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Preface: Geochemistry in Mexico

Prólogo: Geoquímica en México

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This special issue of the Journal of Iberian Geology (JIG) is dedicated to the ongoing geochemical research in Mexico. The idea to publish a collection of papers on the Geochemistry in Mexico was conceived in 2010 during the organization of XX Congreso Nacional de Geoquímica, Temixco, Morelos, Mexico, when the editors-in-chief and, through them, the editorial committee of the JIG were requested to evaluate the proposal of a monograph on this subject. Later, the project of publishing a collection of papers on this general theme was kindly approved by the authorities of the JIG as a special issue of this journal.

It would be difficult to synthesise the wide subject of the historical developments of Geochemistry in Mexico, but we will briefly comment on the highlights of these developments since the Instituto Nacional de Geoquímica (a scientific association) commenced its work in 1990, in Cuernavaca, Morelos, Mexico.

Although the initiation of the geochemical research in Mexico dates back to several decades, special impulse to this field was received when a new scientific organisation "Instituto Nacional de Geoquímica, Asociación Civil" (INAGEQ) was founded by Surendra P. Verma as its (first) President, David J. Terrell as its (first) Secretary, Juan Manuel Barbarín-Castillo as its (first) Treasurer, María Aurora Armienta-Hernández as its First Vocal, and Georgina Izquierdo-Montalvo as its Second Vocal. To inform the Mexican scientists and professionals about the INAGEQ, an informal meeting was held in the Instituto Mexicano del Petróleo, México, D.F., during the same year (1990), when many investigators and some students joined this association. The INAGEQ thus commenced its academic activities to promote geochemical research in Mexico.

The First National Geochemistry Congress (I Congreso Nacional de Geoquímica) was held in Linares, Nuevo León, in 1991 and the proceedings were published as volume 6 of the "Actas de la Facultad de Ciencias de la Tierra, UANL". The contributions of the II Congreso Nacional de Geoquímica, celebrated in Cuernavaca, Morelos, in 1992, were also published in the subsequent volume of the Actas. The III and IV Congreso Nacional de Geoquímica were held, respectively, in Mexico, D.F. in 1993 and Jiutepéc, Morelos in 1994, and the contributions were prepared and distributed as the Memorias del 3er. Congreso Nacional de Geoquímica and Memorias del 4o. Congreso Nacional de Geoquímica, respectively. Subsequent to this, in 1995, the first volume of the "Actas del Instituto Nacional de Geoquímica" (Actas INAGEQ, vol. 1) was published directly by the society. Since then, national geochemistry annual meetings were held each year without fail and the proceedings were published as the Actas INAGEQ (volume 2 onwards).

1 – I Congreso Nacional de Geoquímica, Fac. Ciencias de la Tierra, Univ. Autónoma de Nuevo León, Linares, N.L., September 3-5, 1991;
2 – II Congreso Nacional de Geoquímica, Instituto de Investigaciones Eléctricas, Cuernavaca, Morelos, October 13-16, 1992;
3 – III Congreso Nacional de Geoquímica, Instituto de Geofísica, UNAM, México, D.F., October 18-20, 1993;
4 – IV Congreso Nacional de Geoquímica, Instituto Mexicano de Tecnología del Agua, Jiutepéc, Morelos, October 15-17, 1994;
5 – V Congreso Nacional de Geoquímica, Univ. de Guanajuato, Gto., September 18-22, 1995;
6 – VI Congreso Nacional de Geoquímica, Univ. Autónoma de San Luis Potosí, San Luis Potosí, S.L.P., September 23-27, 1996;
7 – VII Congreso Nacional de Geoquímica, Instituto de Geología, UNAM, México, D.F., September 22-24, 1997;
8 – VIII Congreso Nacional de Geoquímica, Instituto de Geología, UNAM, México, D.F., September 21-25, 1998;
9 – IX Congreso Nacional de Geoquímica, Fac. Ciencias de la Tierra, Univ. Autónoma de Nuevo León, Linares, N.L., Sept. 22-24, 1999;
10 – X Congreso Nacional de Geoquímica, Centro de Investigación en Energía, UNAM, Temixco, Morelos, October 16-20, 2000;
11 – XI Congreso Nacional de Geoquímica, Univ. Autónoma de Baja California and Centro de Investigación Científica y de Educación Superior de Ensenada, Ensenada, Baja California, September 24-28, 2001;
12 – XII Congreso Nacional de Geoquímica, Puerto Vallarta, México, November 4-8, 2002;
13 – XIII Congreso Nacional de Geoquímica, Centro de Geociencias, UNAM, Juriquilla, Querétaro, September 22-26, 2003;
14 – XIV Congreso Nacional de Geoquímica, Univ. de Sonora, Hermosillo, Sonora, September 13-17, 2004;
15 – XV Congreso Nacional de Geoquímica, Univ. Autónoma de San Luis Potosí, San Luis Potosí, S.L.P., September 19-23, 2005;
16 – XVI Congreso Nacional de Geoquímica, Univ. Autónoma de Yucatán, Mérida, Yucatán, September 4-8, 2006;
17 – XVII Congreso Nacional de Geoquímica, Univ. Autónoma del Estado de Hidalgo, Pachuca, Hidalgo, October 1-6, 2007;
18 – XVIII Congreso Nacional de Geoquímica, Univ. de Sonora, Hermosillo, Sonora, October 6-10, 2008;
19 – XIX Congreso Nacional de Geoquímica, Univ. Autónoma de Baja California, Ensenada, B.C., September 21-25, 2009;
20 – XX Congreso Nacional de Geoquímica, Centro de Investigación en Energía, UNAM, Temixco, Morelos, October 11-15, 2010;
21 – XXI Congreso Nacional de Geoquímica, Univ. Autónoma de Coahuila, Monclova, Coah., October 3-7, 2011;
22 – XXII Congreso Nacional de Geoquímica, Univ. Autónoma de Veracruz−campus Coatzocoalco, Coatzocoalco, Ver., Oct. 1-5, 2012;
23 – XXIII Congreso Nacional de Geoquímica, Fac. Ciencias, Univ. Autónoma Estado de Morelos, Cuernavaca, Morelos, Oct. 14-18, 2013.

Fig. 1.- Map of Mexico (modified from Google Earth) showing the locations where national geochemistry congresses were held. The INAGEQ was registered close to the site no. 2.

Fig. 1.- Mapa de México (modified from Google Earth) mostrando las localidades donde se celebraron los congresos necionales de geoquímica. The INAGEQ tuvo lugar próximo al sitio 2.

We are also proud to note that ever since the realization of the First National Congress of Geochemistry in 1991, a commission of researchers is established in each meeting as the judges to evaluate the presentations by students and "Awards for the Best Paper Presentation by Students" are given on the recommendations of this commission or committee. This has made the student participation in these meetings always highly motivated. We also emphasise that the INAGEQ is the only scientific organisation in Mexico that has been doing this job continuously to promote science among the "young blood". Consequently, the science of geochemistry has certainly improved in Mexico through such efforts of the INAGEQ.

The places and institutions where the different meetings were held are shown schematically in Figure 1; this also includes the site of the forthcoming XXIII meeting in October, 2013. The geographical distribution of these national events (Fig. 1) highlights the great achievement of the INAGEQ in the territorial coverage. The national level congresses have been held all over Mexico, which have greatly benefited the local students.

We invite the potential readers of this monograph to attend and participate in the future geochemistry meetings in Mexico, which are planned to take place annually. These meetings are generally attended by around 100 or so participants. No parallel sessions have been ever planned or executed, except when, in two occasions, National Geochemistry Congress was celebrated along with other geoscientific organisations. In future, however, geochemistry meetings are likely to be held generally during the month of October and independent of other organisations. These events, therefore, provide a very homely and pleasant atmosphere for the exchange of ideas and, thus, constitute unique opportunities for the participants to get acquainted with Mexican geology and its scientists and culture.

During the initial stages of the geochemistry publication developments of the INAGEQ (1997 and 1998), peer reviewed proceedings were edited as two subsequent volumes of the Actas INAGEQ (volumes 3 and 4). Later, because the attempts to publish an independent peer-reviewed (purely) geochemistry journal did not materialise for multiple reasons, the peer-reviewed papers by the INAGEQ were published in the Mexican geological journal "Revista Mexicana de Ciencias Geológicas" (RMCG). In fact, the Instituto Nacional de Geoquímica joined several other Mexican institutions and societies to jointly publish the RMCG under the auspices of multiple institutions and societies. Consequently, this Mexican journal was recognised in 2004 by the Institute for Scientific Information (ISI), Philadelphia, to be included in their Science Citation Index (SCI). Since then, the RMCG has maintained its indexing by the ISI.

Now, because the JIG, also recognised by the ISI, has occasionally published monographs on different topics, it has been a good opportunity for the scientists to contribute to this JIG monograph on the Geochemistry in Mexico. We are thankful to numerous scientists and students who contributed with enthusiasm as authors to this monograph, to the reviewers who helped us achieve high standards, and the editors-in-chief of the JIG who guided us throughout this tedious process.

This monograph or special issue of the JIG consists of twelve papers arranged according to the following general themes: (i) three papers are grouped under the theme of data quality and statistics for data handling and interpretation (geochemometrics; Verma (2005) coined this term in Spanish – *geoquimiometría* – for the first time in history, and it has been explicitly used in English recently by Verma, 2012); (ii) four papers in sedimentary geochemistry and environmental research are presented; (iii) three papers in igneous rock geochemistry are then included; and (iv) two papers on new multi-dimensional discrimination diagrams using coherent statistical treatment of compositional data complete this monograph.

The first paper presents new highly precise and accurate critical values for F obtained from Monte Carlo simulations (Cruz-Huicochea and Verma, 2013). These values have proved extremely useful in Fisher´s F and Analysis of Variance (ANOVA) tests. This paper highlights the importance of these tests in geochemistry and presents a specific example related to the evaluation of geochemical data for international geochemical reference material granite G-2 from U.S.A. and comparison of the results with those of the Student t-test (see Verma and Cruz-Huicochea, 2013). The application also covers the inference of tectonic setting for the Eastern Alkaline Province (EAP) of Mexico from new multi-dimensional discrimination diagrams for ultrabasic and basic magmas and discordant outlier-free log-transformed data on samples from this province obtained from the DODESSYS software (Verma and Díaz-González, 2012). The EAP was shown to have a continental rift setting.

The second paper reports new highly precise and accurate critical values for t (Student t test) also obtained from Monte Carlo simulations (Verma and Cruz-Huicochea, 2013). As for the F test, twenty-eight regression models were evaluated to obtain the best regression fitting of the tabulated data. These models allowed successful prediction of interpolated critical values whenever they were not actually tabulated for certain intermediate degrees of freedom. The best models were based on log-transformations, which are likely to be useful for all cases where conventional polynomial regressions fail to perform satisfactorily. This is an important inference about regression technique, because it opens up new frontiers of research in all areas of science and engineering. Specific examples of applications of these t values in geochemistry, chemistry, medicine, and geology are provided.

The third paper evaluates the results of International Atomic Energy Agency inter-laboratory data reported during 1992 and 2004 to estimate analytical uncertainty in the geochemical analysis of geothermal waters (M.P. Verma, 2013). Several different statistical methods were compared. A preliminary evaluation of the analytical accuracy for common cations and anions is also reported from the analysis of synthetic water prepared by dissolving accurately weighed pure salts in purified water. The statistical results were applied to the propagation of uncertainty in the geochemical calculations of geothermal systems. This paper completes the first group of three papers dedicated to the quality control and statistical applications in geochemistry (geochemometrics).

The fourth paper concerns a carbon, oxygen and strontium isotopic study on the shallow marine Mural Formation in the Cerro Pimas locality of northern Sonora, Mexico (Madhavaraju *et al.*, 2013). The carbon isotope curve showed a positive $\delta^{13}C$ excursion followed by a negative event in the lower part of the Los Coyotes member (Lower Albian) of the Mural Formation. The $^{87}Sr/^{86}Sr$ age of the Cerro La Ceja member (115.9 Ma; Late Aptian age) was comparable to the published zircon radiometric age. The numerical age of the Los Coyotes (111.6 Ma and 111.2 Ma) and Cerro La Espina (111.0 Ma and 110.6 Ma) members indicated an Early Aptian age. The whole-rock Sr isotope ages in this study were consistent with the previously published radiometric and biostratigraphic ages.

The next paper reports the results of Co, Sc and Zn measurements on core sediments from the coastal zone of the Santa Rosalía mining region and the adjacent deeper areas of the Gulf of California (Shumilin *et al.*, 2013). Co/Sc and Zn/Sc values in cores from a predominant pollution "hot spot" near Santa Rosalía port were very high, indicating that the thickness of the polluted layer exceeded the length of the cores (75-93 cm). The values of Co/Sc and Zn/Sc decreased drastically in the cores that were collected outside the main "hot spot" below a core depth of 20-34 cm and approached the regional coastal surface sediment background levels. Before the estimation of mean and standard deviation values, the data arrays were processed by the DODESSYS software (a correct statistical procedure; Verma and Díaz-González, 2012).

The sixth paper is concerned with the dispersal of Ag, Cu, and Ni in mine wastes (tailings and ash) from the source of an abandoned gold mine at El Triunfo (Baja California Sur, Mexico) to the adjacent coast of the Pacific Ocean (Sánchez-Martínez *et al.*, 2013). The highest contamination levels of the studied elements were measured in one sample of the tailings. The background levels of these elements were estimated from two independent methods (the regression method summarised by Marmolejo-Rodríguez *et al.* (2007) and the multiple-test method of Verma, 1997). Then, these regional background levels were used to calculate normalised enrichment factors. Moderate to null pollution was interpreted for the area at about 18-49 km from the mine waste zone. This study indicated that historic and contemporary contamination continues to impact the riverine environment close to the pollution site.

The next paper (Sánchez *et al.*, 2013) completes the second group of papers (on sedimentary geochemistry) dedicated to this special issue. It deals with total organic carbon, total nitrogen, elemental (C and N), and isotopic ($\delta^{13}C$) composition of organic matter derived from both marine and terrestrial sources to constrain the relative contributions from marine productivity, mangroves, and continental wind erosion along the southwestern coast of the Baja California Peninsula. The stable carbon isotopic compositions were enriched in ^{12}C in surface sediments at suboxic sites within the oxygen minimum zone. The C:N and $\delta^{13}C$ values indicated that the organic sediment material is predominantly of marine origin, with a minor contribution from the terrestrial sources or mangroves.

The eighth paper commences the third group of contributions (on igneous rock geochemistry), in which chemical analyses conducted on the surface of rock slabs by wavelength dispersive and energy dispersive x-ray fluorescence spectrometry are presented (Vidal-Solano *et al.*, 2013). These authors state that the analyses of glassy rhyolites (ignimbrites and lava flows) in northwestern Mexico allowed them to establish geochemical characteristics of the samples and provided criteria to investigate field relationships of volcanic events. A distance of more than 100 km between the geographical locations of the thickest peralkaline deposits in Sonora, is probably related to a displacement along trans-tensional dextral faults during the Late Miocene.

The ninth contribution presents Sr and Nd isotopic data for the Laramide intrusive arc (broadly parallel to the actual Sonora coastline) presumably formed by the subduction of the (now disappeared or fragmented) Farallon plate beneath the North-American plate during the Late Cretaceous to Early Tertiary (Pérez-Segura *et al.*, 2013). Isotopic ages were also determined by U/Pb in zircons (95 Ma) and isotopic Ar/Ar in potassic feldspar (56 to 71 Ma) from a quartz monzonite porphyry, and by isotopic Ar/Ar in potassic feldspar (56 Ma) from another granodiorite body. The $^{87}Sr/^{86}Sr$ and εNd data suggest that the Laramidic magmas had a significant influence from the Proterozoic basement.

The tenth paper completes the third group of papers dedicated to the igneous rock geochemistry (Velasco-Tapia *et al.*, 2013). It is concerned with the Pliocene–Pleistocene lava flows, mainly of dacitic composition, exposed in the Sierra de las Cruces volcanic range in the central part of the Mexican Volcanic Belt. Most of the samples exhibit diverse mineralogical and geochemical features that support magma mixing and mingling processes with concomitant fractional crystallisation. Both andesitic and dacitic rock types were probably derived from partial melting of different levels of the underlying continental crust. The andesitic enclaves reported in this paper were considered as portions of the intermediate magma that did not mix completely (mingling) with the felsic host lavas, confirming the major role of magma mixing and mingling processes.

The eleventh paper presents a computer program (TecD) for the application of four sets of multi-dimensional discrimination diagrams recently proposed (2004-

2011) in the literature (Verma and Rivera-Gómez, 2013). This bilingual (both in English and Spanish) program allows an efficient application of a total of twenty diagrams based on discriminant-functions of log-ratios of major or immobile trace elements in ultrabasic and basic magmas. Log-ratio transformation is a statistically cherent procedure for handling compositional data (Aitchison, 1986; Agrawal and Verma, 2007). Three examples were presented to highlight the use of TecD. Ocean island setting was inferred for ~56 Ma basic rocks from Faroe Islands (Atlantic Ocean), mid-ocean ridge for ~2700 Ma Archean Abitibi greenstone belt (Canada), and arc setting for ~2950 Ma Mallina basin (Australia). The TecD software should prove useful to scientists from all over the world and is freely available on request from any of the authors of this paper.

The final paper in this monograph used the multidimensional diagrams programmed in TecD to evaluate an extensive geochemical database for basic rocks of northwest Mexico and to infer their tectonic setting (Pandarinath and S.K. Verma, 2013). All the four sets of diagrams confirmed a continental rift setting for on-land basic rocks of <13 Ma age (13 Ma is supposed to be the time of termination of subduction and initiation of rifting in northwestern Mexico). For the on-land basic rocks of >13 Ma age, major-element based diagrams also indicated a rift setting. However, one set of trace-element based discrimination diagrams indicated an arc to rift transition, and the other set of trace-element based discrimination diagrams for the only sample from the Comondú arc, which had the required complete dataset, indicated an arc setting. All the four sets of discrimination diagrams indicated MORB setting for off-shore rocks. These authors concluded that these discrimination diagrams may successfully discriminate the original tectonic setting of comparatively younger and older on-shore rocks as well as sea-water altered deep-sea and dredged rocks.

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