzinnego domu i rozwinięte w okresie filomacko-filareckim uformowały jego niezwykle szlachetną osobowość, przejawiającą się zarówno w życiu prywatnym, jak i działalności społecznej. Nic więc dziwnego, że przy czynnym udziale wielce zasłużonego dla popularyzacji zasług i postaci Ignacego Domeyki oraz organizacji światowych obchodów jego jubileuszu, b. ambasadora w Chile Zdzisława J. Ryna, w 1996 r. powstała grupa postulatorów, wnioskująca o uznanie naszego wielkiego Rodaka za Sługę Bożego. Całym swoim życiem uosabiał on bowiem najwyższe wartości chrześcijańskie: miłość bliźniego, sprawiedliwość, solidarność i braterstwo wszystkich ludzi. Warto przypomnieć słowa ówczesnego rektora Uniwersytetu Jagiellońskiego Stanisława Tarnowskiego, wypowiedziane po nadaniu Domeyce doktoratu honorowego tej uczelni: „...Nie było w nim nic coby nie było wzniosłe... Jawił się jak wcielenie najszlachetniejszych i najzdrowszych sił i uczuć swego pokolenia".