by Octavio Puche Riart and Luis Felipe Mazadiego Martínez
Translated by Rodrigo Legido and Lilén Malugani Guillet

The 10th International Geology Congress, Mexico (1906)

E.T.S. de Ingenieros de Minas de Madrid–Universidad Politécnica de Madrid (Spain). *Email: octavio.puche@upm.es; luisfelipe.mazadiego@upm.es*

Preparation for the Congress

The Committee for the Organization of the *9th International Geological Congress* (Vienna, 1903), taking account of the views of a wide range of scientists, requested the organization of the 1906 Congress by the geologists of the *Instituto Geológico Nacional de México* (IGN). The letter of invitation, dated 3 February 1903, was signed by the paleontologist Karl Dienner (1862–1928), Secretary General of the IGC. The meeting should have the mining engineer José Guadalupe Aguilera Serrano (1857–1941) as its President. The first requirement was the authorization of the dictator of Mexico, José de la Cruz Porfirio Díaz Mori (1830–1911), who had been in power since 1884 (Anon., 1907).

Porfirio Díaz (left); and the medallion for the 10th IGC (1906) (right).

José Guadalupe Aguilera (1857–1941), Director of the National Geological Institute, had previously attended the International Geological Congresses in Washington (1891), St Petersburg (1897), Paris (1900) and Vienna (1903), accompanied by the mining engineer Ezequiel Ordóñez Aguilar (1867–1950), Deputy Director of the *Instituto Geológico Nacional* (Rubinovich, Lozano and Mendoza Vargas, 1998). Though they were well known to the scientific community, the 'bid' for the organization of the IGC could not have come from them personally: it had to come from the Mexican Government. The letter of invitation was sent to General Manuel González Cosío (1836–1913), the Minister of Public Affairs, Colonization and Industry, on whom the Geological Institute depended for its support, and also to the Under Secretary, Gilberto Montiel. Both undertook to submit the proposal to President Díaz (Anon., 1907). The submission was approved by the political powers that be and it was therefore presented as a formal proposal to the IGC in Vienna, where it was approved by the General Assembly on 27 August 1903. At the same time, it was agreed that the XI Congress would be held in Toronto, Canada.

José Guadalupe Aguilera (left) and Ezequiel Ordóñez (right), President and Secretary of the Mexican IGC (oil paintings from the Geological Museum of Mexico).

With the authorization of the Ministry of Public Affairs, an Organizing Committee was formed consisting of Mexican professors of different institutions and other scientists, people in charge of mining companies, experts on the places where the IGC was going to be held, and on its scientific sessions, field trips, etc. as well as some of the foreign geologists who were in the country at that time. An Executive Committee was also formed, presided over by Aguilera. The Secretary-General was the Deputy Director of the *Instituto Geológico Nacional* (IGN), Ezequiel Ordóñez, while other secretaries were the section heads of the Institute: the German geologist Emil Böse (1868–1927), the Swiss palaeontologist Carlos Burckhardt (1869–1935). The mining engineer, Juan de Dios Villarello (1869–1945), was appointed Treasurer. The Organization Committee initially had no fewer than 120 members.

The Executive Committee, assumed responsibility for calling meetings of the Organization Committee. It also requested financial support from the Government for printing the Proceedings and other documents, and also to obtain a commitment to complete the building of the *Instituto Geológico Nacional*, where the 10th IGC was to be held. The construction of the Renaissance-style building, designed by the architect Carlos Herrera López, had begun in 1901 (Azuela, 2009). The President of the Republic decided to give his patronage to the Congress, and with that everything ran smoothly.

The Executive Committee decided, and communicated its views

Executive Committee members of the 10th IGC. Böse, top left (De Cserna, 1990), Burckhardt, top right (Mülleried, 1936) and Villarello (oil painting from the Geological Museum of Mexico).

to the Organization Committee, that a series of geological fieldtrips should be held, and a guidebook for the trips therefore had to be prepared. It was also decided that a silver medallion would be given to all those attending the IGC. They were to be made at the *Casa de la Moneda* (the Mexican Mint). The Government also requested lower-price train tickets for the people attending the Congress and supplied horses from the rural police for use on the field trips.

The first public announcement of the 10th IGC was dated 26 May 1905. Much of it listed the 'Members of Honour', and the Executive and Organization Committees. It was stated that the approximate date for the beginning of the Congress would be 6 September 1906, and the close would be eight days later. In the second notice of November 1905 more information was made available about the fieldtrips. In the third circular of May 1906, after naming renowned geologists who would attend the Congress, an almost definitive schedule of the fieldtrips was given. This was finalized in the fourth announcement of June 1906.

The discussion topics chosen for the Congress were as follows:

1. The climatic conditions of the different geological eras.
2. The relationships between tectonics and eruptive masses.
3. The genesis of metallic deposits.
4. The classification and naming of rocks.

The registration price was set at 8 Mexican *piastras* (20 French *francs*, 20 Spanish *pesetas*).

Field Trips

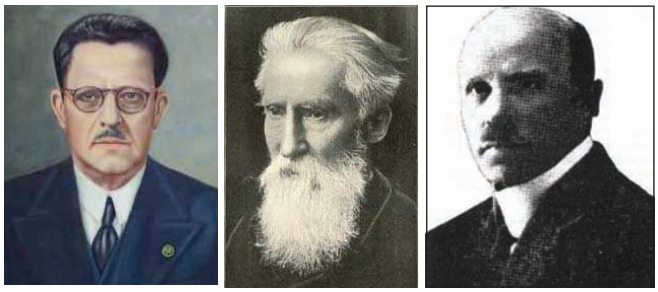
Pre-Congress field trips

1b Excursion to the South of Mexico (20–29 August: up to thirty people): Archaean of the Tomellín Canon, Oaxaca (Guide, Ezequiel Ordóñez). The Mitla Ruins of the Zapotecas (guided by the German anthropologist, then resident in Mexico, and Eduard Georg Seler, 1849–1932). The Lower Cretaceous of Zapotitlán and San Juan de Raya (guide José Guadalupe Aguilera). Seler was one of the pioneers in the study of documents written by early European chroniclers of America and stratigraphic, folkloric, linguistic, and ethnographic investigations, with the objective of analysing the history of pre Columbian societies (López, 2003).

1a Field trip to eastern Mexico (2–4 September: up to 250 people). Neo-volcanic rocks of the Jalapa district (guide Ezequiel Ordóñez). Paleo-Pliocene of Santa María de Tatetla. The Cretaceous rudists of Escamela Hill. The Sierra Madre tectonic area (guide Emil Böse). It was possible to attend both Excursions, 1b, and 1a.

1c Field trip to Jorullo Volcano (20 August–1 September; up to thirty people): visit to the Nevado de Toluca volcano (guided by the mining engineer Teodoro Flores Reyes, 1873–1955) and visit to the Jorullo volcano (guide Ezequiel Ordóñez).

1d Field trip to San Andrés and Tolima (21 August–1 September, up to thirty people): basaltic domes in Agua Fría, the extinct geysers of San Andrés, the small geysers of Ixtlán, and the volcano of Colima (guided by the I.G.N. geologist Paul Waitz, 1876–1961).



Teodoro Flores Reyes (left), guide to the Nevado de Toluca (oil painting from the Geological Museum of Mexico); Eduard Seler (centre), guide to the Mitla Ruins (*Sociedad de Americanistas de París*, Vol. 15, 1923), and Paul Waitz (right), guide to volcano of Colima (De Cserna, 1990).

Post-Congress field trips

3a Field trip to northern Mexico (15 September–4 October, up to 250 people): the craters of Santiago Valley (guide Ezequiel Ordóñez). Silver mines and the geology of Guanajuato (guides Juan de Dios Villarello, Teodoro Flores and the IGN engineer Ramiro Robles). Geology of the surrounds of Zacatecas (guide Carlos Burckhardt) and the Bote silver mine (guide Teodoro Flores). The Pb–Ag mines of Mapimí (guide Juan de Dios Villarello). Sulphur mines of Conejos and limestone with rudists (guide Emil Böse). Cretaceous of the Cerro Murelos. Relationships between the tectonic and the intrusive mass (guides José Guadalupe Aguilera and Emil Böse). Volcanic rocks of the El Parral and its surrounds (guide Paul Waitz). Silver mine of Quebradilla (guide Ramiro Robles). Upper Cretaceous and the tectonics of the Parras region (guide Emil Böse). Jurassic and Cretaceous of Mazapil. Relationships between tectonics and the eruptive mass (guide Carlos

Burckhardt). Aranzazu copper mine (guide Juan de Dios Villarello). Jurassic and Cretaceous of the Sierra de Santa Rosa and the area's tectonic features (guide Carlos Burckhardt). Cretaceous of the Esperanzas district (guide José Guadalupe Aguilera) and coal mines (guides the US mining engineer and Director of the Mexican Coal and Coke Company, Edwin Ludlow, 1858–1924). Upper Cretaceous of Monterrey, Arispe and Canoas and surrounds and the tectonics of the Sierra Madre Oriental (guide Emil Böse), with an optional visit to the oil wells of El Ébano (guide the Irish-American owner of the oilfield, Edward Lawrence Doheney (1856–1935) and Ezequiel Ordóñez). The Choy cavern with cyprinids (guide Emil Böse).

3b Field trip to the Tehuantepec Isthmus (6–13 October, up to sixty people): eastern Sierra Madre tectonics. Paso Real and the Pliocene of Santa Rosa. The Upper Miocene between Santa Lucrecia and Coatzalcoalcos and between Santa Lucrecia and Rincón Antonio. Tectonics of Sierra del Istmo, and the Tehuantepec Archaean surrounding area (guide Emil Böse). This field trip could be undertaken along with the previous one.

Field trips during the Congress

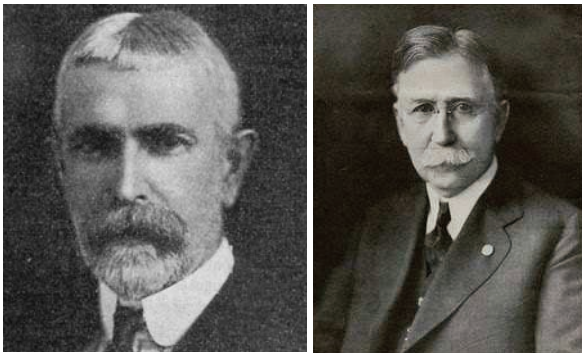
2a Visit, with banquet, to the historic woods of Chapultepec (5 September).

2b Visit to public institutions and buildings in Mexico City and to the Pedregal of San Angel (7 September).

2c Leisure field trip to Cuernavaca and social function (9 September), organized by the *Sociedad Geologica Mexicana*, for those participating in the IGC, members of the *Sociedad* and relatives. This event was attended by 198 people (Anon. 1907b).

2d Field trip to the San Juan de Teotihuacan ruins (11 September).

2e Field trip to the Pachuca silver mines (14 September, with the mining engineer and Director of *Compañía Real del Monte y Pachuca*, Carlos F. de Landero as guide).



With Porfirio Díaz, many foreign mining companies had arrived in the country and collaborated with the 10th IGC. Edwin Ludlow (left) (Norris, 1924) and Edward Doheney (right) (Padrón, 2010) participated as guides.

The Congress attendees were able to participate in activities from 20 August to 13 October and it was possible for them to travel through much of Mexico. The organization of the field trips was undertaken by members of the Executive Committee. The Díaz Government had supported the construction of railroads throughout the country, which facilitated the movement of the excursionists though parts of some of the journeys had to be made on foot or by horse and spending night in tents.

The *Guide des Excursions* (1906) was prepared, with a total of thirty-one field trips, with the respective excursion arrangements (De Cserna, 1990), and was presented to the attendees. In planning the field trips not only geological points of interest but also the existence of railroads that could facilitate access, and the availability of accommodation for the excursionists, were taken into account (Aguilera and Ordóñez, 1906. See Preface to *Guide des Excursions*).

Participants

707 people registered, though only 321 actually participated. If we discount the 153 attendees from Mexico, the number was 168. After Mexico, the second country in importance was USA, with seventy participants. There were only eighty-four Europeans, with a predominance of Germans, who accounted for forty-three people. Asia and Oceania added only three persons and there were none from Africa who actually attended. This meant a decline in the number of attendees compared with previous congresses: 704 (St Petersburg, 1897), 461 (Paris, 1900), 393 (Vienna, 1903).

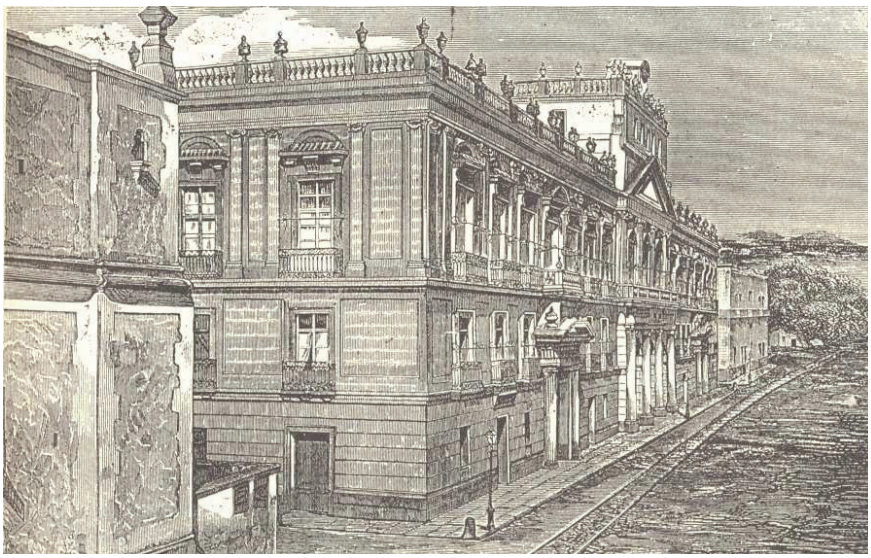
The lack of Europeans was probably due to the difficulties and high cost of transport. To attempt to overcome these problems, the organization persuaded shipping companies, such as the Hamburg–American Line (Germany) or the *Compañía Transatlántica* (Spain), to offer special prices for participants at the Congress. There were also discounts in the railroad prices in the USA and Mexico. The registered countries were 31 (33) and the participants 17 (18) according to the following table.

English was the main language for the papers, with a small advantage over the number of communications in French. This happened perhaps as the result of the presence of an important group of geologists from the USA. There were also some communications in German as well as in Spanish or Italian.

Countries	Registered Members	Attending Members	Countries	Registered Members	Attending Members
Germany	88	43	Spain	2	0
German Colonies	1	0	United States	134	70
Argentina	3	0	France	48	8
Australia	3	1	Great Britain	15	6
Austro-Hungarian			East Indies	5	1
Empire: Austria	35	10	Italy	24	3
Hungary	6	1	Japan	4	1
Bosnia Herzegovina	2	0	Mexico	250	153
Belgium	11	2	Norway	1	0
Bolivia	1	0	Portugal	4	0
Brazil	1	0	Rumania	6	3
Bulgaria	2	0	Russia	26	6
Canada	13	9	Serbia	1	0
China	1	0	Sweden	2	1
Korea	1	0	Swiss	10	1
Cuba	2	2	Transvaal	1	0
Denmark	1	0	Tunisia	1	0
Egypt	2	0	Total	707	321

The Opening Ceremony

On 5 September at 18:30 the attendees left the *Plaza de la Constitución* (El Zócalo) and in several streetcars, and moved to the



The *Escuela Nacional de Ingenieros* (*Palacio de la Minería*), formerly the *Seminario de la Minería de México*, founded by the Spanish in 1792, under the command of Fausto de Elhuyar (1755–1833). The building of the *Palacio de Minería* was completed in 1813, and was therafter the seat of the *Seminario de Minería* (Rubinovich and Lozano, with the collaboration of Mendoza Vargas, 1998).

Attendees in front of the building of the *Instituto Geológico Nacional*, 1906 (Rubinovich and Lozano, with the collaboration of Mendoza Vargas, 1998).

Chapultepec Forest where they were welcomed by the Executive Committee and regaled with a dinner party while an artillery brass band performed.

The President of the Republic of Mexico formally opened the 10th IGC in the *Gran Salón* of the *Escuela Nacional de Ingenieros*, on 6 September 1906, at 11 o'clock, welcoming the attendants and informing them of the efforts made by the Government towards the completion of the *Instituto Geológico Nacional* building. His speech was responded to by the mining engineer and deputy Gabriel Mancera García San Vicente (1839–1925), Honorary President of the Mexican IGC, who highlighted the facilities provided by the Federal Government and the different States where the various field trips were to be undertaken (Rubinovich, Lozano y Mendoza Vargas, 1998).

The scientific sessions began in the new building of the *Instituto Geológico Nacional*.

Issues Discussed

The climatic conditions during the different geological eras

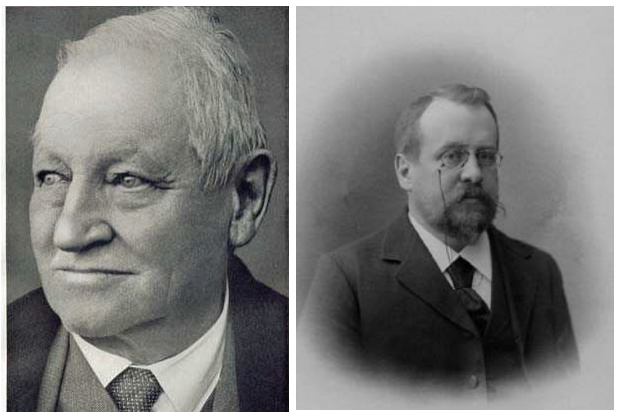
This was one of the main issues dealt with during the Congress, as it was a topic that was attracting much attention at that time. The 8 September session was chaired by the German palaeontologist Friedrich Frech (1861–1917), Professor at Breslau University; and the Monday session by the North American geologist George Ferdinand Becker

In 1905, the German geologist Heinz Albrecht Penck (1858–1945), helped by Eduard Brückner-Preis (1862–1927), had studied the alluvial terraces of the Danube and proposed the existence of four glaciations during the Quaternary, that were named after four tributaries of the river: Günz, Mindel, Riss and Würm. Both Penck and Brückner made numerous studies on glacial sedimentation and climate change, which were written up at the end of the nineteenth century and the beginning of the twentieth. Nevertheless, his foremost work was *Die Alpen im Eizeitalter* (1901–1909). The studies on the so-called drift deposits, and whether they were or were not of glacial origin, were extended to other eras. There was also interest in knowing the climatology and the possible causes of glaciations in the different geological periods.

Penck was registered at the Mexican IGC but he did not participate and the famous four supposed glaciations of the Danube valley were not quoted in any of the papers at the Congress, though Pleistocene glaciations were mentioned in various ways.

The civil engineer and North American geologist Marsden Manson (1850–1931) had published an article in 1891 entitled '*The cause of the Glacial Period and an explanation of geological climates*', while in 1903 he produced '*The Evolution of Climates*' and '*The significance of early and of Pleistocene glaciations*' in 1906. At the Mexican IGC Manson read a presentation by the German–American soil scientist Eugene Woldemar Hilgard (1833–1916), entitled: '*The causes of the glacial Epoch*'. The 'Ice Age' (*Die Eiszeit*) was to become an informal synonym for the Pleistocene.

Hilgard recalled the variety of hypothesis on the causes of climate change, such as that of the Scotsman James Croll (1821–1890), which related glaciations to variations in the eccentricity of the Earth's orbit (cf. *Climate and Cosmology*, 1885, and various earlier works), and to the variations in the direction of the Elysian winds that have an influence on the warm oceanic currents of cold regions. It also mentioned the theories of the American geologist Thomas Chrowder Chamberlin (1843–1928), from the University of Chicago, registered as a US representative at the IGC, who related glacial epochs to the amounts of CO_2 on the atmosphere ('An attempt to frame a working hypothesis of the cause of glacial periods on an atmospheric basis', 1899). This research was conducted during the study of the relation



Penck (left) (*Kolloquium zum 150. Geburtstag von Albrecht Penck, Oktober 2008, Leibniz-Institut für Länderkunde und Gesellschaft für Erdkunde zu Berlin*) and Brückner (right) (*Bern Universitätarchiv*, Switzerland).

of CO_2 with the processes of icing and melting (great glaciations). His intuitions were confirmed many years later, in 1987. John Walter Gregory (1864–1932) of the University of Glasgow established the possible causes of climatic changes. The Mexico IGC also called attention to Permo-Carboniferous glacial deposits in what are now hot or tropical regions, with a different distribution from that of the Pleistocene. They were described by the Antarctic explorer Emil Philippi of Berlin University. The German, Hauptmann (Oskar) Vorwerg, suggested that the glaciations were the result of altitude changes (nobody was thinking yet of latitude changes). However, Carl Diener from Vienna could not see proof of such altitude changes in the Permo-Carboniferous in regions such as India or South Africa. From Australia, Edgeworth David (1858–1934) (Sydney University) described evidence of the glaciation of Late Palaeozoic rocks in South Australia, and also brought to Mexico his analogous observations made in India on his way to the Congress (Branagan, 2005). There is no doubt that advances as regards the knowledge of climate, and particularly the study of till deposits in the different geological periods (in the IGC there were talks about the Cambrian tillite in Australia), later assisted the birth of plate tectonics.

Relationships between the tectonic and the eruptive masses

In 1873, in a paper entitled 'On some results of the earth's contraction due to cooling' the American geologist and mineralogist James Dwight Dana (1813–1895), studying the phenomena of orogenies, had proposed the concept of geosynclinals. In such areas, a complex process of sedimentation–folding–erosion develops. In the same way, in 1875, the Austrian naturalist Eduard Suess (1831–1914) had published a study on the origin of the Alps (*Die Entsehung der Alpen*), highlighting the successive formation of the three great orogenic chains: Caledonian, Variscan and Alpine. It was an opportune moment to raise the question of the global tectonic studies. Nonetheless, Suess work was poorly quoted at the Mexican IGC.

A session on 11 September was partly given over to the topic: *Sur les rapports entre le téctonique et les masses eruptives*. But only two papers were presented: one by Philippe Glangeaud (1866–1930), professor of geology at Clermond-Ferrand, entitled '*Sur le dévelopement de l'activité éruptive dans certains parties du massif central de la France à l'époque tertiare*', and another one from one of the fathers of experimental geology, Stanislas Meunier (1843–1925) of the Paris Museum of Natural History, entitled '*Sur l'histoire générale de la fonction volcanique*'. In the same year, Meunier had published *Les éruptions volcaniques et les tremblements de terre*.

Through the different papers presented at the IGC we can observe that the general idea that folds were caused by pressures directed horizontally, laterally, or tangentially, already existed though at that period the possible causes of magmatic processes in a tectonic–orogenic setting were not yet being studied in the IGCs. But some explanations were offered. For instance, according to Ezequiel Ordóñez, the Sierra Nevada had been formed by volcanic processes: the magmatic materials would have opened paths through the great folds of the Cretaceous rocks, forming the main elongated massif, as if the eruptions were aligned with the axis of the folding, as if the eruptive foci were themselves somehow aligned (cf. Ordóñez, in *Excursión de México a Jalapa, Guide des Excursions*, 1906). To give another example, on the day of the Congress's opening session, French mentioned the occurrence of recent fractures with volcanic flows in the sub-alpine chains of southeast Europe. Little by little, geologists were becoming aware of the relationship between tectonic and eruptive processes.

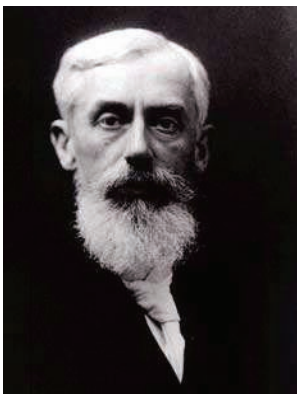
The genesis of metallic ore deposits

The genesis of metal deposits was dealt with during the morning session of 10 September by the American geologist George Ferdinand Becker (1847–1919), a specialist on metallic ore bodies, and during the afternoon by the geologist–paleontologist and President of the Russian Commission, Th. N. Tchernychev (1856–1914), of St Petersburg, Russia.

Mexico has a long tradition of mining for metals and historical silver deposits were visited during the Congress, such as that of Guanajuato (in production since 1548), Zacatecas (1549) and Mapimí (1598), which deposits were discovered by the Spaniards during the first years of conquest. Besides silver, these mines contained lead, gold and several types of metal sulphides. A copper mine, Aranzazu (active since the eighteenth century), was also visited in the region of Santa Eulalia. Writing in 1956 on the mining deposits of Mexico González Reyna has pointed out that: "[u]ntil the beginning of the present century mining exploitation [in Mexico] was confined almost exclusively to gold and silver; and industrial metals such as copper, lead, zinc, antimony, tin, mercury, etc., were only exploited on a secondary scale". Nevertheless with the Second Industrial Revolution there was a growing demand for mining products and in that way the interest in metallogeny, or study of the genesis of metal deposits, increased significantly.

According to Ph. Lagny, the Professor at the School of Mines in Paris, Louis de Launay (1860–1938), had only just coined the word metallogeny in 1905 (Lagny, 2007) though in fact José Guadalupe Aguilera (1857–1941) had proposed the name 'metaloctogenia' in the previous year (Aguilera, 1904). Launay was an active participant at the IGC presenting an extensive work entitled *La métallogénie de l'Italie et des régions avoisinantes.* Previously he had published important works such as: *Formation des gîtes métallifères* (1892) and *Les richesses minérales de l'Afrique* (1903). Nevertheless, he had not yet written the three volumes of his major work: *Gîtes minéraux et métallifères* (1912).

The Mexico IGC had the benefit of the participation of the Swedish–American geologist Waldemar Lindgren (1860–1939) whose most important work *Mineral Deposits* was to appear in 1913, and



Louis de Launay (*Annales des Mines*)

who was also to contribute to the foundation of *Economic Geology*. Lindren delivered a lecture on "The relation of ore deposition to physical conditions".

In the second circular, the participation of Ferdinand Hermann Klockmann (1858–1937) was announced, though he did not register. Klockmann introduced reflection techniques for the microscopic study of metallic ores in the *Königliche Bergakademie* of the Clausthal University in Germany, and published there the first edition of his famous manual for teaching: *Klockmann's Lehrbuch der Mineralogie* (1891).

In a communication '*Sur le remplisage de quelques gisements métallifères*', Juan de Dios Villarejo averred: "Notable European and American scientists had dedicated all their energy to the study of the genesis of metal deposits and the light generated by their erudite works illuminates all of us in Mexico who are dedicated to the study of this branch of geology". However, the genesis of many deposits is still not yet completely clear; but Harry Foster Bain (1871–1948), Director of the Illinois Geological Survey, when describing the deposits of the Mississippi Valley, gathered together the theories of the American geologist Josiah Edward Spurr (1870–1950), who, in 1903 pointed to the intimate relationship between metal mines and igneous rocks (Spurr, 1903). Nevertheless, the Scottish–American, Andrew Cowper Lawson (1861–1952), of California University (Berkeley), established the possibility of the precipitation of metallic sulphides on sea floors. Lawson wrote several reports about ore deposits, including one written in 1906: 'The Copper Deposits of the Robinson Mining District' (*Journal of Geology*, 1907).

Classification and naming of the rocks as well as other oil issues

On 12 September under the presidency of the German palaeontologist and stratigrapher August Rothpletz (1853–1918) of Munich University, the topic was the classification and naming of rocks.

As José Guadalupe Aguilera signalled, in his address as Congress President, an agreement had been reached as to the basis of petrographic classification; and a preliminary effort had been made to achieve a standardised classification of crystalline schists and of the eruptive rocks. But possibly for that reason Professor Alfred Ossan, from Freiburg was the only person present for the meeting arranged for the discussion on the classification and naming of rocks. According to the fourth circular, important oil experts were registered, such as the French geologist Alfred Lacroix (1863–1948), and the North American geologists Whitman Cross (1854–1949, of the USGS), Joseph Paxon Iddings (1857–1920, of the University of Chicago) and Louis Valentine Pirsson (1860–1919, of Yale University), as well as the chemist Henry Stephen Washington (1867–1934, who had a private laboratory in New Jersey). Lacroix had published a number of works on petrology, nevertheless perhaps the most important was written with the mining engineer Auguste Michel-Lévy (1844–1911): *Minéraux des roches* (1888), a pioneering work on the study of the optical properties of rock-forming minerals. The four North Americans had devised an elaborate classification system for igneous rock—denominated CIPW (1902)—based on the quantitative proportions and composition of the constituent minerals. (The name CIPW came from the first letters of the surnames of the system's authors: Cross–Iddings–Pirsson–Washington.) Lacroix and other oil experts of the time thought that the CIPW classification had limitations, because there could be very different rocks presenting similar chemical analyses. Moreover, it was a complex and somewhat arbitrary scheme with a large number of neologisms. It has not survived, as such, into modern petrography.

Alfred Lacroix (left) and Lucien Calleux (right) (*Annales des Mines*).

As regards sedimentary rocks, the participation of the geologist of the mining school of Paris, Lucien Cayeux (1864–1944), should be mentioned. He was a pioneer in the study of such rocks and author of the *Contribution à l'étude micrographique des terrains sédimentaires* (1894), in which he had discussed, among other issues, the formation of oolites and the classification of sandstones.

In the case of metamorphic rocks, Professor Friedrich Becke (1855–1931) of Vienna University spoke on the crystallization of the minerals of slates under pressure, with a communication entitled *Ueber Krystallisationschieferung und Piezokrystal-lisation*. This issue had already been debated at the IGC in Vienna in 1903, where he discussed the opinions of the Austrian Friedrich Hellmuth Berwerth (1850–1918) and Ulrich Grubenmann, Professor of Mineralogy at the University of Zurich (1850–1924). In Vienna, Becke established the concept of 'crystallization force', explaining that idiomorphic crystals could only form in metamorphic rocks in the case of the minerals of greater crystallization force. Grubenmann presented a communication on the classification of the crystalline schists, an issue on which he had published previously. He related the evolution of metamorphism with depth (progressive metamorphism) and in 1904 he had coined names for the different zones of metamorphism: katazone, mesozone and epizone (which are still in use).

Volcanoes

As signalled by the organizers of the IGC in the foreword *to its Guide des excursions* (1906): "the two field trips to the West were going to be exclusively dedicated to the study of volcanic phenomena, which are, in Mexico of unquestionable importance". Mexico is a country where several tectonic plates come together and as a consequence, it is crowded with volcanoes and their visit was the priority issue of the field trips.

It is important to highlight the following visits:

- Jorullo Volcano in the State of Michoacán, height 3,170 m, which had erupted in 1759.
- Nevado de Toluca or Xinantecatl Volcano, in the State of Toluca, which reached a height of 4,690 m and was believed to have erupted in the year 1100, its last eruption being in 1330. Both volcanoes had been visited at the beginning of the nineteenth century by the German explorer, naturalist and mining engineer Alexander von Humboldt (1769–1859).
- The explosion craters of the Santiago de Colima Valley in Jalisco, for which several eruptions had been recorded since 1560.

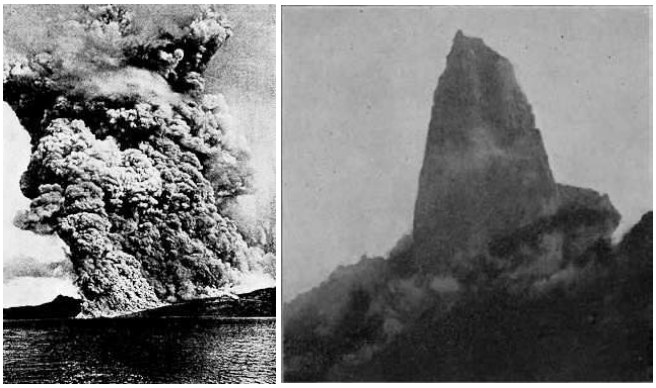
Jorullo Volcano, in Michoacán. Lithograph by Aimé Bonpland in Humboldt (1810).

There had also been some recent catastrophic volcanic eruptions in various parts of the world:

- Santa María, in Guatemala (1902) where the pyroclastic flows of a Plinian eruption caused 6,000 deaths.
- La Soufrière, in the Caribbean island of Saint Vincent (1902), where *nuées ardent* had resulted in 1,500 victims.
- The explosion of Mont Pelée, in the island of Martinique (1902), where a *nuée ardente* had swept the capital Saint Pierre claiming 28,000 victims.
- An eruption of the Vesuvius in Italy in April 1906, with a great emission of lava that devastated the city of Naples, affecting 700,000 people and causing the death of a 100, due to the high temperatures that were reached.
- Also mentioned as important were the phreatic eruptions of the Tacana volcano in Chiapas, Mexico (1900–1903), the Itziaco volcano in El Salvador (1902–1904), the Grimsvötn and Bárðarbunga volcanoes, in Iceland (1902 and 1903 respectively), the Monte Paektu volcano in China (1903), the Sangay volcano in Ecuador (1903), the Erta Ale volcano in Ethiopia (1903 and 1904), Cotopaxi in Ecuador (1903 and 1904), the Santa Ana volcano or Ilamatepec in El Salvador (1904), the Fukutoku–Okanoba submarine volcano in Japan (1904), the Poas volcano in Costa Rica (which ended in 1905 after a lengthy eruption), the Momotombo and Arenal volcanoes in Nicaragua (1905), the Cordon del Caulle volcano in Chile (1905), the Quizapú, Nevados de Chillán and Calbuco volcanoes in Chile (1906), etc.

There is no doubt that the most terrifying eruption was that of Mont Pelée. Alfred Lacroix was sent there by the *L'Académie des Sciences et le Ministère des Colonies* to determine the causes of the 8 May 1902 catastrophe. An observatory of the volcano had built there (the second in the world, the first having been built on Vesuvius in 1847). Positioned in such a place, Lacroix could check how, from the crater of *L'Étang Sec*, there arose a volcanic dome (October 1902) that grew due to the pressure of the confined gases and ended by forming a 300 m high needle, which became unstable and collapsed in March 1905. Lacroix's observations were compiled in *La Montagne Pelée et ses eruptions* (1904), in which work the concept of *nuée ardente* was first introduced. In 1906, Lacroix studied the eruption of Vesuvius, which, after several debates with Italian geologists, enabled him to classify the different types of volcanic eruptions: Hawaiian, Strombolian, Vulcanian, and Peléan (1908) (Burt et al., 2008).

After the eruption of Mont Pelée, a number of scientists from several countries were sent to Martinique on a scientific mission. They included the Hungarian–American mining engineer and geologist, Angelo Heilprin (Professor in the Academy of Natural Sciences of Philadelphia) (1853–1907) from the USA, which led to the publication of: *Mount Pelée and the Tragedy of Martinique* (1903) and *The Tower of Pelée* (1905). Heilprin attended the Mexican IGC and, in the session on 10 September where he spoke about '*Des manifestations volcániques dont il a été à la Martinique*', he explained the phenomenon of the formation of the giant obelisk, or needle, of 1903. Another expedition to the Martinique and St Vincent islands, sent by the Royal Society of London, was that of Tempest Anderson (1846–1913), a member of the British Society for the Advancement of Science, who participated in the session showing, through slides, the phenomena of *nuées ardentes* in St Vincent, which he likened to an incandescent avalanche. His observations were subsequently published in *Recent Volcanic Eruptions in the West Indies* (1904).



Mount Pelée: *nuée ardente* (December 1902) (photograph by Lacroix), and the eruptive needle (1903), (photograph by Heilprin).

The session of 12 September was presided over by the German stratigrapher and palaeontologist August Rothpletz (1853–1918), of Munich University. He invited the Italian mining engineer and author of *L'eruzione vesubiana dell'aprile 1906* (1906) Venturino Sabatini (1856–1921) to speak on "*La dernière éruption du Vésuve*". Tempest Anderson also projected images of such an eruption and presented a communication entitled: "The eruption of Vesuvius". Anderson was an ophthalmologic surgeon whose hobby was photography. But he was also greatly interested in volcanoes and eventually became an expert on them, travelling to numerous places where there were volcanoes in eruption.

There were several other contributions on volcanoes. We may mention particularly a communication by Angelo Heilprin entitled:

'The occurrence and interrelation of volcanic and seismic phenomena', in which he signalled numerous connections, in different places, between earthquakes and volcanoes during the same period of activity. This issue, as will be seen when we deal with earthquakes, was also analysed by other Congress attendees.

Earthquakes

60,000 people died in the Sicilian earthquake of 1903. In the 1904 earthquakes of Costa Rica there was an estimated 5,000 deaths. In January 1906, a strong earthquake of magnitude 8.8 was registered near the coasts of Ecuador and Colombia, causing a tsunami that is thought to have killed more than a thousand people. On 18 April of the same year, there was a movement along 430 km of the San Andreas Fault in California, between Cabo Mendocino and San Juan Bautista. This caused an earthquake of magnitude 7.8 and the subsequent conflagration of San Francisco, in which 3,000 people died. In August another great earthquake occurred in Valparaiso.

The San Andreas Fault had been discovered in 1895 by Andrew Cowper Lawson (1861–1952), Geology Professor at Berkeley; and during the session of 14 September, presided over by Charles Willard Hayes (1859–1916) of the US Geological Survey, Lawson presented a communication entitled: 'The earthquake of San Francisco'.

Fritz (Friedrich) Frech (1861–1917), from the University of Breslau, saw analogies between the earth movements in California and what was observed in Europe, suggesting tectonic alignments and admitting a direct relationship between earthquakes and volcanoes. Lawson, however, distinguished between volcanic earthquakes and tectonic earthquakes. According to Lawson the earth movement of Sonora, Mexico (1878), or the one that occurred in San Francisco (1906), among others, did not have any connection with volcanic activity.

There were also concerns as regards the prediction of volcanic disasters, such as in the case of Johannes Köenigsberger of Freiburg University, who thought that the study of geothermal gradients could be relevant. (From this researcher comes the term 'Koenigsberger Ratio', which measures the relation between remanent magnetization and induced magnetization in the Earth's field). There were also talks such as that of George Becker about earthquakes and electrical conductivity variations, while members of the *Commission de Coopération dans les Investigations Géologiques* proposed the study of gravimetric variations, etc.

In the *Guide des Excursions* (1906), specifically in the chapter that Seler wrote after seeing the Mitla ruins in Oaxaca, an image was reproduced from the *Códice de Mendoza* (*ca* 1540), depicting an earthquake that occurred in 1495. This drawing is one of the oldest known representations of earthquakes.

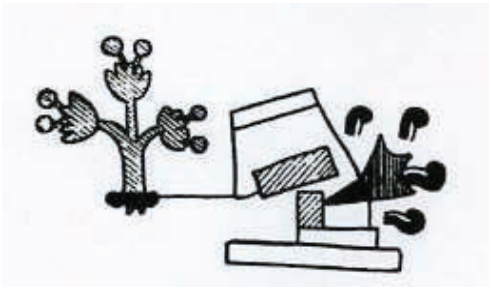


Image of the 1495 earthquake, from the *Códice de Mendoza*. *Libre Guide des Excursions (1906).*

Oil

The mining businessman Charles Candfield (1848–1913), together with his partner Edward Laurence Doheney, drilled the first productive oilfield in the Los Angeles region in 1892. In 1900, they acquired 113 hectares of oilfield in the Mexican municipality of El Ébano, San Luis de Potosí, and soon after they founded the Mexican Petroleum Company (later on Pan American Petroleum and nowadays PEMEX). On 31 January 1902 they found crude in the La Pez well at a depth of 200 m (López Ramos, 1976), though the test drilling ended in 1904 at 550 m, and extraction then began (De Cserna, 1990). Much of the oil produced by Dohoney was used in the Mexican railroads and none was exported until 1911 (Brown, 1993).

On the other hand, the Englishman Weetman Dikinson Pearson (Viscount Cowdray) (1856–1927) settled in the country in 1900 and founded the Mexican Eagle Petroleum Company (Canudas, 2005). He found oil near San Cristóbal in the Tehuantepec Isthmus. Later Cowdray discovered the large Potrero Llano oilfield and subsequently established the Mexican Eagle Petroleum Company (Canudas, 2005), which was later taken over by Royal Dutch Shell.

In 1906, these foreign businessmen turned their eyes to the Tampico–Tuxpan region in the Gulf of Mexico, though the country had not still acquired great importance as an oil producer. All of them received help from the Porfirio Díaz dictatorship, which was concerned with the industrial and commercial development of the country.

El Ébano was visited during the IGC under the direction of Ezequiel Ordóñez, who had been working for Dohoney since 1892. But this field trip did not appear in the *Guide des Excursions* (1906).

Image of the *El Ébano* oilfield, 1902 (Rubinovich,and Lozano, with the collaboration of Mendoza Vargas, 1998).

Geological cartography

During the first day of the Congress, José Guadalupe Aguilera distributed copies of the recently edited *Geological Map of North America* with a scale of 1:5,000,000. The map included the territories of Alaska, Parry Islands (Queen Elizabeth Islands), Greenland, Iceland, Canada, USA, Mexico, Guatemala, Honduras, Nicaragua, Costa Rica, Panama and West Indies, as well as parts of Colombia and Venezuela (Hobson, 1906). The data-collection for the publication had been undertaken by Bailey Willis (1857–1949) of the USGS, which body was in charge of the publication. The geology of Canada was undertaken by James White (1863–1906), geographer of the

Ottawa Department of Home Affairs, in collaboration with Albert Peter Low (1861–1942), Director of the Geological Survey of Canada, and Frank Dawson Adams (1859–1942), among others. Much new information was incorporated. The part for Mexico and Central America had been produced under the direction of José Guadalupe Aguilera. The part for the USA was mainly based on previously published work, but involved much effort to summarize. The stratigraphic terminology was that used by the USGS (with twenty-five colours being used). Bailey Willis and José Guadalupe Aguilera presented the map in their respective communications and there was some discussion, for instance on the use of the term Algonkian and its fit, or otherwise, with international nomenclature.

There is no doubt about the delay in the publication of North America's geological map, as compared with the European map. So it is perhaps unsurprising that Th. N. Techerynchev of St Petersburg complained that the progress achieved in the publication of the European geological map was not represented at the IGC.

López Ramos (1988) has pointed out that: "Several different geologic studies involving maps were undertaken as a result of the X International Geological Congress", for example the *Carte géologique des environs de Zacatecas* (a city and a province in Mexico) (1905). There is no doubt that the IGC promoted the geological development of Mexico, particularly in relation to cartographic issues.

Polar expeditions

At the 10 September session Hjalmar Sjögeen (1856–1922) read a report from his geological compatriot Johan Gunnar Anderson (1874–1970), of the Sweden's National Geological Survey, on the results of the Swedish Antarctic Expedition (1901–1903), made on board the vessel *Antarctic*, under the direction of the geologist Otto Nordenskjöld (1869–1928). The members of the expedition made important discoveries, such as the finding of fossils on Seymour Island (an island near the tip of Graham Land on the Antarctic Peninsula, with fossil deposits from Cretaceous to Eocene), which indicated the existence of a former tropical climate there.

Towards the end of the nineteenth century and the beginning of the twentieth, several scientific expeditions to the polar territories were made, such as the British Antarctic Expedition, also known as the *Discovery* Expedition (1900–1903), the German South Polar Expedition (1901–1903) in which the Congress attendee Emil Philippi (1871–1910) had participated as a geologist, or the expedition to the Northeast Passage (1903–1906) of the Norwegian Roal Admunsen (1872–1928). The latter became the first to reach the South Pole, in 1911. (The North Americans Robert Edwin Peary (1856–1920) and Matthew Henson (1866–1955) had reached the North Pole a little earlier in 1909.)

The International Glaciers Commission, created at the 1894 Congress in Zurich by Captain Marshall Hall (1831–1896), also held a meeting at the Mexican IGC. Initially, the Commission was made up of scientists from countries with alpine glaciers, but after the Vienna IGC (1903) representatives from countries that studied the Polar Regions were also included. The President of the commission was the American Harry Fielding Reid (1859–1944) of the USGS, who introduced the 'elastic rebound' theory in a report on the San Francisco earthquake in 1906. In fact, he was the first to establish that movement on the fault caused the earthquake instead of being a result of it (Reid, 1911). The Commission asked for the collation of data concerning glacial phenomena collected during the polar expeditions.

Comissions and Proposals

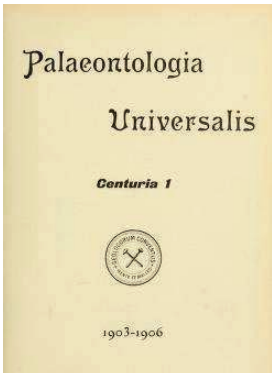
The different commissions held their meetings during the afternoon of 14 September.

The Palaeontologia Universalis *Commission*

During the Paris IGC of 1900 the compilation of a major work listing the different known types of fossils was agreed upon, yielding the book *Palaeontologia universalis*. An International Commission, with the same name, was to be in charge of the organization of the publication. In it, there were to be the original figures, photographs, complete descriptions, and the observations made by the editor of the cards on which the submitted information was recorded. The languages to be used were German, French and English. They intended to publish data for about eighty species each year. Initially the annual subscription was 40 French francs. The publication began under the direction of the Commission's President, Karl Alfred von Zittel (1839–1904), from the University of Munich, with the collaboration of the Secretary, Daniel-Pauline Oehlert (1849–1920), who in 1901 distributed a circular with three examples of how a card should be prepared. These were:

- *Ammonites masseanus* d'Orbigny, 1843, by the mining engineer René Nicklès (1859–1917).
- *Ogygia guettardi* Brongniart, 1822, by Oehlert.
- *Maretia nicklesi* Cotteau, 1889, by Ernest Munier-Chalmas (1842–1903).

Between 1903 and 1906 data relative to the crustacean and molluscs had been published. The edition continued until 1914, being financed by the IGC But the disruptions generated by World War I and Oehlert's death in 1920 put an end to the project (Fischer, 2002).



Palaeontologia universalis.

At the Mexican IGC, the members of the Commission met and decided that Friedrich Frech, Professor of the University of Breslau, should fill the position left vacant by Zittel's death in 1904. Frech directed the meeting, ratifying the incorporation of new members and the re-publication of some of the fundamental paleontological works.

It was also decided to increase the number of entries for each series, and also price (at that moment, there were around 250 subscriptions to the publication). Due to the efficient running of the project, proposals for two similar publications were generated:

- The creation of a *Journal of International Geological Bibliography* was proposed by the Organizing Committee but it was thought that the best solution would be to adapt an already existing magazine such as *Geologische Zentralblatt*, founded in 1900 by F. L. H. Konrad Keilhack (1858–1944), of the Prussian Geological Institute in Berlin and Professor at the Mining Academy. This publication had 850 contributors and had already reviewed 16,000 work, in seven volumes, though it did not include works on mineralogy.
- Also Emil Böse proposed the creation of a commission (even

its members were named) for an *International Journal of Geology, Petrography and Palaeontology*, but this did not come to pass perhaps because there was already a saturation of publications.

Other Commissions (International Cooperation in the Geological, Seismological Research and others)

The *Commission of International Cooperation on Geology* had been created during the Vienna IGC (1903), being headed by the Scottish geologist Sir Archibald Geikie (1835–1924), formerly the Director-General of the Geological Survey of Great Britain and subsequently President of the Royal Society. At the Vienna IGC (1903), the promotion of international cooperation in relation to the following issues was sought from the *International Association of Geodesy*:

- Establishing the accurate altitudes in the mountain chains that are subject to earth movements.
- Measuring the values of gravity at different localities, in order to know the internal distribution of the terrestrial masses, considering issues such as rigidity and isostatic processes.

Geikie did not actually attend the Mexican IGC, though he did send by letter a statement of what had been agreed at the Vienna IGC and this was subsequently published in the *Congress Proceedings*.

On the other hand, Becker presented, in the name of the North American geologist Samuel Franklin Emmons (1841–1911) of the USGS, the Vienna IGC (1903) resolutions for the creation of an *Institut modèle de géophysique*. In the letter he presented to the Congress, Emmons reported that the Carnegie Institution in Washington (founded in 1902) had made an endowment for the establishment of a laboratory, which was soon to be built, dedicated to the study of the behaviour of minerals subjected to great pressures and temperatures. This would also allow data to be obtained on the elasticity, plasticity, or strength of rocks. As has been shown by history, these investigations were to prove fruitful in several fields, particularly in studies of metamorphism, though Emmons was also interested in other issues such as the electric and thermal conductivities of metals and rocks, the processes of magmatic differentiation, seismology, etc.

The Committee for the Spendiarov Prize gave the award (for young geologists) to Th. N. Tchernychev for his work 'Die obercarbonischen Brachiopoden des Ural und des Timan' and the *Commission International des Glaciers* (established in 1894) held a meeting.

The Polish geologist and mining engineer Léonard Jaczewski (1858–1916), from the Organizing Committee of the *Congrès International des Mines et de la Métallurgie, de la Mécanique et de la Géologie Appliquée*, held in 1905 in Liège, made a submission to the Applied Geology Section, requesting the IGC to form a special committee in charge of the study of the geothermal gradient in different parts of the globe.

The Austrian geologist Emil Tietze (1845–1931), Director of the *Geologische Reichsanstalt* in Vienna, proposed the creation of an International Association of Geologists (which subsequently evolved into the International Union of Geological Sciences). It seems that the proposal could not be acted on at the time. It was raised again at the IGC in Belgium in 1922. In fact, the Union did not come into being until after World War II. A long time had to pass before the idea could become a reality (Harrison, 1978).

Conclusions

- The small European participation in the IGC was compensated by the presence of many geologists from the USA, which resulted in a greater use of English in the Congress compared with previous Congresses.
- At the time of the Congress significant advances were being made in palaeontology and stratigraphic nomenclature, favouring cartographic unification. There were also notable progress in the petrographic classification and in mineralogy. For such reasons, the IGC had to impose a fixed time for the presentations, and be rigorous as regards the acceptance of papers, etc.
- There weren't any outstanding new contributions at the Mexican IGC though many new things were said and there was plenty of debate. For example, the description of a crater generated by the impact of a meteorite, the so-called Coon Butte Crater was discussed by Herman Leroy Fairchild (1850–1943) in his paper: 'A meteoric crater in Arizona', which prompted a range of diverse positions on the part of the attendees.
- After having been held every three years, it was decided that the IGC would meet every four years. The Swedish Government, through the mineralogist Hjalmar Sjögeen (1856–1922) proposed, and it was eventually approved, that the next IGC should be held in Stockholm (Sundquist and Nordlund, 2004). Canada, which held the IGC in 1913, had not yet made a formal invitation (it was only presented informally), though Belgium, which did make a formal request, gave up its position to Sweden; and with the Toronto Congress (1913) the routine of organizing an IGC every three years was restored. Thereafter the meetings were held at either three- or four-year intervals until after World War II, when the four-year pattern became permanent.
- In 1956, fifty years later, a second IGC was held in Mexico (see Mazadiego and Puche, 2009).

Acknowledgements

We should like to thank to Luz Azuela and Héctor Mendoza Vargas for their helpful contributions to the information concerning the Mexico IGC, 1906.

Bibliography

Aguilera, J.G., 1904, Reseña del desarrollo de la geología en México. Boletín de la Sociedad Geológica Mexicana, v. 1, pp. 35–117.

Annales des Mines. Les ingénieurs des mines au XIXème et au XXème siècles. www.annales.org

Anon, 1907a, Congrès Géologique International. Compte Rendu de la Xème Session, Mexico, 1906 : Imprenta y Fotocopia de la Secretaria de Fomento. México.

Anon, 1907b, Boletín de la Sociedad Geológica Mexicana, v. 3, pp. 13–14.

Azuela, L.F., 2009, La geología de México en el siglo XIX: entre las aplicaciones prácticas y la investigación básica: Revista Geológica de América Central, v. 41, pp. 99–110.

Branagan, D., 2005, An early view of Permo-Carbonifereous glaciation and its implications, from Australia (1906): Episodes, v. 28, pp. 205–208.

Brown, J.C., 1993, Petróleo y revolución en México: Berkeley University of California Press (Siglo XXI Editores, Madrid–México, Spanish edition, 1998).

Burt, T.P., Chorley, R.J., Brundsen, D., Cox, N.J., Goudie, A.S., 2008, The history of the study of landforms or the development of geomorphology, Volume 4. Quaternary and Recent processes and forms (1890–1965) and the Mid-Century Revolutions: London, The Geological Society.

Byerly, P. and Louderback, G.D., 1964, Andrew Cowper Lawson (1861–1952): Biographical Memoirs of the National Academy of Sciences, v. 37, pp. 183–204.

Canudas, E., 2005, Las venas de plata en la historia de Méjico: Editorial de la Universidad Autónoma de Toluca.

Chalin, J., 1982, El Cuaternario: la historia humana y su entorno: Madrid, Akal (original French edition, Paris, Doin Editeurs, 1972).

CIPW, 1902, A quantitative chemico-mineralogical classification and nomenclature of igneous rocks: Journal of Geology, v. 10, pp. 555–693.

De Cserna, Z., 1990, La evolución de la geología en México: Revista del Instituto de Geología, v. 9, pp. 1–20.

Fischer, J.C., 2002, Conception et suites de la paléontologie française d'Alcide d'Orbigny: Comptes Rendus Palentològuiques, v. 1, pp. 599–613.

González Reyna, J. 1956. Riqueza minera y yacimientos minerales de México. Congreso Geológico Internacional, XX Sesión, México, 1956: Mexico City, Departamento de Investigaciones Industriales, Banco de México.

Harrison, J.M., 1978, The roots of IUGS: Episodes, v. 1, pp. 20–23.

Hobson, B., 1906, A new geological map of North America: Geological Magazine, v. 3, pp. 564–566.

Holmes, A. (revised D.L. Holmes), 1978, Priciples of Physical Geology: London, Taylor & Francis.

Humboldt, A. von, 1810, Vues des Cordillères, et monumens des peuples indigènes de l'Amérique: Paris, F. Schoell, 2 vols.

Lagny, Ph, 2007, Les substances utiles. La métallogénie: Géochronique, v. 101, pp. 42–44.

López, H., 2003, Gulfos y letras: un acercamiento a los estudios histórico-arqueológicos e iconográficos en las décadas de los veinte y treinta del siglo XX en Méjico: Cuicuilpo, v. 28, pp. 34–47.

López Ramos, E., 1976, Desarrollo histórico de la Sociedad Geológica Mexicana: Boletín de la Sociedad Geológica Mexicana, v. 37, pp. 91–98.

López Ramos, E., 1998, Contribución a la historia de la geología de México: Boletín de la Sociedad Geológica Mexicana, v. 49, pp. 3–18.

Mazadiego, L.F., and Puche, O., 2009, The 20th International Geological Congress, Mexico (1956): Episodes, v. 32, pp. 194–207.

Mülleried, K.G., 1936, Carlos Burkhardt (1869–1935): Boletín de la Sociedad Geológica Mexicana, v. 9, pp. 23–29.

Norris, R.V., 1924, Edwin Ludlow: Transactions of American Institute of Mining and Metallurgical Engineers, v. 70, 1213–1215.

Padrón, J., 2010. Doheny en los veneros del diablo: La Corriente, v. 14 (May 2010).

Reid, H.F., 1911, The elastic-rebound theory of earthquakes: Bulletin of the Department of Geology. University of California Publications, v. 6, pp. 413–444.

Rubinovich, R. and Lozano, M., with the collaboration of Mendoza Vargas, H., 1998, Ezequiel Ordóñez vida y obra (1867–1950): Mexico City, Colegio Nacional.

Spurr, J.E., 1903, A consideration of igneous rocks and differentiation as related to the occurrence of ores: Transactions of the American Institute of Mining Engineers, v. 33, pp. 288–340.

Sundquist, B. and Nordlund, C., 2004, Science and honour: The 11th International Geological Congress in Stockholm 1910: Episodes, v. 27, pp. 284–292.

VVAA, 2006, Guide des excursions. Xème. Congrès Géologique International. Mexico, 1906 (avec de nombreuses cartes, planches et gravures): Mexico City, Imprenta del Ministerio de Fomento.