

Alcides N. Sial: 51 years of Scientific Activities

Born at Recife, Brazil, on December 14th, 1942, Alcides Nóbrega Sial is the youngest of the four children of Albérico Sial and Maria do Carmo Nóbrega Sial. He attended the elementary school in the Grupo Escolar João Barbalho (1949-1954), a public school, and the middle school in the Colégio Salesiano (1955-1959), a catholic private school, both in Recife. In January 1960, he entered the Preparatory School for Cadets, Brazilian army, through a keen intellectual selection (163 selected from 3,000), being him the only one selected at Recife. In the Brazilian army, he spent 1960 and 1961 at Fortaleza, Ceará, and 1962 at Campinas, São Paulo. On December 1962, he left the army to pursue undergraduate studies at the University of Recife (former name of the Federal University of Pernambuco - UFPE). From March 1963 through December 1966, he was a dedicated undergraduate student, working for his B.Sc. degree in Geology. Inspired by A. Bhakara Rao and his wife Maria do Socorro work on mineralogy and petrology, Sial found himself dragged into the field of igneous petrology.

On March 1967, Sial was hired as instructor by the UFPE, and for three years he conducted a geological mapping, with Eldemar Menor, of an area of about 3,000 km² (half quadrangles of Taquaritinga do Norte and of Afogados da Ingazeira map sheets) in the states of Pernambuco and Paraíba. In this task, he benefitted from Jean Paul Testemale's experience on mapping Precambrian terrains.

In this period, he worked close to A. Bhaskara Rao who had founded the Mineralogical Club in the Department of Geology of the School of Geology, and who used to encourage Sial's flair for the scientific research. Under his guidance, Sial wrote his first scientific paper "Charnockites from two localities of Pernambuco" that was published in the *Jornal de Mineralogia*, in its 10th anniversary issue (1968). Sial spent much of his spare time with Bhaskara Rao attempting to learn petrology, mineralogy and English and joined Eldemar de A. Menor and Claudio de Castro in activities related to the Mineralogical Club.

In 1970, he was granted a scholarship by the Portuguese Union for Overseas Investigations (Junta de Investigações do Ultramar) and was a trainee for 7 months at the Laboratory of Physical-Chemical Techniques Applied to Mineralogy and Petrology, in Lisbon. He learned optical emission spectrography for trace element analysis, petrochemical calculations and geo-statistics from Raul David Gomes. After this

traineeship, he visited several universities in European countries seeking for a university where he could undertake graduate studies leading to a Ph.D. degree.

Meanwhile, he was contacted by Cordell Durrell, an experienced igneous petrologist of the University of California at Davis (UCD, USA), inquiring on his willingness to come to Davis for graduate studies. Sial ventured going to California on September 1971, to study under Ian D. McGregor's advice for his doctoral degree.

He focused his Ph.D. dissertation on Mesozoic and Tertiary basalts of Rio Grande do Norte and Mesozoic basalts of the Maranhão Basin. Funded by the Brazilian National Research Council (CNPq), he made a comprehensive sample collection from Mesozoic diabase dikes emplaced during the opening of South Atlantic, from and Tertiary basaltic plugs and necks of Rio Grande Norte and Paraíba and of basaltic flows from Grajaú and Porto Franco in Maranhão. He also collected representative peridotite nodules from the Tertiary basaltic plugs and necks that allowed him to estimate the depth of host magma generation.

In 1971, CNPq supported no graduate study abroad and, fortunately, Sial was offered a teaching-assistantship by the Department of Geology of the UCD where he gave assistance in laboratory classes, working 24 hours per week. Thanks to this teaching-assistantship (TA), and to the Brazilian government that kept his university salary paid in Brazil, he could defray the costs of UCD academic fees, and this university granted him the waiver of the tuition fee. As a TA, he helped Robert Twiss (structural geology course), Cordell Durrell (igneous petrology) and with Charles Higgins (field geology) he helped undergraduate students mapping areas in California.

During his stay at that university, Sial developed strong ties of friendship with Cordell Durrell who regarded him as his own son, and from whom he learned a great deal of environmental petrology and Ian MacGregor, a brilliant scientist, who became one of Sial's mentors.

During the three years of permanence at UCD, he updated and broadened his background of igneous petrology and was introduced to the world of phase diagrams, a vital tool in this field. He was also fascinated by the plate tectonics innovative concepts taught by Eldridge Moores, an authority on this modern geodynamic view of mountain building and island arc formation. Being the UCD campus close to the US Geological Survey headquarters in Menlo Park, California, Sial could use their facilities and learn the fission-track (spontaneous fission of ^{238}U) dating method from Charles Meyer.



Field trips: (a) MAGMA Symposium, Espírito Santo (1993), left to right: A.N. Sial, Cristina Pinheiro de Campos, Anthony Fallick, Pierre Sabaté, Ignez Guimarães and Herbert Conceição; (b) Quebrada de La Chilca, Argentine Precordillera, 2010; left to right: Silvio Peralta, A.N. Sial and Claudio Gaucher; (c) Sial in an investigation of the K-T boundary record, Yacoraite basin, Argentina, 1999; (d) Isla Riesco, Patagonia, Chile (1999), with Alejandro Toselli and Miguel Parada; (e) Sierra de Velasco, Argentina, 2010, left to right: Alejandro Toselli, A. N. Sial, Valderez Ferreira and Miguel Parada; (f) Lachlan Foldbelt, Australia, 1991; (g) Lachlan Foldbelt, Australia (Alan White with brown hat); (h) Reserve Faunique de Papinau-Labelle, French Canada, with Louise Corriveau, 1995.

On August 12th, 1974, after arduous but fruitful work, he finished his Ph.D. dissertation, entitled Petrology and tectonic significance of the Post-Paleozoic basaltic rocks of Northeast Brazil. His thesis committee was composed of Ian D. MacGregor, Cordell Durrell and Eldridge Moores. Two years ten months and fifteen days had elapsed since he had arrived to America. Finally he had accomplished one of his most pursued dreams, earning the Ph.D. degree from a prestigious American University.

Upon his return to Brazil on October 2nd 1974, he started teaching elementary structural geology, plate tectonics and phase diagrams applied to igneous petrology, at the Department of Geology (UFPE) in Recife. In this period, he was sometimes invited to teach plate tectonics or phase diagram short courses at the graduate level in other Brazilian universities.

After three years of teaching at the UFPE, he left to the University of Texas (UT) at Austin, for post-doctoral work (September 1977 through September 1978). In this endeavor, he focused on isotope geology, learning from Leon E. Long on the strontium isotope systematics, solid-source mass spectrometry and geochemistry of strontium isotopes.

At Austin, Sial was introduced to low- and high-temperature stable isotope geochemistry by from Lynton Land and also about oxygen gas extraction from silicates using a conventional, high-vacuum extraction line having bromine Br₂F₅ as main reagent. He also learned on hydrogen-isotope geochemistry and how to run an old-fashioned Nuclide gas-source mass spectrometer.

During his stay at Austin, he studied the petrology and isotope geochemistry of samples collected from the Meruoca and Mucambo plutons, Ceará. The Meruoca samples revealed that this epizonal pluton had undergone low-temperature interaction with water leading to strontium leaching and post-crystallization change of its oxygen-isotope signature, generating a bull's eye pattern with ¹⁸O enrichment towards the center of the pluton (whole-rock, quartz, feldspar and biotite patterns). This was the second time such a phenomenon was documented from epizonal plutons.

In 1979, Sial started a preliminary petrological and geochemical study of Neoproterozoic granite-types of the Cachoeirinha-Salgueiro Belt, Transversal zone, northeastern Brazil. These granite types lacked detailed lithochemical and isotopic study and knowledge of their spatial distribution within this belt. Sial led a small group of colleagues in a reconnaissance project to provide these informations.

The previous positive experience at UT encouraged Sial to broaden his background on stable isotope geochemistry and to visit other laboratories in USA. With this purpose, he spent the entire 1983 in the University of Georgia at Athens, where he was exposed to multiple applications of stable isotopes and related laboratorial techniques. In the same year, he spent two months at the Department of Geology of the Memorial University of Newfoundland, learning the analytical method for rare-earth element analysis by X-ray fluorescence from Brian Fryer.

During his permanence in Georgia, Sial studied the petrology, oxygen isotopes, mineral chemistry and rare-earth element behavior of the so-called granite-types of the Cachoeirinha-Salgueiro Belt, leading to recognition of a zoning of the oxygen-isotope pattern in these granitoids across this belt.

The challenging complexity of granites, their metallogeny and importance in reconstruction of geotectonic setting, have stimulated Sial to found of the Nucleus for Granite Studies (NEG) in the Department of Geology of the UFPE on February 1984. Since then, the NEG has developed petrological, geochemical and isotopic studies on granitic rocks of northeastern Brazil, Argentina, Chile, Uruguay and India, mainly on igneous processes and investigation of the source of granitic magmas. Recently, the name of this Nucleus was changed to Nucleus for Geochemical Studies.

From 1984 through 1987, Sial led a large project supported by the PADCT program to the study of granitic rocks from the Cachoeirinha-Salgueiro Belt. Funded by this project, some Master's theses guided by Sial allowed the recognition of calc-alkalic, high-K calc-alkalic, trondhjemitic, shoshonitic, peralkalic and ultrapotassic series plutons in this belt and in the area surrounding it. He also proposed that the alignment of ultrapotassic plutons at the eastern border of this belt was connected to a major deep-structure that was baptized as the "syenitoid line" and recognized later as a terrane boundary by him and Valdez P. Ferreira.

In 1988, as a post-doctor at UGA by the second time, a FINEP funded project allowed Sial to have built two conventional extraction lines (carbonate and silicate) with help and expertise from David Wenner and Andrew Clarke. In this year, he also spent one month in the Geological Survey of Japan at Tsukuba, learning from Akira Sasaki, the technique of extraction of sulfur from rocks using the Kiba solution and gas-source mass spectrometry for sulfur isotopes. In 1991 and 1996, Sial spent couple of weeks in East Kilbride, Scotland, visiting with Anthony E. Fallick the analytical facilities of the Scottish Universities Research and Reactor Centre (SURRC).



Events: (a) Meeting of the Mineralogical Club at Recife, 1969; left to right: Paulo Duarte, A.N. Sial, Billy Johnston Jr. (USGS), Francisco C. P. Coelho (DNPM), Max White; (b) Itaporanga pluton, Paraíba, Workshop on Granites and Associated Mineralizations, 1985; (c) Serra do Teixeira, Pernambuco, 1985: from left to right: Cristina Pinheiro de Campos, Pedro Sartori, Eberhard Wernick, Umberto Cordani, José Marques Correia Neves, A.N. Sial and Valdevez Ferreira; (d) Near the São Tomé basaltic plug, Rio Grande do Norte, Kimberlite Conference field trip, International Geological Congress, 1992; (e) Granites of South Korea field trip, International Geological Congress, 1992; (f) Field trip to Espírito Santo, Workshop on Granitic Magmatism and Associated Mineralizations, 1993; (g) from left to right: Wilson Wildner, A.N. Sial, Valdevez Ferreira, Sonia Esperança (NSF) and Cristina P. de Campos; (h) Second International Symposium on Granites and Associated Mineralizations (Second ISGAM): Donald Hutton and A.N. Sial.

The scientific experience acquired from all these stable-isotope laboratories in USA, Japan and Scotland led him to found, with financial support of the PADCT program, a stable isotope laboratory (LABISE) at the Federal University of Pernambuco pioneering in Brazil the analysis of oxygen isotopes from silicates, in 1990. In this endeavor, he was supported by the UFPE Rector, Edinaldo Bastos, in whose administration was built the physical space to accommodate this laboratory, comprising two high-vacuum extraction lines and a stable isotope ratio analyzer mass spectrometer (SIRA). The high-vacuum extraction lines (carbonates and silicates) were built in the workshop of the University of Georgia and transferred to Recife where they were reassembled by Sial with the help of Gorki Mariano and Valdez Ferreira.

The administration of two rectors of UFPE who followed Edinaldo Bastos, Efreem Maranhão and Mozart Neves Ramos, financially supported the expansion of the physical space of the LABISE to accommodate an X-ray fluorescence laboratory and a sample preparation room.

Sial visited with Prof. John Valley the Department of Geology and Geophysics of the University of Wisconsin, at Madison, for three months, in 2001, learning the minor details on CO₂-based high vacuum extraction line for silicates. Upon his return, the LABISE underwent another physical expansion to accommodate an ion-exchange laboratory, a CO₂ laser-based oxygen extraction line from silicates and oxides (a FINEP project allowed building at the University of New Mexico, Albuquerque by Zachary Sharp), and an elemental combustion system (COSTECH) for carbon and nitrogen analyses, on-line with a Thermofinigan Delta V gas-source mass spectrometer.

In 1985, Sial organized a workshop on Granitic Magmatism and Associated Mineralizations at Caruaru, Pernambuco, gathering about 15 enthusiastic young Brazilian granitologists. He led a field trip to the Cachoeirinha-Salgueiro Belt and brought their attention to granitoids of uncommon mineralogical/geochemical diversity and evolution. The same group of granitologists together with others gathered again in 1987 at Salvador, Bahia, in the International Symposium on Granites and Associated Mineralizations (ISGAM), in 1993 in Rio, and in 1997 in a second edition of the ISGAM, all of these Meetings organized by Sial. Besides the ISGAM series, Sial also organized other international Meetings on two themes: Granitic Magma and Associated Mineralizations (MAGMA) within the frame of the International Geological Congress (31st IGC, 32nd IGC, and 33rd IGC), and on isotope geology (4th South American Symposium on Isotope Geology, 2003). Besides, he has annually organized with

Valderez P. Ferreira, multi-disciplinary Meetings of the Brazilian Academy of Sciences at Recife since 1992.

The study of Neoproterozoic magmatic epidote-bearing granitoids in northeastern Brazil, Paleozoic in Argentina and Tertiary in Chile, represents one of the highlights of the contributions to the granite-petrology field from the NEG-LABISE (papers published in *Lithos* (1999, 2005, 2008, 2011, 2011) or in *Contributions to Mineralogy and Petrology*, 2003). It is worth mentioning the study by Roberto F. Weinberg (visited the NEG-LABISE for one year), A.N. Sial and Ricardo R. Pessoa on magma flow and thermal convection within the magmatic epidote-bearing Tavares pluton, northeastern Brazil. One of the structures of this pluton appears in the front cover of the *GSA Bulletin*, April issue, 2001. In other two studies, Sial and co-authors proposed that the partial digestion of magmatic epidote by its calc-alkaline or high-K calc-alkaline host magma could be used to estimate the speed rate of granite magma ascent (2008, 2011).

Using the laser-probe incremental heating $^{40}\text{Ar}/^{39}\text{Ar}$ dating of biotite and hornblende single crystals from magmatic epidote-bearing plutons, in cooperation with Paulo Vasconcelos (University of Queensland, Brisbane, Australia), Sial demonstrated that these plutons solidified at relatively great depth followed by prolonged cooling interval between the closure temperatures of biotite and hornblende. This finding was in consonance with unusual high-pressure inner thermal aureoles in some of these plutons described in a study Sial conducted in cooperation with Renaud Caby (University of Montpellier, France).

From 1995, Sial's scientific interest was broadened to include isotope stratigraphy and from then on, he started a continuous and fruitful cooperation with colleagues from Argentina (Silvio Peralta, Gilberto Florencio Aceñolaza, R. Narcizo Alonso and Alejandro Toselli), Uruguay (Claudio Gaucher and Jorge Bossi) and Chile (Miguel Angel Parada) and more recently with Robert Frei (Denmark). This group has documented by the first time in South America the isotope record of the Steptoean positive isotope carbon excursion (SPICE) and recognized by the first time the Sunwaptan negative carbon isotope excursion (SNICE) in the Argentine Precordillera. Moreover, they recognized by the first time in South America the record of the Ordovician MDICE, GICE and HICE positive carbon isotope excursions. Together with Claudio Gaucher, Anil Maheswari, Andrey Bekker, Valderez P. Ferreira, Jorge Bossi and Wilson Romano compared the record of the Paleoproterozoic Lomagundi excursion in India, Brazil and Uruguay. They found that this excursion is recorded in both



Awards and Honours: (a) Silver Hammer Award, Brazilian Geological Society, Ouro Preto, Minas Gerais, 1976; (b) Member of the Pernambucoan Academy of Science, with Walter Rosa Borges, Recife, Pernambuco, 1979; (c) Associate-member of the Brazilian Academy of Sciences, with Israel Vargas, Rio de Janeiro, 1981; (d) Full-member of the Brazilian Academy of Sciences, Rio de Janeiro, 1990; (e) Medal of the Centennial Anniversary of the Engineering School, Federal University of Pernambuco, Recife, Pernambuco 1995; (f) Grand Cross, National Order of the Scientific Merit, with President Luiz Inacio Lula da Silva, Brasilia, 2008; (g) Member of the Academy of Sciences for the Developing World (TWAS), Hyderabad, India, 2010; (h) Brazilian Geological Society Northeastern Chapter, Aracaju, Sergipe, 2011.



Awards and Honours: (a) Tribute for scientific contribution to the study of granitic rocks in Brazil during the 8th Hutton Symposium (2015); (b) Professor Emeritus at the Federal University of Pernambuco, March 2016; (c) Marechal Trompowski Medal awarded by the Institute of Academicians of the Military Professorship (IDMM, 2016); (d) José Bonifácio de Andrada e Silva Golden Medal medalist (Brazilian Geological Society, October 2016).

shallow-water and deep-water carbonates negating a significant impact of stromatolite productivity and hypersaline conditions on carbon isotope values of carbonates deposited in shallow-water, open-marine and isolated basins.

In the last six years, he turned his attention to the possible use of Hg (mercury) as a tracer of volcanism during events of extreme climatic changes. At present, he is building a database with Hg analyses, including Hg isotopes (supposedly of volcanic origin) from Cryogenian–Ediacaran cap carbonates and from carbonates across the Cretaceous–Paleogene (K/Pg) and Permian–Triassic (PT) boundaries of several localities. The intent is to evaluate the extension of participation of volcanism versus bolide impact on the mass extinction of the K/Pg boundary.

He has disseminated granite petrology and geochemistry of stable isotopes by teaching short courses in several universities in Brazil, including UFRGS, UFRJ, UFPA, UFPE, UFMG, UFMT, University of Chile (Santiago, 2003), Latin-American Congress (Medellin, 2011) and in several geological Brazilian Meetings.

His contagious enthusiasm for science has attracted many students and he has advised/co-advised thirty-four Master's degree students, eighteen doctoral theses and

some post-doctoral traineeships (Anil Maheshwari, Manoj K. Pandit, Lalchand Govindram Gwalani, from India; Ignacio Sabino Garcia and Lucia Peral Gomez, from Argentina; Marcelo Solari, from Chile; Pedro Morais from Portugal, besides several Brazilian researchers). He has published two hundred thirty-three scientific articles (most of them in international journals in English), about twenty book chapters, three books (an AGU/Wiley book is under preparation) and organized twelve special issues, most in international Journals (Lithos, Chemical Geology, Precambrian Research, Gondwana Research, Journal of South American Earth Sciences, Annals of the Brazilian Academy of Science, Brazilian Journal of Geology (ex- Revista Brasileira de Geociências). He has also acted as ad hoc consultant of several international Agencies: NSF (USA), NSERC (Canada), Israel Science Foundation, Swiss National Science Foundation, German Research Foundation, CONCYTEC (Peru), FONDECYT (Chile), CNPq, FINEP, CAPES (Brazil).

His scientific accomplishments lent him credentials to become a member of the Brazilian Academy of Sciences (1990), corresponding member of the Lisbon Academy of Science (1997), member of the World Academy of Science for countries in Development (TWAS, 2009), Fellow of the Geological Society of America (elected in 1990), member of the Society Resource Geology (Japan) as an invited special foreign member. He holds membership of about 10 other international scientific societies. He has received the Silver Hammer award (1976) and the José Bonifácio Golden Medal from the Brazilian Geological Society (2016); Centennial Merit Medal of the Engineering School of the Federal University of Pernambuco (1995), “best paper award” from the Wadia Institute, India (Tewari, V.C. and Sial, A.N., 2007, *Chemical Geology* 237:82-106, doi: 0.1016/j.chemgeo.2006.06.015), was admitted to the National Order of the Scientific Merit in Brazil, by presidential decree (Commendator and Grand-Cross Classes, respectively on 1996 and 2007), and was also conferred several honors by the Northeastern Chapter of the Brazilian Geological Society. On July 2012, he received a tribute from the 8th South American Symposium on Isotope Geology (8th SSAGI), at Medellin, Colombia, by his significant contribution to the development of stable-isotope geology in South America. The Brazilian Geochemical Society conferred to him a tribute for his contribution to the development of isotope geochemistry in Brazil (2013) and the 8th Hutton Symposium, a tribute for his scientific contributions for the study of granitic rocks in this country (2015).



Ties of Friendship: (a) Brazilian Geological Congress, Ouro Preto, Minas Gerais, 1976, left to right: A.N. Sial, Claudio de Castro, Vilma Campanha, Carlinda C. de Farias, Glicia S. Borba; (b) Leon Abramoff, A.N. Sial and Amir (FACEPE), Athens, Georgia, 1983; (c) A.N. Sial and Gorki Mariano, LABISE, 1992; (d) Christmas party, NEG-LABISE, 1994, left to right (Sial's sons): Erik L. Sial, A.N. Sial, Andrew L. Sial, Valderez P. Ferreira and little Adrian F. Sial; (e) Anthony Fallick and A.N. Sial, East Kilbride, Scotland, 1996; (f) Restaurant Sajonia, 200 Km north of Santiago, Chile, left to right: Miguel Parada, Julio Saavedra, A.N. Sial and Alejandro Toselli; (g) Christmas party, NEG-LABISE, 2000; (h) Left: Davos, Switzerland, Adrian F. Sial and A.N. Sial holding the flag of the Santa Cruz Football Club, 2009; Right: A.N. Sial, attending the soccer game Santa Cruz x Sport Clube, occasion when Santa Cruz became champion of the Pernambucoan Football League, May 2011.

He was a member of the editorial board of *Geology* (1997-2000, Geological Society of America), editorial board of *Gondwana Research* (Elsevier), and currently is a member of the editorial board of the *Annals of the Brazilian Academy of Sciences* (Earth Science Section) and associate-editor of *Geochimica Brasiliensis* of the Brazilian Geochemical Society.

Along his professional career, A.N. Sial has also assumed responsibilities related to scientific policy of Brazilian Agencies like CNPq, CAPES, FINEP, FACEPE and at the UFPE. In this regard, he was a coordinator of the Post-graduation program on Geosciences at UFPE (1990-2002), having introduced the doctoral program. He was also member of the Geosciences Committee at the Brazilian Council for Technological and Scientific Development (CNPq) in the periods of 1979-1982, 1996-1998 and 2004-2007, member of the Deliberative Council of the CNPq (1991-1993), second-secretary of the directory of the Brazilian Academy of Science (1991-1993), member of the technical group of the PADCT program (1995-1997), member of the Upper Committee of FACEPE (1991-1993), Committee for Coordination of the PRONEX (1996-1998) and Adjunct Coordinator for the Geosciences Section in CAPES (1993-1995), among others

A. N. Sial holds a full-professor position at the Department of Geology, Federal University of Pernambuco, since 1989. On December 14th, 2012, by occasion of his 70th anniversary, he retired, after almost 46 years devoted to research and teaching at this university. On his retirement, he left the Department of Geology with four full professors (Valderez P. Ferreira and Sergio P. Neves, Ignez P. Guimarães, Adejardo F. da Silva Filho), and two associate professors (Joaquim A. Mota, and Ricardo J. R. Pessoa) who were his former students. He became an Emeritus Professor at the Federal University of Pernambuco (March 2016) where he keeps full academic activities.

Publications

(a) Selected Papers

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