

Mapping the Pyritic Sludge Spill of the Aznalcóllar Mine by the use of Airborne Daedalus 1268 Data

C. Antón-Pacheco⁽¹⁾, J. C. Gumiel⁽¹⁾, E. de Miguel⁽²⁾, J. A. Gómez⁽²⁾, J. G. Rejas⁽²⁾, M. Giménez⁽²⁾,
J. E. López-Pamo⁽¹⁾, D. Baretino⁽¹⁾ and G. Ortíz⁽¹⁾

(1) Instituto Geológico y Minero de España, C/. Ríos Rosas, 23, 28003 Madrid. España.

(2) Instituto Nacional de Técnica Aeroespacial. Torrejón de Ardoz, Madrid, España.

The failure of the Aznalcóllar mine impoundment in April 1998, holding several million tons of pyrite stockpile, flotation tailings and acid water, produced a slurry flood along the Agrío river, a tributary of the Guadiamar which drains Doñana National Park. The fine-grained sulfide deposit covered 2600 ha of riverbanks and adjacent farmlands, extending to the upper Entremuros area, 45 km downstream from the mine. Removal of the pyritic sludge was carried out by mechanical methods. Three multispectral airborne surveys (Daedalus-1268) were performed over the affected area in different periods to evaluate the efficiency of this system for monitoring soil condition during and after the sludge removal. Geometric and radiometric corrections were applied to the data. Chemical, mineralogical and spectral reflectance analyses on the pyritic sludge and its alteration products have permitted to interpret multispectral data. Digital classification has allowed mapping the pyritic sludge as well as the highly soluble efflorescence salts which present a high acidity potential. Detailed maps, at 1:10 000 scale, of the remnant sludge deposits and alterations have been produced and were used to monitor the progression of the pyritic sludge removal at different steps.

The application of geochemistry of carbonates to an exploration project of raw materials to the cement industry. Triassic and Jurassic calcareous formations in the Iberian Range, Spain (NE of Aragonian Branch)

J. M. Baltuille, J. Locutura and J. Vega

Instituto Geológico y Minero de España, C/. Ríos Rosas, 23, 28003 Madrid. España.

The working area is around of Morata de Jalón (Zaragoza, Spain) and has an extension of 15 km² and the stratigraphic and geochemical characteristics of calcareous series were studied during this project. The investigated stratigraphic series are of Mesozoic age and are made up by high carbonate marine formations varying from Triassic to Lower Jurassic. Geochemical analysis were carried out over 57 samples. All of this calcareous rocks should be pass a standard specifications regarding the quality requirements for the raw materials for the production of Portland cement. The following results have been obtained by this research: 1. Geological mapping of the area at 1:25,000 scale. 2. Stratigraphic study of all carbonatic formations of the region. 3. Geochemical study of 57 samples that have been checked to the chemical requirements for the production of Portland cement. 4. Definition of the lithologies with optimum conditions for the cement manufacture. 5. Evaluation of a limestone resources of 100,000,000 tones with a chemical content of 96 % in CaCO₃, 0.8 % of MgO and 53.5 % of CaO.

Urban geochemical mapping in Madrid. Application to environmental diagnosis

A. Bel-Ian and J. Locutura

Instituto Geológico y Minero de España, C/. Ríos Rosas, 23, 28003 Madrid. España.

The main objective of this study has been the multielement geochemical characterization of the urban and periurban soils in a large city. This aim includes the analysis of spacial distribution of trace and major elements and the establishment of their concentration levels, the definition of the element associations and the study of their origin, natural or anthropogenic, and finally the classification of the urban space based on the potentially harmful elements distribution and the recommendation of detail studies in areas with problems. The geochemical content of elements in soils is mainly a function of their primary features and of contaminants contribution (overall by diffuse atmospheric sedimentation). This complex relationship has been approached in this study by means of different kinds of samples and of geochemical data: soil samples (4 samples/ km²), sediment dust from atmospheric aerosol and tree leaves. The treatment and graphic representation of the geochemical information has allowed to know the elementary distributions and estimate their background contents, the main geochemical associations and their most possible origin (lithologic or antropogenic, mainly from industrial sources or traffic). This study contributes to the knowledge of the current state of urban contamination and it will be useful to control and to study its future evolution.

Sr-Nd-Pb Isotope data for basaltic rocks from La Gomera, Canary Islands

J. L. Brändle⁽¹⁾, E. Ancochea⁽¹⁾, M. J. Huertas⁽¹⁾, C. R. Cubas⁽²⁾ and F. Hernán⁽²⁾

(1) Depto. de Petrología y Geoquímica, Univ. Complutense - Inst. Geología Económica. C.S.I.C., Ciudad Universitaria. 28040 Madrid (España).

(2) Depto. de Edafología y Geología, Universidad de La Laguna. 38204 La Laguna, Tenerife (España)

Nd, Sr, and Pb isotope ratios from La Gomera are advanced, compared and discussed in this work. La Gomera, show striking contrasts with La Palma and Hierro, the other two westernmost islands of the Canarian Archipelago: the much older activity of La Gomera ranges from at least 12 Ma to about 2 Ma, so with no recent activity at all, whilst the two other islands built up by very recent activity less than 3 Ma and 1 Ma respectively. La Gomera is formed of two major volcano stratigraphic units: the Old Basaltic Series and the Recent Series. All rocks are alkaline, from middle to strongly alkaline: basalt - trachyte, and basanite - phonolite. The isotopic variation in La Gomera lavas ($87\text{Sr}/86\text{Sr} = 0.70305$ to 0.70331 ; $143\text{Nd}/144\text{Nd} = 0.512875$ to 0.512918 ; $206\text{Pb}/204\text{Pb} = 19.057$ to 19.999 ; $207\text{Pb}/204\text{Pb} = 15.583$ to 15.658 ; $208\text{Pb}/204\text{Pb} = 38.943$ to 39.691 and $207\text{Pb}/206\text{Pb} = 0.7818$ to 0.8194) can be explained by mixing of a HIMU plume, depleted upper mantle (DMM) and enriched sublithospheric mantle (EM-I and EM-II). These isotopic compositions fall within the general range of the canarian rocks, but they represent the highest Sr and Pb isotope ratios, close to those from the old and eastern island (Fuerteventura) and far from those from La Palma and Hierro. The Old Basalts and the Recent Basalts from La Gomera are similar in their Pb and Nd isotope ratios, but show different Sr isotope ratios, lower those of the Recent Basalt (0.70307 average) than those of the Old Basalts (0.70324 average).

Litho-geochemical database support to the new geological map of Tenerife

J. L. Brandle⁽¹⁾ and F. Bellido⁽²⁾

(1) C.S.I.C., 28040 Madrid. España.

(2) Instituto Geológico y Minero de España, C/. Ríos Rosas, 23, 28003 Madrid. España.

A litho-geochemical database has been made simultaneously with the design of the new version of the geological map (1:100000) of Tenerife, to characterize the volcanic units and the evolution of the main edifices and complexes (Ancient Edifices, Cañadas, Dorsal, Teide-Pico Viejo and Peripheral Vents) taking into account petrological, geochemical and chronological data. The results confirm that the basanite (or basalt) - tefrite - phonolite (or trachite) trend dominates the evolution of all edifices. A weak enrichment in silica and alkalis is found in the basic terms of the younger units. In all cases a compositional gap is marked between 47%-55% SiO₂. The discriminating analysis shows an high degree of overlapping in the basic terms of all edifices pointing out that volcanic episodes are mainly resulting from the evolution of the volcanic structures and do not correspond to significant changes in the petrogenetical processes. The litho-geochemical database linked to other type of geological information, enables an interactive updating, reclassification and handling of data in parallel with the field works. It is then possible to work in 'real time', checking the development of the geological map simultaneously with the changes introduced in the petrological models of the evolution of Tenerife Island.

The unix simplex-sample space for compositional data

M. Bren⁽¹⁾ and J. A. Martín Fernández⁽²⁾

(1) University of Maribor, FOV, Kranj, Slovenia.

(2) University of Girona, Dep. for Inf. and App. Math., Girona, España.

It is well known that the adequate sample space for compositional data is the unit simplex - which, equipped with the perturbation operation and scalar power multiplication, is a real vector space. We'll discuss the centered logratio transformation, a homeomorphism of the n-dimensional unit simplex onto a n-1 dimensional real hyperplane - subspace of the usual Euclidean real vector space. We'll define and also discuss the inner product in the vector space of the unit simplex and the centered logratio transformation as a homeomorphism of the unitary spaces that preserves orientation, angles between vectors, and transforms lines into lines. Examples of simulated data sets and of real geological data sets will be presented to visualize the three way compositions in ternary diagrams and in a real plane with the usual Euclidean metric which is a benefit because of our Euclidean seeing. We also stress that all statistical techniques: principal components, discriminant analysis, cluster analysis... are grounded on this Euclidean seeing.

Industrial minerals and sustainable development in Iberoamerica

B. Calvo

Departamento de Ingeniería Geológica. Escuela Técnica Superior de Ingenieros de Minas.
Universidad Politécnica de Madrid (España).

Iberoamerican countries are very well known for their metallic mining products. Little is known about the Industrial Minerals and Rocks (IMR) potential, although they are beginning to play an important role in the development of this region. The exploitation of construction materials, dimension stone, clays, salts, gems, fertilizers, prime materials for chemicals and many others can provide a source of richness and a technological challenge for these countries. Academic institutions and state agencies have understood this opportunity and are preparing national inventories, maps and databanks with useful information for companies and investors. It is important to have a whole idea of the possibilities of Iberoamerican countries in exploiting their own IMR resources. It is important to know, not only the proved amount of minerals, but also the possible use, the mining costs and the final prices, depending on the applications. The Iberoamerican Network on IMR (CYTED) is working on a map and a manual about these materials in Latin American countries, and some data are given in this paper. It is relevant to point out the importance of sustainable development, in which the adequate social satisfaction is the first priority, and the preservation of the environment. Availability of information and the impact of technology choice will lead to a recognition of the important role of small and medium scale sector. IMR are shown as important sources of employment and national and regional income.

Industrial minerals network in Latin America

B. M. Calvo

Departamento de Ingeniería Geológica. Escuela Técnica Superior de Ingenieros de Minas.
 Universidad Politécnica de Madrid (España).

In this paper, some clues are given about world population growth and natural resources demand. The role of industrial minerals and rocks is pointed out, and the need of preserving sustainable development in mineral exploitation and benefit. Some propositions are made about the initiatives that Latin American countries could take in order to get the maximum benefit of their industrial minerals resources. Besides, the Ibero-American Industrial Minerals and Rocks Network (RIMIN) is introduced, and some data are giving about its aims and procedures.

The Earth can be considered as a closed system in which the natural resources are supposed to meet the requirements of all the living beings in the planet. From a human point of view, a system must be established in which minerals, energy, water and food are to be preserved, in order not only to answer the current demand, but also to ensure the future development of mankind. In this system, the demand is due to the growth of human population and to the increasing needs of developing countries. The offer is given by the whole of the resources. Not all of them will be considered in this paper, but only a small but very important part of the so-called mineral resources, namely the Industrial Minerals and Rocks, which play an outstanding role in meeting the human requirements.

The human population growth is far from being linear. In fact, it seems an exponential function, depending on so many factors that human beings do not know yet when upper limit will be reached. World population grew slowly since the early times of mankind until the end of the Middle Age. The new continent colonization, the opening of new commercial routes and, afterwards, the industrial revolution, allowed an increasing world population growth since the 17 th Century (Fig 1). It can be notice, however, that main development of human population on Earth is being reached in the present centuries. In 1750 people on Earth were about 0.8 billion. In 1900 had not attained 2 billion. Nowadays we have crossed the 6 billion boundary. A closer look to the graphics explaining this growth shows a great difference between rich and poor countries. While Japan has a very little expected population growth since the beginning of the 21 st Century, other countries, as Nigeria, will increase it in five times in only one century. Demographers suggest that by 2100 AD the world population will have attained a constant size of about 11 billion persons (Hammond et al, 1996) (Fig 2). Besides, the demand for natural resources increases at a much higher rate. According to United Nations Agriculture Office (FAO) studies, the fertilizers production has been nine times bigger in 1990 that in 1950. The world population has only doubled in the same period. Obviously, it will be difficult to meet the future demand of which the population growth is bigger, and the gross national product is smaller. Finally, the waste and the environmental damage of the resources treatment must be considered. The amount of waste left for disposal is much greater than the volume of metal extracted or goods used. To obtain 5 kg of copper from copper-bearing raw material, with 5% of metal content, 995 kg of rock must be moved, crushed and Fig. 1. Growth of the world's population thorough history. (Data from the population Reference Bureau) Fig 2. Projected growth of populations to the year 2100. (From Demeny, 1984

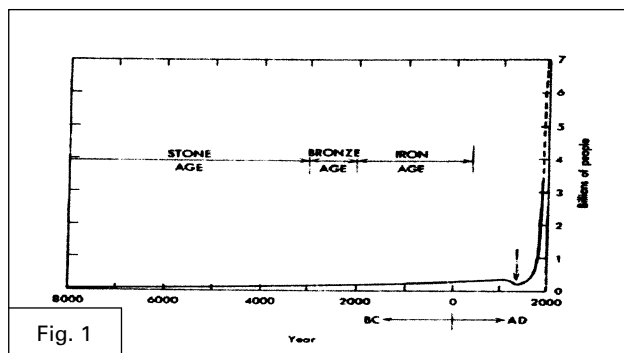


Fig. 1

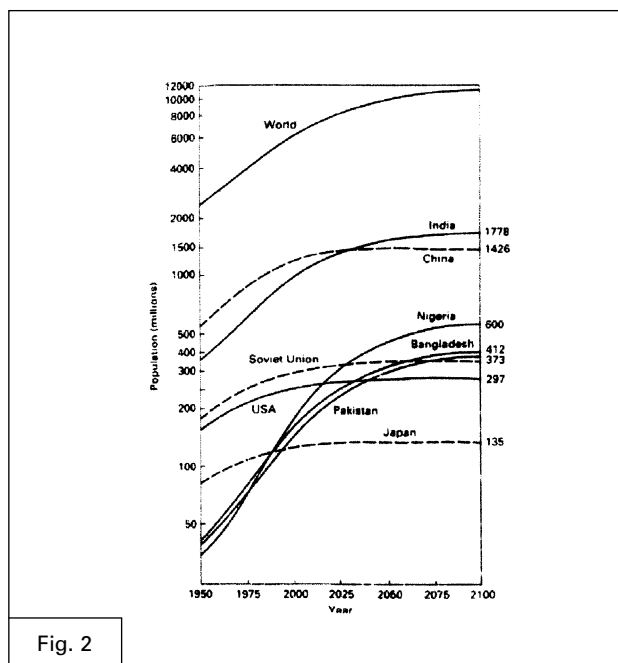


Fig. 2

Composition and evolution of extrasolar terrestrial planets

I. Casanova

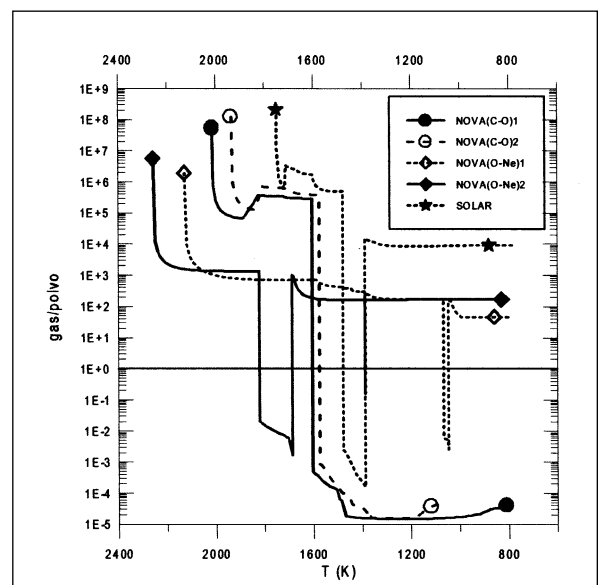
Universitat Politècnica de Catalunya, Institut d'Estudis Espacials. Mòdul B1, Campus Nord. 08034 Barcelona, España.

Introduction

Conventional solar nebula models on planetary formation suggest that the composition of planets formed around a star strongly depends on the chemistry of the initial molecular cloud. Equilibrium condensation of gases ejected from two different types of novae suggest that (1) systems with a very high dust/gas ratio (10^8 x solar) may develop during cooling of C-O novae and, (2) graphite becomes a stable and abundant mineral at 800 K even when the initial gas C/O ratio is less than unity (O-Ne novae environments). At such high dust/gas ratios, supermassive rocky planets may be formed from C-O novae ejecta at short distances from the central star. On the other hand, substantial amounts of solid carbon in protoplanetary materials may yield to substantial differences in the primary differentiation of a terrestrial planet. First, a carbide-rich (rather than metallic) core may form. Given that the density of (Fe,Ni)_xC is substantially lower than that of a metallic Fe,Ni alloy, core segregation may happen slowly, due to lower density contrast between metal carbide and silicates, and inefficient core formation is thus possible. This would certainly have strong implications on the development of an intrinsic magnetic field, the efficiency of planetary outgassing and the composition of the (non-captured) atmosphere. Also, immiscible excess carbon may yield to the formation of a graphite-rich crust, with relatively high thermal conductivity, where fast dissipation of internal heat might substantially reduce the time span of geological activity of even large bodies. Condensation of novae ejecta Novae ejecta are a significant contributor to molecular clouds from which protoplanetary systems may form. In this work, equilibrium condensation calculations on four different cases (José and Herranz, 1998) have been carried out, on the basis of previous work showing that such calculations are adequate for the simulation of the composition of terrestrial-like planets (Casanova and Portela, 1996; Valeriano and Casanova, 1997): 1. NOVA (C-O) 1: the chemical composition of the outermost ejected layer where the mass of the white dwarf is 1.15 solar masses, accretion rate is 2×10^{-10} solar masses /yr and 50% mixture between the white dwarf core and ejected material. 2. NOVA (C-O) 2: same as NOVA (C-O) 1 but for the closest layer to non-ejected material. 3. NOVA (O-Ne) 1: same as NOVA (C-O) 1 but adopting a Ne-O composition of the white dwarf core. 4. NOVA (O-Ne) 2: same as NOVA (C-O) 2 but adopting a Ne-O composition of the white dwarf core. The evolution of the gas/dust ratio as a function of temperature is graphically described in Fig. 1. C-O novae have very similar condensation sequences. the most interesting feature of such sequences is that the gas/dust ratio decreases rapidly at 1600 K, suggesting a high-efficiency condensation event. At temperatures between 1100 and 800 K, the gas ratio is approximately 8 orders of magnitude higher than the solar analog, implying that the residence time for solid materials in the molecular cloud is much higher than in the primitive solar system, yielding to a prolonged accretion and subsequent possibility of formation of supermassive terrestrial-like planets. Ne-O novae ejecta show a condensation sequence very similar to the solar case (as far as gas/dust ratios) but significant chemical differences exist, including the preservation of graphite as a stable component at temperatures as low as 800 K with an initial C/O ratio of 0.6. This observation opens new possibilities towards understanding the formation and stability of solid carbon species during planetary formation processes. Specifically, graphite stability at temperatures as low as 800 K permits reaction between solid carbon and metals (Fe,Ni) to produce metallic carbides. If the planet grows to the extent of developing significant partial melting, a carbide-rich rather than a metallic core will form, leading to less efficient segregation and, ultimately, a planet without a central core. If graphite content exceeds the stoichiometric abundance required for the formation of metallic carbides, excess carbon will "float" to develop a graphite-rich crust.

References

- José J. and Herranz M. 1998 *Astrophys. Journal* 494, 680
Casanova I. and Portela J.C., 1996. *Geogaceta* 20, 62
Valeriano J. and Casanova I., 1997. *Actas del I Congreso Ibérico de Geoquímica* 624.



Continental shelves in the Quaternary-implications for sequence stratigraphy

F. L. Chiocci⁽¹⁾, F. J. Hernández-Molina⁽²⁾ and G. Lericolais⁽³⁾

(1) Università La Sapienza, Roma, Italy.

(2) Universidad de Cádiz, España.

(3) IFREMER, France.

The Quaternary stratigraphy of continental margins is usually undertaken by means of high-resolution low-penetration seismics that allow a very good depiction of subsurface geometry and acoustic facies of seismic units. Detailed study of cores - where available - support facies interpretation and allows datation of the deposits. Such increasing knowledge of internal architecture and stacking pattern of the recent units making up the continental shelves, and the correlation with global sea-level curve, led to the emergence of data that can have relevant bearing on sequence stratigraphy model and concepts that have scanty dealt with high-frequency sedimentary deposits. First-generation sequence stratigraphic models assume a nearly sinusoidal sea-level curve, a quite constant (or slowly variable) sedimentary supply and progradation occurring essentially during high- and low-stands. On the contrary, due to the profound asymmetry and high-frequency and amplitude of glacioeustatic changes, the development of systems tracts is extremely uneven in time and space. Continental shelf systems respond to changes caused by external factors such as climate, eustasy and tectonics, as well as - at high resolution scale - to internal and/or local factors which may have in certain circumstances a pronounced effect on the stratigraphic record. Stratigraphic expression of the Plio/Quaternary boundary and Middle Pleistocene Revolution (920 kyr) will be discussed. In support, correlation of shelf depositional sequences landwards and basinwards and the high order(s) of depositional sequences, as well as more specific but meaningful features as occurrence gas, valley incision within systems tracts, types of basal unconformities, paleoclimate indicators will be presented.

Permian basin development in the northern central Andes: transtension associated with Gondwana break-up

E. Díaz Martínez⁽¹⁾, V. Carlotto⁽²⁾, T. Sempere⁽³⁾ and J. Cárdenas⁽²⁾

(1) CSIC-UCM, Madrid, España.

(2) UNSAAC, Cusco, Perú.

(3) IRD, Lima, Perú.

The Permian sedimentary record in the northern Central Andes of Peru (Tarma-Copacabana and Mitu groups) and Bolivia (Titicaca Group) consists of heterolithic marine and continental successions deposited under warm and semiarid conditions at low latitudes. A transtensional regime is inferred for the overall Permian sedimentary and tectonic evolution of the region. A large and elongated basin (mixed carbonate-siliciclastic homoclinal ramp) developed in the Late Carboniferous-Early Permian, including synchronous magmatism and evaporite deposits. This initial phase is interpreted as a result of partial rifting and crustal thinning resulting from extensional overlap between transtensional fault systems. Increased strike-slip movement in the Late Permian-Early Triassic, in conjunction with fault trace variations, originated positive reliefs due to local compression and uplift, as well as narrow, elongated and strongly-subsiding basins with anoxic conditions and deposition of hypersaline organic-rich marine shales (Ene Fm.). Active magmatism continued during this phase, characterized by lava flows, pyroclastic and epiclastic volcanic deposits (Mitu Group). Individual sub-basin sags resemble half-grabens, with a master normal fault along one side, and oblique normal faults within the sag dying out away from the master fault. Permian faults (transcurrent and listric) were reactivated and reversed during Mesozoic and Cenozoic deformation, and may themselves be inherited from pre-Carboniferous evolution. The Abancay deflection represents a major transcurrent zone influencing both tectonics and sedimentation in the region. We interpret the overall Permian basin development in the northern Central Andes as a result of transtension related with the initial phases of Gondwana break-up.

Soil dynamic characteristics in the Caracas Valley using microtremor measurements

T. Enomoto⁽¹⁾, M. Schmitz⁽²⁾, N. Abekí⁽³⁾, I. Matsuda⁽³⁾, K. Masaki⁽⁴⁾, V. Rocabado⁽²⁾, M. Navarro⁽⁵⁾
and A. Sánchez⁽²⁾

(1) Kanagawa University, Yokohama, Japan, enomotot@cc.kanagawa-u.ac.jp.

(2) FUNVISIS, Caracas, Venezuela, mschmitz@funvisis.internet.ve.

(3) Kanto Gakuin University, Yokohama, Japan, abeki@kanto-gakuin.ac.jp.

(4) Aichi Institute of Technology, Toyota, Japan, masaki@ce.aitech.ac.jp.

(5) Universidad de Almería, España.

From seismic refraction investigations realized after the 1967 Caracas earthquake, a map of the sedimentary thickness for the central valley of Caracas was derived, which indicates sedimentary thickness of up to 300 m (Los Palos Grandes area). The studies revealed a strong relationship between the occurrence of damage and the sedimentary thickness in the Los Palos Grandes area as well as to local soil conditions in the Caraballeda area at the coast (Litoral Central). Nevertheless, no analysis of the dynamic response of the soils has been realized then. First microtremor measurements (about 80 sites in a 500 m grid) were realized in 1994 and 1997. A clear relationship was derived between the thickness of the sedimentary layers and the predominant period of the soils, which is longer than 1 s for the thick sediment sites and about 0.2 s for the rock sites. Complementary measurements were realized in 1999 in order to cover the whole sedimentary valley (total of about 300 sites). Additionally, microtremor array measurements were realized at 3 sites in order to confirm the S-wave structure of the sedimentary infill. The evaluation of the ground characteristics (including soil classification and ground shaking characteristics) and the main characteristics of Caracas city (buildings, lifelines, population, etc.) form part of an integrated study, which aims to give a zonation for the seismic risk assessment, disaster reduction and recommendations for the local government

Climatic control of landslides in Spain

M. Ferrer

Instituto Geológico y Minero de España, C/. Ríos Rosas, 23, 28003 Madrid. España.

Rainfall is the main triggering factor of landslides and rockfalls in Spain, affecting natural or excavated slopes. Precipitation intensity and duration controls, with some other geological and morphological factors, the magnitude and typology of slope movements. In this work some aspects related to the influence of meteorology and climate on the occurrence of landslides in Spain are analysed. Landslides are the most extended geological risk in Spain, with the highest economical losses after floods and erosive processes. At local scale, the analysis of meteorological series and rainfall data associated to the occurrence of landslides allows the deduction of general precipitation thresholds for the triggering of new landslides or reactivations of ancient movements. At regional scale, from the analysis and review of the climatic parameters which control the landslide processes, some general criteria can be established on the influence of precipitation in the triggering of slope movements in Spain. Parameters as daily and hourly maximum precipitation intensity and net infiltration in the terrain have a definitive influence on some type of slope movements. The application of these climatic criteria in areas with different geological and morphological characteristics allows the establishment of a relative climatic susceptibility degree for slope movements occurrence in different regions in Spain.

Geological and hydrogeological control of a large landslide (Benamej, Southern Spain)

M. Ferrer, J. C. Garca and A. Iglesias

Instituto Geolgico y Minero de Espaa, C/. Ros Rosas, 23, 28003 Madrid. Espaa.

The paper stands out the definitive importance of the knowledge of detailed geological and hydrogeological characteristics to understand the geomechanical behaviour of a natural slope affected by a large landslide. A large historical landslide has been affecting catastrophically during centuries the village of Benamej, in Crdoba (Andaluca). The movement affects a natural gentle slope 1000 m long between the village and the river in the bottom of the valley. The periodic backward movements of the upper tension crack, 400 m long, have worn down streets and houses of the village. For years, different studies, investigations and works have been carried out in order to stabilize the slope, without any satisfactory result due to the complex characteristics of the site and the lack of detailed and adequate geological investigations. Last important movement, in August 1997, was the trigger for the decision of a detailed geological, hidrogeological and geotechnical investigation, including boreholes and laboratory and in situ hidrological and mechanical tests. The final objective is the design of definitive corrective measures based on the knowledge of the behaviour of the landslide and the influence and control of the different geological materials and tectonic structures, distribution of water levels, flows, acuifers, hidrological parameters, etc. The geological, hidrogeological and geotechnical models have been prepared, and the corresponding stability analysis modelling the behavior of the terrain have been performed with adequate mathematical methods.

Industrial minerals and rocks map of Iberoamerica

A. Gajardo⁽¹⁾, M. Lombardero⁽²⁾, M. Regueiro⁽²⁾, M. Maya⁽³⁾ and B. Calvo⁽⁴⁾

(1) Servicio Nacional de Geologa y Minera. SERNAGEOMIN. Chile.

(2) Instituto Geolgico y Minero de Espaa, C/. Ros Rosas, 23, 28003 Madrid. Espaa.

(3) INGEOMINAS. Departamento de Minas. Medelln. Colombia.

(4) Escuela Tcnica Superior de Ingenieros de Minas. UPM. Espaa.

The Industrial Minerals and Rocks (IM&R) mining sub-sector has, over the last few years, shown a steady and strong growth in most Iberoamerican countries. Such growth, directly related to the industrial and social development, has been founded in private independent mining enterprises, with very little national governmental support. It is clear that prospecting and mineral planning tools are needed if future enlargement for this mineral industry is desired. Financed by the CYTED Program, and within the Thematic network RIMIN, a new vision of the Industrial Minerals and Rocks in Iberoamerica has been drafted in cartographic form. The map pretends to show in a very visual and intuitive manner the IM&R potential of Iberoamerica in relation with its geological setting and origin. The map has a scale of 1:7 500 000 and occurrences are shown as symbols indicating substance, genesis, morphology, mining state and identified by a numeric code. Geological base includes lithology and age for sedimentary, volcanic and metamorphic rocks, and a colour code for plutonic acid, intermediate, basic and ultrabasic rocks. This map will be of special use for geoscientists, prospectors, mining companies and national mineral planning authorities.

Cretaceous metamorphic evolution of the Isle of Pines, NW Cuba: tectonic implications

A. García-Casco⁽¹⁾, R. L. Torres-Roldán⁽¹⁾, G. Millán Trujillo⁽²⁾ and P. Monié⁽³⁾

(1) Dpto. de Mineralogía y Petrología, Universidad de Granada, Fuentenueva s/n, 18002-Granada, Spain.

(2) Instituto de Geología y Paleontología, Vía Blanca y Carretera Central, La Habana, Cuba.

(3) Lab. de Tectonique et Géochronologie, URA CNRS 1371, USTL, Place E. Bataillon, 34095 Montpellier Cédex, France.

The Isle of Pines, NW Cuba, is a coherent metamorphic terrane that probably represents a southern portion of the continental margin of the Yucatan Block during Mesozoic times. Metamorphism in this terrane records two steps: a) Prograde metamorphism spanning low- to high-grade conditions that developed at pressures of 8-12 kbar and is contemporaneous with early fabrics (D1). b) A decompression plus cooling step, contemporaneous with the main deformation in the area (Smain=2) and accompanied by fluid infiltration. Metamorphism terminated in the Uppermost Cretaceous (68 ± 2 Ma, $40\text{Ar}/39\text{Ar}$ dates on muscovite and biotite). The P-T evolution of metamorphism in the Isle of Pines suggests shortening (D1) and crustal thickening due to the collision of the passive continental margin with the Cretaceous island arc of Cuba, rather than to subduction of the margin under the island arc. The decompression step is compatible with tectonic extension (D2) during the late Cretaceous, rather than with a separate thermal pulse or the thermal relaxation accompanying erosion of a thickened crust. This tectonic extension can be correlated with the initial development of the Yucatan Basin during the late Cretaceous. In spite of having developed almost contemporaneously with them, the metamorphism of the Island of Pines terrane is not easily correlated with that of other neighboring high pressure (e.g. Escambray) and low pressure (e.g., Mabujina) terranes, and is likely to represent a distinct tectonic element in the development of the of the Cretaceous Cuban orogenic belt.

The first Spanish contribution to the Geosites Project: a list of geological frameworks set by consensus

A. García-Cortés, A. Barnolas, F. Bellido, J. Fernández-Gianotti, J. Locutura, A. Martín-Serrano, C. Quesada, I. Rábano and J. J. Durán

Instituto Geológico y Minero de España, C/. Ríos Rosas, 23, 28003 Madrid. España.

The Geosites project, initiated by the IUGS Global Geosites Working Group and also supported by UNESCO, aims to produce a global inventory of the earth's geological heritage. This global inventory requires a systematic methodology, which is based on the selection of geological frameworks with international significance, in every country. These frameworks are tectonic events, time or regional geotectonic elements, etc.. (Wimbledon et al. 1996). The second step of this methodology is the selection of the most valuable and representative sites of these geological frameworks (geosites). Fortunately, the geological diversity of Spain provides a great number of frameworks with global significance; in addition, the high quality of outcrops (due to topographic and climatic reasons) will allow the selection of illustrative geosites. In this paper a list of Spanish geological frameworks set by consensus is presented. It was prepared following the Geosites Project methodology without taking into account the National Inventory of Geosites, which is in progress and covers a 40% of the Spanish territory. The Geological Survey composed a preliminary list, which was sent to all the University Departments of Geology, Mining Schools and Research Centers, for its analysis, discussion and improvement. The result of this request was the selection of 25 "frameworks" which are the first Spanish contribution to the Geosites Project.

Deglaciation and holocene climate and sea level. Atlantic-Mediterranean littoral (Iberia)

J. L. Goy, C. Zazo, C. J. Dabrio, L. Luque, F. González, J. Lario and F. Borja

Dpto. Geología, Fac. Ciencias, Universidad Salamanca, 37008-Salamanca (España).

Climatic and sea-level changes in Southern Iberia littoral (36°-37°N/2°-7°W) are analysed after the sedimentological record of estuaries/deltas infill, outcropping beach barrier-lagoon systems, aeolian dunes with interbedded paleosoils and alluvial fans. Chronostratigraphy is based on AMS and conventional radiocarbon ages and archaeological-historical data. Pollen, micro- and macro-fauna and stable isotopes (C, O) have also been studied. Reconstruction of paleogeographical evolution of different coastal environments along time is based on mapping of littoral outcropping sediments together with boreholes. Sea-level changes. The oldest marine deposits in the estuaries are recorded at ca. 12,000 yrBP, followed by a stabilization at ca. 9,500 yrBP. Rapid sea-level rise took place between 8,500 and 6,500 yrBP. Maximum flooding is recorded in estuaries at 6,500 yrBP coincident with the development of beach barrier systems in the open coasts and a sea level height in Mediterranean coasts at 1.5-2m a.p.s.l. At ca. 4,000 yrBP fluvial input surpassed the already negligible rate of sea-level rise. Then the general sea level presents a still-stand or falling trend. Climate Change. Humid conditions between 14,000 and 10,500 yrBP. Wetter and warmer conditions between 10,500 and 4,500 yrBP (Atlantic coast). At 4,200 yrBP starts the characteristic aridity and seasonality of present mediterranean climate. A major change occurred at 2,700-2,500 yrBP (direction of prevailing winds almost coincident with the present conditions) starting an important accumulation phase in coastal dunes: Humid conditions (2,000-600 yrBP) in Atlantic coasts. Increasing aridity during the last 500 yr. This work has been supported by The 97-00 Project of the Fund. Ramón Areces and by the Spanish DGICYT Projects PB95-0109 (CSIC) and PB95-946 (USAL). It is a contribution of the INQUA Sea Level and Neotectonics Commissions.

Paleobiogeographical relations between South America and the North Gondwanan biogeographic domain during the Ordovician

J. C. Gutiérrez-Marco⁽¹⁾, F. G. Aceñolaza⁽²⁾, G. F. Aceñolaza⁽²⁾ and I. Rábano⁽³⁾

(1) IGE (CSIC-UCM), Madrid, España.

(2) INSUGEO (CONICET-UNT), Tucumán, Argentina.

(3) Instituto Geológico y Minero de España, C/. Ríos Rosas, 23, 28003 Madrid. España.

The study of FADs of benthic organisms along the peri-Gondwanan margin of South America, Africa and southern Europe, allows us to determine Ordovician biodiversification centers and migration routes among these areas, with regard to common taxa displayed at generic and even specific levels. The most significant patterns were identified among taxa recorded from the latest Cambrian to mid Arenig of Argentina and Bolivia, whose FAD in proto-Avalonia, North Africa and Western Europe Gondwanan areas took place in the Middle Ordovician or in the early Caradoc. This is exemplified by some echinoderms, brachiopods and trilobites, indicating that a one-way migration route was established from west to east, extending as far as Bohemia. The presence of eastward marine currents along the South American margin of Gondwana by the Early Arenig is supported by the arrival of warm water trilobites, such as *Carolinites genacinaca* (an epipelagic and paleoequatorial species), as far south as Bolivia. The simultaneous record of an eocrinoid and a bellerophonitiform mollusc in two areas lying originally about 8000 km apart also show the lack of barriers to migration of epipelagic shelly faunas across perigondwanan platforms during the Arenig. The drifting of Avalonia from Gondwana, and the impending closure of the Iapetus, promoted an anti-clockwise gyre on the marine currents during the Upper Ordovician, preventing the direct arrival of more South American immigrants to Gondwanan Europe. The *Nesuretus* fauna survived in South America during the Caradoc, and few north-Gondwanan emigrants reached South America during these ages, such as some draboviid and heterorthid brachiopods, and the lyrodesmatid bivalves. An active faunal exchange started again by Hirnantian time, at a subprovincial biogeographic level.

Ordovician biodiversity in the Iberian Peninsula: a preliminary appraisal

J. C. Gutiérrez-Marco⁽¹⁾, G. F. Aceñolaza⁽²⁾, I. Rábano⁽³⁾ and G. N. Sarmiento⁽¹⁾

(1) IGE (CSIC-UCM), Madrid, España.

(2) INSUGEO (CONICET-UNT), Tucumán, Argentina.

(3) Instituto Geológico y Minero de España, C/. Ríos Rosas, 23, 28003 Madrid. España.

The Iberian Peninsula (Spain and Portugal) contains extensive outcrops of Ordovician rocks, with 450 taxa of diverse invertebrate groups so far recorded. These taxa include trilobites, brachiopods, molluscs, echinoderms, graptolites, scyphozoans and bryozoans, but not microfossils (except ostracods) or ichnofossils. Their vertical distribution shows different patterns of extinction and recovery, mainly related with periods of great global transgressions and regressions, and with climatic crises. However, these patterns are not homogeneous, so that each group is here analyzed separately. The percentages of general biodiversity are strongly dependent on sedimentary facies and environments prevailing during long periods and over large areas near the polar coasts of Gondwana. In the Lower Ordovician we report only 33 different species, and the diversity percentages are biased due to the existence of inappropriate facies for preservation of macrofossils (Armorican Quartzite and equivalents) combined with the widespread stratigraphical gap representing most of the Tremadoc. On the contrary, the Middle Ordovician shales show the highest percentages of faunal diversity, with 409 different species. The return to coarse clastic and episodic sedimentation during the Late Ordovician coincides with an apparent decrease in biodiversity which may be misleading. The fossil record is restricted to relatively few palaeontological horizons, mostly related to the presence of coquina beds or thin limestone units such as the Urbana Limestone and equivalents, where in fact biodiversity is relatively high. A total of 141 species have so far been recorded in the Upper Ordovician of the Iberian Peninsula.

A new Late Holocene progradational sedimentary body on the onshore-offshore transition domain: the infralittoral prograding wedge

F. J. Hernández-Molina⁽¹⁾, L. M. Fernández Salas⁽²⁾, F. Lobo⁽¹⁾, L. Somoza⁽³⁾ and V. Díaz del Río⁽⁴⁾

(1) Facultad de Ciencias del Mar, Univ. de Cádiz, España.

(2) Esgemar (Estudios Geológicos Marinos, S. A.), España.

(3) Instituto Geológico y Minero de España, C/. Ríos Rosas, 23, 28003 Madrid. España.

(4) Instituto Español de Oceanografía, España.

Numerous studies of the sedimentological and geomorphological aspects of coastal and continental shelf sedimentary environments have been carried out during this century. However, research on beach deposits has mostly been carried out from an excessively "terrestrial" point of view and has been concerned with coastal defense, while studies of continental shelves have been dominated by a "marine" point of view, addressing geological issues. Additionally, marine studies focus mainly on the connection between the continental shelf, slope and basin. Therefore, literature on the sedimentary characteristics of the nearshore-to-offshore transition on wave-dominated coasts is limited. The reasons for this include methodological limitations, such as the presence of short-period multiples and reverberation of the seismic signal, and the navigational limits of research vessels. The present paper features new insights into a progradational sedimentary body, the Infralittoral Prograding Wedge (IPW), has been developing below the storm wave base between the onshore (beach) and the offshore (inner continental shelf) depositional zones during the Late Holocene. The main lithosome is composed of large-scale cross-beds, prograding seaward and paralleling the shoreline, which are formed by avalanches of sediments swept by waves from shallower littoral environments. Cross-beds downlap onto finer-grained offshore sediments, and in turn, are overlaid by shoreface deposits. Sediment transport which produce the IPW is generated by downwelling storm currents and their associated seaward bottom

Seismicity and seismotectonic of Peru from broad-band data

H. Tavera⁽¹⁾ and E. Buforn⁽²⁾

(1) Institut Geophysic of Peru, Lima, Peru

(2) Departament of Geophysic, Faculty Physics Univ. Complutense, Madrid, España.

In this study, the main characteristics of the seismicity and focal earthquakes mechanisms occurred in Peru is presented. The distribution of the shallow, intermediate and deep seismicity is analyzed. The focal mechanism of 20 earthquakes occurred between 1990 and 1996 has been calculated from the first-motion polarities of P waves. Ten earthquakes have shallow depth focus, eight intermediate depth and two are deep. Using digital records of broad-band of IRIS, GEOSCOPE and GEOFON networks; the orientation of the source, the source time function, the depth and the seismic moment, have been calculated from P and SH waveforms to teleseismic distances. The earthquakes with shallow focus show complex rupture processes with predominance of inverse fault and axes of pressure oriented majority in E-W direction. This earthquakes with intermediate focus show of simple rupture process and axes of tension oriented in parallel direction to convergence of plates. Deep earthquakes present axes of tension oriented in E-W direction in border Peru-Brazil and N-S in Peru-Bolivia limits. The results of this study and the other authors are evaluated in order to elaborate a seismotectonic scheme for Peru. The results indicate that Peru is subjected by two different stress deformation. The first is associated to the shallow seismicity with clear variation of compression stress of NW-SE in north region, E-W in center and SW-NE in south region. The second stress regime, is due to intermediate and deep seismic activity with parallel horizontal tension to the direction of convergence of Nasca and South America plates.

Late Cretaceous-Early Tertiary juxtaposition of paleoproterozoic basement blocks in NW Sonora, Mexico: testing the Mojave-Sonora megashear hypothesis

A. Iriondo⁽¹⁾, L. M. Martínez-Torres⁽²⁾ and M. J. Kunk⁽¹⁾

(1) USGS, MS 974, Box 25046, DFC, Denver, Colorado, USA.

(2) Depart. de Geodinámica, UPV, Apartado 644, Bilbao, España.

The Paleoproterozoic Caborca and North America basement blocks in the Quitovac area in NW Sonora, Mexico, are separated by the hypothetical, NW-trending, Late Jurassic Mojave-Sonora Megashear (MSM). Ages of eleven metamorphic white micas, from dynamically metamorphosed rocks associated with the MSM, were determined using ⁴⁰Ar/³⁹Ar geochronology. These ages are characterized by disturbed ³⁹Ar released spectra and range from 45 to 65 Ma. They represent the minimum possible age for the ductile fabrics. However, that these ages denote regional uplift, or even thermal resetting of older fabrics, is rejected because the compressional fabrics clearly affect Late Cretaceous (U-Pb: ~79Ma) granites in the Quitovac area. In addition, the existence of well-constrained (post-peak metamorphism) mesothermal gold mineralization in the region at 50-55 Ma, requires a major orogenic event in the Late Cretaceous-Early Tertiary that would trigger such regional phenomena. Although no clear constraints have been obtained for all the ductile fabrics in the region, we conclude that the Late Cretaceous-Early Tertiary is the most likely time for the widespread regional (dynamothermal) metamorphism associated with the thrusting of the Caborca block into the North America block. Our data does not support the current hypothesis that these fabrics are exclusively related to movements along the Jurassic MSM. However, this study does not preclude the existence of older fabrics in the region. If the hypothetical MSM exists, we propose its trace should be postulated to the SW of the Quitovac region.

Slope instability susceptibility maps in Spain

L. Laín Huerta and M. J. Domínguez-Cuesta

Instituto Geológico y Minero de España, C/. Ríos Rosas, 23, 28003 Madrid. España.

Slope instabilities are an important process in Spain. Because of the relief and climatic conditions variety, all instability types have place along the country. In order to evaluate their spatial distribution there is an investigation project (CICYT Ref. AMB97-1091-C06-02) which main objective is to make a terrain susceptibility automatic cartography of slope instability. There are six investigation groups (Universities and others investigation centres) each one of them studies one region and a type of mass movement. One of these groups is the Natural Hazard Department of Geomining and Technological Institute of Spain (ITGE). We are studying two different processes in two different places: Rock-fall in natural granitic cliffs in the north of Madrid and landslides in a Tertiary relief in Guadalajara province. Each type of movement takes place under concrete conditions and the object is to know which ones are those conditions. There are many parameters that can be regionalized and Geographical Information Systems are basic tools to automate the cartography of them. With the aid of the GIS, the aim is to know the territory surface where favourable conditions (determinant and triggering factors) are present. At the moment we are preparing a rock-fall susceptibility map in order to check it in other granitic relieves. Even we have the landslides map from Guadalajara area and we are analysing the parameters that have influence in their triggering, to be able to extrapolate them to other zones.

Comparative analysis of the Late Quaternary 4th Order Depositional sequence in the continental shelves of Southern Spain

F. Lobo and F. J. Hernández Molina

Facultad de Ciencias del Mar, Univ. de Cádiz, 11510 Puerto Real (Cádiz). España.

High resolution seismic profiles have been used to make detail comparative study of Late Quaternary stratigraphic architecture in Southern Spain, between a wide (30 km) a smooth (0, 32[∞]) tinal shelf of the Gulf of Cádiz with high sediment input, and a very narrow (< 10 Km) and steep (0,54[∞]) continental shelf of the Alboran Sea with low sediment supply. A 4th-order Type 1 depositional sequences (100-110 kyr) composed of FRST, LST, TST and HST have been determined in both areas. FRST developed during the regressive interval of isotopic stage 3. LST is related the beginning of isotopic stage 2 when sea-level was around 120 m below its present level. TST is characterised by backstepping and aggradational deposits developed between 14-6.8 Kys during sea level stillstands inside the general trend of sea level rise. HST has developed between 6.8 kyr BP (eustatic maximum) and present, and it characterized by the modern deltaic and infralittoral bodies in the inner shelf. The Late Quaternary sedimentary evolution of the continental shelf was controlled by the last 4 th order asymmetric relative sea-level cycle. The following considerations can be extracted: A) Volumetrically, the FRST and LST are the most important components of the sequence. B) RST, LST, and HST are characterize by low-energy prodeltaic facies and high-energy infralittoral prograding wedge. C) TST comprises a wide variety of coastal depositional, and D) Isopachs maps of each systems tracts show a parrallel distribution along the shelf, with a relatively constant thicknes. This work has been supported by projects DGICYT PB94-1090- C03 and CICYT MAR-98-0209 of the Spanish Research Programme, and also in relation to a Spanish-Portuguese scientific agreement. This work is part of the 396 IGCP Project "Continental Shelves in the Quaternary"

Influence of tidal currents on the Holocene sedimentation processes in the continental shelf of the Gulf of Cádiz

F. J. Lobo⁽¹⁾, F. J. Hernández Molina⁽¹⁾, L. Somoza⁽²⁾, J. Rodero⁽³⁾, A. Maldonado⁽³⁾ and A. Barnolas⁽²⁾

(1) Facultad de Ciencias del Mar (Universidad de Cádiz), Puerto Real (Cádiz), España.

(2) Instituto Geológico y Minero de España, C/. Ríos Rosas, 23, 28003 Madrid, España.

(3) Instituto Andaluz de Ciencias de la Tierra, Granada, España.

The analysis of seafloor geomorphologic features in a sector of the Gulf of Cadiz continental shelf with high-resolution seismic reflection profiles and surficial sediment samples reveals a well defined distribution pattern of bedforms controlled by the hydrodynamics of the area. Almost all of those bedforms are distributed over a shallow physiographic feature known as the Barbate High, and three distribution zones are distinguished according to the orientation pattern of submarine dunes. These bedforms are considered to be modern features of Holocene age, and therefore they provide useful information about the circulatory patterns established over the continental shelf during that period. The current flows that generate the bedform fields are attributed to a complex interaction of several hydrodynamic processes. East-southeastward migrating sand waves located in inshore zones are generated by the interaction of the southeastward moving Atlantic inflow with the sea-floor. The most noticeable characteristic is the presence of west-northwestwards moving bedforms over the continental shelf, because in this area the general circulation is southeastward directed. This bedform field is attributed to the existence of northwestward directed flows over the Barbate High in relation to ebb tidal currents in the Strait of Gibraltar, when current direction is reversed over the Barbate High and probably deflected to the outer zone of this shallow geomorphologic feature. As a result of this complex flow pattern, a clockwise sand transport pattern over the Barbate High is established during the present highstand interval, resulting in an activity of bedforms evidenced by the presence of superimposed bedforms.

Contamination of the Guadiamar River aquifer after the Aznalcóllar Mine accident, SW Spain

M. Manzano⁽¹⁻²⁾, E. Custodio⁽³⁾, C. Ayora⁽¹⁾ and P. Navarrete⁽³⁾

(1) Earth Science Institute, Spanish Council for Scientific Research (CSIC), Lluís Solè Sabarís s/n, 08028 Barcelona, España.

(2) Civil Engineering School, Technical University of Catalonia (UPC), Jordi girona 1-3, Build. D2, 08034 Barcelona, España.

(3) Instituto Geológico y Minero de España, C/. Ríos Rosas, 23, 28003 Madrid, España.

The fault of a mine tailing dam in Aznalcóllar (Sevilla, SW Spain) in April 1998 flooded some 4,000 ha of the Guadiamar river flat and farmland with sulphide slurry. The metallic mud settled along a 35 km long and narrow strip of river valley, invading a significant number of open farm wells. To the end of the river valley some 2 ? 106 m³ of highly metal polluted water with colloid size particles was retained during two months at the border of the Doñana National Park marshes. After the settling of the particles this water was in situ treated and evacuated to the sea (Atlantic Ocean) afterwards. Groundwater sampling and analyses started immediately after the accident to determine the alluvial aquifer pollution extent. However, only the overflowed wells along the Guadiamar valley showed up contamination mainly with Zn, Mn, Fe, Co, Ni, Cd, As, Tl, and SO₄⁼. None of the non-flooded wells showed contamination. Groundwater monitoring has been periodically carried out up to the present, including several boreholes drilled after the accident both by the Water Authority and by the mine owner, Boliden-Apirsa. One and a half year after the accident, the wells initially contaminated have been cleaned and maintain a good quality, while none of the other wells show a groundwater deterioration. However, by January 1999 the new boreholes showed that the alluvial aquifer is contaminated by the set of metals characteristic of the mine in a narrow and elongated sector of some 3 km downflow the dam. Up to now it is not clear if the plume is a consequence of the 1999 accident or if it existed before. Environmental isotopes doesn't help to discriminate, because the aquifer is thin (25 m) and has been traditionally used as an one-season reservoir for irrigation during spring. Work going on includes the construction of an experimental geochemical barrier just downflow to the contamination plume.

Detecting influential observations in multivariate spatial linear models

A. F. Militino, M. B. Palacios and M. D. Ugarte

Universidad Pública de Navarra, Pamplona, España.

The aim of this paper is to detect influential observations for both estimation of the location parameters and prediction in a multivariate spatial linear model. The diagnostics that we propose are a natural extension of those already proposed in the univariate spatial case. They are also based on case-deletion idea which is a basic tool in evaluating statistical models. In order to avoid the difficulties of computation in the multivariate case, we provide formulae which make the procedure feasible. An illustration of the results will be given using a real data set.

Platinum-rich chromitites in arc-root complexes: an example from NW Spain

T. Moreno⁽¹⁾, W. Gibbons⁽²⁾, R. Lunar⁽³⁾ and H. Prichard⁽²⁾

(1) Geology Dept. Colgate Univ, Hamilton, NY 13346, USA.

(2) Dept. Earth Sciences, Cardiff Univ., Cardiff, UK, CF1 3YE, UK.

(3) Dept. Cristalografía, Univ. Complutense, Madrid 28040, España.

Chromitites with up to 13,400 ppb of total PGE occur in layered dunites within a HP granulite-eclogite-ultramafic suite stacked over the Gondwanan margin in NW Spain. The high grade suite is separated from the underlying continent by meta-ophiolite. The PGE-bearing layered dunites occur as two main units sandwiching a layered pyroxenite. This (crustal) layered complex rests upon a basal (mantle) harzburgite with chromite-rich dunite pods. Pt, Pd and PPGE/IPGE all increase upwards in both dunite units, with a pronounced negative Ru-anomaly developing in the highest dunites where the most chromite and PGE-rich samples occur. Harzburgites always show flat patterns in chondrite diagrams, whereas dunitic pods in harzburgites have a distinctive negative slope with depletions in Pt and Pd. The repetition of dunite above and below pyroxenites in the layered intrusion, with both showing similar patterns in chromite and PGE chemistry, suggests magma replenishment during a multiple intrusion history. Both harzburgites and pyroxenites show Al-rich spinel locally partially replaced by garnet. High pressure conditions are further suggested by high values of Fe and Cr (Cr#0.6) in chromitites, an abundance of garnet in some pyroxenite layers, and association with high pressure granulites (13kb) and eclogites (17kb). Chromite and PGE chemistries reveal close similarities with dunitic chromites in recognised magmatic arc-root settings such as the Jijal Complex in Pakistan and the Tonsina and Talkeena Complexes in Alaska. Discrimination diagrams define a new field for such arc-root complexes, partly overlapping with (but showing greater Fe+Ti enrichment than) ophiolites.

Special features of some chloride-sodic fresh groundwaters in Campo Arañuelo aquifer (SW Tajo Basin-Spain)

I. Muñoz⁽¹⁾, M. Espa⁽¹⁾, A. Andrés⁽¹⁾ y R. Vicente⁽¹⁾

(1) Geology Dept., Alcalá University, Alcalá de Henares, España.

An aquifer with a simple flow system is developed in Campo Arañuelo detrital basin. Its groundwaters composition goes from bicarbonate-calcic to bicarbonate-sodic ones, and with a mineralization between 100 and 1000 $\mu\text{S}/\text{cm}$. In several points appears a set of chloride-sodic groundwaters with a conductivity between 800 and 2800 $\mu\text{S}/\text{cm}$, located in anomalous positions in their flow paths. The objective of this study is try to determine the origin of these "anomalous" groundwaters, taken into account that several brackish manifestations with a chloride-sodic character and a mineralization between 3000 and 13000 $\mu\text{S}/\text{cm}$, also appear in the basin's granitic borders. These groundwaters could be considered as coming from deep flows through basement's faults, discharging due to a hydraulic potential difference. The research starts from two assumptions: (a) the anomalous groundwaters could come from a mixing between detrital groundwaters and granitic groundwaters, or (b) could be the result of deep flows in the detrital aquifer out-flowing due to groundwaters exploitation in irrigated land. It has been studied groundwater's chemical characteristics through a hydrogeological profile, considering ionic relations, typical in a detrital aquifer, as well as those that seem to give some data about granitic flows. Seing that the ionic relationships do not correspond with the typical relationship in detrital aquifer, due to their high chloride contents, and likewise, the low mixing percentage are differing with granitic groundwaters chemical characteristics, it can be said that the obtained results are not conclusive.

Ni-Cu-PGE sulphide mineralization associated to mafic cumulates: the case of Aguablanca, SW Spain

L. Ortega⁽¹⁾, R. Lunar⁽¹⁾, F. García-Palomero⁽¹⁾, J. Sierra⁽¹⁾, J. R. Martín Estevez⁽¹⁾, H. M. Prichard⁽¹⁾ and T. Moreno⁽³⁾

(1) Universidad Complutense, Madrid, España.

(2) Atlantic Copper, Huelva, España.

(3) University of Cardiff, Cardiff, UK.

Aguablanca is an economic Ni-Cu-PGE sulphide deposit with geologically estimated reserves of 35 Mt grading 0.7 %Ni, 0.6%Cu and 0.75 ppm Pt+Pd+Au. The ore is hosted by gabbroic cumulates of the late Variscan Santa Olalla Plutonic Complex (SW Spain). The mineralization is located in two subvertical lenses that contain disseminated sulphides grading into massive ore, often cross-cut by chalcopyrite-bearing veins. The mafic igneous rocks exhibit a pervasive alteration to a calcite + epidote assemblage. The ore mineralogy consists of coarse crystals of pyrrhotite with exsolutions of pentlandite, anhedral chalcopyrite and platinum group minerals (PGM) that include merenskyite, moncheite, palladian melonite and sperrylite hosted by sulphides. Locally, the ore has undergone brecciation along with intense replacement of pyrrhotite by pyrite. In the brecciated areas, PGM occur both within sulphides and in the contact between mineral phases. The observed mineral assemblages are the result of a complex evolution through four stages: 1) magmatic crystallization of a monosulphide solid solution at high temperature; 2) subsolidus recrystallization during subsequent cooling; 3) brecciation and hydrothermal precipitation of pyrite; and 4) supergene alteration of primary ores. Therefore, Aguablanca is a mineralization formed by magmatic processes, now exhibiting reequilibration mineralogy and textures. PGE distribution was mainly controlled by the magmatic sulphide-rich liquid. However, some hydrothermal remobilization could have occur during the brecciation of the ores.

Cluster analysis of spatially dependent data

V. Pawlowsky-Glahn⁽¹⁾, S. Jiménez-González⁽¹⁾ and J. J. Egozcue⁽¹⁾

(1) Universidad Politécnica de Cataluña, ETSECCPB, Departamento de Matemática Aplicada III, Barcelona, España.

Cluster analysis is a useful technique to detect different populations in a data set. When data are spatially dependent, it is necessary to apply techniques which take into account both the similarity of samples in the variable space and their spatial dependence. This can be done using a modified version of Ward's method based on a spatial extension of the Mahalanobis distance, which incorporates an estimate of the matrix of cross-covariances for each spatial distance considered. But the estimation of the cross-covariance matrix as a function of distance assumes data to belong to the same population. To solve this problem, an iterative approach is used. It is based on the assumption that the groups have different spatial means but identical patterns of spatial variability and that the variables considered are stationary within each group. This is equivalent to assume that the semivariograms and cross-semivariograms are the same within each group. Thus, at each iteration the number of assumed clusters is increased and the semivariograms and cross-semivariograms are recomputed using only pairs of samples from same groups until the function stabilises. Case studies have been performed to illustrate the approach using simulated and real granulometric data. Results, compared to those obtained with the traditional method of Ward, are less spherical in variable space and spatially more homogeneous; the price is a larger variability in variable space.

Extreme value and multinomial distributions for scaling biostratigraphic events

V. Pawlowsky-Glahn⁽¹⁾, E. Gil-Bescos⁽¹⁾, J. J. Egozcue⁽¹⁾ and F. Agterberg⁽²⁾

(1) Universitat Politècnica de Catalunya, ETSECCPB, Departament de Matemàtica Aplicada III, Barcelona, España.

(2) Geological Survey of Canada, Ottawa, Canada.

The program RASC for automatic positioning of biostratigraphic events is based on first or last occurrences of characteristic fossils in logs, which are assumed to follow a gaussian distribution. The mean of the distribution associated to each fossil is identified with its relative position in time. In practise, it is not possible to determine the real distribution of either first or last occurrences of a fossil due to scarcity of samples, but it can be assumed that it is in general non-symmetric and thus non-gaussian. Therefore, it seems reasonable to substitute the gaussian with extreme value distributions, which are considered in statistical literature to be the most adequate available models for modelling first and last occurrences. To do so, it is been necessary to use Fourier transforms and numerical integration. An alternative consists in using a multinomial distribution, where the unknown parameters are the position in time. Estimation can then be performed using a maximum likelihood approach. Using the multinomial model it is also possible to formulate a generalised likelihood-ratio test to compare different models. The different models have been applied both to real and simulated data. As expected, results are very similar for small samples, while for larger samples significant differences can appear.

Ceramics in Spain

M. Regueiro⁽¹⁾, E. Sánchez⁽²⁾, V. Sanz⁽²⁾ and E. Criado⁽³⁾

(1) Instituto Geológico y Minero de España. Ríos Rosas, 23. 28003 Madrid, España. m.regueiro@itge.mma.es

(2) Instituto de Tecnología Cerámica. Campus Universitario. Carretera de Borriol. 1004 Castellón. Spain

(3) Instituto de Cerámica y vidrio. CSIC. Carretera de Valencia km. 24,300. 28500 Arganda del Rey. Madrid. España. e.criado@icv.csic.es

The Spanish ceramic industry has experienced a amazing growth in the last four years. Such expansion has affected all sector, but has been particularly noteworthy in those directly related to construction: tiles, glazes, bricks and roof tiles. A combination of an extraordinary exporting effort, together with a record figure in new housing projects (415 000 houses in 1999), are responsible for such outburst. Other sectors, such as refractories have undergone significant growths due to the high rate of steel production increase, also in historical record figures (15m t in 1999). All this sectors doubled altogether the growing rate of their main European competitors. Raw material production has had an even more effervescent trend, almost doubling 1995 production. Such dynamic growth has been associated to a remarkable quality increase and to an unparalleled technological innovation process. Spanish ceramic industry has had a spectacular evolution in the past few years. The most optimistic forecasts have been greatly surpassed in most ceramic sub-sectors, in particular in those directly related with construction as a record figure in new housing projects was reached last year with 415 000 new houses. The huge internal demand has resulted in shortage of bricks in many areas of the country. In fact Spain has a great tradition in ceramic product consumption, and its the third world consumer in absolute figures (after China and Brazil, with higher population). Outstanding growths in car and food containers production have also been responsible for production increases in other ceramic sub-sectors such as refractories. The raw materials sub-sector has seen a ten-fold increase in research and development on new mining projects, in particular in feldspars and ball clays. Many new manufacturing plants of porcelain tiles and bricks are now under construction. Finally a Spanish company has become, after purchasing the actives of another multinational, the second world sanitary ware producer.

The sector's turnover has rocketed from 663 000 Mpta (US\$ 4 250m) in 1996 to almost 1 billion pta (US\$ 6 410m) representing today 1,18 % of the GDP. The tile industry, which has experienced a 40% growth in 3 years, from 400m sqm in 1995 to 564m sqm in 1998 and a turnover of 555 000 Mpta pa (US\$ 3 557m) is the most important sector, followed by brick and roof tile production (20,9 Mt per year). Spain produces every year almost 9 million pieces sanitary ware, around 600,000 t of glazes and frits and 388 000 t of refractory materials. Tableware (60 million pieces), giftware, traditional ceramics and sectors of recent development such as technical and advanced technical ceramics, complete the panorama of Spanish ceramic areas which will be reviewed in the following text. Excellent raw materials, research and development, a world-wide strong marketing policy and the drive of the internal demand, has turned Spain in one of the most technologically advanced countries in ceramic production of the world. (1,2)

Figure 1, included below shows an estimation of Spanish ceramic production value by sectors

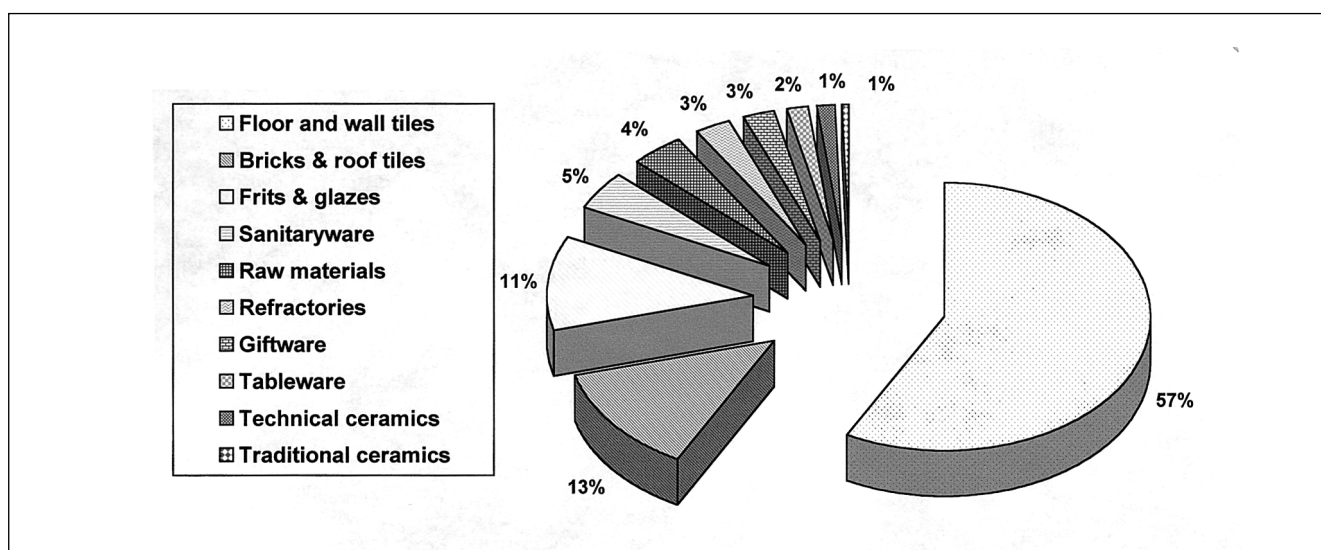


Figure 1. Spanish ceramics production value (% Mpta)

Rebound strength of carbonated rocks

L. Rodríguez Bouzo⁽¹⁾, M. Torres Alonso⁽²⁾ and M. Gutiérrez Claverol⁽³⁾

(1) Department of Geology University of Salamanca, España.

(2) Department of Exploitation and Prospecting of Mines, University of Oviedo, España.

(3) Department of Geology, University of Oviedo, España.

Rebound strength of rocks is very important because it permits an estimated calculus of uniaxial compressive strength. This fact and that this test is easy to apply, quick and cheap have contributed to its large applications on a great variety of materials. This test has been performed on four carbonated Carboniferous lithostratigraphic formations situated in the south slope of the Cantabrian Mountains (north of Spain). Two models of hammer have been used (Schmidt hammer L and N) and a correlation between both has been established. The aim of this correlation has been to correct the N model measurements to render possible its use on rocks; this model is special for concrete. The measurements have been made on different kind of samples (core drill, block and in situ test) of several dimensions. Our results show the influence of kind of sample, its dimensions and the sort of surfaces to measure. Because of the great influence in the results of the diameter of the samples (core drill), the test in situ is the more suitable, overall because the measurement on different sorts of surfaces (joint, bed) give similar results. This occurs in the case of surfaces free of irregularities and with a low degree of weathering. The uniaxial strength estimated shows a predominance of middle values.

Extensional tectonic and inversion in the Argentine central Andes between 30° and 31° S latitude

L. Rodríguez Fernández⁽¹⁾, N. Heredia⁽¹⁾ and R. García Espina⁽¹⁾

(1) Instituto Geológico y Minero de España, Ríos Rosas 23, 28003 Madrid, España.

The crustal structure in a cross-section through Cordillera Frontal has been analyzed. The Cordillera Frontal presents a polycyclic structure and two large groups of rocks can be distinguished: a Gondwanic (Paleozoic) basement, and a Andean cover. The basement is constituted by marine sedimentary units, intruded by Upper Paleozoic granitoid rocks. The most important Gondwanic structures, are East verging thrust and related folds. The Andean cover has a volcanic and volcanoclastic origin with some interbedded continental sedimentary rocks. The lower Permo-Triassic unit is linked to an extensional tectonic event and a Neogene sequence is connected to a compressional tectonic event that produced the inversion of the previous extensional features. The structures related to the Triassic extensional tectonic process are normal faults, grouped in bands N-S, with downthrow of the Western blocks and merge to a common detachment level dipping to the W. This geometrical configuration defines a half-graben model. The Neogene compressional structures are reverse faults and thrusts. The deep geometry of these reverse faults is in turn influenced by the geometry of the Mesozoic extensional system, which would be only partially inverted. The amount of shortening calculated from Cordillera Frontal cross sections is of about 10%. This fact contrasts with the estimated shortening of over 50% at the Precordillera. All this shows that most of the shortening in the Cordillera Frontal was transferred to the Precordillera through the detachment fault. These facts also show that Cordillera Frontal unit is an uplifted block in which the extensional struct

Calc-silicate rocks from greenschist - to granulite-metamorphic facies of the Sierras pampeanas of Tucumán, Northwest Argentina

J. N. Rossi⁽¹⁾, A. J. Toselli⁽¹⁾, J. Saavedra⁽²⁾ and M. Basei⁽³⁾

(1) Instituto Superior de Correlación Geológica-CONICET, Tucumán, Argentina.

(2) Instituto de Recursos Naturales, Salamanca, España.

(3) Instituto de Geociencias, Sao Paulo, Brazil.

Calc-silicate rocks of the metamorphic basement of the Sierras Pampeanas in the province of Tucumán (northwest Argentina) are wide spread distributed. These rocks consist of thin beds, lenses and boudins centimeter to decimeter thick, intercalated with polydeformed and polymetamorphic turbidites, of late Proterozoic to lower Cambrian sedimentation age. In greenschist facies, calc-silicate are represented by quartz, epidote, tremolite-actinolite and albite. The paragenetic minerals of the amphibolite facies are quartz, andesine, hornblende, garnet, diopside, clinozoisite-epidote and titanite as accessory. In granulite facies the mineral association is quartz, labradorite, hypersthene, scanty biotite with zircon as accessory. In all facies the fabric is granoblastic and with hornfels aspect. It is frequently banded, homogeneous or mineral zoned. Calcite when present, is only a secondary mineral. Whole rock geochemistry of major and trace elements discards a basic to intermediate volcanic origin, suggesting a sedimentary protolith origin composed of calcareous turbidites, most likely marls. Rare Earth- and multielements analysis of calc-silicate data fits well with the uppercrust average and shale composites proposed by different authors. Geologic relationships of the calc-silicate rocks analysed are suggestive of a passive continental margin origin located at the west margin of Gondwana.

Fission track thermo-chronological study of the Barnard Point pluton (Livingston Island, Western Antarctica)

I. Shell⁽¹⁾, G. Poupeau⁽²⁾, J. M. González-Casado⁽¹⁾ and J. López-Martínez⁽¹⁾

(1) Dpt. Geología y Geoquímica, U. Autónoma de Madrid, Madrid, España.

(2) Institut Dolomieu, CNRS-U. Joseph Fourier, Grenoble, France

Livingston Island is a part of the South Shetland Archipelago, a Mesozoic - Cenozoic island arc located at the Northwest of the Antarctic Peninsula, between an inactive subduction zone (the South Shetland trench) and an incipient back-arc basin (the Bransfield basin). In the Southeastern coast of the Livingston Island, the Barnard Point tonalite pluton presents Rb-Sr and K-Ar (whole rock and mineral) ages in the 46-40 Ma range. Its cooling below 400°C is estimated to have occurred 40.9±2.7 Ma ago (W. Kelley, 1999). We dated by fission-tracks the apatites of four tonalites taken between sea level and an altitude of 400 m. The four central ages are concordant at 18.7±1.2 (mean and standard error) Ma. Confined track distributions and optimisation of the data indicate that track recording started about 27-28 Ma ago. This is concordant with an $^{40}\text{Ar} / ^{39}\text{Ar}$ age of 29.3±0.7 Ma found for the biotites of a pegmatitic dyke, which suggests a mid-Oligocene cooling from 300°C to less than 120°C within a few Ma. From 18-13 Ma to 4-3 Ma, a slight temperature increase occurred, probably related to the extension processes in this region. During the Plio-Quaternary, an acceleration of the cooling rate is probably related to the beginning of the Bransfield basin formation and rifting and the fast uplift and denudation of this region.

Dimension stone exploration in the Vila Real region (northeast of Portugal)

L. M. O. Sousa⁽¹⁾, C. A. C. Pires⁽¹⁾ and L. M. Suárez del Río⁽²⁾

(1) Geology Department of Universidade de Trás-os-Montes e Alto Douro, Vila Real, Portugal.

(2) Geology Department of Universidad de Oviedo, Oviedo, España.

The exploitation of ornamental rocks, especially granites, has been greatly increasing for the last ten years in Portugal, including the region of Vila Real (Northeast of Portugal). Extraction units are not always installed in the most appropriate places thus leading to negative repercussions in that concerning their economic viability, territorial planning and environmental impact. In this report we present the evaluation of nine granites outcropping in this region regarding their suitability to provide quality ornamental rock. On a first stage, eighty-three potential sites for the installation of quarries have been selected taking into account research carried out by analysing aerial photographs and by direct observation of namely fracturing and alteration. The second stage of evaluation has been performed regarding the following features of the studied places: topography, accesses, rock weathering, thickness of the soil layer and/or the weathered material, fracturing, reserves and environmental impact, evaluated on a scale of five levels (0 to 4). By considering these items according to their relative importance, the sites can be evaluated through the application of an exploitability index ranging from 0% (ideal situation) to 100% (least favourable situation). The application of this methodology to the studied granites has provided average values of the exploitability index ranging from 14% to 50%. These results have made it possible to establish a ranking of the granites, pointing to fracturing and accesses as the most negative aspects and topography and weathering as the most favourable ones.

Geochemistry of famatinian highly peraluminous granites from northwestern Argentina

A. J. Toselli⁽¹⁾, J. N. Rossi⁽¹⁾, J. Saavedra⁽²⁾, A. N. Sial⁽³⁾, V. P. Ferreira⁽³⁾ and E. Pellitero⁽⁴⁾

(1) INSUGEO - CONICET, Tucumán, Argentina.

(2) IRNA-CSIC, Salamanca, España.

(3) NEG-LABISE, Recife, Brazil.

(4) Universidad de Salamanca, Salamanca, España.

During the Famatinian Cycle, Lower Cambrian - Lower Devonian, the magmatic intrusivity in northwestern Argentina was very important. But not all granites have the same textural and mineralogical features. It is possible to characterize the different granitoids as constituted of quartz, micropertthitic microcline, plagioclase, apatite, zircon, tourmaline, and rare magnetite and pyrite. The two-mica granites contain cordierite, andalusite and sillimanite, although cordierite and andalusite are more abundant in the leucogranitic equigranular facies. They have coarsely porphyritic to subhedral granular texture. Modal classification indicates that all these granitoids belong to the monzogranite -granodiorite-tonalite family and that metasedimentary enclaves are typical of all of them. Likewise, all these groups have A/CNK 1 ratios, and their distinctive mineral associations indicate different chemical compositions and conditions of crystallization. The batholiths are emplaced at low pressure (P2-4 kbar), under high H₂O activity, and exhibit sharp, discordant contacts with low-pressure biotite-muscovite-andalusite-sillimanite-cordierite schists. The major-element data indicate a peraluminous calc-alkalic trend. The chondrite-normalized REE patterns and multi-element spidergrams point to a probable origin through crustal (metasediment?) anatexis. Both major and trace elements point to a collisional tectonic environment of inner Continental Magmatic Arc or Colisional through the interaction of crust material with deep melts, or by crustal anatexis.