



**27th Colloquium
of African Geology**

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**17th Conference
of the Geological Society of Africa**

Aveiro · Portugal

book of abstracts



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preface

WELCOME FROM CAG27 LOC

On behalf of the Local Organizing Committee of “27th Colloquium of African Geology/17th Conference of the Geological Society of Africa – CAG27”, we would like to welcome you to this important meeting regarding “Africa: The key player for a better and sustainable world” that we feel privileged to host.

This Conference, sponsored by the Universidade de Aveiro and the GeoBioTec Research Centre, under the auspices of the Geological Society of Africa (GSAf), is an opportunity to continue the scientific exchanges between researchers from all over the world in the field of Geosciences, and to demonstrate the high scientific research standards that are being carried out over the world. The participants in the conference will have the opportunity to share their expertise in a range of scientific fields, such as geology, geological resources, environmental risks, environment and human health, sustainable development, education, and tourism in Africa.

The CAG27 has received considerable international attention from around the world. We are happy to announce that 250 researchers from 38 countries (Algeria, Australia, Austria, Belgium, Brazil, Cameroon, Czech Republic, Dem. Republic. Congo, Dem. Republic of Korea, Egypt, Ethiopia, France, Gambia, Germany, Ghana, Italy, Kenya, Madagascar, Mali, Morocco, Mozambique, Namibia, Nigeria, Malawi, Norway, Portugal, Republic of Korea, Rwanda, Senegal, South Africa, Sudan, Tanzania, Togo, Tunisia, Uganda, United Kingdom, Zambia, and Zimbabwe) will be joining this Conference, highlighting the importance of this event.

The conference has been organized into 5 days sessions that include a wide range of topics, such as: So1 – Crustal Evolution of Africa value; So2 – Igneous and Metamorphic Petrology; So3 – Tectonics and structural geology; So4 – Stratigraphy, Sedimentology & Paleontology; So5 – Isotope Geology; So6 – Earth’s mineral resources and sustainable development; So7 – Weathering, Climate and Surface Processes; So8 – Geophysics; So9 – Ocean Sciences; S10 – Geoparks, Geotourism and Geoethics for Promoting Earth Heritage in Africa; S11 – Geohazards, Natural and human-induced environmental hazards and disasters; S12 – Geosciences Education in Africa; S13 – Integrated approaches in Geology (Medical Geology, Geophysics and Geochemistry).

The Scientific Committee compiled an interesting program of oral and poster presentations. The CAG27 Board, the committees and all the people involved in this year’s symposium are pleased to present the Book of Abstracts and hope that this document will provide you with an important basis of the recent advances in medical geology. It contains the one-page of the accepted abstracts prepared by each author. The conference includes 5 relevant Plenary Lectures (S. Felix Toteo, Luis Filipe de Menezes Pinheiro, Rui Manuel Soares Dias, Lahcen Daoudi e K’tso Nghargbu), 5 Keynotes (João Mata, Rui Castanhinha, Fernando Tavares Rocha, José Feliciando da Silva Rodrigues e João F.B.D. Fonseca), 2 workshops, as well as 165 oral presentations, organized in 3 parallel sessions and also 83 poster communications. To complement the conference’s academic program, we have also organized two post-conference technical field trip to visit the (a) Thermal/SPA Complex of S. Pedro do Sul and regional geology and (b) the Lourinhã Formation, the paleobiodiversity of Portuguese Upper Jurassic dinosaurs.

We are also pleased to welcome you to our city. Aveiro is deeply influenced by a lagoon called “Ria de Aveiro” which gives the city a unique distinctive character, where tradition and nature combine with a keen sense of modernity.

Truthful acknowledgments to the Scientific Committee for their reviewing of the conference papers, ensuring that we all have a productive and inspiring CAG27 conference and, also to the administrative staff of Universidade de Aveiro for all their support dealing with the fees and the expenses. My personal thanks to the conference organizers for their detailed and careful preparation of the program and to Prof. Álvaro de Sousa for the creative design of the Conference.

We are also greatly indebted to the GeoBioTec Research Centre, FCT – Fundação para a Ciência e Tecnologia, UNESCO, TAP Air Portugal, Termas de S. Pedro do Sul, Museu da Lourinhã, ROCA, TeKa and Sepcanalitica, for their financial support.

We sincerely wish you an enjoyable stay in Aveiro. We hope that this event will bring us all together in sharing, debating and constructing knowledge, and provide a forum for meeting new friends and developing new networks and collaborations for our future work.

And please, feel at home!

Eduardo Ferreira da Silva
(Chairman)

WELCOME FROM PRESIDENT OF GSA

Welcome again to the 27th Colloquium of African Geology taking place in this beautiful city of Aveiro- “the Venice of Portugal.” It is my delight to write a short preface to this abstract volume.

Prof. W.G. Kennedy assisted by Tom Clifford convened the first Colloquium of African Geology at the University of Leeds in March 1964. It was eventually taken over by the Geological Society of Africa in 1996. Since then, the Colloquium has grown tremendously

This year, a record of 36 countries from the Oceania, South America, Asia, Europe and Africa are represented by their best early career and senior earth scientists. This is one of the highest in recent times, with over 280 registrations and thirteen themes of symposium, ranging from the core geological themes of evolution of Africa, igneous, metamorphic, tectonics and structural geology to, of course the economic geology themes covering mineral resources, and sustainable development. The geoenvironment is adequately covered as themes on ocean sciences, weathering, climate and surface processes, geohazards and natural and human induced environment hazards and geotourism are adequately covered. The not too new but rejuvenated specialisations of geoscience education, and medical geology have attracted interesting attention. In all, about 248 presentations, comprising 165 oral and 83 poster presentation are expected, with the mineral resources and sustainable development and crustal evolution of Africa themes having the highest number of expected presentations of 49 and 39, respectively.

It is hoped that these presentations with their depth and resourcefulness, with expectedly new grounds to be broken, will enrich our geoscientific space and do justice to the general theme of the Colloquium- Africa: A key player for a better and sustainable world.

Wishing you all fruitful scientific sessions!

Prof. Olugbenga Okunlola
FNMGS, FASI, FGS.
President, Geological Society of Africa

tribute

**Manuel Carlos Serrano Pinto
(1936-2011)**

I congratulate the Organizing Committee for this tribute, which, as a long lasting friend and colleague of Manuel Carlos Serrano Pinto, I would like it to be the moment for the due recognition. For all he has given to this University, the Geology and intercultural relations.

We were friends, not a friendship made of words, but a continuous companionship for over 60 years. We were together both in difficult times (death of parents, brother, mother in law, and his diseases, renal crisis and ocular tension) but also in joyous moments (birth of children and grandchildren) and in various unrepeatable situations as it happened when we spent a whole week eating rice with beheaded mackerels or in a christening ceremony where the baptismal basin was a plastic vase.

Married to an extrovert person with an unlimited capacity to socialize, he was able to establish circles of conviviality, as, for example, with families Lemos de Sousa (licenciatura), Britaldo Rodrigues (geochemistry) and George Hornnung (dating).

We met at Coimbra, at the then Liceu D. João III, although not in the same class. His was class D, where 4 of future eminent geologists also were, and he was quickly integrated, having eventually joined the Raposo Marques Orpheon.

His capacity, allied to his permanent need for clarity, enabled some colleagues, doing their military service, to complete the Petrology discipline without attending classes, by using his notes. When he had finished his military period he contacted me in Mozambique and I had the opportunity to propose his admission in the Geological Survey, which was accepted by Eng. Jorge Gouveia.

I left to Leeds and he undertook the coordination of the geological cartography of the central region of Mozambique. When I came back we discussed over a methodology which, via the 1/250000 mapping could enable the publication of 1/100000. We decided to integrate the geochemical prospection, without great additional costs. Serrano Pinto went then to Leicester for a master degree, which, at the time, was the only one, and had already been done by José Santos Oliveira. The following event was the establishment, in collaboration, of the first Geology course in the University of Lourenço Marques, presently Eduardo Mondlane.

In 1973 I left Mozambique and by influence of Profs Portugal Ferreira and Victor Gil moved to the University of Aveiro. Serrano Pinto then joined the Department of Geosciences, after a short stay in Luanda.

In the wake of the general sympathy towards the 25th of April Movement, a meeting on plate tectonics took place in the U.A with the participation of renowned geologists. Also due to his pleasure in conviviality, we organized, with help from many colleagues, the 1st Meeting of Portuguese Geologists, inspired by those in Mozambique organized by Prof. Gaspar Soares de Carvalho.

Along with the development of the Geological Engineering course in the U.A the first master degree course in Geochemistry in Portugal was created with the help of Prof. Aires-Barros.

When my academic assignment changed Serrano Pinto took over the Presidency of the Scientific Council of the UA, therefore leading the changes that took place at that time.

In his last years he tried to develop programs to bring back the memory of previous scientific advances and scientists. With other colleagues he established a team dedicated to the History of Science with valuable publications. When Prof. Júlio Pedrosa decided to implement the knowledge of China and Chinese language in the UA he asked Serrano Pinto to coordinate the masters degree in this area, having in mind that he had always been interested in the scientific works of the missionaries in that country.

I cannot finish without remembering how much Luís Serrano and myself, who shared the same room with Serrano Pinto, feared his arrival in the morning with his long list of phone numbers to call.

There are people who leave behind an indelible mark of their personality and creativity, and when they leave us because their time with us has come to an end, they remain forever in our memories. I'm talking about Professor Manuel Carlos Serrano Pinto, a Portuguese geologist with very close ties to the Portuguese-speaking countries, especially Brazil, Angola and Mozambique. Himself married to a lady born in Mozambique, his visits to Mozambique with his family were frequent.

Professor Serrano Pinto obtained his degree in Geological Sciences from the University of Coimbra, Portugal, having obtained a Masters in Geochemistry and a PhD in Geochemistry and Geochronology from the University of Leeds, UK.

Known for his excellent teaching and scientific research, Professor Serrano Pinto has published more than 160 scientific papers in several journals, many of them dealing with African geosciences. In the early days of his career, Professor Serrano Pinto participated in several activities as a geologist in the Geology and Mining Services of Angola and Mozambique during colonial times. In Mozambique he still taught at the then University of Lourenço Marques (the colonial name of the Mozambican capital - now Maputo), now University Eduardo Mondlane.

Having returned to Portugal, he worked at the University of Aveiro where he developed a large part of his activity as a geologist, scientist, educator, and introduced the course of Environmental Geochemistry at graduate and postgraduate (masters) levels. This was the first post-graduate course in Geosciences of Portugal. In addition, Professor Serrano Pinto coordinated the first Portugal-Brazil Masters in Environmental Policy and Management.

His teaching and course design activities extended to participation in the coordination of the Master of Communication and Education in Sciences, Director of the Center of Asian Studies and coordinator of the Master's Degree in Chinese Studies of the University of Aveiro.

He was an active organizer of scientific events related to Geochemistry, in particular Iberian events and events of Portuguese speaking countries, with a strong African presence. He also founded the Geochemistry Group of the Portuguese Geological Society.

Professor Serrano Pinto played a major role in the 21st Colloquium of African Geology (CAG21) in Maputo in 2006, and this, together with his strong links to Africa, prompted GSAf to invite him to be the Goodwill Ambassador of GSAf to Portugal, which he gladly accepted. In this condition, he participated in the CAG23 in 2011 in Johannesburg, South Africa, where he expressed the interest to bring the CAG back to Europe, in this case Portugal.

Unfortunately, immediately after his return, he suddenly passed away (2011), and this project was postponed, but in 2018, under the leadership of Professor Eduardo Anselmo Ferreira da Silva, his dream came true. The Geological Society of Africa is deeply grateful to Professor Ferreira da Silva, and his team, and to the University of Aveiro, for making the dream of our great friend Manuel Serrano Pinto reality.

More could be said of the work of this great Man. We miss his friendly presence, never overreacting or speaking loud, calling others to reason in all his calm and serenity.

The GSAf takes this opportunity to render to Professor Serrano Pinto the most sincere and profound homage.

Lopo Vasconcelos
Professor
GSAf Newsletter Editor

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- 194 Aeromagnetic survey and interpretation in Cabo Delgado, Mozambique: inputs in geology and tectonics
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plenary

Strengthening Earth Science Education Initiative in Africa through institutional networking

Sadrack Felix Toteu, UNESCO Nairobi, Kenya

Abstract

In 2011, UNESCO launched the Earth Science Education Initiative in Africa to trigger the development of the next generation of earth scientists in Africa who are equipped with the necessary tools, networks and perspectives to apply sound science to solving and benefiting from the challenges and opportunities of sustainable development. Thanks to the successful partnership between UNESCO and Sida (PCA 2014-2017), the initiative has entered in an implementation phase with two important projects. The first was design to support the African Network of Earth Science Institutions (ANESI) as a platform of exchange and collaboration between African training and research institutions. In two years implementation, more than 130 African geoscientists have moved from their home institution to another African institution to conduct research, follow short courses, or support, through specific lectures, those institutions in need of experts in a particular field. The second project is a showcase of the potential of a strong network of experts to address a specific research problem of regional-scale interest, in this case, the Environmental and Health Impacts of Abandoned Mines in Sub-Saharan African Countries (refer to as AB mines project). More than 100 scientists were involved in the study of 29 sites in 17 countries focusing on environmental assessment, testing plants to rehabilitate contaminated sites, conducting outreach and education programmes for communities, and advising local governments. In this presentation, we will highlight lessons learnt from the two projects and propose a way forward to sustain the momentum generated by the project, with the goal of strengthening Earth science education in Africa through institutional networking.

Short CV

Current position: Retired UNESCO staff, BP 4998, Nlongkak, Yaoundé, Cameroon (sftoteu@yahoo.fr)

Education: BSc: (University of Yaoundé, Cameroon, 1977); MSc (University of Nancy, France, 1979); PhD, University of Nancy-1 (France), 1987, title: The geochronology of the main structural units of the Poli region: crustal accretion in the Pan-African belt in northern Cameroon. Postdoc: Prof William Randall Van Schmus, (University of Kansas, USA, Year: 1990-93), theme: reconstruct the main crustal blocks in Cameroon from Archean to Neoproterozoic. Experience/Employment: Recruited a young researcher in 1981 at the Institute for Geological and Mining Research, Yaoundé (Cameroon) and transferred to its in Garoua. I took over the direction of the centre from 1993 to 2007 when I left for sabbatical professorship at the University of Botswana. Then I moved for a one-year visiting Professorship (Lonmin Senior Fellowship) at the University of Cape Town (2008-2009), and to the Nelson Mandela Metropolitan University (Port Elizabeth), where was offered a full professor position (2010), but left to coordinate the UNESCO Earth science activities in sub-Saharan Africa (2010-2016) in the UNESCO Office in Nairobi. Accomplishments: Having realised that the progress in understanding the Precambrian geology of Cameroon relies on geochronological data, I started and pursue for more than 20 years an intensive geochronological data collection using my connection with various institutions abroad (CRPG of Nancy, France, Isotopic Geochemical Laboratory of the University of Kansas in US, GEUS in Denmark, Dept. of Geosciences, University of Mainz, Germany, University of Cape Town in South Africa Today, I proudly claim the paternity of an impressive geochronological database in the central African region. This scientific activity culminated with the only IGCP ever implemented in Central Africa (IGCP-470). In 2009, I was invited by the African Earth Observatory Network of the University of Cape Town to contribute the Africa Alive Corridors Initiative, particularly in designing the African Pole of Rotation, the corridor having the Cameroon Volcanic Line as geological foundation. I have contributed to the Tectonic Map of Africa that I officially launch on the behalf of all the co-authors, during the 23rd Colloquium of African Geology in January 2011. In sum, this active research has resulted in high ranked publications. Therefore, I have been invited contribute to earth science journals either as reviewer, or as member of the editorial board, or as associated editor and to be member of IGCP Scientific Board. I have instrumental promoting and implementing the UN-declared International Year of Planet Earth in the African continent (2008). As UNESCO staff, I have revitalised the UNESCO's Earth science activities in Africa and especially through designing projects and raising funds to support capacity building of experts and institutions in the continents. In this regards, I have been instrumental in establishing the African Network of Earth Science Institution (ANESI), a platform of collaboration and exchange among institutions in Africa, and to bring teams of scientists across Africa to research on the important issue of environmental and health impacts of mining activities in Africa.

I have also served the Earth science community regionally and globally in many capacities, including: (a) Vice-President and President of the Geological Society of Africa for Central Africa (2001-2008); (b) Member of the

Board of the International Year of Planet Earth (IYPE), representative of Africa (2007-2010); (c) Member of the Nominating Committee of the International Union of Geological Sciences (IUGS) for 2008-2012; (d) Leader of the IGCP-470 (2002-2006), and Member of the UNESCO/IUGS IGCP Scientific Board (2008-2010); (e) Associate Editor of Journal of African Earth Sciences since May 2008-2011; (f) Member of the Editorial Board of Precambrian Research since 2006-2011; (g) Member of the Nominating Committee of the International Union of Geological Sciences (IUGS) for 2008-2012; (h) Deputy Secretary General (since 2006) President (since 2016) for Africa at the Commission of the Geological Map of the World (CGMW); (i) Chair of the Advisory Committee of the PanafGeo (Eurogeosurveys/AOGS), 2016.

Recognitions: i) United States Fulbright Programme Award, 1993, ii) Granted the title of «Kentucky Colonel» of the State of Kentucky (USA) in 2005; ii) Price of Excellence in Geosciences by the Ministry of Scientific Research and Innovation (Cameroon) in 2007; iii) Lonmin Senior Fellow of the African Earth Observatory Network (AEON); iv) Honorary Member of the Geological Society of London, 2011; v) Fellow of the African Academy of Sciences, 2014.

Hydrocarbon-rich fluid seepage in the Gibraltar Arc System

Luis Menezes Pinheiro, Geosciences Department and CESAM, University of Aveiro, Portugal

Abstract

Extensive areas of mud volcanism and gas seepage form in the oceans in all kinds of geodynamic settings and host some of the most interesting deep-sea chemosynthetic ecosystems. In the deep S. Iberia and Northwestern Moroccan margins, an area often described as the “Gulf of Cadiz”, and in the Alboran Sea, extensive multinational and multidisciplinary research carried out since 1999, largely in the scope of the IOC-sponsored Training Through Research (TTR) Floating University Program, has allowed the discovery of large fields of mud volcanoes and other seafloor structures associated with gas seepage, such as pockmarks and diapiric ridges. More than 60 mud volcanoes of various sizes, reaching more than 3km in diameter and a few hundred meters in height, have been identified in these areas by geophysical surveys, confirmed by coring and underwater high-resolution video surveys. Most of these structures concentrate in the compressional accretionary wedge of the Gulf of Cadiz, related to the Africa-Eurasia convergence since the Cenozoic, but also in the Alboran Sea, in an extensional setting. Recently, similar structures were found west of the accretionary wedge along the Azores-Gibraltar Fracture Zone. Thermogenic gas hydrates, a potential alternative energy source for the future, have been recovered from several mud volcanoes in this area, and a large diversity of chemosynthetic communities, including new species for the science, has been identified. Evidence of major past episodes of methane release from depth have been recorded by the occurrence of vast fields of methane-derived authigenic carbonate crusts and chimneys, some of which composed of dolomite, precipitated through anaerobic methane oxidation by consortia of archaea and bacteria. Such episodes of methane release from the deep sea, in particular associated with gas hydrate dissociation in deep sea sediments, may have had a significant impact on past climate change.

Short CV

Associate Professor in Marine Geology and Geophysics, University of Aveiro (UA). PhD in Marine Geophysics, Imperial College, London. President, Portuguese Committee to the IOC of UNESCO, National Delegate to the Executive Council. Coordinator of the Sea Technology Platform of the University of Aveiro. ECORD National Delegate, Integrated Ocean Drilling Program. Coordinator of the Coordinating Group for Research Ships & Shiptime Allocation, Portuguese Science Foundation (2006-at present). Member of the Coordinating Comm. Assoc. Laboratory CESAM. Effective Member of the Academy of the Navy.

Coordinator/participant in a high number of national and international research projects. Participation in 50 Research Cruises (21 international; 29 national) – Chief/Co-Chief Scientist in 34 (12 international; 22 national). Former Director, Marine Geology Department, Geological and Mining Institute. Author/co-author of more than 250 publications, including 58 papers in international journals (52 ISI), with 1489 citations; h-index 21. Research interests: Marine Geology and Geophysics; geophysical data processing and interpretation; structure and evolution of continental passive margins; rifting mechanisms and Ocean-Continent Transition; tectonics; mud volcanism, hydrocarbon-rich fluid seepage shallow gas and gas hydrates; Seismic Oceanography; hydrocarbon reservoir characterization.

Palaeozoic evolution of Morocco: from Gondwana to Pangaea

Rui Manuel Soares Dias, Earth Sciences Institute (ICT), Geosciences Department, University of Évora, Portugal

Abstract

The Gondwana supercontinent was the most long-lasting and stable continental block in the Earth geodynamics. The Palaeozoic evolution in its north to northwest margin is fundamental to understand a crucial period of our planet; the transition from the Neoproterozoic Pannotia supercontinent to the Pangaea one.

The assembling of the last supercontinent, mostly in the Upper Carboniferous to the Permian times, gives rise to the Ouachita-Appalachian-Mauritanide-Variscan complex orogen. Although Morocco had a slightly marginal position to this fold belt, the coeval deformation are here well represented by a heterogeneous deformation. Such complex pattern mainly results from the reworking of the Palaeozoic basins. Indeed their heterogeneous and localized distribution, coupled with the importance of their boundary faults, result in the complexity of the Moroccan Palaeozoic deformation.

This deformation could be interpreted mostly as the result of an important dextral transpressive regime along the E-W to ENE-WSW trend. Such regime was induced by an WNW-ESE main shortening during the Upper Carboniferous to the Permian. The presence of older major E-W high angle faults, induced an important strain partitioning which explains the juxtaposition of adjacent blocks with a strong diverse deformation.

Such geodynamics is compatible with the dextral oblique collision between Gondwana and Laurussia in the Upper Palaeozoic.

Short CV

PhD in Internal Geodynamics by Lisbon University in 1994, where he has been teaching from 1982 to 1996. In 1996 he moves to the Évora University where he is currently Associated Professor with Habilitation. His main scientific activities, concerning structural geology and tectonics, have been developed in Portugal, Morocco and Eastern Timor, where he has supervised 30 PhD and MSc theses in cooperation with local universities. This work has given rise to 55 papers in specialized magazines and more than 200 works in scientific meetings. For more than 20 years he is deeply involved in science divulgation, being Executive Director of the Estremoz Science Centre, an interactive museum in Earth Sciences belonging to "Ciência Viva" the Portuguese network of Science Centres. Since 2014 is President of the Portuguese Geological Society.

Palaeogeographic controls on clay minerals occurrences in upper jurassic-cretaceous sediments of Morocco: a comparison with Tethyan and Atlantic adjacent basins

Lahcen Daoudi, Laboratoire de Géosciences et Environnement, Département des Sciences de la Terre, Faculté des Sciences et Techniques, Marrakech, Morocco

Abstract

Clay mineral assemblages of upper jurassic and cretaceous sediments deposited in several basins of Morocco, are studied on more than 1000 samples distributed on 40 sections. These clay assemblages are controlled by the evolution of the sedimentary environments through time.

In the Upper Jurassic to Early Cretaceous, the clay mineral assemblages identified are usually dominated by illite, sometimes by chlorite or illite-smectite mixed layer. Kaolinite and smectite occur in smaller quantities. The inputs of illite and chlorite coming from Precambrian and Palaeozoic belts (Anti Atlas, Meseta and High Atlas), result from the destabilization of the Atlantic and Tethyan margins, caused by the opening of the Atlantic, Atlas gulf evolution, and rejuvenation of the High Atlas range. Off the Moroccan coasts, clay mineral assemblages are similar to those encountered in the Moroccan basins and reflect the same sedimentary features. The differences recorded are marked by the occurrence of smectites southward of Morocco. This reflects the stability of the African basement relatively to the instability of the Alpine Chains in North-West Africa.

The Albian-Cenomanian interval is marked by a dramatic change from strongly illite and kaolinite dominated clay mineral assemblages in the lower and middle part of the Albian to progressively more smectite dominated assemblages from the late Albian onwards. Upper Cretaceous corresponds to more stable periods leading to the formation of the smectite-rich paleosols and confined environments which favoured genesis of fibrous clays. Clay minerals identified in this period suggest a warm and a seasonally humid climate. Moreover, sea level changes at different scales appear to control partly the input of clay minerals. Complex relationships between clay minerals and eustatic movements are related with depositional environments in this period. Short CV: Associated Professor at the University of Marrakech. Graduation in Geology, University of Marrakech,, Master in Geosciences (Raw materials), University of Paris XI (France), PhD. in Geosciences (Mineralogy), University of Sciences and Technologies of Lille (France), and DSc. in Geosciences (Clay Science), Cadi Ayyad University of Marrakech. Director of the Laboratory « Géosciences et Environnement » since 2010 and Expert evaluator for CNRST « Centre National de Recherche Scientifique et Techniques » since 2014. The main research interests include Clay mineralogy and geochemistry, Industrial minerals, Sedimentology and Pedology, Environmental Geology, Marine and Coastal Geology and Geography. Published 85 full papers in international and national journals and proceedings such as: Economic Modelling; Empirica, FinanzArchive; Journal of Applied Economics; Public Choice; Applied Economics Letters; Journal of International Money and Finance; Journal of International Financial Markets, Institutions & Money ; Regional Studies; Review of World Economics. Co-authored a book on introductory financial economics and another on economics and public finances. Responsible of 12 international and 8 national research projects

Member of Scientific commission of The Faculty of Sciences and Technologies of Marrakech, 2008 and Member of the Board of the Moroccan Society of Clays, since 2006.

Medical Geology, mining, and economic diversification in Africa

K'tso Nghargbu, Department of Geology and Mining, Nasarawa State University, Keffi, Nigeria

Abstract

Given the fast depletion of fossil fuels across the globe with Africa inclusive, mono commodity economies are seeking numerous forms of economic diversification programs. This is more so, considering the fact that there is a strong push from the big economies of the world to reduce utilization of hydrocarbon resources, especially for energy generation. Based on the foregoing, more activities relating to solid minerals mining are on the rise in most African countries, hence resulting in different sorts of attendant negative consequences. On the other hand, new mineral resources are also being discovered with beneficial health impacts. This paper seeks to encourage responsible mining in order to curtail the prevalence of geomedical diseases, as well as the exploration and exploitation of geomedical resources for the promotion of health resort medicine in Africa and beyond. For Africa, and indeed the entire globe, more resources mean more wealth or more diseases depending on how we strike the balance between responsible mining and wealth creation. Our policy/law makers within Africa and elsewhere on the globe must take deliberate steps towards increasing health and wealth at the same time, as only a healthy people can create a healthy economy. **Keywords:** Medical geology, mining, healthy people, healthy economy, policy.

Short CV

Medical Geologist at Nasarawa State University. Graduation in Geology and Mining (Second Class Upper Division), University of Jos, (Nigeria), Master in M. Sc Geology, Ahmadu Bello University, Zaria, (Nigeria), PhD. in Ph. D. Geology, Ahmadu Bello University, Zaria, (Nigeria). Deputy Director Linkages, NSUK 2016.

The main research interests include Mining and Environmental Geo sciences with special interest in Medical, Hydro & Balneo-Geology. The present research topic is related to the Medicinal Value of Selected Springs within West Africa. Published 12 full papers in international and national journals. Authored a book, Co-authored a book and 5 book-chapters on Balneology & Physical Medicine and Medical Geology.

Prof K'tso Nghargbu is a Council Member, NMGS & Leader of the Medical Geology Specialist Group in Nigeria, is Member representing Africa and The Middle East on the board of the International Society for Medical Hydrology and Climatology (ISMH) and also the Chairperson, Polish Balneology and Physical Medicine Association, Nigeria Chapter. Member scientific board of the "Journal-Acta Balneologica" and "Journal-Techirghiol Balneological" and Reviewing editor, Journal of Earth Science and Engineering, published by David Publishing, New York, U.S.A. He is also Chairman/Convener of technical sessions on medical geology within and outside Nigeria.

keynote

Volcanism at the Cape Verde Archipelago

João Mata, Faculty of Sciences, University of Lisbon, Portugal

Abstract

The Cape Verde Archipelago is a hotspot generated by the impingement of a deep-rooted mantle plume on the African plate. The outcropping volcanic rocks preserve a 26 Ma history of magmatism, the last eruption having occurred in 2014-15 at the Fogo Island. The archipelago is characterized by a remarkable inter- and intra-island geochemical heterogeneity to which contributed ancient (> 1Ga) recycling of crustal materials and the interaction of the ascending plume magmas with the old (120-140 Ma) oceanic lithosphere. The archipelago is known as the most important occurrence of carbonatites on an oceanic environment.

During the talk, the most important geochemical characteristics of the Cape Verde islands will be reviewed, while the associated genetic processes will be discussed.

Short CV

João Mata is Associate Professor at the Faculdade de Ciências da Universidade de Lisboa, where he obtained his PhD degree in 1996. He is a research member of the Instituto Dom Luiz, one of the most important Earth Science research units of Portugal. A significant part of his scientific activity has been developed in order to contribute to a better understanding of the evolution of the mantle, through the study of magmatic rocks in oceanic islands. Magmatism associated with passive margins have also been one of the focus of his research. This activity has resulted in publications in some of the most prestigious journals in the field (Earth and Planetary Science Letters, Chemical Geology, Lithos, Contributions to Mineralogy and Petrology and others). He witnessed the last eruption occurred in the Cape Verde archipelago and recently published a paper on the elemental and isotopic characteristics of the 2014 erupted lavas. (Research ID: I-3352-2012; Scopus Author ID: 7102806167).

Implementation of Earth Science Education in Mozambique: the UPM/UA case

Fernando Joaquim Fernandes Tavares Rocha, Geobiotec Research Centre, Geosciences Department, University of Aveiro, Portugal

Abstract

Till recent times, Higher Education training in Geosciences in Mozambique was in charge of Eduardo Mondlane University (UEM), which ruled this Mission with great effort, thanks to the commitment and quality of its Faculty and Graduates. The Pedagogical University of Mozambique (UPM), which was essentially focused on Education and Teachers training had, in 2010, a deep evolution, turning to provide also formation on Science and Engineering. The Department of Geosciences of the University of Aveiro (DG/UA), of Portugal, which at the end of the last century had collaborated with UEM in this field, was then contacted by UPM, in early 2012, to put forward a training program for UPM faculty to constitute the core of human resources in the area of Geosciences, which UPM wanted to implement in its delegations of Beira and Nampula, due to the urgent need for human resources capacity building in this area of growing importance for Mozambique. The program has, as main action, the frequency, at DG/AU, of MSc courses on Earth Sciences by UPM geosciences faculty members with graduation degree not only in Geosciences but also on related fields, such as geography, physics, chemistry and mathematics. Students develop, in addition, other curricular and extra-curricular training actions in order to acquire a more complete formation for the exercise of their future functions on UPM. Other actions included the technical support for UPM teaching (1st Cycle) lab. facilities implementation, curricular design and development, and strategic planning.

Such a program has been developed over the last 4 academic years. A first group of 8 trainees attended and successfully completed the MSc in Geomaterials and Geological Resources in 2014; a second group of 7 trainees completed the MSc in Geological Engineering in 2016. All are now on teaching exercise in UPM (delegations of Beira and Nampula); some of them are already beginning PhD programs.

The implementation of the program ran on a very satisfactory way for both parties and the excellent results obtained were object of recognition by the UPM in its 30th birthday public ceremony in Maputo (2016). In a recent visit to the UA, a delegation of the UPM chaired by its Rector had new business meeting in DG/UA which establish guiding principles for new and more developed stage of cooperation addressing the areas: a) pos-graduated training at MSc level (2nd cycle) and PhD(3rd cycle), of UPM faculty; b) collaboration of DG/UA faculty in UPM undergraduate and graduate studies, seminars and scientific monographs, dissertations and PhDs and internships; c) of scientific and technological research, through UPM human and material capacity building, mainly focused on support to the local and regional economic players.

Short CV

Born in Lisbon on 7 January 1956. Degree in Geology from the University of Lisbon, in 1984; PhD in Geosciences (Geology) from the University of Aveiro, in 1994; DSc (Habilitation) in Geosciences (Clay Science) from the University of Aveiro, in 2000. Full professor (Mineral Resources, Geosciences Department) since 1st August 2002 and Director of GEOBIOTEC Research Centre since 2007. Has played several positions at the University of Aveiro, including: Head of the Department of Geosciences (1998 to 2002, 2011 to 2015), Pro-Rector (infrastructures and Campii management, 2003 to 2007) and Vice-Rector (research, innovation and technology transfer, 2008 to 2010). After a brief passage (1984/85) by the private sector of public works as Engineering Geologist, developed academic career at the University of Aveiro since 1986, with scientific and pedagogical activity in the fields of mineral resources, marine and coastal geology, and medical and environmental geology. Supervised 6 PosDocs, 27 PhDs and 39 MSc thesis and published 172 papers indexed on Science Citation Index (H-Index=19).

Rui Castanhinha, GEAL-Lourinhã Museum and Biology Department/CESAM, University of Aveiro, Portugal

Abstract

Mozambique is one of the most important sites in the world for geological and paleontological studies. It contains innumerable fossiliferous outcrops of several geological ages. There are several fossils that have been collected in sediments from the Karoo Supergroup, range from the Paleozoic (e.g. Permian synapsids from the Niassa Province) to the Mesozoic. The extension and abundance of the Mozambican paleontological heritage justified, in the recent years, the implementation of several activities to promote its sustainable development and proper conservation. The main goals have been: 1) to discover, study and increase the collection of fossils of Mozambique, creating a center of excellence in the field of paleontology; 2) to educate new scientists and technical staff; 3) to improve the conditions of research and teaching in the Mozambican academy; 4) to collaborate with the extractive industry and private partners in order to study and preserve the Mozambican heritage. As a result of the existing paleontological richness, Mozambique is starting to strengthen the teaching capacity by providing training to new scientists and technicians. With this in mind, it is expected that the country may fill its academic and research needs in the next years, namely in such a multidisciplinary area as Paleontology. Simultaneously, a new fossil preparation laboratory is being set up to teach how to clean, consolidate and study fossils. In order to develop new valences, state-of-the-art technologies are also being used to describe the anatomy of specimens (e.g. X-ray computed tomography and three-dimensional data processing workstations). In addition, several fieldwork campaigns are in motion in partnership between national and international institutions, and also local populations. By the discovery of new fossils, we expected that Mozambique will have the necessary academic and scientific staff to become completely independent in the area of Paleontology and a reference in higher education by following the highest international standards.

Short CV

He founded in 2006 the Journal of Paleontological Techniques as Editor-in-chief (www.jpaleontologicaltechniques.org). Two years later, having won a scholarship from the Jurassic Foundation for this purpose, he started to study the dinosaur eggs and embryos from the Jurassic of Lourinhã. He defended his PhD in Evolutionary Biology by Universidade Nova de Lisboa (ITQB/IGC) in 2014 and collaborated subsequently, as a Post-Doctoral Researcher, at the Instituto Superior Técnico (LATR/IST/CTN). He is collaborating, as PI, with the Museu da Lourinhã studying the Upper Jurassic fossils of the Lourinhã Formation over the last years. He is Assistant Professor at the Universidade de Aveiro and his research is centered in three main areas: evolutionary comparative anatomy (mainly extant vs extinct vertebrates), paleontology of Mozambique, and Paleo-Evo-Devo studies (ontogeny and morphology). Rui Castanhinha co-funded in Mozambique an international collaborative project called Projecto PalNiassa in 2009 (www.palniassa.org) and described a new fossil species in the country: *Niassodon mfumukasi*. He has also supervised over a dozen of theses and academic works and have been involved in science outreach ever since.

A European Geological Survey in a huge geological mapping project in Africa

José Feliciano da Silva Rodrigues, National Laboratory of Energy and Geology (LNEG), Portugal

Abstract

The National Geology Plan of Angola (PLANAGEO) is one of the biggest projects of today in the world, regarding the knowledge of the geological infrastructure of a country. The National Laboratory of Energy and Geology (LNEG) is an R&D state institution in which are included all the activities of the former Portuguese Geological Survey. LNEG is one of the members of the spanish-portuguese consortium (UTE- IGME/LNEG/Impulso) operating in the PLANAGEO.

The international call for tenders was launched in the beginning of 2011, and after the selection of candidates the works began in the first semester of 2014 with the aerogeophysics campaign (radiometric and magnetic), followed by the first geological field reconnaissance and logistics preparation.

The scientific and technical preparation of the works has had to respond to a simple but important question: how to undertake such a huge campaign of aerogeophysical survey and geological mapping in an area of about 470.000 km², and also works of mineral exploration in some selected areas in a short period of time – 5 years of intended duration for the project?

Nearly four years have passed since the beginning of the project. Therefore, it is possible to draw up an appraisal of the fulfilled goals, and to do an initial assessment of the chosen work methodology and its implementation as well.

In geological mapping the chosen methodology has a clear epistemological basis, because a clear option was made between two possible paths: evidence driven research and model driven research.

The model driven approach is mainly reflected in the preparation of the works, namely in the design of the GIS data model and in the design of the legend architecture for the continuous geological map of the country.

In LNEG, we think that even in very large-scale and demanding projects it is possible to do operational research to constantly improve and modernize the know-how of a geological survey in a context of institutional collaboration

Short CV

Born in Porto on 13 December 1966. Degree in Geology from the University of Porto in 1989. PhD in Geology (internal Geodynamics) from the University of Lisbon in 2008. His professional career has been developed in three main areas: exploration geologist in the private sector (alluvial diamond exploration in Lunda Province – NE of Angola); assistant professor in Mining Engineering Department of Porto University (teaching Geoscience disciplines for mining engineers); and, mainly, geological mapping in the Portuguese Geological Survey (with mapping works in Portugal, Angola and Peru). Presently is coordinator of the LNEG technical team for the Angola's Geology National Plan (PLANAGEO) and one of the coordinators for the 1:250.000 geological map of Angola within the PLANAGEO. His main scientific activity and research interests concern structural geology, tectonics and mapping of orogenic regions.

20 years of African Earth Sciences research, and counting

Joao F.B.D. Fonseca, C4G – Collaboratory for Geosciences, UBI, Portugal

Abstract

It is often said that you can leave Africa, but Africa will never leave you. This may explain why African Earth Sciences have been a recurrent topic of research in my career, with emphasis on geo-hazards. In this talk I will review the first steps in geophysical monitoring of the Fogo Volcano, Cape Verde, in the early nineties, including the monitoring of the 1995 eruption, and the subsequent steps through FCT projects VIGIL and ALERT, and FP7 project MIAVITA. The participation of C4G in the monitoring of the 2014/2015 eruption, and its ongoing study through FCT Project FIRE will also be described.

On a different note, the investigation of the southern tip of the East African Rift in central Mozambique will be described in detail, showing the results of a temporary deployment of broadband seismic network in the scope of FCT Project MOZART (Mozambique Rift Tomography). Besides clarifying the seismotectonics of the region, this project contributed also to a better understanding of the crustal structure of Mozambique.

Finally, a brief description of research projects starting now (SUGGEST-AFRICA) or under evaluation (SHAZAM) will be given, and a plan to strengthen Earth Sciences cooperation with Africa in the next decade will be presented and discussed.

Short CV

Dr Joao Fonseca is a researched with Portuguese and Cape Verdian nationality. He holds a Ph.D. degree in Geophysics by the University of Durham, UK (1990), and is currently the Technical Director of C4G – Collaboratory for Geosciences, a research infrastructure of the Portuguese Strategic Roadmap. He was born in Luanda, Angola, and attended the University of Lisbon for his first degree. After returning from the UK he joined IST, the school of engineering of the (then) Technical University of Lisbon, where he taught Geophysics and supervised several Ph.D. theses in that domain. Dr Joao Fonseca coordinated several research projects in Africa, concerning volcanic monitoring (Cape Verde) and seismotectonics (Mozambique), and co-authored 16 papers in peer-reviewed international journals with direct relevance to African Earth Sciences.

United Nations framework classifications for fossil energy and mineral reserves and resources (UNFC) and Africa mineral and energy resource classification and management system (AMREC) business model canvas for mineral industry in Africa

Arisekola Tunde Muritala, Vice Chair, EGRC, Technical group Chair AMREC/PARC, Nigerian Geological Survey Agency Abuja, Nigeria

Abstract

The principal objective of UNFC is to enhance international communication by providing a generic classification framework for reporting fossil energy and mineral reserves and resources on land, continental shelf and seabed worldwide. UNFC has been developed to meet, to extent possible, the needs of applications pertaining to international energy and mineral studies, government resource management functions, corporate business processes and financial reporting standards.

A key benefit of UNFC is the potential to provide a common basis for minerals and petroleum sectors, whose classification system have been developed primarily for mining of solid minerals and production of fluids respectively, but which now address the increasingly overlap between the two extractive industries. Example of this overlap, include the mining of natural bitumen or coal for processing into synthetic oil or gas. Importance of environmental and social issues in the context of resource extraction is appropriately recognized in line with Africa Mining Vision (AMV) and Sustainable Development Goals(SDG)

UNFC is generic principle-based system in which quantities are classified on basis of three fundamental criteria of economic and social viability (E). Field project status and feasibility (F), and Geology Knowledge (G), using a numerical coding system. Combination of these criteria create and three dimensional system. E.g. E1, E2, E3 for (E), F1, F2, F3 for (F) and G1, G2, G3, G4 for (G).

It is important to note that this Framework Classification was developed by United Nations to capture all mineral endowments around the world either economically viable today or not. Its allow Government of member States of United Nation to properly document and track all categories of it minerals resources. Several bridging documents were developed to correlate UNFC with CRIRSCO and PMRS templates.

The African Mineral and Energy Resources Classification and Management System (AMREC) is a unique continental system for the management of the whole mineral and energy value chain in Africa. No country in Africa currently has a comprehensive resource classification and management system. With the exception of South Africa, no country in Africa has a code for reporting mineral and energy resources to stock exchanges and financial institutions, which is key if foreign investments are to be attracted. AMREC is essentially based on the principles of UNFC, with modifications of Africa peculiarities.

Short CV

Tunde M. Arisekola was born 1st May 1962 in Offa, Kwara State, Nigeria. Completed his primary school at L.E.A. Katsina Road, Kaduna in 1974. He had his secondary school education at Ansar Ud Deen College Offa, Nigeria, passing out in 1983 with West African School Certificate (O/L). Tunde M. Arisekola was admitted into the University of Ilorin, Nigeria, where he graduated in 1987 with a B.sc. (Hons) in Geology. He furthered his education at the University of Ibadan, Nigeria, where he bagged M.Sc in Mineral Exploration (Geochemistry Option) in 1998. Following the mandatory one-year youth service to the country as a corper at Mobil Producing Nigeria Ltd. from 1987 to 1988, Tunde M. Arisekola joined the Nigerian Geological Survey Agency in 1989 where he is working till date and has risen to the position of Director, National Geosciences Research Laboratories, Kaduna -Nigeria. Since joining the Nigerian Geological Survey Agency in January 1989, Tunde M. Arisekola has participated in a number of projects, including: (a) Limestone investigation in Somo, near Shagamu, and Onigbedu area. A cottage cement factory of 300 tones per day has been set up in Onigbedu, South Western Nigeria based on the investigation (1999); (b) Participated in the ground follow up to the air borne geophysical survey of Ogun State which led to the discovery of Arugudu phosphate deposit (2005); (c) Exploration of Pegmatite

belt in Osun State, South western Nigeria for speciality metals and gemstone (2006); (d) Geochemical Mapping of GRN No6Eo4 covering parts of Osun, Kwara, and Ekiti States from June -October (2007) ; (e) Geochemical mapping of Iwo-Oyo sheet, part of GRN No6Eo3 from May – July 2008; (f) Geochemical mapping of Apomu and Ondo sheet, part of GRN No5Eo4 from August-Oct.2008; (g) Coordinator, South West Zone Nigeria, NGS/BGS National Geochemical programme, 2009; (h) Coordinator, NGS/ PMU National Geochemical mapping project Zuru and Koton-Karfi Cells Central Nigeria, 2010; (i) Team leader, Gold Exploration in Ifewara, South Western Nigeria 2011 for Osun State Government by NGS. Project completed, six volumes reports submitted. Foreign investors taking over the project; and (j) Team Leader, Evaluation of Kaolin Resources of Isan Ekiti, South Western Nigeria, 2017. Investor Friendly Report Submitted. Tunde M. Arisekola published several papers in International ISI Journals and is a Lead Author in six research papers that were presented at the following international conferences: 9th Biennial SGA meeting in Dublin, August, 2007. Digging Deeper Vol. 2 pp 1497- 1499, The 33rd International Geological Congress in Oslo, August 2008. Programme/Author index pp165, NMGS Conference and won NMGS/TOTAL award, as third best technical paper presented at Calabar NMGS Conference 2010, CAG23 Meetings in Johannesburg, South Africa January 2011. Tunde M. Arisekola is a Membership of Professional and International Organisations such as: Vice Chair, Expert Group on Resource Classification {EGRC} at UNECE, Geneva(2014 till Date); Chief Counterpart for International Atomic Energy Agency (IAEA) for the following projects in Nigeria: RAF/2011 Sustainable Uranium Resources Development C7-INT2.019/001: Inter-regional Deploying Technology and Management of Sustainable Uranium Extraction Project; Currently Fellow and Council member Nigerian Mining and Geosciences Society (NMGS) and Registered by Council of Nigerian Mining Engineers and Geoscientists (COMEG); Technical Coordinator AMREC Working Group, under African Union Commission.

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**Crustal Evolution
of Africa value**

Palaeoproterozoic eclogites in the Eburnian-Transamazonian orogen of Cameroon and the Ubendian-Usagaran orogens of Tanzania: significance for Palaeoproterozoic plate tectonics

V. Schenk

Institute of Earth Sciences, Heidelberg University, INF 234-236, 69120 Heidelberg, Germany (volker.schenk@geow.uni-heidelberg.de)

Abstract

Lenses of retrogressed eclogites occur in a 100 km wide zone in the Nyong Complex of Cameroon, a remnant of the Eburnian-Transamazonian orogen, and trace a Palaeoproterozoic suture between the Congo and São Francisco Cratons. Similarly, the two eclogite occurrences in the Ubendian and Usagaran orogens along the southern border of the Tanzania Craton mark the site of Palaeoproterozoic sutures between the Tanzania Craton and adjoining Archaean crustal blocks (Bangweulu block, unnamed block in the East African Orogen). These three occurrences of Palaeoproterozoic eclogites show trace element patterns (depleted in LREE) similar to those of mid-ocean ridge basalts, indicating that the precursor melts formed in a depleted mantle source and that the eclogites formed from oceanic crust. Despite numerous plagioclase 'exsolutions', up to 30 mol% jadeite component is preserved in omphacite and points to minimum pressures of ca. 18-20 kbar at ca. 750-800 °C for the Nyong and Usagaran eclogites. For the Ubendian eclogites, the peak conditions are lower, at least at 15 kbar and 700 °C, but not well constrained due to later penetrative orogenic overprinting. The ages of eclogite metamorphism have been constrained by U-Pb zircon dating at 2.09 Ga (Nyong), 2.0 Ga (Usagaran) and 1.87 Ga (Ubendian). In all three orogenic belts the eclogites are associated with belts of low-P/ high-T granulites (garnet±cordierite-sillimanite) of ages nearly identical to those of the subduction metamorphism. The granulite belts are interpreted as paired belts associated to the high-P/ low-T oceanic subduction and formed in the hot plate above a subduction zone. Isobaric cooling textures (Nyong) and a well constrained anticlockwise PT path (Usagaran) in the high-T belts are in agreement with this interpretation. The only other known Palaeoproterozoic subduction related eclogites of MORB chemistry are those in the Belomorian province (1.9 Ga; Russia). The African eclogites (all with MORB chemistry) indicate that during the formation of the Nuna supercontinent the Palaeoproterozoic oceanic lithosphere around the Congo-Tanzania Craton was thick, cold and rigid enough to become subducted in a similar fashion to cold oceanic lithosphere in the modern plate tectonic regime. However, apparent geothermal gradients of 12-14 °C/km for the Palaeoproterozoic eclogites are higher than those of Neoproterozoic and Phanerozoic eclogites and are interpreted as the result of warm subduction in a hotter Palaeoproterozoic Earth.

Paleo-, Meso-, and Neoproterozoic orogenic imprints in the Livingstone Mountains of Tanzania: evidence from petrology and ion microprobe dating of zircon and monazite

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Abstract

The Livingstone Mountains, a poorly studied mountain range at Lake Nyasa, is situated in an area where three orogenic belts of different ages seem to be overlapping: the Ubendian-Usagaran belts, the Irumide Belt and the East African Orogen (EAO), whose formations are linked to the assembly of the supercontinents of Columbia, Rodinia and Gondwana, respectively. Granulite-facies migmatitic metapelites and two orthogneisses were studied petrologically and by ion probe dating of monazite and zircon to decipher their tectono-metamorphic history and to find out if and to which degree the rocks of the Livingstone Mountains were affected by the different orogenies. Zircon dating of one orthogneiss revealed its magmatic age at about 2.2 Ga. Texturally controlled ion probe U-Pb dating of monazite inclusions in inclusion-poor garnet cores (Grt 1) of a Grt-Sil-Bt migmatite in combination with discordant zircon data point to a sillimanite-garnet grade metamorphism at 1857 ± 27 Ma during the Ubendian-Usagaran orogeny. Oscillatory zoned concordant zircon of the second orthogneiss was dated at 997 ± 8.6 Ma, whereas monazite inclusions in Ca-rich garnet core zones and in matrix of Grt-Sil-gneisses revealed a high-grade metamorphism at 1067 ± 20 Ma during the Irumide orogeny. Magmatic zircon of the Mesoproterozoic orthogneiss displays low Th/U metamorphic overgrowth zones ($< 20 \mu\text{m}$), which is in agreement with the presence of Neoproterozoic concordant monazite in low-Ca poikilitic garnet rims (Grt 2) and matrix of metapelites dated at 653 ± 9.1 Ma. This latter age is consistent with known metamorphic ages of the 'Eastern Granulites' in the EAO but is older than those of the 'Western Granulites' and of the Neoproterozoic reworking of the Ubendian Belt (c. 550 Ma) (Möller et al., 2000; Boniface et al., 2012).

The two texturally distinct growth zones of garnet are homogeneous in Fe and Mg, but the inclusion-poor core (Grt 1) contains an outer Ca-rich mantle which itself is overgrown by a Ca-poor poikilitic rim (Grt 2). Thermobarometry using the composition of the poikilitic garnet rim and matrix minerals yielded 770-820 °C and 7-8 kbar, which we interpret as the conditions during the Neoproterozoic metamorphic event. The growth zone with elevated Ca reflects kyanite-grade metamorphism during the Mesoproterozoic Irumide orogeny. Garnet 1 inner cores, some of which preserve Paleoproterozoic monazite and sillimanite inclusions, have compositions similar to Grt 2 and thus suggest similar conditions during the Paleoproterozoic and Neoproterozoic metamorphic events at garnet-sillimanite grade. Partial breakdown of garnet to Sil/Ky-Bt-Pl-Qz reflects late-stage near-isobaric cooling under relatively high pressures following Neoproterozoic peak metamorphism, previously reported only for the 'Eastern Granulites' of the EAO (Appel et al., 1998). In summary, texturally controlled dating of monazite and of separated zircon grains reveals that the Livingstone Mountains represent a crustal block that was overprinted by three high-grade metamorphic events of which at least two were associated with granitoid magmatism. Our isotopic ages correlate with published ages of the adjoining orogens but deviate significantly (40-100 Ma older) from U-Th-total Pb monazite dates recently published by Boniface & Appel (2017) for these multiply overprinted rocks.

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Tonian rifting events on the Congo – São Francisco palaecontinent: new U-Pb and Lu-Hf data from the Boma region, West Congo Belt (DR Congo)

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Abstract

The West Congo Belt (WCB) together with its counterpart located in eastern Brazil, the Araçuaí orogen, represents a Pan-African orogenic system developed within an embayment shaped into the Congo-São Francisco palaecontinent in Neoproterozoic time. The WCB segment at Bas-Congo region (DR Congo) represents an ENE-verging belt thrust onto the Sangha aulacogen, making up a prominent salient into the Congo craton foreland. This salient is rich in anorogenic igneous rocks hosted by the Kimeza basement. Our study is based on U-Pb (SHRIMP) and Lu-Hf (LA-ICP-MS) analysis on zircon crystals from granitic rocks of the Shinkakasa plutonic complex (SPC) and its host basement, located on the West Boma sector at the westernmost Bas-Congo region. The Kimeza basement includes mylonitic orthogneisses of granodioritic composition. The SPC comprises non-metamorphosed granitic to syenitic and mafic to ultramafic rocks, displaying magma mixing features. Lithochemical data show that the SPC granitic and syenitic rocks belong to the rift-related A-type group. The studied samples and respective analytical results (MCA, magmatic crystallization age in Ma; TDM, Lu-Hf model age in Ga; eHf, epsilon Hf(t)) are: #166103, granodioritic orthogneiss (MCA, 2069±17; TDM, 2.50–2.59; eHf, -0.71 to -4.06), representing the SPC host rocks; #166104, foliated syenogranite rich in pink K-feldspar (MCA, 869±14; TDM, 1.94–2.29; eHf, -8.31 to -18.10); and rocks from a SPC zone rich in magma mixing features, like #166101, gray syenogranite (MCA, 911±13; TDM, 1.90–2.01; eHf, -7.10 to -10.90); #166102, monzogranite poor in mafic minerals (MCA, 909±25; TDM, 1.89–2.35; eHf, -7.41 to -19.89); and #117590, porphyritic quartz syenite (MCA, 880±13; TDM, 1.89–2.06; eHf, -7.64 to -10.98). Both 166101 and 117590 samples are rich in brown biotite and bluish green amphibole, displaying igneous flow. Moderately juvenile zircon grains suggest a magmatic arc setting for the Kimeza basement. Lu-Hf isotopic signatures from SPC granitic rocks suggest distinct magma evolutions in space and time. Samples 166101 (911±13 Ma) and 117590 (880±13 Ma) record relatively less evolved magmas, mostly derived from the Kimeza basement. Samples 166102 (909±25 Ma) and 166104 (869±14 Ma) represent more evolved magmas, including an older crustal component. This also suggests two magmatic phases for only one rifting event. The first SPC phase, around 910 Ma, correlates to the bimodal Seke-Banza subsurface magmatism (Inga/Lufu-type rhyolites, microgranites and high-level granites and underlying Gangila-type tholeiitic amygdaloidal basalts; formerly referred to as Mayumbian and upper Zadinian groups) of the WCB. The second SPC phase, around 880–870 Ma, is equivalent of A-type magmatic rocks found in other WCB regions (e.g., Mayumba complex, Gabon). In the Araçuaí orogen, there are correlatives of both SPC phases in the large Bahia-Minas anorogenic province (BAMAPO, ca. 940–870 Ma). Our data also reinforce the fact that more than one Neoproterozoic rifting event preceded the Araçuaí-West Congo orogen, i.e., the Noqui (E4, ca. 1000 Ma), the Seke-Banza - Boma - Mayumba - BAMAPO (E5, 940–870 Ma), and the Lower Diamictite volcanic rocks - South Bahia alkaline province (E6, 735–670 Ma) events, which followed three (E1 to E3) older events apparently only found in Brazil.

The Mao gneiss dome (Bas-Congo region, DR Congo): missing link between the geologic setting of the Boma and Matadi areas in the West Congo Belt.

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Abstract

The Pan African West Congo Belt (WCB) is part of the Araçuaí-West Congo Orogen (AWCO) formed during Gondwana amalgamation (550 Ma). The AWCO is underlain by 2.1 Ga Eburnean-aged gneissic basement. The WCB extends from SW Gabon to NW Angola along the Atlantic Ocean. The NNW-SSE striking segments of the fold-and-thrust belt show eastward decreasing deformation and regional metamorphism. The westernmost part of the Bas-Congo region of DR Congo reveals the deepest crustal segment of the belt (amphibolite facies) (Tack et al., this meeting).

In the Boma area (westernmost Bas-Congo region), 930-870 Ma bimodal rocks of the Shinkakasa Plutonic Complex (SPC) displaying magma mixing features intrude 2069 Ma orthogneissic basement (Pedrosa-Soares et al., this meeting). In the Matadi area, fifty km to the East, metaquartzites of the Mesoproterozoic Nzadi Group (Baudet et al., this meeting) overlie gneissic basement and are intruded by the 1.0 Ga Noqui peralkaline granite (De Grave et al., this meeting).

In between, the Mao area (20 x 20 km) is poorly known because of difficult access. The preliminary geologic sketch map is based on remote sensing of the 1970-ies supported by little field data. It shows complex gneiss dome morphology, locally surrounded by metaquartzites and intruded by a circular alkaline granite (7 km diameter). New U-Pb single zircon dating by LA-ICPMS has been performed respectively on the three rock types. The 2036 ± 11 Ma augengneiss of the dome is in line with available ages for the Eburnean-aged basement of the WCB. The 1008 ± 10 Ma and 990 ± 10 Ma ages for the alkaline granite are in line with the 1.0 Ga Noqui peralkaline granite (Matadi area). The maximum deposition age of the Matadi metaquartzites is 1126 ± 29 Ma and the provenance analysis histogram is in line with those of the metaquartzites of the Matadi type area. In addition, field mapping in progress reveals bimodal intrusive rocks reminiscent of the Tonian SPC within the gneiss dome.

The Mao area thus shows a geologic setting combining features of both the Boma and Matadi areas. Unlike the Matadi area and because of the deeper level of crustal exposure, the Mao granite intrudes the Mao basement dome, which itself is surrounded by the overlying Matadi metaquartzites. Similarly to the Boma area, the Mao dome is intruded by Tonian intrusive rocks of the SPC-type.

In the WCB the Mao dome is not an isolated feature. A similar gneiss dome morphology extends to the North in DRC (Luki-Temvo dome) and probably even in southern Congo-Brazza (Mfoubou area). It abounds in NW Angola (Noqui-Tomboco geologic sheet map). In the easternmost part of the Araçuaí Belt of Brasil basement domes have not been recognized.

The geodynamic origin of the 2.1 Ga gneissic domes surrounded by Late Mesoproterozoic metaquartzites and intruded by 1.0 Ga (per)alkaline granites is debatable. It may be explained in terms of tangential extensional detachment of the Eburnean-aged basement of the AWCO followed by updoming as a result of emplacement of (per)alkaline granites (Theunissen et al., this meeting).

The West Congo Belt of the Bas-Congo region (DR Congo) revisited: a patchwork of individual tectono-metamorphic domains as a result of reactivation following Gondwana amalgamation and South Atlantic ocean opening

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Abstract

The Pan African West Congo Belt (WCB) is part of the Araçuaí – West Congo Orogen (AWCO) formed during Gondwana amalgamation (550 Ma). It is a 1.400 km long, NW-SE to N-S trending fold-and-thrust belt parallel to the Atlantic ocean, extending from SW Gabon through the Republic of Congo-Brazzaville and the Democratic Republic of Congo (DRC) up to NW Angola. In the WCB, the AWCO is underlain by 2.1 Ga Eburnean-aged basement, whose migmatites and gneisses belong to the Palaeoproterozoic Kimeza Supergroup. The Neoproterozoic West Congo Supergroup (WCS) comprises – from old to young - the Matadi, Seke-Banza / Tshela and Cataractes groups (Baudet et al, this meeting).

To the East of the WCB, the foreland of the belt comprises Archaean and/or Eburnean-aged crystalline rocks. However, the crystalline foreland gives rise in its central part (Bas-Congo region, DRC and adjacent southern Republic of Congo-Brazzaville) to a NE-SW to E-W trending aulacogene. This so-called “Sangha” aulacogene consists of subtabular unmetamorphosed sedimentary rocks of the Neoproterozoic Cataractes Group. To the West, the fold-and-thrust belt shows East verging decreasing deformation and regional metamorphism dated in the Bas-Congo region at 566 Ma.

Reappraisal of the new 1:500.000-scale geological map of the Bas-Congo region (Baudet et al., this meeting) based on 1) scattered published and unpublished structural data of Bas-Congo 2) available off-shore and on-shore geophysical data between Gabon and Angola of the last thirty years and 3) new Bas-Congo data (field, geochronology, petrochemistry, ... ; several abstracts, this meeting) gives new insight in the structural complexity of the new map.

Two systems of structures can be distinguished: 1) NE-SW to E-W trending basement structures and “weakness zones” of inferred Palaeoproterozoic age, which were reactivated during Cretaceous times as a result of South Atlantic ocean opening; they are parallel to the trend of the Sangha aulacogene and formed shear zones and faults under brittle regime (Delvaux et al, this meeting) and 2) NW-SE to N-S trending Pan African thrust fronts parallel to the trend of the WCB.

In the Bas-Congo region, two block faulted units of first order are exposed, separated by an E-W trending transcurrent shear zone. Due to uplift, the southern unit reveals a deeper, more complex crustal section of the fold-and-thrust belt including from W to E three successive thrust fronts of first order. They separate respectively 1) amphibolite facies (Boma and Mao areas, this meeting) from greenschist facies rocks, 2) retrograde greenschist facies basement rocks and lower WCS rocks (Matadi area, this meeting) from greenschist facies Neoproterozoic WCS rocks and 3) Cataractes Group rocks from the aulacogene domain.

Combination of the two systems of structures led to a patchwork of individual tectono-metamorphic domains separated by inherited structural discontinuities. Within each domain only a limited part of the Bas-Congo geological setting and virtual lithostratigraphy is exposed. Some of the envisaged domains even show Cenozoic up to subactual reactivation. It is thus essential to take this prominent structural control into account during revision of geological mapping and lithostratigraphy as currently in progress.

Présence d'une structure circulaire multi-anneaux à l'ouest de la ville de Yaoundé (Leboudi-Minkoameyos) : cratère volcanique, effondrement karstique, dôme migmatitique ou astroblème?

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Abstract

Le plateau sud-camerounais, d'une altitude moyenne de 700 m, héberge dans la zone Leboudi-Minkoameyos, une multitude de collines et de bassins d'allure concentrique et en marche d'escaliers, illustrant une structure circulaire, à deux anneaux. Son diamètre est de 19 à 20 km et sa profondeur comprise entre 400 et 500 m. Cette morphologie sinueuse, multi-anneaux dont les remparts culminent à plus de 1000 m d'altitude, caractérise une dépression tel un modelé en bon saltatoire généré par la propagation d'une onde de choc. Cette structure s'est mise en place au sein des roches métamorphiques notamment les gneiss et les migmatites si bien qu'elle pourrait être qualifiée d'une série de dômes migmatitiques. Mais les critères morphologique et pétrographique observés, ne sont pas caractéristiques des dômes migmatitiques. La morphologie visible est une dépression et non un dôme. Un tel édifice observé sur un autre corps céleste du système solaire, comme Mercure ou la lune, se verrait attribuer la nomenclature d'astroblème complexe. Sur Terre, les trois types d'édifice géomorphologique circulaire qui existent sont les cratères volcaniques, les effondrements karstiques et les astroblèmes. L'absence de formations volcaniques et de formations sédimentaires, marqueurs respectifs du volcanisme et de la sédimentation accorde une large crédibilité à cette structure sur son identification en tant que cratère d'impact météoritique. La présence de brèches d'impact polygéniques et de Pdfs sur les minéraux de quartz inclus dans les formations gneissiques constitue des critères imparables du métamorphisme de choc justifiant la mise en place de cette dépression suite à un impact météoritique à l'Ouest de la ville de Yaoundé.

Critères imparables d'un métamorphisme de choc à Linté et ses environs (région du grand Mbam au Cameroun) : signature d'un impact météoritique

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Abstract

Linté et ses environs sont une vaste surface aplanie semblable à une pédiplaine. Elle correspond à la partie nord du plateau sud-camerounais. C'est en fait une continuité de la plaine Tikar qui représente une zone de transition entre le plateau sud-camerounais, les hauts plateaux de l'Ouest et le plateau de l'Adamaoua. En termes de coordonnées géographiques, le secteur d'étude est quadrillé entre les latitudes 4°30'0.00" et 5°00'0.00"N puis les longitudes 11°30'0.00" et 12°00'0.00" E. Les études sismologiques ont montré un amincissement anormal de la croûte par rapport à la position du Moho qui est à 23 km environ de profondeur au niveau du secteur d'étude. Cette profondeur révèle une ablation de 12 km de la croûte terrestre. Les données gravimétriques réalisées sur l'analyse spectrale ont confirmé cet amincissement crustal.

En analysant la géomorphologie du secteur d'étude et ses environs, il en découle que le réseau hydrographique est circulaire et radial. Il est disséqué par les massifs en hauteur formant les structures géologiques à grands rayons de courbures. Ces massifs sont sculptés de cônes de percussion de hauteur centimétrique à plurimétrique et d'une ouverture moyenne de 30°. Dans la présente étude, ils apparaissent sous forme de structures coniques ou sub-incurvées donnant l'allure de queue de cheval à la surface des roches qu'ils affectent. Ces cônes de percussion développent aussi des striations de 1 à 12 cm avec des intersections variables convergent en éventail vers la source de pression au niveau de l'apex. Les gauchissements ainsi que les failles compartimentent le socle ; ils singularisent très bien la géométrie circulaire régionale dont le diamètre du bourrelet central est de 70 km en moyenne. En pétrologie, nous avons mis en exergue des brèches d'impacts polygéniques. Ces brèches sont caractérisées par un mélange plus ou moins hétérogène de fragments de roches du socle constituées des granites et gneiss. Les fragments sont liés entre eux par un ciment vitreux ou clastique compacté et induré par la température et la pression. L'aspect morphologique précédemment décrit donne à ces corps lithologiques l'aspect d'un béton armé. Au microscope, nous notons la présence des minéraux choqués : le quartz est affecté de PDF's et le feldspath est dégradé en des plages de Maskelynite. L'état de choc est caractérisé par les microstructures de déformations planaires telles que les PF's (Planar fractures) et les PDF's (Planar Deformations Features). Les verres diaplectiques ou la Maskelynite dans les feldspaths, le phénomène de mosaïcisme et la fusion partielle du quartz expriment eux aussi cet état de choc. Les différentes microstructures planaires, le mosaïcisme et les fontes des phases minérales, sont autant d'effets induits par le passage de l'onde de choc à l'échelle du minéral ; ce sont par conséquent des preuves ou des critères imparables du métamorphisme de choc et de la signature d'un impact météoritique à Linté et ses environs.

Mise en évidence d'un astroblème dans le Nyong et Kellé : localité de Messondo (région du Centre)

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Abstract

La grande dépression annulaire observée dans la Région du Centre, Département du Nyong et Kellé, située à 03°42'3,6" de latitude Nord et à 10°30'50,4" de longitude Est, pourrait être un supposé Astroblème (ou structure d'impact météoritique) encore non répertorié.

Les études géomorphologiques mettent en évidence (images satellitaires), une structure annulaire à quatre anneaux de forme circulaire, avec un diamètre au-delà des 70km, un réseau hydrographique circulaire et radial, un relief avec des altitudes variant entre 47m et 857m. Ces différents anneaux se présentent comme des murs de reliefs alignés et ondulés laissant apparaître entre eux des zones rappelant des couloirs qui, sur le terrain correspondent souvent à des dépressions ou à des bas-fonds.

L'analyse pétrographique et même géochimique ont respectivement mis en évidence, une importante couverture superficielle constituée de brèches à clastes de quartzites aérodynamiques, les cônes de percussion, des structures planaires (PFs, PDFs) caractéristiques des états choqués des minéraux; et enfin la présence d'Iridium dans les échantillons. Les phénomènes de mosaïcisme et de vitrification qui sont les critères caractérisant habituellement le métamorphisme de choc, seul phénomène capable de générer des pressions et températures extrêmes (100 GPa et 5000° C). Est-ce le cas pour la structure annulaire observée dans la localité de Messondo ?

Au vu de tous ces critères évoqués ci-dessus, la structure annulaire faisant l'objet de cette étude, ne serait-elle pas un cratère d'impact météoritique ?, façonnée par l'impact au sol d'un gigantesque bolide venant de l'espace et évoluant vers le Nord-est. Il serait donc impératif d'élucider toutes les preuves direct et indirect liées à la nature exacte de cette structure annulaire.

Interpretation de la variation des épaisseurs de la croûte au nord du craton du Congo et essai de proposition

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Abstract

Le socle du Golfe de Guinée a longtemps été l'objet de plusieurs modèles tectoniques divergents, mais convergeant tous vers une même hypothèse orogénique: celle d'une fermeture de bassin océanique au moyen d'une subduction panafricaine de polarité nord au Nord du Craton du Congo (latitude 4°N). Une tectonique tangentielle animée par des failles très anciennes, qui aboutit à une fermeture de bassin à la faveur d'une subduction au Nord du Craton du Congo. C'est cette fermeture qui serait à l'origine des déformations du bâti lithologique observées, des nappes charriées au Panafricain en direction du Sud sur le Craton du Congo et des produits volcaniques du Crétacé, du Tertiaire et de l'Actuel suivant l'arc volcanique du Cameroun de direction globale N30°E à partir de l'Océan Atlantique.

L'interprétation de la variation des épaisseurs crustales dans la sous-région d'Afrique Centrale, révèle un gap conséquent jusqu'à près de 24km d'épaisseur de Croûte. Il est fortement indiqué de reconnaître en toute logique un important déblayage superficiel de la Croûte, qui a causé un délestage subséquent du Manteau sous-jacent lui permettant ainsi d'entamer sa remontée vers la surface. La Croûte étant l'enveloppe superficielle de la planète Terre, et dont l'épaisseur en un point est la distance verticale entre le dit point en surface et son équivalent en profondeur sur l'interface avec le Manteau (le Moho), la carte des épaisseurs de Croûte dans une zone comme celle du Golfe de Guinée est en même temps celle des profondeurs du Moho dans la même zone.

La construction des courbes de variation de cette profondeur du Moho le long de n'importe quel méridien (10°E et 13°E par exemple) révèle l'existence au Nord du Craton du Congo d'une remontée systématique du Manteau vers la surface. Cette ascension mantellique, exclut donc l'existence d'une zone de subduction au niveau du parallèle 4°N dans la partie Nord du Craton du Congo depuis le Précambrien, puisque les traces de cette ascension mantellique en surface peuvent être remontées jusqu'au Précambrien. La remontée du Manteau vers la surface étant plus importante lorsqu'on évolue en direction du Nord, il devient impossible d'admettre une extension vers le Nord, du Craton du Congo au Cameroun, ni à Yaoundé, encore moins jusqu'à Ngaoundéré.

Les modèles de subduction et d'érosion n'étant pas appropriés à l'explication d'un tel état des lieux, celui d'un cataclysme saurait-il expliquer l'amincissement crustal observé, l'ascension du Moho au Nord du Craton du Congo depuis le parallèle 4°N jusqu'au lac Tchad, la présence d'anomalies gravimétriques positives radiales et circulaires, celles d'iridium, des brèches, des PDFs, des verres diaplectiques, du mosaïcisme et des cônes de percussion? La structure géomorphologique annulaire du Dja révélée par le réseau hydrographique bouclé et concentrique au cœur du Cameroun de près de 4000 km de diamètre qui s'étend de la longitude 6°25'59"E à celle 20°10'32"E et de la latitude 3°56'28"N à celle 10°16'49"N, rappelle une cicatrice liée à des bombardements depuis l'espace, générant un astroblème, dont le pic central est localisé dans la boucle du fleuve Dja au Sud-Cameroun s'étendant du méridien 12°25'27,337"E à celui 13°54'13,908"E et du parallèle 2°36'29,433"N à celui 3°36'15,64"N.

Revision of the tectonic evolution of the Kivu Belt (NW Mesoproterozoic Kibara belt in DR Congo): evidence of a marked Pan-African imprint

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Abstract

The Kivu Belt (KVB) in Eastern DR Congo, which stretches between the Congo River and the great lakes of the western East African Rift branch, forms the western part of the Mesoproterozoic Karagwe-Ankole Belt (KAB). The latter has been defined on the eastern side of the rift, mainly in Rwanda and Burundi. The Kivu Belt which lies on the western side of the rift is the least well known part of the former Mesoproterozoic belt of Central Africa and has been only included in the 1:2M geological map. No more detailed maps exist despite the fact that more detailed published and un-published maps, geological archives and recent observations exist. In support of a revision of the geology of this area, we compiled the existing chronological framework to establish a revised chronology of geological events, for the Kivu and adjacent Karagwe-Ankole belts, from the Paleoproterozoic to the late Cenozoic rifting event. It evidences a multistage evolution (magmatism, mineralization, sedimentation, metamorphism, ductile and brittle deformations) and, in particular, the importance of Pan-African reactivations. Evidence for Pan-African reactivations have been noted as early as in the 1960's with the first geochronological studies, by anomalously young Ar/Ar, K/Ar, Rb/Sr ages, suspected to be resetting ages. With more and more modern ages obtained recently, the presence of an early Cambrian Pan-African reactivation (555-536 Ma) is confirmed. This reactivation occurred mainly in the brittle domain the most clear effects are the N-S folding and E-W thrusting of the late Neoproterozoic (Cryogenian) Itombwe Supergroup. But late Pan-African deformations in the adjacent Mesoproterozoic Akanyaru Supergroup, which have often been assessed to a late Mesoproterozoic deformation phase, appear to be more widespread as previously believed and are mainly expressed in a brittle way. A brittle fracture and fault-kinematic analysis has been performed on 12 well-exposed sites. Paleostress inversion allowed to reconstruct a tectonic stress field characterized by a general E-W horizontal compression, in a strike-slip to thrust faulting regime. This brittle stage, correlated with the late stages of the 555-536 Ma reactivations, could be related to the E-W collision of the Dhawar (India) and the East African Orogen, and subsequent interaction with the Congo Craton.

Anomalies géochimiques en iridium dans les granites de Gunbela (Adamoua, centre-Cameroun): une signature irrévocable d'un impact météoritique au Cameroun

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Abstract

Le secteur de Gunbela (No6°41'34,1" et E14°08'31,6" ; 960 m) est situé dans la zone de l'Adamaoua à 25 km au NW de Meiganga, en position topographique quasi médiane le long de la Dorsale camerounaise.

C'est une platitude avec de faibles variations d'altitude, aux thalwegs étroits et longitudinaux, appartenant au plateau sud-camerounais. Une carrière ouverte à 7 km du village Gunbela a permis de mettre en évidence trois types pétrographiques. On distingue des granites à deux micas, des granites à orthose et des gneiss. Les granites ont une texture microgrenue. La méthode d'analyse géochimique par spectrométrie de masse PGM-NAA (par fusion du sulfure de Nickel et par activation neutronique.) en rapport avec les éléments du groupe des GPE a été réalisée sur un échantillon de granites à deux micas. Le résultat révèle une teneur en iridium de 0,002 ppm, soit 40 fois la teneur crustale en cet élément sur Terre (0,00005 ppm). L'enrichissement de ces granites en iridium est-il lié à un phénomène endogène ou alors peut-on lui trouver un lien avec un autre mécanisme d'incidence exogène?

L'iridium est un élément chimique appartenant aux métaux de transition du groupe des platinoïdes. Il est très abondant dans les météorites où la teneur atteint régulièrement des valeurs de 0,5 ppm.

Sur Terre, cet élément chimique est produit par le volcanisme mais les quantités restent relativement faibles. En conséquence, le volcanisme ne saurait apporter un excédent aussi élevé en iridium tel qu'observé à Gunbela. L'apport en iridium des granites de Gunbela est donc d'origine extraterrestre certainement lié à un impact météoritique provoqué par la chute d'une météorite.

Signatures d'un métamorphisme de choc dans deux dépressions elliptiques le long du parallèle 4°N: une évidence d'un double impact météoritique dans le socle quartzitique paléoprotérozoïque des localités d'Etong-Néfante (région du Centre-Cameroun).

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Abstract

Aux confins du Département du Mbam et Inoubou dans l'immense forêt équatoriale du centre-Cameroun, s'illustrent deux dépressions elliptiques qui surplombent le socle paléoprotérozoïque essentiellement quartzitique dans les localités d'Etong et de Néfante. Ces deux structures qui diffèrent par leurs dimensions géométriques moyennes avec $b=11\text{km}$ et $a=1.5\text{km}$ et $a=18\text{km}$, $b=6\text{km}$ respectivement pour les dépressions d'Etong au Sud ($N4^{\circ}37'20''/N4^{\circ}45'46''$; $E10^{\circ}57'09''/E10^{\circ}49'02''$), et la dépression de Néfante au Nord ($N4^{\circ}49'33''/N4^{\circ}41'34''$; $E10^{\circ}48'08''/E11^{\circ}00'$). Celles-ci sont délimitées par une faille active senestre de direction NW-SE dont le rejeu aurait accompagné l'affaissement de la zone de Néfante au cours du violent choc météoritique qui lui a donné naissance. Ces deux entités géomorphologiques adjacentes au Sud de la zone, se matérialisent sur le terrain et sur les images satellitaires par des grands édifices quartzitiques qui culminent entre 1025m et 1064 m d'altitude respectivement à Etong et Néfante. Ces massifs rocheux disposés en anneaux et dont les courbures épousent les ellipses desdites structures, sont une parfaite illustration de la propagation sur le terrain, d'une onde de choc donc la propagation en bonds saltatoires et à vitesse supersonique, serait le moteur d'une telle structuration dans les conditions de température et pression élevées, qui conférerait au socle un comportement hydrodynamique.

De la périphérie jusqu'au cœur, y-compris les flancs et les sommets de ces dépressions, des lithologies spécifiques d'un phénomène exogène ont été identifiées et décrites : il s'agit des brèches polygéniques composées de (quartz-micas-feldspath-tourmaline-magnétite) sans ciment ; les brèches monogéniques riches en quartz ; les dolérites à labrador identifiées le long de la faille NW-SE, les cônes de percussion riche en quartz et les roches sombres similaires aux coulées volcaniques.

Une observation au microscope optique de ces différentes roches a permis de mettre en évidence dans les minéraux de quartz des microstructures planaires à savoir des PDFs, PFs, le phénomène de mosaïcisme, et de nombreuses vitrifications ; les micas par contre présentent les kinks bands tandis que dans les roches sombres les cristaux de fer présentent les lignes de Neumann. Le diagramme des conditions du métamorphisme de Stoffler et Grieve montre que toutes les déformations ainsi mises en évidence dans nos lithologies entrent dans le champ du métamorphisme de choc. Ceci valide ainsi l'hypothèse d'un double choc météoritique qui aurait induit ces déformations métamorphiques et façonné ces deux structures, dans des conditions de température et pression très élevées $T=1000^{\circ}\text{C}$ et $P=10\text{Gpa}$, ceci dans un contexte géologique où les conditions de métamorphisme les plus élevées sont celles des granulites (10kbar et 800°C).

Des péridotites à spinelles et à couronnes de dunités de Yaoundé: des marqueurs le long du parallèle 4°N de l'anomalie gravimétrique positive et linéaire de Collignon, l'une des conséquences d'un impact météoritique

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Abstract

Les formations géologiques de la zone de Yaoundé sont constituées de métamorphites. On y distingue des quartzites, des schistes, des micaschistes des gneiss migmatitiques et d'autres types qui recristallisent sous forme nodulaire ou lenticulaire notamment les pyroxénites, les biotites, les grenatites et bien d'autres. Au sein des gneiss migmatitiques, des péridotites ont été mises en évidence sur le mont Nkol Nyada et à Nkolmbong. Il s'agit respectivement des péridotites à couronne de dunités de forme nodulaire et des péridotites à spinelles en boules. Elles ont cristallisé au sud du parallèle 4°N, respectivement à une distance d'environ 10 km de celui-ci. Cette latitude héberge une anomalie gravimétrique positive et linéaire, d'orientation E-W, due à une présence des matériaux de forte densité au travers de la Croûte. La présence des péridotites en surface confirme, du point de vue pétrographique et géophysique, ladite anomalie contrairement aux gneiss et granulites initialement mentionnées ou évoquées pour en être à l'origine. Les péridotites à spinelles qui proviennent d'une profondeur comprise entre 30km et 70km, arrivent en surface via de grands couloirs tectoniques directement connectés au Manteau. L'absence d'orogènes et d'ophiolites à Yaoundé écarte toute hypothèse d'une origine orogénique. En outre, les nodules de péridotites (dunités) se retrouvent en dépit des incompatibilités minéralogiques, incrustées au sein des métamorphites et non dans les volcanites comme dans les cas habituels. Par conséquent, les péridotites de Yaoundé paraissent ne point avoir une origine endogène mais certainement, semblent découler d'une incidence exogène. Elles sont liées à un impact météoritique de grande ampleur, responsable de la fragilisation du socle suivant une direction radiale E-W. Cette ouverture tectonique a causé une chute de la pression lithostatique sus-jacente qui provoque à son tour une migration du Manteau sous-jacent et une cristallisation subséquente des roches mantelliques en surface. Ces formations lithologiques en même temps qu'elles révèlent l'existence d'importantes failles profondément enfouies à Yaoundé, sont caractéristiques de l'anomalie gravimétrique positive et linéaire de Collignon observée depuis l'Atlantique, jusque Bangui en RCA le long du parallèle 4°N.

L'exhumation tardi-orogénique du terrane de Laouni, Latea, Bouclier Touareg, Algérie

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Abstract

Le terrane de Laouni, de l'ensemble LATEA dans le bouclier Touareg, appartient à la chaîne panafricaine trans-saharienne. Il est constitué de gneiss migmatitiques dérivant de protolithes paléoprotérozoïques et recouverts par des marbres à olivine-spinelle, des métapélites à grenat-sillimanite-cordiérite-biotite et des quartzites. Les deux ensembles renferment des niveaux lenticulaires d'amphibolites, métagabbros et métanorites avec ou sans grenat et de pyroxénites à grenat. Ces roches sont rééquilibrées dans les conditions de faciès granulite ($T > 800^{\circ}\text{C}$) et rétro-morphosées successivement dans celles des faciès amphibolite et schiste vert. Des lentilles de rétro-éclogites affleurent en reliques dans des amphibolites à grenat. L'ensemble est intrudé par des granitoïdes calco-alkalins hautement potassiques, d'origine mixte, croûte et manteau et datés entre 640 et 590 Ma.

L'analyse des déformations et des structures migmatitiques, couplés aux données géochronologiques permettent de retracer trois événements panafricains postérieurs aux conditions de haute pression (rétro-éclogites), équilibrées à une pression de 17 kbar et une température de 750°C et datées à 654 ± 5 Ma (LA-ICP-MS/U-Pb sur zircon) dont les structures ont été totalement oblitérées.

Le stade précoce est marquée par une foliation anatectique en conditions de faciès granulite (800°C), datée à 577 ± 11 Ma (FE-EPMA/U-Th-Pb sur monazite), associée à des cisaillements normaux, faiblement obliques et tapissés de leucosomes à grenat, des plis d'entraînement intrafoliaux, des plis en fourreau orientés NE-SW à N-S et parallèles aux linéations minéral et d'étirement. L'ensemble de ces déformations sont générées par des détachements crustaux qui ont exhumé des roches ramenées antérieurement à des profondeurs crustales. Il succéderait à un stade d'exhumation précoce par flottabilité ou par extrusion tectonique.

Les structures du stade précoce sont reprises par une tectonique transpressive ayant formé les principales directions structurales, NW-SE et N-S à NE-SW, où coexistent des structures décrochantes, décro-chevauchantes et chevauchantes. Ces structures sont géométriquement et cinématiquement cohérentes et compatible avec un raccourcissement de direction Est-Ouest. Au cours de ce stade, se développent des structures extensives ou transtensives qui expriment une extension de direction Nord-Sud.

Le stade tardif, développé syn-refroidissement, est caractérisé par des structures cassantes marquées par des décrochements et des failles normales fortement pentés. Ce stade accompagne l'exhumation jusqu'au refroidissement final et exhume les cisaillements normaux et les détachements précoces ductiles faiblement pentés. Cette évolution montre un continuum, dans un contexte de convergence et de collision, entre la cinématique de haute et de basse température, responsable de l'exhumation dans le terrane de Laouni.

Indices de minéralisations dans la potentielle structure d'impact météoritique de Messondo (région du Centre-Cameroun)

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Abstract

Le Cameroun est un pays en voie de développement comme la plupart des pays d'Afrique Centrale. Il serait nécessaire pour ces pays de faire recours à leurs richesses naturelles pour se faire une place dans le monde. Dans le secteur Pouma-Boumnyébel, il a été découvert un potentiel cratère d'impact à Messondo de 80 Km de diamètre et 5024 Km² de superficie. Ce cratère et ses environs regorgent de plusieurs minéralisations à savoir : Mn (80 ppm), Co (11-121 ppm), Cr (16,4-13602 ppm), Ni (10,6-2228 ppm), Pb (0,7-17ppm), Th (0,1-25,6 ppm), Au (0,3-4,3 ppm), Cu (1,6-104 ppm), U (0,2-3,74 ppm), Ir (0,59-12 ppm), Al (Al₂O₃=130-180 ppm) et le Fer (Fe₂O₃= 80-560 ppm). Le Manganèse et le Fer ont des indices uniquement dans les quartzites. Ces résultats ont été obtenus par l'analyse de 26 échantillons de roches par la méthode INAA et par fluorescence X (XRF). Les différents indices de minéralisations sont représentés dans tous les faciès du secteur d'étude. Suivant l'indice d'acidité, ces faciès sont divisés en deux groupes : les roches acides à intermédiaires (micaschistes, gneiss, amphibolites, migmatites et mylonites) et les roches basiques à ultrabasiques (enclaves de biotitites, gneiss à amphibole, amphibolites, pyriboles, serpentinites, talc-schistes et gabbros). Le Cobalt, le Chrome, le Nickel et l'Alumine présentent des teneurs élevées dans toutes les roches des deux groupes sauf dans les amphibolites pour l'Alumine. Dans les roches acides à intermédiaires, l'Iridium, l'Uranium et l'or sont absents dans les migmatites ; le Cuivre est absent dans les migmatites et les mylonites tandis que le Plomb se trouve uniquement dans les gneiss à biotite. Dans les roches basiques et ultrabasiques, l'Iridium et le Cuivre sont absents dans les enclaves de biotitites à épidote, les amphibolites, les pyriboles, les gabbro-norites et les talc-schistes, mais l'Iridium est présent dans les pyriboles sans grenat et le cuivre dans les talc-schistes sans grenat ; l'Or et l'Uranium sont absents dans les enclaves de biotitites à épidote, les amphibolites et dans les pyriboles sans grenat ; l'Or est aussi absent dans les gabbro-norites ; le Thorium est absent dans les pyriboles sans grenat et dans les gabbro-norites, tandis que le Plomb n'est présent que dans les enclaves de biotitites à épidote, les amphibolites, les gabbro-norites et les talc-schistes.

Lake Bosumtwi, the youngest rampart crater on Earth?

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Abstract

The morphologies of ejecta blankets differ according to the mechanism of emplacement. As a result of ballistic trajectories on airless bodies, the thickness of ejecta decreases with increasing radial distance. On Mars, the presence of volatiles is responsible for distinct morphologies characterized by a distal rampart [1]. For single-layered ejecta, a crater rim, a circular depression or moat, and a distal rampart are identified on topography. The distribution of ejecta around the Ries impact structure was shown to share features with double-layered ejecta on Mars [2]. To date, the Ries structure is a unique case of preservation of an ejecta rampart on Earth [2]. A subtle topographic outer ring was previously identified from remote sensing data at the Bosumtwi impact structure (age : 1.07 Ma) [3]. However, its origin, either as the edge of the ejecta blanket or a ring fault produced during the formation of the transient cavity and its subsequent collapse remained unclear [3]. New analysis of the topography of the Bosumtwi impact structure from denoised SRTM data [4] reveals a circular depression (moat). The topography increases outward and forms a circular ridge. The ridge is slightly sinuous and essentially continuous. The ridge and moat are not observed in the southeastern part of the structure which is affected by pre-existing topography (Obuom range, oriented N45), associated with Birimian metasediments and Tarkwaian metavolcanics. The elevation of the ridge is locally up to 100 m above the topography beyond the ridge. It is also preceded inward by hummocky terrain contrasting with the relatively smoother topography within the moat. The elevation over the moat is typically a few tens of meters lower than the ridge. Its elevation is comparable with that of the surrounding topography in several places. The width of the ridge is typically a few km (see also [4]). The ridge coincides with an annular positive K anomaly identified from an airborne radiometric survey [5]. Beyond the ridge, a smooth annulus extending up to 12 – 13 km from the crater center may be highlighted in the roughness map derived from SRTM data. Recent field observations reveal that the rim and ridge are associated with exposures of brecciated Birimian metasediments [5]. In contrast, the moat is associated with a thin lateritic cover (typically 1 m), and has a lower concentration of K, relative to rim and ridge. The lowest K concentrations are observed outside of the ridge, where a thick and presumably ancient laterite cover is observed.

Based on these observations, we conclude that the present topography of the environs of Lake Bosumtwi shares similarities with rampart impact structures on Mars. The distance of the rampart falls within the range of observed values on Mars [6]. The variation of the concentration of K within the different units (rim, moat, ridge and surrounding terrains) is consistent with on-going erosion of the rim and rampart, responsible for the noted exposure of excavated metasediment. The working hypothesis that the Bosumtwi impact structure could constitute a second example of a rampart crater on Earth will be further investigated.

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Evolution of the Proterozoic Matadi supra-detachment basin in the West Congo Belt (Democratic Republic of Congo) and implications for the Pan-African Araçuaí-West Congo Orogeny

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Abstract

The African part of the Pan-African - Brasiliano Araçuaí-West Congo Orogen (AWCO) extends from Gabon into Angola as the NW striking West Congo Belt (WCB). It consists of a distinct eastern and western litho-structural domain. Pan-African NW folding is most evident in the eastern domain with a consistent Neoproterozoic lithostratigraphy. In the western domain poorly defined Neoproterozoic metasedimentary sequences alternate with 0.9 Ga magmatism and Palaeoproterozoic basement; they describe complexly arranged structures all over the western domain. In the Democratic Republic of Congo (DRC), the Brazzaville Congo and Angola these metasediments include the Matadi quartzites Formation (Nzadi Group). In two discrete western DRC areas, next referred to as “Boma” and “Kimeza” recent studies show that the Matadi beds are 1.12 Ga deposits intruded by 1.0 Ga granites (Baudet et al., Nseka et al., this meeting). Chronologically this fits well with respectively E3 and E4 extensional events as defined by Pedrosa-Soares and Alkmin (2011). Here we first explain how the E3 and E4 extensional events develop differently in both areas related to paleo-crustal levels, i.e. an upper (Kimeza) and a lower plate (Boma) level, separated by a low-angle detachment zone. We then claim that both events represent key positions for better understanding the extensional history, preceding the AWCO. We describe and present arguments supporting (1) that in the Boma area the 1.12 Ga Matadi beds reflect a supra-detachment sedimentary sequence on top of an amphibolite facies mylonitic foliated roof in the Palaeoproterozoic basement; (2) that crustal detachment extension culminated in extensive 1.0 Ga granite intrusions that form the Boma gneiss dome and imprint complex internal structures; (3) that, contrastingly, in the adjacent Kimeza area, the Matadi sediments unconformably overly a non-foliated greenschist facies retrograde Palaeoproterozoic basement; (4) that in its western boundary only one single 1.0 Ga granite intrusion forms a local updoming and a thermal imprint in the 1.12 Ga sediments; (5) that contrary to the complexly arranged supra-detachment Matadi beds in the Boma gneiss dome, the Matadi beds in the Kimeza area, remain nearly undeformed except nearby the single 1.0 Ga intrusion.

Considering that on the scale of the AWCO, the E3 event started with listric fault-bounded 1.18 Ga Espinhaço deposits in Brazil, we conclude that the extension subsequently evolved into a detachment with the 1.12 Ga Matadi supradetachment sediments upon the lower plate and that the detachment eventually plunges under the thick, non-extended Kimeza plate boundary with unconformably overlying Matadi beds. After the E3 event the extension culminated in updoming of thinned crust by extensive 1.0 Ga E4 granite intrusions, only one of which intruded the thick Kimeza basement at its western boundary. Whereas E3-4 are confined to ductile stretching of the lower crustal segment of Boma, subsequent E5 continental rift magmatism concentrated on the lower-upper-plate boundary zone along the limb of the 1.0 Ga gneiss dome.

The Lower Diamictite Formation of the Cataractes Group, West Congo Supergroup (Bas-Congo region, DR Congo): a 678 My marker of extensional episodic activity during breakup of Columbia

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Abstract

The Panafrican West Congo Belt (WCB) is part of the Araçuaí – West Congo Orogen (AWCO), formed during Gondwana amalgamation. It extends from SW Gabon to NW Angola and displays eastward decreasing deformation and regional metamorphism.

In Bas-Congo region (DRC), the Neoproterozoic West Congo Supergroup comprises – from old to young - the Nzadi, Seke-Banza / Tshela, Cataractes Groups (Baudet et al 2013 and see also this meeting). The latter consists of Sansikwa, Haut-Shiloango, Lukala and Mpioka Subgroups. The Sansikwa Subgroup is composed of 3 Formations, the Lower and the Middle members and on the top, the Lower Diamictite Formation (LDF). The lithological composition of the LDF is not uniform but includes true diamictites with interlayered pelitic sequences with subordinate arenites and lenticular subaqueous and subaerial tholeiitic basalts. None glaciogenic features have been recognized in the sediments but gravity mass deposit characteristics have been identified. Doleritic/gabbroic feeder system of the lavas has given an U-Pb baddeleyite emplacement age of 694±4 Ma (Straathof, 2011).

New detrital zircon geochronology and provenance analysis of the LDF on a sample overlying the basalts gives a maximum depositional age of 678±4 Ma. The matching results between the two ages, for the basalts interbedded and for the LDF provenance analysis younger population, give a good accuracy for the LDF deposition age.

In SW Gabon (Thiéblemont et al., 2009), the 700 Ma emplacement age of the Bas-Congo LDF is confirmed by an unprecise SHRIMP age ($\leq 713\pm 49$ Ma) on a tuffaceous rock, ascribed to the base of the Louila Formation (equivalent of the Bas-Congo Haut-Shiloango Subgroup). However, both macroscopic and microscopic re-examination of the dated rock indicates that it is similar to pelitic rocks interlayered in the LDF of Bas-Congo (Tack, personal communication). The 678 Ma age is also in agreement with the results of detrital zircon provenance analysis populations of the younger Lukala (707 Ma) and Mpioka (721 Ma) Subgroups of the West Congo Supergroup and of the Phanerozoic Inkisi Supergroup (719 Ma) in Bas-Congo (Straathof 2011; Affaton et al 2015).

The 678 Ma emplacement age of the LDF is in line with Neoproterozoic episodic extensional activity of Columbia, recorded by specific lithologies marking both exogenic (LDF) and endogenic (tholeiitic mafic magmatism) geodynamic processes as proposed in the “Zipper Rift Model”. Our 678 Ma age in the WCB constrains the loosely bracketed 735-670 Ma age for the same extensional tectonic episode (“E6”), as reported from the Brazilian side of the AWCO (Pedrosa-Soares and Alkmin, 2011).

Finally, in the absence of glaciogenic sedimentological features and because of the extensional tectonic setting, a Sturtian glaciogenic origin due to exogenic processes for the LDF can be excluded. Moreover the recent detailed studies of the stratigraphy of the LDF allows to propose a stratigraphical upgrade from Formation to Subgroup (Baudet et al., this meeting).

references

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Impact breccias and shock metamorphic features in Mora ring structure (Golda Zuelva): an evidence of impact cratering process

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Abstract

The Mora ring structure is a single significant circular scar in the southwestern part of the Mora city, Cameroon, central Africa (lat. 10° 56' 50.4759" N, long. 14° 01' 40.7651" E). This pattern which was defined by remote sensing and GIS studies, is about 8 Km diameter and show concentric annular rims with uplift central hill of 2 Km diameter. Elevations decrease 1070 m from the central peak to 450 m outward in the west basin. Geomorphology and geology data confirm an intricate system of circular to radial distribution of faults, and highly deformed rocks which a various range of impactites, from parautochthonous rocks to allochthonous units. The pre-impact rocks were shattered into boulders and breccias composed of angular fragments of varying sizes imbedded in a matrix of fragments and rock flour from centimetre to decimetre sizes. This structure is a part of the mount Mandara Mountains and belong to the crystalline basement. Without being diagnostic markers, the impact breccias are rocks revealing the process of shock wave spreading which produce a wide variety of physical, chemical, mineralogical, and other effects in materials through which it pass. The topographic expression still visible and preserved, suggests this complex impact crater is probably young. Although its impact origin was already proposed in the 1986, 2014, 2015 and 2016s, information on its review geology and shock features was unknown and still based on the remote sensing and GIS literature. We recently carried out a field trips on december 2016 to well understand the geology and the origin of this scheming structure. We present here the main geomorphological and geological characteristics of the Mora ring structure obtained by integrated remote sensing and geological field work, as well as structural and petrographic analysis.

Dapiric intrusion and solution collapse are rejected as possible origins for the Mora ring structure on the basis of stratigraphic, structural and petrology evidence. Although crystalline rocks are present, igneous or mantle origin is also rejected because all these rocks being affected tremendously by shock event.

This paper supports the idea that the bedrock of Golda Zuelva and its surroundings area were affected by a major cataclysmic event caused by the collision of an extra-terrestrial hypervelocity body on the local crustal basement. The presence of circular rims, deformed rocks, circular patterns of normal faulting, impact breccias, shatter cones, a central uplift hill and shock lamellae as Planar Fractures (PFs) and Planar Deformation Features (PDFs) in minerals are consistent with impact models as we can see on the moon or on other solar system bodies.

The end of the Early Proterozoic Glaciation and the Ongeluk – Hekpoort Large Igneous Province of the Kaapvaal Craton, South Africa

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Abstract

The contact of the lower Proterozoic volcanics of the Ongeluk Formation to the underlying glacial Magkanyene Formation has been described in many papers and served as a major evidence for the Snowball Earth hypothesis. This boundary was described as an unconformity by Altermann and Hälbich (1991). Evans et al. (1997), ignored the lacuna separating these formations and postulated low latitude deposition of the Magkanyene glacials, based on a paleo-pole measured for the overlying Ongeluk lavas. Moore et al. (2001), found conformable relationships between the Ongeluk and Magkanyene, which was disputed by Altermann (in Melezhik et al., 2013). The age and depositional environment of the Ongeluk Formation are also disputed; in the widespread literature the 2.222 Ga Ongeluk is referred to as the lateral correlative of the geochemically indistinguishable (Humbert et al., in preparation) lavas of the terrestrial Hekpoort Formation in central and eastern Kaapvaal craton (Cornell et al., 1996; Moore et al., 2012) and as submarine extrusion because occasional pillow lavas occur in the middle and northern Griqualand West sub-basin. This age and regional correlation have been refuted by Gumsley et al. (2017), based on 2.426 Ga baddeleyite age from a dike intruding the Ongeluk Formation.

In an attempt to resolve the above contradictions, new outcrops have been mapped and a drill core was recovered from the Ongeluk Formation, also penetrating the Magkanyene and reaching the underlying Koegas Formation, thus penetrating the stratigraphic boundaries below and above Magkanyene. The Ongeluk Formation is indeed locally conformable on the Magkanyene glacials, where these are thinly bedded and fine grained. There, it starts with subaquatic tuffs, partly rippled, passing upward into massive lavas, often displaying vertical columnar jointing and thus probably cooled terrestrially. In other places an unconformity is apparent and can be followed hundreds meters along outcrops exposing the paleotopography developed on the Magkanyene. The Ongeluk tuffs and lava flows fill the paleo-lows on the Magkanyene surface. Pahoehoe spongy lava flow-tops were found c. 2 meters above the unconformable base of the Ongeluk. Together with occasional sub-vertical pipe amygdals at the base of flow, they indisputably evidence terrestrial outflow.

The outcrops sampled by Gumsley et al. (2017) consist of coarse dikes (containing baddeleyite), regionally isolated or intruding aphanitic lava with hyaloclastite, but lacking clear evidence of being part of the Ongeluk Formation, although they were mapped as such (Geological Map, sheet Postmasburg, 1:250000). Geochemically however, this lava is identical to Ongeluk.

The correlation of the Ongeluk and Hekpoort formations remains improbable and the age of 2.426 Ga for the Ongeluk is well possible. The coordinates of one of the outcrops given by Gumsley et al. (2017) are misplaced. The lack of geochemical data and outcrop description in Gumsley et al. (2017), renders this particular date somewhat questionable as the true Ongeluk age.

The deposition of Ongeluk volcanics varies locally between subaerial to pillow lava, subaquatic flows, across the western Kaapvaal craton. Where the contact is conformable, it is subaquatic and where unconformable, it is terrestrial. This implies a post-glacial, inter-lacustrine deposition with a relatively short time gap terminating the Snowball Earth before the onset of volcanism.

Geochemistry, Sr-Nd isotopes and U-Pb data on the Neoproterozoic syn-kinematic granitoids from the Batié, West Cameroon: implications for crustal evolution in Central Africa

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Abstract

U-Pb on zircon, major and trace elements, Nd and Sr isotopic compositions are reported for the Batié granitoid complex belonging to the Central African Fold belt of Central domain in West Cameroon. The Batié granitoid complex crops in Paleoproterozoic gneissic basement and is covered partly by Tertiary basaltic rocks. Tectonic and metamorphic evolution of the belt is believed to have occurred during the Pan-African orogenesis. The U-Pb on zircon age of 516 ± 7 Ma for deformed granodiorite confirms its syn-kinematic emplacement. The 620 ± 3 Ma emplacement age of the I-type biotite granite and its high-K calc-alkaline, metaluminous to weakly peraluminous nature are in agreement with the post-collisional transpressive movements along the central Cameroon shear zone and the Sanaga fault induced linear lithospheric delamination, allowing the uprise of mantle magmas, and triggering the partial melting of the old lower continental crust of the Congo craton's northern boundary.

Their negative $\epsilon_{\text{Nd}_{610}}$ values (-12 to -9) and TDM = 2 Ga imply that it is derived from an older Paleoproterozoic protolith including a LREE enriched crustal component. The late Pan-African shear (mylonitisation) imprint is shown by Sr isotopic and U-Pb data (548 Ma for deformed granodiorite) indices opening of Rb-Sr whole rocks system.

The above geochemical and isotopic data are witness of the remobilized Paleoproterozoic crust with restricted new injection in the upper continental crust of the mantle magma, during the Pan-African in West Cameroon in particular and in the central domain of the Central African pan-African fold belt in general.

Nd isotope and geochemistry of the medium-grade-gneisses of the Nuba Mountains, Sudan: new evidence to support the Abutulu suture as the eastern boundary of the Saharan Metacraton in southern Sudan

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Abstract

Medium-to high-grade gneisses occupy the western part of the Nuba Mountains of southern Sudan and form a belt of ≈ 300 km width. This belt is bounded by two sutures; the Kabus ophiolitic melange (former location of the eastern boundary of the SMC) to the east and the Abutulu suture (newly assigned location for the eastern boundary of the SMC) to the west. These gneisses were interpreted by different workers to represent a pre-Pan-African crust of possibly Archaean to early Proterozoic age.

New geochemical and Nd isotope data reveal that the geochemistry of the medium-grade gneisses of the western Nuba Mountains is typical of calc-alkaline I-type granitoids. These gneisses display a REE pattern characterized by LILE enrichment indicating formation in an arc/back-arc environment. This arc was active around 860 ± 64 Ma (Sm-Nd 4 WR isochron). The close interval between the TDM Nd model age (average of eight gneiss samples ≈ 950 Ma) and the crystallization age (860 ± 64 Ma) suggest the absence or the insignificant involvement of pre-Neoproterozoic materials. Eight gneiss samples yield a consistent $\epsilon_{Nd860 \pm 67}$ Ma values (average $\approx +6.1 \pm 1$). These values are best considered to reflect the derivation of the Nuba Mountains gneisses from a depleted mantle source during an early Neoproterozoic time.

The results show that the gneisses of the Nuba Mountains were derived from juvenile Neoproterozoic igneous rocks similar to those of the Arabian Nubian Shield. Rocks of the pre-Neoproterozoic Saharan Metacraton (SMC) must exist to the west of the Abutulu suture.

525 Ma riebeckite in a quartz vein into the Noqui granite: evidence for a late Pan African extensional event in the West Congo Belt (Matadi area, Bas-Congo region, DR Congo)

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Abstract

The Pan African West Congo Belt (WCB) is part of the Araçuaí – West Congo Orogen (AWCO) formed during Gondwana amalgamation (550 Ma). In the WCB, the AWCO is underlain by a 2.1 Ga Eburnean-aged orogenic system. The WCB extends from SW Gabon to NW Angola parallel to the Atlantic ocean. Its central part displays an ENE-verging fold-and-thrust belt with eastward decreasing deformation and regional metamorphism dated in the Bas-Congo region (DR Congo) at 566 Ma. This age is in line with the 585-560 Ma ages for the paroxysm of AWCO as obtained from the Araçuaí Belt of Brazil.

The Neoproterozoic West Congo Supergroup comprises – from old to young - the Nzadi, Seke-Banza / Tshela and Cataractes Groups (Baudet et al, this meeting). In the Matadi area (Bas-Congo region), the 1.0 Ga Noqui peralkaline granite intrudes the metaquartzites of the Matadi Formation (Nzadi Group; De Grave et al, Baudet et al., this meeting), whereas overlying Formations are not affected by the intrusion.

The Noqui granite is composed of mesoperthite, quartz, aegyrine ± lepidomelane ± opaques ± riebeckite and has an A1-type geochemical composition. Pegmatites have never been observed.

In the Fretin quarry (northern part of the granite body, Kinzaio locality) a quartz vein is exposed. It consists of colourless coarse-crystalline quartz, centimetric monomineralic dark prismatic riebeckite (locally fibrous and/or with bluish luster) and platy ilmenite (both minerals confirmed by X-ray diffractometry). The vein has a zig-zag pattern trending almost N 10–20°E over about 5 meter long. It is composed of en-echelon right- stepping tension gashes linked with shear fractures. The gashes are filled dominantly with the quartz and occasionally with the riebeckite and ilmenite. The pattern of the fractures and mineral filling suggests that they formed in brittle-ductile transitional conditions. A brittle fracture analysis and tectonic stress inversion was performed, using the orientation of both the tension gashes and the shear fractures, and processed with the Win-Tensor program. Results show that they formed in a transtensional stress regime, with ENE-WSW horizontal extension. This vein thus suggests segregation, remobilization and migration of fluids in cracks and fissures opened by extensional tectonic activity giving rise to neocrystallization of minerals in the vein.

⁴⁰Ar-³⁹Ar dating of the monomineralic riebeckite, devoid of any deformation, has given one single plateau age for the crystallization of the riebeckite of 524.6 ± 4.6 Ma. This age thus dates the tectonic event (tension gashes and shear fractures under transtensional regime) corresponding to late-orogenic extension after the main 566 Ma ENE-WSW Pan-African compression that structured the WCB. Whether the 525 Ma event also relates to extensional collapse, exhumation and/or lateral escape post-dating the AWCO compressional history is debatable.

Finally, in the Matadi area and adjacent NW Angola (Noqui-Tomboco map sheet) abundant sub N-S trending lineaments truncate and off-set Pan African regional fold structures. Field data suggest that they formed under brittle regime. The study of their significance is still in progress (Delvaux et al, this meeting).

Xixano copper–zinc mineralization and its significance for geological evolution of northern Mozambique

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Abstract

The Xixano Complex in the north of Mozambique is a N-S trend elongated geologic structure, confined within Mesoproterozoic rocks of Nairroto/Montepuez and Marrupa gneissic Complexes, which outcrops on its southern edge and truncated by the NE-SW trending Lúrio Belt. The Xixano Complex consists of metasupracrustal rocks enveloping predominantly mafic igneous and granulitic rocks which are easily distinguishable on the satellite and geophysical images due to its high radiometric signature. The Complex comprises meta-sediments and meta- volcanics, which were strongly deformed, metamorphosed to granulite grade and locally migmatized. On the basis of recent field data we present a re-interpretation of the lithostratigraphy and propose a model for Copper-Zinc ore formation within regional tectonics framework. In this study, 4 samples were used for Pb/Pb isotopic analyses, 10 for REE and 50 for petrographic study. An additional set of 229 chemical analyses of surface and drill core samples with major and trace elements were also considered.

The data set of 229 chemical analyses was examined for hydrothermal alteration trends and two trends were defined on the diagram, regional diagenetic and hydrothermal alteration. The hydrothermally altered trends show AI from 78 to 80 and CCPI from 83 to 98. For estimation of origin, the majority of samples plotted on the Zn/Cu area, on the ternary diagram of Zn-Cu-Pb. Out of 229 samples, 37 plotted on the ternary plots of gahnite end members showing two fields: metamorphosed massive sulphide deposits and S-poor rocks in Mg-Ca-Al alteration zones and metamorphosed massive sulphide deposits in Fe-Al metasedimentary and metavolcanic rocks.

Petrographic examination showed that part of biotite is filling the fractures of the sulphides and silicates, indicating that they crystallized after sulphides and during metamorphic and deformation phase. Corona textures of gahnite around sulphide are visible, indicating the formation of gahnite as a result of sulphide consumption during metamorphism. A second phase of garnet recrystallization was also observed in combination with biotite and was interpreted as formed during retrograde phase. Metamorphic assemblages are characterized by gahnite-garnet - biotite- (sillimanite) and Garnet-sillimanite-cordierite.

The Pb isotope study indicate and an age of 881 Ma for sulphide mineralization and the Plumbotectonic model suggests orogenic lead, probable mobilized during a continental rifting as a consequence of Marrupa/Nairroto opening during the initiation of Neoproterozoic continental rifting or juvenile ocean floor deposits, with melting of hydrated mafic crust, as demonstrated by low HFSE (Zr < 200 ppm) in the felsic rocks and Pb isotope behavior.

The deposit is interpreted as metamorphosed VMS. The study concluded that the cataclastic, annealing and fracture-filling textures in pyrite represent the granulite facies at 735 Ma and suggest that the precipitation of sulphide is prior to the referred metamorphic event.

Origines tectoniques et extra-terrestres des déformations observées dans le secteur Pouma-Boumnyébel (Centre-Littorale, Cameroun)

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Abstract

Le secteur Pouma-Boumnyébel est situé dans la zone de transition entre les zones mobiles éburnéenne et panafricaine d'âges paléoprotérozoïque et néoprotérozoïque respectivement. Au Sud de ce secteur se trouve le grand cratère de Messondo. L'objectif est de caractériser le régime de déformation dans chacune de ces deux unités lithostratigraphiques. Les résultats obtenus font ressortir sur le plan géomorphologique deux unités morphotectoniques affectées par des processus morphogénétiques différents à savoir : le domaine éburnéen et le domaine panafricain. Sur le plan régional, le secteur Pouma-Boumnyébel se situe dans un grand réseau de cisaillements dont les directions principales sont NE-SW, E-W et NW-SE avec une polarité générale dextre. Les matériaux et les fractures ont subi une rotation de 20° vers la gauche pour le cisaillement dextre et vers la droite pour le cisaillement senestre. La carte de fractures montre deux systèmes de cisaillements de Riedel orientés NE-SW et NW-SE où R et R' forment l'angle de 2Ø voisin de 60° en admettant l'axe Z comme bissectrice. Et Z fait un angle de 45° avec la direction du cisaillement général. En plus le système NE-SW présente deux directions de décrochements senestres en relai à droite: N-S, NE-SW et deux familles NW-SE en relai à droite senestre et en relai à gauche dextre, tandis que le système NW-SE montre deux directions de décrochements dextres en relai à gauche dans les sens NW-SE et N-S. A toutes les échelles, les boudins asymétriques, les plis et les filonnets sont affectés par un cisaillement senestre orienté E-W et NE-SW qui rejoue dans le sens dextre. Les caractéristiques du système de Riedel où P et R font un angle entre 25 et 35°, P et R' forment un angle variant entre 88 et 95° et R et C font un angle de 10 à 20° indiquent un régime de cisaillement simple classique. Deux familles de failles décrochantes sont identifiées : une première famille senestre, senestro-normale à senestro-inverse avec basculement des matériaux vers le NE et la seconde dextre à dextro-normale avec basculement des blocs vers l'WSW. Au niveau des cours d'eau deux directions de fractures NNE-SSW et WNW-ESE s'entrecoupent et donnent naissance à des chutes liées à la structure <<en marche d'escalier>>. Cette structure serait la conséquence d'une succession de failles normales liées à une ouverture ou rifting. Le jeu du cisaillement, les failles normales, les failles décrochantes, les failles mixtes, et la rotation des axes de déformation sont simplement le reflet d'un état des lieux chaotique lui-même généré par un ou plusieurs contextes de déséquilibre qui sont généralement dus au désordre engendré par la mise en place d'un autre contexte plus tardif de métamorphisme de choc. Une première phase de fracturation aurait eu lieu pendant les chutes des météorites avant la période libérienne. Le fait que les teneurs en Iridium soient anormalement élevées (de 4000 à 240000 fois la valeur en Iridium dans la croûte terrestre : 0,00003-0,00005 ppm) implique l'influence de l'impactisme dans ce secteur.

Les brèches polygéniques dans l'astroblème complexe de Leboudi-Minkoameyos : une signature pétrographique d'un impact météoritique et d'un enrichissement ferrifère des matériaux locaux suite à la chute d'une sidérite d'un kilomètre de diamètre dans la zone de Yaoundé (région du Centre-Cameroun)

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Abstract

L'astroblème complexe de Leboudi-Minkoameyos est une structure circulaire multi-anneaux de 20 km de diamètre et d'une profondeur d'environ 500 m. Situé à l'Ouest de la ville de Yaoundé au point de coordonnées 03°52'34"N; 11°24'23"E ; 838 m d'altitude, ladite structure présente deux types pétrographiques majeurs à savoir : les gneiss et les migmatites qui forment la roche trame, et qui affleurent sous forme de dômes. En outre, on distingue des pyroxénites, des grenatites, des amphibolites et des péridotites. Une pétrographie particulière recouvre les affleurements gneissique et migmatitique sur de larges étendues et sur plusieurs mètres d'épaisseur. Il s'agit des brèches polygéniques. Ce sont des roches métamorphiques de couleur mixte (rouge, jaune, blanc, noire), de forme aérodynamique, de taille centimétrique à métrique, comprenant une proportion variable de cristaux de quartz et de feldspaths noyés dans une matrice fine, amorphe et riche en fer. La texture vésiculaire de ces blocs faite de nombreux canaux à bordures ferrifères observés à la périphérie et à l'intérieur de ces blocs, témoignent d'un dégazage important. Cet ensemble forme une structure bréchifiée extrêmement solide et difficile à briser. La forte densité de ces matériaux est due à l'importante teneur en fer qu'ils renferment et qui apparaît parfois sous forme de lamelles dans certains blocs. La structuration pétrographique de ces brèches y compris leur enrichissement en fer, prouvent qu'ils proviennent d'un impact météoritique d'une sidérite d'un kilomètre de diamètre sur le socle métamorphique de Yaoundé. Les PDF's affectant les grains de quartz scellés dans ces blocs par le ciment sombre amorphe en sont un argumentaire majeur de validation d'un tel impact météoritique. La propagation des ondes de choc et de relaxation responsables de la compression, de la décompression et de l'excavation de la roche cible, ont généré de fortes pression (> 200 Gpa) et température (~ 4000°K), au point d'impact, à l'origine de la formation de l'astroblème complexe. En outre, ces ondes ont provoqué la désintégration et le mélange des matériaux locaux et sidéritique, l'excavation du sol, la fabrication mécanique des brèches et l'éjection des produits à des vitesses supérieures à celle du projectile (sidérite).

poster

O1

**Crustal Evolution
of Africa value**

Les figures de Neumann, preuves de l'existence des reliques météoritiques dans les coulées sombres riches en Fer dans les localités d'Etong et Nomalé (région du Centre-Cameroun)

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Abstract

Connues pour leurs aspects sombres et fondus, les coulées basiques denses des localités d'Etong (4°41'05"N; 10°54'07"E) et Normalé (4°46'27.35"N; 10°54'33.7"E) ont une faible répartition spatiale. C'est une gamme de roches unique en son genre, dans un contexte géologique où les roches du socle sont constituées essentiellement de quartzites, de gneiss, et des brèches à quartz.

Ces coulées sont disséminées sous la forme de petits blocs multiformes, de dimension centimétrique, dans les plantations, sur les versants du chaînon Boal (4°46'59.2"N; 10°54'33.7"E) dans la localité de Nomale, et sur les versants des chaînons du cratère d'Etong. Ces lithologies assimilables aux fontes métalliques des forgerons, présentent des vésicules et des petits cristaux de quartz noyés dans une matrice vitreuse. Les dites cavités et cristaux de quartz démontrent respectivement, un dégazage des coulées au contact de l'air, et une contamination du matériau basique avec le socle acide de nature quartzitique.

Des études microscopique et géochimique de ces roches révèlent une texture vitreuse riche à 71% de fer, dans laquelle sont noyés quelques cristaux vitrifiés de quartz, et où s'illustrent surtout, des enclaves de réseaux de lignes subparallèles encore appelés lignes de Neumann. Observées sur des sections de météorites ferreuses (hexaédrites, octaédrites), les dites lignes, prouvent l'existence d'un lien étroit entre ces coulées massives denses et un géocroiseur issu d'un des réservoirs de notre système stellaire.

Ce lien étroit se traduit par une chute d'une immense météorite ferreuse sur le socle quartzitique, suivie d'un phénomène de fusion crustale, d'une remobilisation, et d'un enrichissement en fer dans des coulées initialement produites au cours du volcanisme fissural d'âge Tertiaire ou Crétacé. Les conditions de température et de pression ayant régné au cours de l'impact du géocroiseur sont respectivement de l'ordre de 1000°C et 10 gigapascals. Les coulées sombres et massives de Nomale et Etong, constituent donc une mémoire géologique de l'histoire violente de notre système solaire, mais aussi une preuve incontestable du rôle des météorites ferreuses dans l'évolution de notre socle en particulier celui des localités de Nomale et d'Etong.

Multidisciplinary characterization of serpentinites, implication to the geodynamic evolution of the Touareg shield in the Neoproterozoic

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Abstract

Chains of deeply serpentinitized peridotites are exposed along narrow shear zones in the Pan-African belt of the Western Hoggar (Algeria). These rocks were interpreted as altered mantle rocks marking the sutures between blocks originally separated by oceanic domains. Through a multidisciplinary approach, we investigated several representative serpentinite bodies to decipher the nature of their mantle protolith and shed light on their origin and significance.

Two episodes of serpentinization corresponding to deformation episodes have been recognized. First, a high temperature interaction of the peridotites with hydrothermal fluids (at 400–600°C) resulted in an episode of almost total serpentinization. Antigorite is the sole stable serpentine mineral, which shows a mesh textures indicating that serpentinization probably occurred in a static environment. A second, low temperature, episode (200°C) is revealed by lizardite veins and bastite along pyroxenes cleavage. These latter fill joints and fractures of olivine and clino/ortho-pyroxene megacrystals that resisted to alteration, resulting in a pseudomorphic texture. These minerals point to serpentinization by seawater. In addition, talc rich layers developed along normal faults pointing to a lubrication of the faults planes by fluids that made exhumation of serpentinites easier. Evolution under decreasing temperature is also underlined by magnetite and ferrian chromite. Finally, a late episode of carbonation, characterized by the precipitation of magnesite in veins has occurred.

Field data suggest that the serpentinite massifs were tectonically emplaced, first in an extensional EW setting associated with a shallow eastward dipping decollement fault. Then, they were reworked in a N-S transpressive tectonics that affected the whole Hoggar massif during the Panafrican orogeny.

Major and trace element compositions of the serpentinites are roughly consistent with a mantle origin but further comparison with mantle rocks is hampered by hydrothermal alteration. Calcium was severely leached from the samples whereas several incompatible elements – notably U and the Light Rare Earth Elements (LREE) – were enriched. Eu anomalies, both positive and negative, and low Zr/Nd values negatively correlated with U/Th indicate that the Middle REE (MREE) were also strongly modified by alteration. In contrast, the Heavy Rare Earth Elements (HREE) seems to be stable consistent with the mantle array suggesting that they have preserved the composition of the peridotite protolith. Sc and the High-Field Strength Elements Nb, Ta, Zr, and Hf also probably preserved their original contents. Based on the low Al_2O_3 and HREE (0.5 - 1% Al_2O_3 ; 0.01 - 0.08 chondrite-normalized Yb), the analysed serpentinites are akin to the harzburgite and may therefore represent lithospheric mantle from oceanic or back-arc basins.

These results suggest a mantle origin for serpentinites in the Western Hoggar, which progressively intruded the crust as a result of successive deformation episodes under decreasing temperature, including hydrothermal processes.

Brittle faulting on the western side of the Congo Basin between Kinshasa and Brazzaville may have caused the capture of the Congo River system and its connection to the Atlantic in the Oligocene

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Abstract

After major submarine erosion in the Early Oligocene, sedimentation in the deep-sea Congo fan on the African Atlantic margin started at about 30 Ma ago, marking the capture of the Congo Basin drainage system by the lower Congo River, and its connection to the Atlantic Ocean through the West Congo Belt. This is marked by an important increase in terrigenous supply, related to widespread changes, generally discussed in terms of climatic, oceanographic or epeirogenic (of the African continent) factors. Another factor that has not been explored yet is that it could be of tectonic origin.

The point of capture of the Congo Basin drainage system is just below the Stanley Pool, between Brazzaville and Kinshasa, where the hard Early Palaeozoic arkosic sandstones of the Inkisi Group outcrop. This is marked by a series of rapids in which the course of the river is guided by two sets of prominent fractures that affect the Inkisi arkoses: a NNW-SSE and a NE-SW set. The last set is also well expressed in the overlying Cretaceous to Paleogene aeolian sands, indurated by silicifications on top.

A detailed analysis of the fractures allows to reconstruct the tectonic stress evolution responsible for their formation by fault-kinematic and palaeostress analysis. We have identified two major brittle events, each one beginning by the development of tension fractures under a transtensional stress field and evolving into strike-slip faulting. The older system which corresponds to a NW-SE horizontal compression do not seem to have affected the entire aeolian sands, while the youngest system, related to an E-W to ESE-WNW compression affected the indurated part of the aeolian sands. These events appear to be of regional importance as large topographic lineaments of similar orientation as the two fracture sets are observed on a large part of the Atlantic margin between the ocean and the Congo Basin. The source of tectonic stress that generated these fractures is believed to be related to the opening of the Atlantic Ocean. The first stage could be related to the initial South Atlantic rifting and development of the Albian-Aptian Western-Central African Rift (Benue Trough...) or to Late Santonian compressional event recorded in Northern Africa. The second stage could be driven by ridge push forces related to the drifting of the opening of South Atlantic. The activation of the NE-SW fracture set during this second stage is proposed as a driving mechanism that controlled the capture of the Congo River system through the West Congo Belt, linking it to the Atlantic Ocean and initiating sedimentation in the Congo deep-sea fan. In this view, the development of this second set of fractures could be of early Oligocene age.

Linking the reworked Rhyacian basement of Western Gondwana: U-Pb evidence for Kimezian Supergroup correlations

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Abstract

The West Congo Belt together with its counterpart located in Brazil, the Araçuaí orogen, represents a Pan African-Brasiliano orogenic system developed within an embayment shaped into the Congo-São Francisco palaeocontinent. The Araçuaí-West Congo Orogen basement evolved from the assemblage of Archean and Paleoproterozoic crustal blocks during a Paleoproterozoic orogenic process that lasted approximately between 2.2 and 2.0 Ga. This event marked the consolidation of San Francisco-Congo continental block that was probably part of an extensive Paleoproterozoic continent (e.g. Atlântica Palecontinent). The ancient Archean cores from San Francisco and Congo were amalgamated along an orogenic belt know as Itabuna-Curaçá-Salvador in Brazil, and Eburnean in Africa. The reconstruction of this orogenic system was possible along a cratonic connection on both sides of the Atlantic Ocean, the Bahia-Gabon cratonic bridge: a bond that remained from Paleoproterozoic to Mesozoic and was not deformed by the Neoproterozoic orogeny. However, the reconstruction becomes much more complex in the dismembered and reworked Araçuaí-West Congo orogen basement, where the units are exposed in the form of gneissic-migmatitic complex, constituting highly deformed autoctonus to para-autoctonus terrains. U-Pb data for Kimezian Supergroup plutonic bodies provide ages ranging between 1.9 and 2.1 Ga. The plutons Les Saras and Güeña are interpreted as calcium-alkaline intrusions related to the building of a magmatic arc in continental margin. Also suggest an active continental margin environment for this Paleoproterozoic magmatism (2083-1915 Ma). A plausible correlation to available data is the Mantiqueira Complex. Both Mantiqueira and Kimezian are probably related to two orogens that developed along the banks of Archean cratons nuclei of the São Francisco and Congo. The orogenic evolution was diachronic; magmatism in the Mantiqueira Complex expires on ca. 2041 Ma, but it extends to ca. 1915 Ma in Kimezian region. Those complexes were separated by a large ocean with unless one island arc, the juvenile Juiz de Fora-Pocrane complex - Rhyacian reworked basement of the Araçuaí Orogen, with crystallization ages ranging from 2.08 a 2.19 Ga. Those complexes disclose an intricate and prolonged magmatic and metamorphic evolution prior to the Pan-African tectonic reworking. Those Paleoproterozoic belts represent the external sector of a larger orogen whose internal zones are preserved in the cratonic bridge that runs along the eastern side of the SFC facing the Atlantic Ocean. Evolution of the Brasiliano-Pan African Araçuaí-West Congo Orogen disrupted and deeply reworked a segment of this Paleoproterozoic orogens to the south of the cratonic bridge.

The Araçuaí (Brasiliano) - West Congo (Pan African) orogenic system: an updated GIS compilation

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Abstract

The Araçuaí (Brazil) - West Congo (Central Africa) Orogen is a branch of the Brasiliano - Pan African orogenic system formed during the Gondwana assembly in late Neoproterozoic and early Palaeozoic times. Since ca. 250 Ma after Pangaea breakup and sea-floor spreading, several segments of the Brasiliano-Pan African orogenic system have been exposed on both sides of the southern Atlantic ocean (e.g. Araçuaí, Ribeira and Dom Feliciano belts in South America; West Congo, Damara-Kaoko, Gariép and Saldanha belts in Africa). The Araçuaí and West Congo belts correspond to the northernmost branch of this orogenic system. Both belts are counterparts of a single, Wilson cycle-related orogen evolved in the embayment outlined by the São Francisco and Congo cratons.

Problems arise with understanding the geodynamic processes controlling the roughly symmetric geometry as well as the peculiar confinement of the orogen. To clarify this, a GIS-based compilation to create a 1:1 million restitution of both complementary Araçuaí and West Congo counterparts in their original Gondwana position is in preparation. Work started in 2017 for the GEOSUDESTE 2017 initiative.

We present here the first version of the compilation for the African – West-Congo part, spanning Gabon, Rep. Congo, DR. Congo and Angola, based on compilation of published geological maps at 1/200.000 scale and smaller, completed with recent fieldwork results from the authors respectively DR. Congo, R. Congo and Gabon.

The integration is based on a proposed uniform lithostratigraphy for the belt, by correlating the mapped units in each country to a formalized sequence matching current lithostratigraphic rules and insights.

This formalized lithostratigraphy was compiled to reflect published works since 1970 and results from recent field work in DRC, Rep. Congo and Gabon by MRAC and BRGM that are presented in other contributions in this colloquium under theme 1. It aligns and amends the most recently published West-Congo Supergroup lithostratigraphy of Gabon, Rep. Congo and Angola to the lithostratigraphy of the West Congo Supergroup in DR. Congo as it is there, in the Kongo Central province (formerly Bas-Congo), that the most complete section for the entire Supergroup can be observed.

Caracterisation des deux regimes de compressibilite du metamorphisme de choc dans les mineraux à charpentes des lames minces a linte (Grand Mbam-Cameroun)

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Abstract

La zone de Linté est située dans le grand Mbam (Région du Centre-Cameroun). Elle est délimitée au Nord et à l'Est par le plateau de l'Adamaoua, à l'Ouest par les hauts plateaux et au Sud par le plateau sud camerounais. Le secteur d'étude est quadrillé entre les latitudes 4°30'0.00" et 5°00'00"N puis les longitudes 11°30'00" et 12°00'00" E. Le socle est essentiellement composé de granites, métagranites et des gneiss. Les études menées sur le terrain ont permis de confectionner des lames minces sur des échantillons de granites et gneiss. Les observations au microscope optique de ces lames minces ont mis en exergue : des microstructures planaires, les phénomènes d'isotropisation ou verre diaplectiques et de fusion sur les mineraux à charpentes que sont le quartz et feldspaths. Il est à noter que ces microstructures planaires sont les planar fracture ou PF's qui sont des multiples fissures parallèles et entrecroisées espacés de 15 à 20 µm. Leur apparition exige des conditions thermobarométriques comprises entre 5 et 8 Gpa pour la pression et 100°C pour la température. Nous avons en plus des planars fractures, les planars Deformations Features ou PDF's qui sont les marqueurs de la désorganisation des plans cristallographiques comprimés. Ils sont parallèles et régulièrement espacés de 2 à 10 µm. Leur apparition nécessite une pression de 10 à 35Gpa. Les déformations cristallographiques de ces mineraux ainsi que ces phénomènes y afférents, sont une preuve tangible du passage de l'onde choc dans les granitoïdes et les métamorphites de la zone de Linté. Les microstructures et les transformations minéralogiques ainsi observées sont la rémanence du metamorphisme de choc. Elles ont permis de définir deux régimes de compressibilité sur la base de la courbe P-V de Rankine Hugoniot. Nous avons entre autre, le régime de compressibilité de basse pression matérialisé par les microstructures planaires, et le régime de compressibilité de haute pression révélé par les phénomènes de verres diaplectiques et la fusion du quartz. Pour les verres diaplectiques, les mineraux affectés ici présentent des plages de vitrification denses non biréfringentes tout en conservant leurs structures originelles. Les quartz sont transformés en verre Libyen et les feldspaths en Maskelynite ou verre thertomorphique. La pression nécessaire pour l'acquisition d'un tel phénomène dans les mineraux est supérieure à 37 Gpa. En ce qui concerne le phénomène de fusion du quartz, celui observée dans la présente étude est différent d'un équilibre normal ; car seules les parties du minéral ayant atteint leur point de fusion coulent.

The Silet superterrane (Western Hoggar, Algeria): a collage of exotic terranes

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Abstract

The Silet superterrane, located in the western Hoggar (Tuareg shield), is classically considered as a juvenile island arc accreted to the LATEA metacraton (Liégeois et al, 2003). Current data show that the Silet superterrane results from an accretion of several exotic terranes made up of Neoproterozoic mantle and oceanic formations, overthrust onto the LATEA western margin during the 650-630 Ma climactic shortening episode. The terranes form two north-south trending narrow strips, separated by the Tin-Dahar Fault, a strike-slip shear zone displaying talcschists, amphibolites, and serpentinites. The eastern group, referred to as NISS, yields negative Nd isotopic signatures ($-2.91 > \epsilon_{Nd} > -8.10$). By contrast, the western group, referred to as PISS, yields positive Nd isotopic signatures ($+0.52 < \epsilon_{Nd} < +4.57$) (Bechiri-Benmerzoug, 2009).

NISS is made up of two terranes: (1) Taklet-Iharedj terrane and (2) Anou Eheli terrane. They display Pharusian I volcano-sedimentary series, crosscut by high-K plutons, e.g., 839 ± 4 Ma (Caby et al, 1982) Taklet, and TTG batholiths, e.g., 638 ± 6 Ma Eheli. Taourirt A-type granite ring complexes, e.g., Teg'Orak, postdate the final episode of the Panafrican orogeny.

PISS comprises three terranes: (1) Irrelouchem terrane, (2) Tin-Tekadiouit terrane and (3) Tioueïne terrane. Compared to NISS to the east and the In-Teidini terrane to the west, PISS is characterized by juvenile nature and various rock types. The Pharusian I volcano-sedimentary series are crosscut by TTG plutons, e.g., 868 ± 8 Ma (Caby et al, 1982) Timesselarsine and 742 ± 5 Ma Tamteq. The ca. 680 Ma (Dupont, 1987) Pharusian II Amded volcano-sedimentary series and Irrelouchem volcanic series are crosscut by TTG batholiths of TTG, e.g., 651 ± 6 Ma Ahambatou and 648 ± 3 Ma Silet. In addition, mafic to ultramafic cumulates gabbro-dioritic stocks and small masses of two-mica granites occur. The entire area is cut by tholeiitic to alkaline doleritic dyke swarms. Ediacaran Taourirt A-type granite ring complexes have zircon crystals yielding positive ϵ_{Hf} values (e.g., Tin-Erit and Tioueïne, Azzouni et al, in preparation).

To sum up, the Silet superterrane is a collage of exotic terranes, comparable to suture areas known worldwide, like the North American Pacific margin.

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A complex paleoproterozoic evolution of Al-Fe granulites revealed by P-T path and geochronology of zircon and monazite in the In-Ouzzal terrane (western Hoggar, Algeria)

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Abstract

The In-Ouzzal Terrane (IOT) is an elongated block North-South and more than 400 (km) in length. Its northern part is 80 (km) in width (at the level of In-Hihaou massif), but thins until complete disappearance to the south towards Malian borders where it is relayed by the Iforas granulitic unit.

The majority of the orthogneiss and paragneiss lithologies of the IOT, present geochemical characteristics of the Archean crust (3.3 - 2.5 Ga). However, its mineral assemblages and structural characteristics were mostly overprinted during the Eburnean (2 Ga) granulitic stage by an ultrahigh temperature (UHT) metamorphism exceeding 1000 °C.

The present study concerns the Al-Fe granulites which outcrop in a little known region at southwestern part of In-Ouzzal in its south-eastern part (Amesmassa area). These granulites are mainly composed by quartz, corundum, spinel, garnet, sillimanite, biotite, perthitic feldspar and ilmenite. Phase relationship and classical thermobarometry coupled with pseudosections calculated in the NCKFMASHTO system suggest a clockwise P-T path. They are also, characterized by prograde evolution at high pressures (800 to 1050 °C and 9 to 11 kbar), and followed by an isothermal decompression (7-6 kbar) then an isobaric cooling to 700 °C. This P-T path is identical to that determined in other regions of the In Ouzzal terrane.

New Laser-ablation U-Th-Pb analyses of zircon and monazite have been realized combined with their internal structures revealed by BSE imaging from four samples of these Al-Fe granulites. The primary results suggest three major events: 1- the existence of at least one metamorphism older than 2.5 Ga, completely obliterated by the paleoproterozoic metamorphism; 2- A high temperature metamorphism between 2.1 and 1.9 Ga during the paleoproterozoic ; 3- a moderate thermal event between 1.8 and 1.75 Ga. These geochronological results are completed and combined with a detailed phase's relationship study of the Al-Fe granulites to discuss the corresponding geodynamic contexts.

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Igneous and Metamorphic Petrology

Crustal anatexis in Ahouli-Mibladen granitoid complex: a window to the middle crust below Moroccan Eastern Variscan Meseta

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Abstract

S-type granites, derived from partial melting of metapelites, are important in the reconstitution and definition of the thermal state of the continental crust. These rocks, and their enclaves and xenoliths record all petrogenetic processes and provide answers to fundamental issues such as the nature of the source materials, partial melting processes, mechanisms of magmatic mixtures and PT conditions prevailed during the processes of partial melting and emplacement.

A large number of granitoid bodies with various nature and dimensions punctuates the Moroccan Variscan belt. The Ahouli-Mibladen complex provides an exceptional opportunity for studying these issues. In this part of Moroccan Eastern Meseta, epizonal Cambro-Ordovician metasediments, are intruded by voluminous massifs of granitoids defining an I-type metaluminous suite (Gabbrodiorites, hornblende-granodiorites, biotite (Bt)-granites) associated to anatectic rocks defining a peraluminous S-type suite. This latter is constituted by migmatites, garnet (Grt) and cordierite (Crd)-bearing granites, Crd-bearing microgranitic dykes and differentiated two-micas leucogranitic stocks of the Poulet and Perdreaux massifs. The “Hill swarm of enclaves” (area 2.5 km²) located NE of the complex consists of a cumulate-like texture Crd-granite containing transported and amalgamated euhedral Grt and metasedimentary xenoliths. Anatectic granites comprises two types of Crd: Crd (X_{Fe}=0.4) associated to restitic Bt (X_{Fe}=0.65) and Crd (X_{Fe}=0.6) participating to the coarse grained texture of the Bt (X_{Fe}=0.7) bearing granitic matrix. They are interpreted as respectively peritectic and cotectic. Grt shows complex zoning profiles in elemental transects and chemical mapping with: i) in the central and middle parts of Grt a bell-shaped profile for Mn, Ca and X_{Fe} and reverse bell-shaped profile for Mg and Fe typical of prograde growth zoning; these parts of the Grt are peritectic; i) in the external part an increase in Mn and Ca, and a decrease in Mg and Fe characterizing a retrograde Grt rim growth.

P and T conditions of the metamorphic and anatectic processes are estimated from pseudosections using *Perple_X* software and associated *Werami* routine. The biotite dehydration melting reaction producing anatectic melt with Crd and Grt as the main peritectic phases would take place under granulitic facies conditions reaching 830-870 °C and 5.3-6.3 kbar. It would allow the formation of a significant amount of peraluminous melts forming, during their ascent and emplacement, the S-type suite.

These new data, in Ahouli-Mibladen complex, constrain the metamorphic and magmatic evolution of the Moroccan Variscan belt. During the Variscan orogeny, the emplacement of mantle derived mafic magmas in large reservoirs at 18-20 km depth leads an isobaric heating and the melting of the surrounding metapelitic photolith. Later differentiated I-type and S-type sets are emplaced concomitantly with limited mixing and mingling during their final crystallization at a depth of 8-9 km estimated from the PT conditions of the contact metamorphism aureole (600°C, 3 kbar).

These results give direct new information about the unknown Moroccan Hercynian mid-crust and allow discussing the nature, the metamorphic state and the age of Paleozoic terranes basement

High-pressure eclogite metamorphic rocks from the egeré terrane (central Hoggar, south Algeria): petrology, geochemistry and P-T path

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Abstract

The Egeré terrane (Central Hoggar, South Algeria) reveal witnesses of high-pressure metamorphism featuring both mafic eclogites and kyanite-bearing metapelites. The mafic eclogites are observed as large lenses embedded in marble, metapelite and quartzite, and their petrological investigations display that the high pressure primary paragenese consist of omphacite-garnet-rutile-quartz and epidote. Garnet is zoned with Fe-rich core and Mg-rich rim. Through decompression of these rocks, omphacite destabilized into very thin symplectites of albite and clinopyroxene in addition to the development of pargasite + plagioclase kelyphites and finally the formation of anhydrous plagioclase+diopside coronas marked the end of the retrograde path. Furthermore, porphyroblastic omphacite has a jadeite content of up to $X_{Jd} = 0.36$, which is the highest yet observed for eclogite facies rocks from the Tuareg Shield.

Besides the abundant mafic rocks, metapelites also preserve high-pressure relics. The peak HP metamorphic assemblage is inferred to have been garnet-kyanite-phengite-quartz-rutile and k-feldspar. Garnets characterizing the studied samples are strongly zoned particularly in grossular, and exhibit distinctive Mn bell-shaped profiles related to their prograde evolution. Furthermore, phengitic white micas are featured by mineral composition that suggests crystallization under relatively high pressure conditions. A number of retrograde reactions that took place in this type of metapelites are inferred to have developed between the thermal peak and the solidus along decompression.

The geochemical results reveal an E-MORB affinity for the eclogite's basaltic protoliths, whereas the metapelitic protolith is similar to the North American Shale Composite (NASC) and to the Post-Archean Australian Shale (PAAS); furthermore, the source of sediments is likely a mixture of felsic and intermediate rocks deposited predominantly in a passive margin

The textural observations noticed in both mafic and felsic rocks are interpreted via the application of P-T pseudosections. These phase diagrams were calculated in a $Na_2O-CaO-K_2O-FeO-MgO-Al_2O_3-SiO_2-H_2O-TiO_2-Fe_2O_3$ (NCKFMASHTO) system. Detailed assessment indicate that the Egeré rocks followed a clockwise PT path, with a prograde trajectory till the metamorphism peak conditions (18 kbar and 650-700 °C), that was followed by strong decompression down to around 8-9 kbar and 700-750 °C. This evolution is related to collision episode following the continental subduction during the Pan-African orogeny.

Cadomian magmatism and metamorphism at the Iberian Massif (Western Europe, Central Portugal)

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Abstract

Late Neoproterozoic to the Early Cambrian sutures are related to the collisional events that occurred during the assembly of the supercontinent Gondwana. In the Iberian Massif (Central Portugal, near the Abrantes area) a Neoproterozoic suture is exposed at the contact between the Ossa-Morena Zone and the Central Iberian Zone, where a well preserved Cadomian basement crops out. The Cadomian arc magmatism generated calc-alkaline magmas of acid composition and peraluminous character, at 692 ± 77 – 60 Ma, 569 ± 3 Ma and 548 ± 4 Ma. Their trace element contents, identical to the bulk continental crust, suggest a mature continental arc. Their Sr and Nd initial isotopic signatures, $(^{87}\text{Sr}/^{86}\text{Sr})_i = 0.7057$ to 0.7117 and $\epsilon\text{Ndt} = -5.2$ to -8.1 , indicate partial melting of metasedimentary and meta-igneous crust in different crustal levels. The range of ϵNdt isotopic signatures and TDM model ages (1.53 to 1.69 Ga) reflect the involvement of old crustal sources, which is characteristic of Cadomian type-terranes. Paleoproterozoic and Neoarchean inherited zircons (1.9–2.8 Ga) are consistent with a West African craton provenance, which is in agreement with Late Neoproterozoic reconstructions that place the Ossa-Morena Zone and other Cadomian-type terranes adjacent to the West African craton. The final phase of the Cadomian arc magmatism (544.2 ± 1.7 Ma; 544.3 ± 2.5 Ma; 544 ± 2 Ma) is represented by calc-alkaline magmas of basic to intermediate compositions with intraplate and active continental margin affinities. Their Sr and Nd initial isotopic signatures, $(^{87}\text{Sr}/^{86}\text{Sr})_i = 0.7053$ to 0.7084 and $\epsilon\text{Ndt} = -2.9$ to -3.4 , indicate partial melting of meta-igneous lower crust and mantle. They exhibit old TDM model ages from 1.22 to 1.81 Ga. Coeval magmatism is observed in several areas of the Avalonian–Cadomian belt. Evidence for a major metamorphic event near the Late Neoproterozoic–early Cambrian boundary (ca. 540 Ma) is preserved in metamorphic monazite (540 ± 3 Ma; 540 ± 5 Ma; 539 ± 2 Ma) and in metamorphic zircon (539 ± 3 Ma). P-T phase equilibria modelling indicates metamorphism under amphibolite facies conditions, near the transition to the granulite facies ($P = 7$ – 8 kb, $T = 640$ – 660 °C). It is interpreted as the continental arc accretion of the Ossa Morena Zone with the Iberian Autochthon passive margin (future Central Iberian Zone).

Sr, Nd and Pb isotope systematics of the Neogene Volcanism in the Algerian Tell Belt: new Constraint on the Geodynamic Evolution of the Westernmost Mediterranean

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Abstract

The geodynamic evolution of the Western Mediterranean is closely linked to the spatio-temporal evolution of the Cenozoic magmatism in this region. Here, we present a detailed Sr-Nd-Pb study of Cenozoic volcanism from the external and the internal zones of the Algerian Tell belt, a segment of paramount importance to unravel the Alpine geodynamic evolution of the westernmost Mediterranean. The age of the studied volcanics rocks ranges from 17 to 3 Ma, and covers the temporal and spatial evolution of magmatism from calc-alkaline rocks with a clear signature of subduction (commonly referred as to orogenic magmatism), followed by progressively younger sub-alkaline and alkaline volcanism. On the basis of their major and trace element composition, the Tell Cenozoic volcanic rocks can be classified into three main groups: (1) a Si-poor group that is composed of basalt, trachybasalt and basaltic trachyandesite; (2) a Si-intermediate group —ranging in silica from 56 to 66 wt. %— that is composed of andesite, dacite, trachyandesite et trachydacite; and a (3) Si-rich group —with silica contents generally greater than 66 wt.%— that is constituted by trachydacite, dacite and rhyolite. The Si-poor group occurs only in the External zone and it is characterized by non-radiogenic $^{87}\text{Sr}/^{86}\text{Sr}$ ratios, high initial $^{144}\text{Nd}/^{143}\text{Nd}$ ratios, significant variation of $^{206}\text{Pb}/^{204}\text{Pb}$ and $^{207}\text{Pb}/^{204}\text{Pb}$ ratios, and relatively constant $^{208}\text{Pb}/^{204}\text{Pb}$ ratios. The Si-intermediate and Si-rich groups from the Internal and External zones show substantial differences. The $^{206}\text{Pb}/^{204}\text{Pb}$ ratios of External zone volcanism are relatively constant [18.68–18.86], while they vary significantly in the Internal zone volcanism [18.55–18.92]. On the other hand, the initial $^{207}\text{Pb}/^{204}\text{Pb}$ and $^{208}\text{Pb}/^{204}\text{Pb}$ ratios in the Internal zone volcanism [38.81–38.95] are significantly higher than those of the External zone [38.68–38.84]. These differing isotopic signatures reflect variable source contamination by subducted sediments similar to those now occurring in the Oligocene Flysch units, and crustal contamination by Kabylia crust in the Internal zone volcanism. A deeper primitive asthenospheric mantle source in the western External zone is increasingly patent in progressively younger Silica-intermediate and -poor volcanism. This spatio-temporal evolution of the Cenozoic evolution of the Tell magmatism is intimately correlated with the deep structures imaged by seismic tomography in this region that show the importance role of slab tearing in the western Tell external zones, and remnants of two subducted slabs beneath the eastern Tell.

Petrology, geochemistry and U-Pb zircon geochronology of Neoproterozoic granites from the Pan-African orogenic belt in southeastern Togo, West Africa

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Abstract

Granitic bodies from the eastern side of the Pan-African Dahomeyide suture zone, i.e. close to the Togo – Benin border, have been studied from petrological and geochemical analyzes, and from U-Pb zircon ages determination.

Petrologically, the studied granites from two main plutons, Sihimé and Glito, are generally massive, although slightly anisotropic, and medium- to coarse-grained. The Sihime pluton is composed of biotite-amphibole bearing granites and subordinate biotite-rich granites with schlieren structures, whereas Glito pluton consists of two-mica granites and display a weak foliation along margins. Granites from Sihime contain K-feldspar, quartz, plagioclase (An₁₋₁₈), annite and ferro-edenitic amphibole with accessory minerals such as zircon, allanite, apatite and titanite. Granites with schlieren structures from Sihime pluton display the same mineralogy but containing siderophyllite and rare muscovite. The Glito pluton granites differ of those from Sihime pluton by the occurrence of microcline phenocrysts up to 2 cm long, which are embedded in a medium- to fine grained-matrix of quartz, oligoclase destabilised into sericite and epidote and show mymerkitic textures.

Geochemically, all granites are enriched in silica and total alkali, and depleted in MgO and CaO, high LILE content (i.e., K, Rb, Th), display highly-fractionated REE patterns with LaN/YbN ranging from 9.64-16.07 and 2.91-5.59 for Sihime and Glito granites, respectively. The rocks show well-pronounced negative Eu anomalies (Eu*/Eu: 0.45 and 0.25 – 0.52 for Sihime rocks and Glito granites, respectively). These granites are also characterized by metaluminous to weakly peraluminous features. Granites from Sihime belong to alkaline or shoshonitic series and display a slightly ferroan character, whereas granites from Glito pluton are magnesian with calc-alkali nature and belong to high-K calc-alkaline to shoshonitic series. Therefore, the studied granites yield essentially a typical I-type signature rather than S-type chemical characteristics.

Granite samples were prepared at the Geochronological Research Center in São Paulo University, Brazil. Isotopic data were obtained using a NEPTUNE inductively coupled plasma-mass spectrometer (LA-ICP-MS) in situ zircon analyses coupled with a 193 nm excimer laser ablation system.

U-Pb dating of zircons from the granites of Sihime and Glito yielded ages ranging from 600 Ma to 583 Ma which are interpreted as crystallization ages. The granite samples from a more southern location in the Sihime area yield the youngest U-Pb zircon ages (593.1 ± 6.6 Ma, 583.0 ± 3.4 Ma), whereas the oldest Neoproterozoic ages (600.8 ± 1.4 Ma) were obtained in northern location at Glito area. These ages are younger than the metamorphic peak age of the suture zone rocks (Affaton et al., 2000), and are in agreement with previously published zircon ages of granitoids from the Benino-Nigerian shield in Benin (Adissin, 2012). In Togo, these are the first U-Pb zircon ages to document Neoproterozoic granitoids considered to be associated to the post-thickening thermal relaxation and possibly to transtension tectonics during the late panafrikan orogenic events.

Preliminary petrological inferences on the high-grade metamorphic rocks exhumed by the South Rif Thrust, Prerif, Northern Morocco

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Abstract

The exhumation of deep crustal rocks along major shear zones is common, yet a highly debated subject, particularly when occurring during recent tectonic events. This is the case of the South Rif Thrust (SRT), a significant shear zone analogous to those described at the Betic Cordillera in Spain. The SRT separates two major geodynamic domains in Northern Morocco: a) the Prerif, to the North, mostly composed of Miocenic sedimentary units on top of a stratigraphic sequence continuously deposited since the Triassic; and b) the Western Meseta, to the South, mostly composed of Paleozoic metasedimentary units, correlated with the Iberian Variscan Belt [1]. Associated to the SRT, and exhumed by its activity, there is a dismembered and exotic high-grade metamorphic belt representative of the middle and lower crust. Also in this region, several thermo-mineral waters occur, whose deep circulation can be traced back to the SRT [2].

Detailed geological mapping, structural, stratigraphic and petrographic analyses on this dismembered and highly deformed exotic sequence reveal the presence of low- to high-grade metasediments (including migmatites and felsic granulites), but mostly high-grade metabasic and basic rocks, including amphibolites, mafic granulites and gabbros.

Preliminary geothermobarometry in the mafic granulites provides an important characterization of the infra-crustal conditions of the pre-Alpine geodynamics and of the activity and exhumation along the SRT since the Miocene: a) the mafic granulites endured M1 metamorphic peak conditions of $T = 1030\text{ °C}$ at $P = 8.5\text{ kbar}$, which is consistent with typical conductive continental crust geothermal gradients ($\sim 30\text{ °C.km}^{-1}$); b) M2 retrogression occurred by near isothermal decompression at $T = 820\text{ °C}$ and $P = 3.5\text{ kbar}$, implying an initial vertical uplift of $>18\text{ km}$ of the granulite-facies rocks to very shallow levels; c) during this period, the geothermal gradient in the region surpassed 60 °C.km^{-1} ; d) exhumation and retrogression continued by almost isobaric cooling at $T < 750\text{ °C}$ and $P = 1.7 - 3.0\text{ kbar}$ with an M3 amphibolitization of the granulites after late water inflow.

The overall metamorphic evolution of these deep crustal rocks is compatible with a clockwise P-T path, involving initial fast tectonic exhumation, followed by thermal readjustment to shallower levels. This is consistent with the currently observed geothermal gradients in the area ($\leq 42\text{ °C.km}^{-1}$) [2] which may still be a reflection of the events during the Miocene.

These petrological constrains on the tectonic processes associated with the exhumation of this lower crust segment and the activity of the SRT during the closure of the Alboran Basin are key to understanding the circulation of deep hot waters, which are an important part of the economy of this region in Northern Morocco. Publication supported by FCT- project UID/GEO/50019/2013 - Instituto Dom Luiz.

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The post collisional calc-alkaline felsic volcanism of El Jadida (Moroccan Coastal Block): geochemistry and geochronology

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Abstract

Investigated Ediacarian volcanic rocks of El Jadida Coast correspond essentially to two main types of facies: rhyolite and rhyolitic ignimbrite rock falls blocks. The whole is overlain by a thick Upper Neoproterozoic /lower Cambrian chaotic and dolomitic series.

Rhyolite sample displays a vitreous texture locally cryptocrystalline and contains a mineral association composed of plagioclase, orthoclase, quartz and ferromagnesians completely replaced by opaques. These components are included in a groundmass locally devitrified in a secondary microcrystalline assemblage.

Rhyolitic ignimbrite present different textures (porphyric, eutaxitic, cryptocrystalline) and its mineral assemblage includes plagioclase, quartz, orthoclase, opaques, zircon and xenoliths.

Geochemically, rocks are shoshonitic – to high-K calc-alkaline, peraluminous ($A / CNK > 1.12$) and display features of rocks formed in a post collisional geodynamic context.

They are similar to Ediacaran magmatism found in Morocco (e.g. Tahiri et al., 2010; Belkacim et al, 2017; Ouabid et al., 2017 and references there in), in the Iberian Massif (e.g. Rubio-Ordóñez et al, 2013 and references there in) and in the Pan-African Dahomeyides belt in Ghana, Togo, Benin and Nigeria (Kalsbeek et al., 2012 ; Adissin Glodji ,2012).

Concordant U–Pb zircon data yield Ediacaran mean ages for rhyolitic ignimbrites facies (between 577.2 ± 3.1 Ma and 580.8 ± 1.4 Ma) and rhyolite facies (between 605 ± 11 Ma and 577.7 ± 3.8 Ma).

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Geochemistry, mineralogy and modes of occurrence of scandium in carbonatites and alkaline igneous rocks of Africa

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Abstract

Review of scandium (Sc) geochemical data for rocks of carbonatite and alkaline origin indicate that Sc is present in sometimes anomalous quantities in these rocks. Unfortunately only limited analyses in the published literature include geochemical data for Sc. Inventories such as georoc (<http://georoc.mpch-mainz.gwdg.de/georoc/>) have been utilised as well as unpublished exploration data from a number of recent projects to demonstrate the potential of these rocks to host economic deposits of Sc.

Geologically Sc occurs enriched in certain pegmatites, under-saturated alkaline silicate, carbonatite as well as mafic igneous rocks. Sc may be preferentially concentrated within more mafic units or members of the silicate rocks directly associated with carbonatite. The rock types identified as important hosts of Sc in alkaline complexes include clinopyroxenites, essexites and apatite-enriched hydrated rocks including vermiculites and glimmerites.

Within carbonatite and related alkaline rocks, there is a clear association of Sc with early crystallised mineral phases such as apatite, clinopyroxene, zircon and aeschynite. Sc appears in anomalous quantities (> 50 ppm) in many of the examples investigated (earth crust background 16 ppm). Highly enriched and potentially economic quantities of Sc (250 – 500 ppm) have been identified at the Glenover carbonatite and pyroxenite complex in South Africa, and within the Karingarab carbonatite in Namibia. Enrichment during weathering through supergene processes of regolith development is identified as an important mechanism in enrichment to potentially economic levels of Sc (believed to be 300 ppm). The role of fluorine and chlorine is critical in the transport process of Sc in the weathered zone. The behaviour of Sc during later dissolution and precipitation in the weathering environment may occur independently of the REE.

Presently economic deposits of Sc regarded to be economically viable are located within the weathered laterite surface of mafic lavas, red mud (bauxite residue) and as a by-product of Ni laterite mining. It is proposed that supergene enrichment of Sc over alkaline silicate and carbonatite rocks needs lateritisation processes for this to successfully take place. Understanding this important aspect of regolith development provides another target for further exploration of Sc resources.

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Granulites of the Xixano Complex, northern Mozambique - geology, geochemistry and metamorphic evolution

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Abstract

The Xixano Complex forms a ~NNE-SSW oriented tectonic slice of the Cabo Delgado Accretionary Complex of northern Mozambique, north of the Lurio Belt and forms part of the greater East African Orogenic belt stretching from the Arabian-Nubian Shield to northern Mozambique.

The granulites of the Xixano Complex are dominantly meta-basic in composition with assemblages of Opx+Cpx+Grt+Plag+Qtz+Amph. Additional compositions include meta-peridotitic, meta-troctolitic, meta-pelitic, meta-manganiferous gondite and calc-silicate rocks. Abundant field evidence of dehydration melting is evident in the field in the form of garnet-pyroxene bearing tonalitic gneisses. The meta-peridotitic rocks have an assemblage of Opx+Cpx+Ol+Pl+Spl which form corona textures with plagioclase having a cloudy appearance due to spinel exsolution lamellae. The meta-troctolitic rocks have a mineral assemblage of Ol+Pl+Cpx+Opx and may be related to a younger intrusion. The meta-pelitic rocks have assemblages of Grt+Sill+Spl+Ru and Crd+Spl+Sill+Qtz. The meta-manganiferous gondites have an assemblage of Grt+Cpx+Qtz+Opaques+Graphite with the garnet being spessartine rich. The calc-silicates have an assemblage of Wo+Grt+Cpx+Scp, typical of high grade metamorphism of calcareous sediments.

P-T studies using THERMOCALC from the various assemblages are interpreted to define an initial clockwise near isothermal decompression P-T path at ~9000C from ~12kb to ~8kb after which near isobaric-cooling from ~9000C to ~6000C followed by gradual cooling and decompression.

The bulk rock compositions are interpreted to represent an ophiolitic ocean-floor setting comprising MORB-like metabasic rocks with associated deep water ocean floor pelitic and chemical sedimentary rocks which have been deeply buried and subsequently exhumed during the East African Orogeny and the amalgamation of N. Gondwana.

Limited available geochronological data from the Xixano Complex suggest metamorphism between ~740 and ~640Ma. Depositional ages from carbonates from the Xixano Complex of ~800-750Ma have been reported. Radiogenic isotope Sr-Nd data are juvenile plotting close to 0 with ϵ_{Nd} and ϵ_{Sr} values calculated at 600Ma. Lead isotope data from the sulphides suggest an age of ~880Ma (Cune et al., 2018 this issue).

The radiogenic isotope data are comparable to published and unpublished data from Central Dronning Maud Land, Antarctica (CDML), supporting correlations between rocks of N. Mozambique and CDML. In addition, the meta-manganiferous gondites may be comparable to the spessartine-bearing ferro-manganiferous rocks from Damara-age rocks from the Otjusun area of Namibia. The similar ages of the Xixano Complex rocks and the Damara Orogeny in Namibia support a possible correlation between the Damara Belt and rocks of the Cabo Delgado Complex of northern Mozambique, possibly supporting a continuation of the Mozambique Ocean between the Kalahari and Congo-Tanzania Cratons which has been disrupted by the amalgamation of north and south Gondwana 550-600Ma ago.

African oceanic crust generation in northern Mid-Atlantic Ridge: a contribution from MORB chemistry of the Lucky Strike segment, Azores region

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Abstract

The Lucky Strike Segment (LSS) is one of the eight second-order segments, existent between Pico (~38°N) and Oceanographer (~35°N) major discontinuities of the Mid-Atlantic Ridge (MAR), which at these latitudes separates the American and Africa lithospheric plates. The LSS has a total length of ~65 km, is bounded by two second-order non-transform discontinuities, has a typical morphology of a slow-spreading centre (well-developed rift valley, with rectilinear and subparallel axial valley walls) and shows a great depth contrast along axis, from 1650 mbsl on the central topographic high to more than 3000 mbsl at the ends of the segment.

All LSS lava samples have E-MORB characteristics, but distinct degrees of incompatible element enrichment are observed: the most enriched MORB are spatially restricted to the central topographic high of the segment and are characterized by higher more-to-less incompatible element ratios (e.g. La/Sm: 3.2-3.6; Nb/Zr: 0.34-0.37; K₂O/TiO₂: 0.40-0.68), higher Sr-Nd-Pb radiogenic values and are more volatile-rich (higher H₂O and CO₂ pre-eruptive contents) compared to the rest of LSS lavas (La/Sm: 1.2-1.6; Nb/Zr: 0.12-0.14; K₂O/TiO₂: 0.16-0.28). The least enriched samples are found, along axis, through the entire LSS and have geochemical characteristics that are within the long wavelength scale geochemical variation along the MAR between 31°N and 41°N (“ambient” mantle). Conversely, the central LSS most enriched MORB's establish a local enrichment spike displaced from regional trend, and are interpreted as resulting from melting more-fertile mantle heterogeneities.

The magmas generated in the LSS sub-oceanic mantle (either from the enriched mantle domains or from the ambient mantle) are highly focused, preferentially to the segment centre, by sub-lithospheric processes. In the MAR, this mantle melt supply is thought to occur in a discontinuing fashion (magmatic cycles) because the thermal structure of the ridge is controlled by a more limited transfer of heat and mass from the earth's deep interior to the crust resulting from the slow spreading lithospheric associated rate.

As the heterogeneities form lower solidus domains, they will start to melt deeper in the mantle, but generating lower melt fractions, compared to the ambient mantle. Because of the high pre-eruptive CO₂ concentrations, these enriched magmas will have their density reduced. After reaching the magma overpressure level in the axial magma chamber (AMC), the magmas will be transported to the crust's surface. The limit of neutral buoyancy of these volatile-rich magmas is envisaged to never be reached and, thus, magmas are delivered vertically to segment centre. Further magmatism, originated from melting the ambient mantle, as the magma cycle proceeds, will be aggregated in the AMC, mixed with the most enriched magmas or, alternatively, only evolving through crystal fractionation processes. The disruption of pressure equilibrium of the magmatic system as a result of distensive tectonics, and the subsequent magnitude of internal overpressure in the magma reservoir will control the magma delivery along the Lucky Strike segment, through horizontal dyke propagation.

P-T path and geochronology of granulites from Tamanrasset block (Hoggar, Algeria): evidence of a neoproterozoic deposition and metamorphism.

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Abstract

The high grade unit from the Tamanrasset block (Hoggar, Algeria) is mainly composed of monotonous migmatitic gneisses, with locally still recognizable metasedimentary and metabasite layers. Corundum-bearing amphibolites occur in boudinaged lenses parallel to the foliation in these migmatitic gneisses. Metasedimentary formations consist mainly of biotite-garnet-sillimanite-kyanite metapelites interbanded with scarce calc-silicate rocks and minor olivine-spinel marbles. Metapelites contain numerous lenses of amphibolites, metanorites and garnet-pyroxenites. The metapelites are characterized by compositional layering and a foliation produced by the transposition of earlier compositional layering. Reactional textures in metapelites and garnet pyroxenites supplemented by P-T pseudosections suggest a clockwise P-T trajectory with nearly isothermal decompression. Peak metamorphic pressure-temperatures conditions of 650-700 °C and 13-14 Kbar (high pressure amphibolite facies) were followed by increasing temperature and decreasing pressure to 800°C and 5-6 kbar (granulite facies). In an attempt to bracket the timing of deposition and metamorphism of the metasedimentary unit of Tamanrasset, more than 200 zircons have been analysed in metapelites. Two varieties of zircons have been recognized according to the internal structure of the grains; the first population represents the cores of zoned grains, which are inherited or detrital. They show an age that ranges from 2700 Ma to 670 Ma. This wide range is interpreted by multiple provenances of the detrital grains. Moreover, these cores reveal a high Th/U ratio. The second population includes the new-formed metamorphic zircons and the overgrowths that enclose the inherited cores of the first zoned zircon population. The analyses show an age well constrained at 632 ± 3.0 Ma and display very low Th/U ratios close to zero. The achieved results suggest that the sediment deposition occurred after 670 Ma, before the high pressure metamorphism that believed to took place at 630 Ma. The location of the Tamanrasset block and the calc-alkaline plutons exposed west of the 4°50' fault in the Iskel terrane suggest that metamorphism formed in a west-dipping subduction setting.

poster

02

**Igneous and
Metamorphic
Petrology**

Etude morphostructurale du volcanisme tholéïtique à l'apex du bombement lithosphérique du Hoggar (Taharaq nord – Egéré Aleksod – Hoggar – Algérie)

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Abstract

Le Hoggar a été le siège d'une importante activité magmatique qui se manifeste de l'Eocène au Quaternaire. Ce volcanisme se localise le long des grands accidents d'échelle lithosphérique qui séparent certains blocs qui le composent. Le secteur volcanique étudié dans ce travail, se situe sur le terrane Egéré-Aleksod, au Nord des formations volcaniques du Djebel Taharq (Ait-Hamou, 2000) précisément au sommet du bombement lithosphérique du Hoggar, au niveau du massif de la Tellertebe. Ce bombement est associé à une anomalie gravimétrique négative dont l'extension délimite en gros la province volcanique cénozoïque. Les manifestations volcaniques les plus anciennes (35 Ma) se situent au centre de l'anomalie, qui correspond exactement à notre région étudiée et sont d'affinité tholéïtique alors qu'elles sont plus récentes et d'affinités alcalines à hyperalcalines vers la périphérie.

Les plus anciens appareils volcaniques du Hoggar qui se situent au sud-est de l'amadghor, se démarquent par une édification presque circulaire attribuée à une activité particulière, signalé par Rémy (1960), n'a fait l'objet d'aucune étude structurale et pétrologique jusqu'à présent.

Pour essayer de comprendre le contexte géodynamique de mise en place de ce volcanisme, nous avons suivi la méthodologie de NKono et al. (2009). Elle consiste à faire une cartographie de la distribution des structures volcaniques, des failles et des linéaments qui les accompagnent en utilisant des images satellitales de moyenne résolution, telles que les Landsat 7 ETM et les modèles numériques de terrains (DEMs Digital Elevation Models ; SRTM : Shuttle Radar Topography Mission). Cela permet de vérifier s'il existe une relation entre l'activité de ces failles et le volcanisme étudié. Nous avons fait également, une cartographie détaillée des appareils volcaniques ; puis nous avons effectué un traitement numérique permettant la réalisation de rosaces des directions préférentielles de leur distribution. Nous avons utilisé dans cette étude différentes méthodes de traitements numériques des images Landsat 7, à savoir les différentes compositions colorées réalisées sur les images originales, les rapports de bandes et l'analyse en composantes principales, ainsi que les filtres directionnels (matrice 3x3) à 0°, 90° et 45° ont permis, dans la région volcanique du Taharaq Nord, la réalisation d'une carte de discrimination lithologique détaillée dans un SIG, ainsi que l'identification de la majorité des accidents. Il apparaît sur le plan lithologique que les structures ignées présentent à la fois des caractères de batholites, et de volcans (coulées de laves et produits de projections).

Composition and petrogenesis of talc-schists and amphibolites in Wonu-Apomu and Ilesa areas, southwestern Nigeria

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Abstract

Field relationships, petrographic, x-ray diffraction and geochemical studies of amphibolites and talc-schists from Wonu-Apomu and Ilesa areas, southwestern Nigeria, were carried out with a view to unravel their petrogenetic affinity and compare their petrochemical trends.

Field relationships showed that the talc-schists occur as lenticular bodies within amphibolites in the schist belts. Petrographic studies of the amphibolites show that hornblende, ca-plagioclase and quartz are the dominant minerals, while biotite, anthophyllite, tremolite, actinolite, chlorite, pyroxene and opaques are present as accessory minerals. Thin section examination of the talc-schists, on the other hand, reveals talc in groundmass, as the main mineral, with variable amounts of chlorite, anthophyllite, tremolite and actinolite as minor minerals. X-ray diffraction studies of the talc-schists further reveals the presence of Al-bearing pyrophyllite and Cr-bearing clinocllore. These minerals, which have similar physical characteristics and diffraction peaks with talc and chlorite, respectively increase the intensity of talc and chlorite on the x-ray diffraction chart. The overall mineralogical data shows that the talc-schists are composed of 30% talc, 20% pyrophyllite, 21% anthophyllite and 28% chlorite.

Chemical data of the amphibolites showed that they have lower silica (44.86 – 50.62%), and magnesia (7.85-12.05%) contents compared with the talc-schists with (51.23 – 61.15%) and (26.02 – 30.06%) for silica and magnesia, respectively. The amphibolites are enriched in Al₂O₃ (>14 %), Fe₂O₃ (>12.40 %), CaO (>8.10), Na₂O (>3.10 %) and K₂O (>5.0 %) contents than the talc-schists. Silica, magnesia, alumina, lime and ferric oxide content of the talc-schists vary with the mineralogical differences between the samples. Trace element data showed that the amphibolites are enrichment in Ba (>137 ppm), Sr (>122 ppm), Rb (>33 ppm), Zr (55 pm) and Y (>37 ppm) but impoverished in Cr (<62 ppm), Ni (<57 ppm) and Zn (<83 ppm) while the talc-schists are enhanced in Cr (>3600 pm), Ni (>1620 ppm) and Zn (>160 ppm) contents, suggesting a tholeiitic precursor for the amphibolite and a komatitic precursor for the talc-schists. Other petrogenetic indices, such as, low K, Rb, Rb/Sr (<0.29), K/Rb (< 49.55), Ni/Co (<1.05), Ga/Y (<1.05) and CaO / Al₂O₃ (< 0.72) plus discriminant plots, such as Na₂O + K₂O vs SiO₂, Ga vs Y, Fe₂O₃ vs SiO₂, SiO₂ vs CaO, Zr/Y vs Zr, TiO₂ vs SiO₂, Cr vs Ni, Fe₂O₃ – Na₂O + K₂O – MgO, Fe + Ti – Al – Mg and TiO₂ – K₂O – P₂O₅, all indicate the emplacements of the precursor tholeiitic and komatitic rocks within the continental crust, where they are subjected to the same hydrothermal metamorphism.

Caractéristiques et cartographie des séries mafiques-ultramafiques et des charnockites granulitiques du bassin d'Abeleyel, Tekhamalt, In Ouzzal, Hoggar, Algérie

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Abstract

Le terrane de l'In Ouzzal (Hoggar occidental) est une croûte continentale archéenne (3.2-2.7 Ga) remobilisé d'une façon importante au Paléoprotérozoïque (2.0 Ga). Il est formé de deux unités majeures toutes deux archéennes: la première correspond à des orthogneiss charnockitiques datés entre 3.2 et 2.7 alors que la seconde est constituée de métasédiments composés de marbres, quartzites à magnétite, granulites Al-Mg et Al-Fe communément associés à des lentilles basiques (métanorites, pyroxénites à spinelle, pyrigarnites) et ultrabasiqes (lherzolites et hazburgites) datée à 2.65 Ga (Ouzegane et al., 2003). Le métamorphisme éburnéen est caractérisé par un cheminement horaire au cours duquel de très hautes températures ont été atteintes à relativement haute pression (≥ 1050 °C à 10-11 kbar) permettant l'apparition de paragenèses exceptionnelles à corindon-quartz, saphirine-quartz et saphirine-spinel-quartz. Un stade de décompression s'est ensuite produit ramenant ces formations à des conditions de 5-7 kbar et 700-800°C (Ouzegane et al., 2003 et références incluses).

Ce travail est une étude multidisciplinaire intégrant aussi bien la cartographie d'un bassin de roches vertes, celui d'Abeleyel et de son encaissant charnockitique, qu'une étude pétrographique, géochimique et thermobarométrique de ces deux types de lithologie.

Dans le bassin d'Abeleyel, la série métasédimentaire est composée de métashales migmatiques à grenat-spinelle-sillimanite quartz et grenat-orthopyroxène-cordiérite quartz, La présence de l'assemblage spinelle-quartz et l'utilisation de la composition des feldspaths ternaires confirment le métamorphisme de UHT à 1000 °C.

L'étude géochimique montre que les charnockites montrent des compositions K_2O/Na_2O , $(La/Yb)_N$ comparables à celles des séries TTG archéennes et les anorthosites associées correspondent à des cumulats produits par le liquide ayant donné ces charnockites.

Les roches ultrabasiqes sont des pyroxénites cumulatives. Les métanorites montrent une affinité avec les basaltes komatiitiques et les tholeiites hautement magnésiennes archéennes.

Une cartographie détaillée du bassin d'Abeleyel a été réalisée associant des données de terrain et l'imagerie satellitale (Landsat 7 ETM+). La composition colorée 731, par exemple, permet de mettre en évidence le bassin de ceinture de roches vertes d'Abeleyel en teinte sombre bleu verdâtre et les charnockites de l'encaissant en teintes plus claires. Le bassin de forme sigmoïdale montre une variation dans la direction de la foliation (de NE-SO à E-O) bien visible sur la CP1.

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The mafic and ultramafic rocks-type of the Yadène complex: petrographical, mineralogical and geochemical features (North-eastern Algeria)

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Abstract

The Tertiary igneous activity in the Maghrebides chain, north of Algeria is related to the tectonic history of the western Mediterranean region. This magmatism is represented in the Kabylie of Collo (NE Algeria) by a variety of volcanic, sub-volcanic and plutonic rocks. The Ultramafic rocks are distributed mainly in the internal zones of Alpine chain from the West to the Est. The Yedène mafic and ultramafic rocks were first described by Bouillin and Kornprobst (1974) as sub-products called layered complex. They are embedded in the upper Oligo-Miocene Kabyle and olistostrome hornfels formation that was metamorphosed at the contact with the Cap Bougaroun granite. The layered massif of Yaddene area is composed of ultramafic rocks that consist of olivine, orthopyroxenes (enstatite), clinopyroxènes (mostly augite) and rare plagioclases, and mafic lithologies composed plagioclase (anorthite), amphiboles (actinolites) and rare quartz. The ferromagnesian minerals show high Mg#. The most ubiquitous accessory mineral is chromian spinel which often included in olivine crystals. The REE spider-diagram shows that these rocks result from a subduction zone and typically an island arc tholeiite. The process which control the genesis of the Yadden rocks are: (1) the contamination of parental melts with continental crustal material, and (2) fractional crystallisation. The Yadden ultramafic rocks did not suffer deformation when compared to those of Cap Bougaroun massif. However, both peridotites show high accessory chromian spinel contents.

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Using chemical potentials to explain reaction textures in a 5 cm large sillimanite nodule from UHT In Ouzzal terrane (In Hihaou area – Western Hoggar, Algeria)

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Abstract

The interpretation of reaction textures to derive retrograde conditions and P–T paths without considering their spatial development is unlikely to be reliable, as textures do not typically form in this way or routinely record this information. An example is taken from UHT In Ouzzal terrane, which is a north-south elongated block in the Tuareg Shield (southern Algeria). The formations in this terrane are subdivided in two units: lower crustal unit consists of high-grade granitic orthogneisses made up of enderbites and charnockites and supracrustal unit characterized by metasedimentary rocks, including marbles, magnetite-bearing quartzites and Mg–Al granulites. Mg–Al granulites show multi-layer corona and symplectite reaction textures that pervasively replace peak metamorphic porphyroblasts. Pseudosection calculations give near-peak estimates of $900 \pm 20^\circ\text{C}$ and 8 ± 0.5 kbar. The nodule texture primarily involves sillimanite, plagioclase, sapphirine, spinel, garnet and quartz. All of these minerals are nominally anhydrous, and can be modeled in the $\text{Na}_2\text{O}-\text{CaO}-\text{FeO}-\text{MgO}-\text{Al}_2\text{O}_3-\text{SiO}_2$ (NCFMAS) chemical system. Quartz was in contact with the sillimanite nodule prior to texture formation, and is in contact with the outer coronas of garnet and plagioclase. Therefore, quartz is taken to be in excess, at least during formation of the initial coronas. The formation of plagioclase and garnet coronas requires the diffusion of CaO and Na_2O to the sillimanite nodule, with garnet requiring additional FeO and MgO. Both minerals have relatively constant compositions across the texture, and fixing the composition of each effectively fixes the Ca–Na and Fe–Mg ratios and couples the two variables. If Al_2O_3 is taken to be the immobile component, then the textural development can be quantified in $\mu\text{MgO}-\mu\text{CaO}$ space at 8.2, 8.1 and 8 kbar at 900°C

Interactions between dioritic and granodioritic magmas within the Pan African Amsel batholith (Central Hoggar, Algeria): an approach through the study of plagioclase crystals.

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Abstract.

In the Laouni terrane (LATEA, Central Hoggar, Algeria), the 599 ± 3 Ma suite in the calc-alkaline Amsel granodioritic batholith shows a large variety of mostly dioritic enclaves. Plagioclase phenocrysts were observed in both dioritic enclaves and granodiorite. They display oscillatory zoning patterns, sieve textures and resorbed contours, evidencing magma mixing processes. Collected samples form a complete series from AM73 (diorite), showing plagioclase phenocrysts with oscillatory zoning and resorption patterns related only to decompression, and AM119 (granodiorite), representing the ultimate stage of mixing of the felsic magma with the mafic magma. From plagioclase compositions and zoning patterns, the following scenario was identified: (i) the two magmas, stored separately within two discrete batches, formed closed systems evolving through fractional crystallization of plagioclase followed by amphibole, (ii) the evolving mafic magma rose up and began to mix with the felsic magma in a ca. 15 km-deep chamber, materialized by plagioclase riddled textures, (iii) mixing episodes occurred repeatedly with progressively decreasing magma volumes, materialized by non-resorbed and normally zoned plagioclase crystals coexisting with sieve textures and oscillatory zoning patterns. Plagioclase growth and textures depended on mixing duration within the felsic magma chamber.

Petrography, geochemistry and the geodynamic significance of the Jurassic-Cretaceous gabbro-syenite intrusions of the Eastern High Atlas, Morocco

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Abstract

The High Atlas belt of Morocco experienced a tectono-magmatic event during the Jurassic – Cretaceous period that is marked by the emplacement of intrusive, sub-volcanic and volcanic rocks into the Paleozoic and Mesozoic series.

Field mapping, structural analysis, facies description and geochemistry of intrusive rocks allow distinguishing nine gabbros-syenites intrusive complexes into the Palaeozoic basement, Triassic units and Lower liasic sediments. These magmatic bodies are mainly exposed along an ENE-trending anticline ridge and their stratigraphic emplacement is mainly controlled by major faults and halokinetic structures.

Petrographic description of these intrusions revealed a mineralogical composition ranging from olivine-bearing gabbros to syenite. The gabbros exhibit intergranular texture and a various primary mineral assemblage for each intrusion, mainly represented by olivine, pyroxene, plagioclase, biotite, apatite, sphene and opaque minerals. The Tazmamart intrusion is an olivine and biotite-bearing gabbros that could represent primitive magma source. “Differentiated” rocks are represented by syenitic veinlets and apophyses dissecting the gabbroic intrusions. Tarfafa intrusions are cored syenite and gabbroic towards the margins. They are mainly fine grained and microgranular texture showing a mineralogical composition essentially formed by alkaline feldspar, plagioclase, quartz, amphibole, apatite and sometimes the sphene, and opaque minerals.

The chemical analyses from nine gabbro-syenite rocks are of transitional to alkaline magmatic affinity. Trace elements spider diagrams allow distinguishing a differentiated process within the same mafic and the acidic rocks. The REE patterns are similar uniform and are relatively enriched in LREE with flat HREE patterns. According to the trace elements spider diagrams and REE patterns, the mafic and acidic rocks are either co-genetic (magmatic differentiation) or formed probably by distinct magmatic pulses. Geotectonic diagrams of the Eastern High Atlas Jurassic –Cretaceous magmatism suggest an affinity of continental intraplate magmatism.

Depositional styles of upper Ediacaran terrestrial volcano-sedimentary successions in the NE Edge of Saghro inlier, Eastern Anti-Atlas, Morocco

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Abstract

Detailed geological mapping investigations in the NE edge of Saghro inlier (Eastern Anti-Atlas) are used to characterize the depositional styles of upper Ediacaran volcano-sedimentary successions. In order to achieve our goals different cross sections have been made covering different Ediacaran outcrops.

The Ediacaran volcano-sedimentary succession is represented by monocline series slightly tilted to the NW (30° to 50°).

Different volcano-sedimentary lithofacies have been mapped: 1) rhyolitic ignimbrite, generally lithics and crystals rich, moderate to strongly welded, 2) andesitic lava complex, represented by thick vesicular and crystals rich, 3) SiO₂-rich lava, crystals rich, 4) laminated volcanoclastic fine silt to gravel deposit, 5) hydroclastic complex composed mainly by pellital lapilli, 6) poorly sorted, clasts to matrix supported polygenic conglomerates composed mainly by basement meta-sedimentary clasts, 7) Ignimbritic dyke showing block of clasts and vertical centimetric flame, 8) subvolcanic systems dominated by andesitic dyke swarm and also rare silica-rich dyke have been mapped.

Associated to these lithofacies diverse volcanic styles have been recognized such as: i) ignimbrite related to collapse of eruption column or pyroclastic formation from fissure, ii) andesitic lava complex, iii) SiO₂-rich lava dome, iv) fallout deposit probably related to lava dome collapse, v) Phreatomagmatic eruption related to minor scoria cone, vi) caldera complex with feeding dykes, vii) debris flow deposit, viii) dyke system.

The Ediacaran depositional styles in NE flank of Saghro inlier are dominated by silica rich eruptions volcanic complexes, commonly associated with minor silica poor volcanic activities.

Les formations carbonatées de l'In Ouzal : comparaison minéralogique et géochimique des marbres granulitiques et des carbonatites de l'In Ouzal (Nord Ouest Hoggar)

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Abstract

Les marbres granulitiques de l'In Ouzal d'âge archéen présentent une composition minéralogique très diversifiée. Deux grands groupes se distinguent : Les marbres à olivine-spinelle et les marbres à grenat ± wollastonite ± scapolite. Les marbres à olivine spinelle montrent des minéraux particuliers comme des phlogopites (X_{Mg} 0.68 – 0.79) riche en baryum 11.68% et la dissakisite riche en cérium (9.55 – 12.28 %). Dans ces roches la forstérite est entourée d'une double couronne de diopside et de dolomite la séparant ainsi de la calcite suivant la réaction $2 \text{ forstérite} + \text{calcite} + 2\text{CO}_2 \rightarrow \text{diopside} + 3 \text{ dolomite}$. Des exsolutions de dolomite dans la calcite témoignent des très hautes températures atteintes par ces roches (900°C - 1000°C). Dans les marbres à grenat ± wollastonite ± scapolite, la scapolite présentent des compositions chimiques variables en fonction des associations minéralogiques. En présence de la wollastonite la scapolite est de type mizzonite avec un équivalent en anorthite qui varie entre 47.8 à 51.9. En absence de la wollastonite, la scapolite est de type méionite avec un équivalent en anorthite qui varie entre 70.16 et 89.42. Des valeurs aussi élevées témoignent des hautes températures atteintes par ces roches et permettent également l'apparition de l'anorthite suite à la déstabilisation de la méionite suivant la réaction $\text{méionite} \rightarrow 3 \text{ anorthite} + \text{calcite}$. Cette réaction se produit pour un équivalent en anorthite supérieur à 075. En présence de quartz des couronnes de grenat apparaissent autour de méionite et de la calcite suivant la réaction $\text{méionite} + 3 \text{ quartz} + 5 \text{ calcite} \rightarrow 3 \text{ grossulaire} + 6 \text{ CO}_2$. Le développement d'un grenat riche en andradite peut s'expliquer par une réaction d'oxydation d'un clinopyroxène ferrifère: $4 \text{ heddenbergite} + 2 \text{ calcite} + \text{O}_2 \rightarrow 2 \text{ andradite} + \text{quartz} + \text{CO}_2$.

Les marbres à grenat ± wollastonite ± scapolite montre de nombreuses similitudes minéralogiques avec les carbonatites de la région d'Ihouhaouène (Nord In Ouzal) qui sont aussi à wollastonite, calcite, quartz, clinopyroxène et montre des textures réactionnelles à grenat coronitique et des symplectites à calcite quartz autour de la wollastonite. La distinction que l'on peut faire entre les carbonatites et les marbres c'est la composition particulière des calcites des carbonatites qui sont riches aussi bien en terres qu'en strontium. Pour les minéraux porteurs en terres rares comme les apatites une distinction nette est faite entre les apatites des carbonatites (jusqu'à 10% de REE) et les apatites des marbres (< 0.5%). Les éléments en traces et terres rares des carbonatites ainsi que leur composition isotopique en carbone (Ouzegane et al., 1988; Fourcade et al., 1996) qui suggèrent une origine mantellique permettent de bien les distinguer des marbres.

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Apatite REE-enrichment in archaen carbonatites and alkaline magmas in Ihouhaouene area (In Ouzzal terrane, Hoggar, South Algeria)

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Abstract

Ihouhaouene area in In Ouzzal terrane (Hoggar, South Algeria) is composed by numerous carbonatite complexes systematically associated to syenites. They represent one of the oldest carbonatite emplaced at 2 Ga. Various types of carbonatites are distinguished by their pegmatitic and brecciated appearance. These carbonatites are principally composed of calcite, apatite, alkali feldspar, wollastonite, diopsidic and hedenbergitic clinopyroxene +/- sphene, allanite, quartz and garnet. Late carbonatite intrusions appear in small pegmatitic veins rich in apatite (3-50 mm). All carbonatites are calciocarbonatites (38-50 wt% CaO) with silica content ranging from 5 to 28 wt% SiO₂. The high silica content is interpreted as assimilation of syenite material during emplacement. Carbonatites have high Rare Earth Element concentrations with high LREE/HREE fractionation (e.g. 1088 ppm La, La/Yb= 144-198) and variable concentrations in Th (26.5-197 ppm). The REE concentrations are mainly controlled by apatite phenocrysts (30-40 vol.%) with 4-9 wt% REE. In late pegmatitic carbonatite, REE-rich apatites are green-yellow phenocrysts with britholite exsolution (up to 40 vol.%, Ca₄(REE)₆(SiO₄PO₄)₆(OH,F,Cl)₂). Britholites are hexagonal and occur as fine lamellar exsolutions (<10 um) in the same crystallographic axis (001) than apatites or as irregular-shaped grains (10-200 um). All britholites contain 8-16 wt% La, 21-43 wt% Ce and 7-12 wt% Nd. The apatite-britholite exsolutions correspond to a substitution of the Ca²⁺ and P⁵⁺ by trivalent rare-earth elements (REE³⁺) and Si⁴⁺. The REE substitution is accompanied by a change in volatile composition with F-rich apatite and Cl-rich britholite indicating that Si and Cl-rich hydrothermal fluids are present at the late stage of carbonatite evolution leading to REE-enrichment and the crystallization of REE minerals. We suggest that the Ihouhaouene carbonatites and syenites crystallize from the same magma and occur from immiscibility at the solvus of mantle at 2-3 GPa and 1225- 1350 °C.

Ser_Box_(1,1): a MatLab standalone program to classify the serpentine group minerals and calculate the non-ideal activity of antigorite endmembers

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Abstract

The Ser_Box_(1,1) is a standalone program which was developed in a MatLab® environment to enable the user calculating the chemical formula of the serpentine group minerals. The program is able to calculate the Fe³⁺ and the Fe²⁺ in order to balance the total charge of the formula to be electrically neutral. The program are able to distribute the cations into different crystal sites and therefore calculate the ideal activities of the antigorite and the tschermak antigorite endmembers. Previous experimental data allows us to calculate interaction energy (W) between the antigorite and the tschermak antigorite based on Landau theory. The interaction energy is used to calculate the non-ideal activities of the antigorite endmembers. This new information on the crystal chemistry of the antigorite mineral will be used to develop a new geobarometer in the greenschist, amphibolite facies conditions, while the antigorite chemistry can be used as a new geothermometer at high pressure conditions environments (i.e. eclogite facies conditions). The program code and the necessary support files can be obtained from the author.

Metamict U-rich pyrochlore from Epembe Sövitic Carbonatite Dyke, NW Namibia

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Abstract

The Epembe carbonatite is a 10 km long dyke located about 80 km North of Opuwo, NW Namibia. It hosts distinct lenses of carbonatite, each lense unique in composition and perhaps intruded the complex successively. The internal structure of the dyke forms a medium- to coarse-grained intrusion predominantly composed of calcite with minor dolomite, ankerite and accessory such as apatite, aegirine, pyrochlore and minor zircons.

30 grains of pyrochlore from Epembe were analysed using electron microprobe EPMA-1600 to determine the compositional variation. The major oxides composition shows low total ranging from 96.33-99.86 wt.%. The pyrochlore group minerals of Epembe belong to the pyrochlore subgroup. Nb is the dominant element in the B-site, although there are noticeable variation in Ta and Ti content. The high UO₂ (11.26 - 26.75 wt.%) classify the pyrochlore group mineral from Epembe as metamict. Two type of pyrochlore species namely Calciopyrochlore (U content up to 16.47 at.%) and the Uranopyrochlore (U content from 20.72 at.% to 45.31 at.%) have been identified. The pyrochlore chemistry shows a compositional trend from magmatic Ca-rich varieties toward late stage U-rich Kenopyrochlore variety. It is therefore suggested that the successive intrusive phases of carbonatite assimilated primary pyrochlore and together with the invasion of hydrothermal fluids enriched in minor Si, Sr, Ba and Th resulted in a remarkable shift in chemical composition of the pyrochlore. Enrichment in elements like U, Sr and Th generate metamictization, alteration and A-site vacancy. There is an ultimate Ca and Na loss with increasing vacancy but the uranium enrichment in the pyrochlore from the Epembe carbonatite does not depend on cation deficiency hence it is undoubtedly from a primary source related to carbonatite magmatism. The dynamic from which such pyrochlore-rich rocks manifested remain unclear and might be a product of cumulate process or liquid immiscibility of a carbonate-silicate pair.

oral

03

**Tectonics
and
structural
geology**

Geomorphic indexes and drainage pattern analysis in response to active tectonics from south Rifian Ridges (Moroccan Rif Cordillera)

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Abstract

Due to the collision between the African and European plates, Miocene to Pliocene activity of South Rifian Ridges (SRR) accommodate the convergence between the Western and Central Rif and the Western Moroccan Meseta foreland, with a South to Southwestward motion with respect to stable Africa. The present-day activity of SRR leads the formation of two thrusting arcs of ramp propagation folds separated by Volubilis piggy back basin. In such area, drainage pattern is very sensitive to active processes and can be used to evaluate recent deformations. However no geomorphic features analysis has been done to determine the influence of tectonics in this area and the drainage network response.

In order to better understand the activities of these structures, we designed the tectonic geomorphology of the eastern arc of South Rifian Ridges and interpreted the effect of tectonic activity on the geomorphological evolution using geomorphic markers such as mountain front, sinuosity, valley floor width-to-height ratio, drainage basin asymmetry factor, basin hypsometric curve and integral, longitudinal river profile and Normalized steepness index (ksn).

Our geomorphic analysis suggests that the quaternary landscape evolution was governed by tectonic and erosional processes with a relatively high degree of tectonic activity along the faults bounding the southern and eastern mountain fronts of the eastern arc, associated with growth of anticlines that varies from North-East to South-West. Moreover fault zones exert a strong influence on the morphology of the streams and adjacent area.

New 1/500.000 scale GIS-based geological and mineral resources maps for Kongo Central province (DR Congo) with an updated lithostratigraphy of the West Congo Belt

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Abstract

The Kongo Central province (previously Bas-Congo) covers 3 full and 6 partial square-degrees. In the 1960ies only half of the coverage was published (sheets Kinshasa, Inkisi, Luozi, Ngungu; 1/200.000) following field and prospection mapping.

The new GIS-based cartographic compilation of geological and mining archives allowed to produce a complete coverage with 3 missing 1/200.000 geological and mineral resources sheets (Matadi, Kai-Mbaku and Tshela-Moanda) and one single 1/500.000 map (geology, mineral resources).

The province can be divided in three geological units: the western coastal plain and the eastern plateau with Mesozoic to Cenozoic tabular sequences, and in between, the hilly Pan-African West-Congo Belt (WCB). The WCB is the easternmost part of the Araçuaí–West Congo Orogeny (AWCO) which extends from SW Gabon to NW Angola. In Kongo Central its trend changes from N-S to NW-SE. The Sangha aulacogen in the foreland is sub-perpendicular.

Recent field and geochronological data (De Grave et al., Baudet et al., Pedrosa-Soares et al., Nseka et al., this meeting) led to major updates of both earlier lithostratigraphies and geodynamic models.

The basement consists of the 2.1 Ga gneissic Kimeza Supergroup.

The overlying West Congo Supergroup (WCS) comprises the Late Mesoproterozoic and Neoproterozoic units. Three magmatic events constrain the extensional history of the WCS (several abstracts, this meeting): 1) 1.0 Ga Noqui and Mao (per)alkaline granites (De Grave et al., Nseka et al., this meeting), 2) 0.930 to 0.870 Ga bimodal magmatism and 3) 0.694 Ga tholeiitic basalts.

The Inkisi Subgroup consists of redbeds deposited during the Paleozoic before Karoo.

A model of tangential extensional detachment of the basement followed by updoming as a result of the 1.0 Ga magmatic event is proposed for the Meso-Neoproterozoic extensional evolution of the WCB (Theunissen et al., this meeting). Gondwana amalgamation (0.550 Ga) resulted in AWCO and the thrust-fold WCB, with eastward verging decreasing deformation and regional metamorphism (amphibolite to greenschist facies up to sedimentary rocks) giving rise to different tectono-metamorphic domains (Tack et al., this meeting).

The new mineral resources map reports 1068 metal indices for 800 localities. The main mineralisation, (e.g. Bamba-Kilenda, Toni, Kussu Senge) comprises epigenetic Cu-Pb-Zn sulphides (along a EW and NE fault system)

Hydraulic fracturing jobs main results in Bir Ben Tartar Petroleum Field

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Abstract

Hydraulic fracturing operations are used to enhance oil and gas recovery from unconventional resources and to stimulate tight reservoir production. In this domain, progress has been made worldwide. However, hydraulic fracturing still, in some cases, do not show good oil production results and could even lead, when it was not perfectly done to recover more water than expected . In this case, huge expenses will increase the contrast between the expected and the actual cost of the Frac-Job program. That is why being aware and prevent it in time is highly recommended.

A study of Bir Ben Tartar field located in the Southeast of Tunisia was established in collaboration with MedcoEnergi, Shlumberger, Etap and the Faculty of Sciences of Tunis. Two producing areas observed in the tight sandy Ordovician reservoir containing high amount of quartz and having low porosity and permeability: Jeffara and BBT formation. Average porosity is about 10%, water saturation is about 60% and permeability average is 0.1 md. A statistical study was established in this area to see the impact of Frac-Job operations on oilproduction.

Hydraulic fracturing results showed that most of the vertical wells presented good production results after the hydraulic fracturing operations. However, horizontal wells are having problem with its water cut since the fracture propagates deeper than the oil water contact. One well was converted to injector one because it was producing huge water amount in a short time, which can be mainly due to the unsuitable estimation of geomechanical parameters precisely young's modulus, poisson ratio, minimum and maximum horizontal stress and fracture gradient.

Based on results, formation mechanical properties adjustment according to structural geological, geophysical and petrophysical data help to optimize the fracture design and give more optimistic production results which, will ensure the success of forecasted operations.

From confined orogen to passive margins: temporal constraints on the break-up evolution of the Araçuaí – West Congo orogen (D.R. Congo - eastern Brazil)

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Abstract

The Araçuaí – West Congo orogen (AWCO) was formed during the Pan-African – Brasiliano orogeny (late Neoproterozoic), and is confined by the São Francisco – Congo craton (SFCC). Its formation, in a process called nutcracker tectonics, was preceded by at least six rifting events in a protracted extensional regime (1.77 Ga – 678 Ma). None could completely sever the SFCC connection to the north (Bahia-Gabon cratonic bridge). During the Early Cretaceous (~130 Ma), the AWCO finally separated, due to the opening of the South Atlantic Ocean. Today we find the eastern part of the AWCO on the African continent as the West Congo Belt (Angola, D.R. Congo, Congo Brazzaville and Gabon), and its western counterpart on the South American continent (Brazil). The complex history of this area resulted into two passive margins with a range of older inherited structures predating the Cretaceous break-up.

The CoBra (D.R. Congo – Brazil) thermochronology project is part of an international cooperation with focus on the syn- and post-tectonic processes related to the opening of the South Atlantic. The project aims to place passive margin evolution and the role of inherited structures herein in an absolute time frame. The outstanding technique to investigate tectonic processes in the upper crust is multi-method low-temperature thermochronology. More precisely we use quantitative modelling (Markov chain Monte Carlo) of the combined apatite fission track (AFT) and apatite (U-Th-Sm)/He (AHe) thermochronometers. The AFT analyses were performed using our new protocol for data acquisition and processing. For this purpose we acquired basement samples on E-W and N-S (along-trend) profiles on both sides of the AWCO (Brazil: Minas Gerais, Espirito Santo; Lower Congo). The Brazilian margin shows AFT ages ranging between Late Cretaceous and Paleogene. Length date indicate distinct events, which can be interpreted as the effect of basement denudation due to post-rift uplift of the passive margin. Data from the Congolese part indicate Mesozoic to Cenozoic denudation as well and hence further constrains the tectonic evolution of the AWCO.

Peralkaline granite bodies of the West Congo Belt (Matadi area, Bas-Congo region, DR Congo): evidence of a 1.0 Ga lithospheric-scale extensional event during long-lived Columbia breakup

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Abstract

The Pan African West Congo Belt (WCB) is part of the Araçuaí – West Congo Orogen (AWCO) formed during Gondwana amalgamation (550 Ma). In the WCB, the AWCO is underlain by a 2.1 Ga Eburnean-aged orogenic system, whose migmatitic gneisses belong to the Palaeoproterozoic Kimeza Supergroup. The WCB extends from SW Gabon to NW Angola parallel to the Atlantic ocean. Its central part displays an ENE-verging fold-and-thrust belt with eastward decreasing deformation and regional metamorphism. In the Bas-Congo region of DR Congo, the belt is separated by a thrust front from the foreland domain (Sangha aulacogen). The Neoproterozoic West Congo Supergroup comprises – from old to young - the Matadi, Seke-Banza / Tshela and Cataractes Groups (Baudet et al, this meeting).

In the Matadi area, the Noqui peralkaline granite intrudes the metaquartzites of the Matadi Group, showing thermal metamorphism. Moreover, hypabyssal peralkaline rocks cut into the parent metaquartzites. The Gangila amygdaloidal metabasalts (lower formation of the Seke-Banza Group), overlying the Matadi metaquartzites, are not affected by the intrusion.

The Noqui granite is composed of mesoperthite, quartz, aegyrine ± lepidomelane ± opaques ± riebeckite. New LA-ICPMS emplacement ages (1018 ± 19 Ma and 1043 ± 25 Ma) for the granite and related hypabyssal equivalents confirm the earlier SHRIMP age of 999 ± 6 Ma. Unlike previously considered, they indicate that the Matadi Group is older than the Neoproterozoic (Baudet et al, this meeting). The Noqui granite has an A1-type geochemical composition. It originated from a deep-seated OIB-type source affected by crustal contamination resulting into evolved liquids.

The Noqui granite is separated by a NW-SE trending fault from the Mpozo syenomonzonite. Two new LA-ICPMS ages (1948 ± 10 Ma and 1947 ± 30 Ma) show that despite of the cartographic and compositional similarities, this body is unrelated to the Noqui granite and is a part of the nearby Kimeza basement.

During the 550 Ma AWCO, the Kimeza basement and the WCB units were thrust partly upon each other. In the Matadi area, all rocks were affected by tectonic overprinting of variable intensity under greenschist facies conditions (retrograde for Noqui, Mpozo and Kimeza crystalline rocks and prograde for the metasedimentary rocks of the Matadi Group and the metabasalts of the Gangila Formation). Late Pan-African N-S trending shear zones and corridors, cross-cutting earlier structures, formed under brittle conditions, amongst others in the Noqui granite (Tack et al, this meeting).

The 1.0 Ga Noqui granite is not an isolated feature. Comparable 1.0 Ga alkaline rocks are known in Bas-Congo (Mao granite; Glorie et al, this meeting) and in the Republic of Congo-Brazzaville (Mfoubou granite). In NW Angola several massifs of (per)alkaline granites are documented but recent work, including dating, is lacking. The 1.0 Ga granites mark a subregional lithospheric-scale intrusive event, which corresponds to one of the successive extensional and rifting events occurring during the long-lived Columbia breakup history preceding the AWCO and Gondwana amalgamation. They play an essential role in the conceptual geodynamic model for the WCB evolution (Theunissen et al, this meeting).

Detrital zircon geochronology and provenance analysis of the Matadi metaquartzites and Yelala metaconglomerates: lithostratigraphic implications for the West Congo Supergroup (Bas-Congo region, DRC)

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Abstract

The West Congo Belt (WCB) is part of the Araçuaí – West Congo Orogen (AWCO), formed during Gondwana amalgamation. It is underlain by 2.1 Ga migmatitic gneisses of the Palaeoproterozoic Kimeza Supergroup. It extends from SW Gabon to NW Angola and displays eastward decreasing deformation and regional metamorphism. During AWCO, the Kimeza basement and WC groups were partly thrust upon each other.

The Neoproterozoic West Congo Supergroup (WC) comprises – from old to young - the Nzadi, Seke-Banza/Tshela, Cataractes Groups (Baudet et al, 2013 and this meeting, in particular for the correspondances with the previous lithostratigraphy).

In the Matadi area, the Nzadi Group comprises three Formations (from bottom to top): 1) Palabala (metaphyllites), 2) Matadi (metaquartzites), 3) Yelala, (metaconglomerates).

New field evidence and sample data indicate that the Palabala Formation is composed of mylonitic rocks, described as “phyllites”, derived from various protoliths outcropping in the region: Kimeza gneiss, Mpozo syenomonzonite and Matadi metaquartzite. Because this “formation” is a tectono-structural unit it must be removed from the Nzadi Group lithostratigraphy; due to mylonitization the unconformity between the Nzadi Group and underlying Kimeza Supergroup is unobserved.

Detailed mapping shows that the 1000 Ma Noqui granite intrudes the Matadi Formation (De Grave et al., this meeting), constraining its age as pre-Neoproterozoic.

Maximum ages of detrital zircons of samples of Matadi Formation is 1210 ± 30 Ma (LA-ICPMS), indicating that deposition occurred during the Mesoproterozoic. This age is in line with the age of zircons in Matadi Formation from Boma area (1126 Ma; Nseka et al, this meeting). The bulk of the zircons have Palaeoproterozoic ages, with only few zircons older than 2.5 Ga, in line with a derivation from the Kimeza basement source. The Matadi Formation has been deposited between 1000 Ma and 1210 Ma. It marks, in Bas-Congo region, a new arenaceous Mesoproterozoic sedimentation event during the breakup of Columbia comparable with the upper part of the Brazilian Espinhaço Supergroup which witnessed three successive Mesoproterozoic extensional events at 1.70, 1.57 and 1.18 Ga.

The bulk of the zircons of one sample from the Yelala Formation duplicates the results of the Nzadi Formation, except for three zircons with a maximum age of 968 ± 15 Ma which is interpreted as a recrystallization age. The deposit age of the Yelala would be later than 968 Ma and define a hiatus between this Formation and the previous Mesoproterozoic Matadi Formation.

Structural Evolution Modelling of a Suture Zone controlled by a Cratonic Buttress – The Case of Kaoko - Dom Feliciano Orogenic System, Implications on West Gondwana Amalgamation and correlations across the Atlantic Ocean

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Abstract

The matters surrounding the amalgamation of tectonic blocks during the Brasiliano / Pan-African orogeny have been the main subject of study of several works in recent years. From the integration of different kind of data, the similarities between the Brusque, Paranaguá and Kaoko Terranes are highlighted, and, therefore, it is assumed that they have evolved in a cogenetic way in the same collision system. This system would be the result of a complex collision mainly controlled by the geometry of the basement blocks. Considering the African counterpart of the collision system, the Curitiba Terrane would have a movement for SSE and the Angola Craton for NNW, while the Luís Alves Terrane, in the Brazilian side, a relative movement for N. This information is corroborated by magnetic and gravimetric data. The oblique collision between the blocks would have occurred with the development of a dextral transpression in the Itajaí Perimbó Shear Zone, separating the Luís Alves Terrane from the Brusque Terrane, a sinistral transcurrence represented by the Palmital Shear Zone separating the Luís Alves Terrane from the Paranaguá Terrane and a frontal thrust, represented by the Icapara and Serra Negra Shear Zones, separating the already amalgamated block from the Luís Alves and Curitiba Terranes of the Paranaguá Terrane. The proposed structural and tectonic models imply new correlations across the Atlantic Ocean, between Brazilian and African counterparts. A lot of studies, regarding the amalgamation of Gondwana supercontinent have been carried out by several authors (Cordani et al. (2003), Schmitt, et al. (2004, 2016), Trompette (1994)). A continental block with the present Curitiba Terrane and Angola Craton (plus the small tip of the Cabo Frio Terrane) collided with the Luis Alves Terrane, here assumed as an exotic terrane, resulting in cordilleran arc terranes of Brusque, Paranaguá and Florianópolis by the closure of an ocean different from the northern Adamastor Ocean (Araçuaí and Ribeira Orogenic Belts (Heilbron et al., 2004, 2008; Pedrosa-Soares et al., 2008)). If this assumption is correct, a possible cratonic bridge between Brazil and Africa should exist, and also split apart during the opening of the Atlantic Ocean in the Early Cretaceous. This interpretation also implies that this segment of the West Gondwana could be divided into two orogenic systems, the Araçuaí-Ribeira and the Dom Feliciano Brusque-Paranaguá plus Kaoko Orogenic Belts (Passchier et al., 2002; Frimmel et al., 2001; Goscombe et al., 2003; Goscombe & Gray, 2007). The northern part of the South Adamastor Ocean, represented by the Paranaguá, Brusque and internal Kaoko Orogenic Belts could be developed in a sort of constraining space situation, similar to what was proposed to the Araçuaí-West Congo belts by Alkmin et al. (2006) and Pedrosa-Soares et al. (2001). On the other hand, the Florianópolis Terrane and the Western Kaoko Terrane could be correlated as arc related terranes. From this model of geodynamic evolution produced by the geological interpretations generated in this work, it was possible to contribute to the development of a map of the possible configuration of West Gondwana with the links between the similar terranes.

Role of N-S strike-slip faulting in structuring of north-eastern Tunisia; geodynamic implications

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Abstract

Three major compressional events characterized by folding, thrusting and strike-slip faulting occurred in the Eocene, Late Miocene and Quaternary along the NE Tunisian domain between Bou Kornine-Ressas-Msella and Cap Bon Peninsula. During the Plio-Quaternary, the Grombalia and Mornag grabens show a maximum of collapse in parallelism with the NNW-SSE SHmax direction and developed as 3rd order distensives zones within a global compressional regime. Using existing tectonic and geophysical data supplemented by new fault-kinematic observations, we show that Cenozoic deformation of the Mesozoic sedimentary sequences is dominated by first order N-S faults reactivation, this sinistral wrench system is responsible for the formation of strike-slip duplexes, thrusts, folds and grabens. Following our new structural interpretation, the major faults of N-S Axis, Bou Kornine-Ressas-Messella (MRB) and Hammamet-Korbous (HK) form an N-S first order compressive relay within a left lateral strike-slip duplex. The N-S master MRB fault is dominated by contractional imbricate fans, while the parallel HK fault is characterized by a trailing of extensional imbricate fans. The Eocene and Miocene compression phases in the study area caused sinistral strike-slip reactivation of pre-existing N-S faults, reverse reactivation of NE-SW trending faults and normal-oblique reactivation of NW-SE faults, creating a NE-SW to N-S trending system of east-verging folds and overlaps. Existing seismic tomography images suggest a key role for the lithospheric subvertical tear or STEP fault (Slab Transfer Edge Propagator) evidenced below this region on the development of the MRB and the HK relay zone. The presence of extensive syntectonic Pliocene on top of this crustal scale fault may be the result of a recent lithospheric vertical kinematic of this STEP fault, due to the rollback and lateral migration of the Calabrian slab eastward.

Radarsat-1 image processing for regional-scale geological mapping with mining vocation under dense vegetation and equatorial climate environment, Southwestern Cameroon

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Abstract

In Cameroon, a great part of the southern portion is marked by a dense forest environment underlain by diversified geological formations which resulted from several successive orogeneses. This tectonic activity favored the concentration of some mineral deposits. The geological formations in this environment outcrop very rarely and discontinuously notably along rivers and apex of mountains. Thus, in situ mapping is tedious and costly. Besides, forest canopy, dust, clouds and fog in this area obscure geological information on aerial photos and optical satellite images.

This study evaluates the potential of Radarsat-1 Synthetic Aperture Radar (SAR) data processing for geological investigation (lithological discriminations and lineament investigations) in this environmental context. This approach used textural analysis based on Grey Level Co-occurrence Matrix (GLCM) on the Radarsat-1 mono-band image, followed by Principal Component Analysis (PCA) performed on eight normalized co-occurrence indices created (mean, variance, homogeneity, contrast, dissimilarity, entropy, second moment and correlation). Three of the indices, the mean, variance and homogeneity, highlighting the morphostructure of the study area and facilitate lithology discrimination were retained. PC1 band was multiplied by itself (as PC1xPC1 image) to enhance the information contained in this neo-canal and to reduce noise during filtering. Directional filters were then applied to the PC1xPC1 image at 0°, 45°, 90° and 135° directions and the structure lines were extracted manually in a GIS software.

From the results obtained, color-composite produced image map contain lithological units easily identified such as continental and coastal deposits, sedimentary stack, micashist, garnet micashists, micaceous quartzites, charnockitic orthogneisses, and coincided with those already existing on an old geological map from Maurizot et al., 1986 and non-published geological map after IRGM geological field campaign. A total of 572 lineaments features (fractures and major faults) were identified on the filtered images and mapped. Major structures (faults) were considered as those clearly identified on the four directions while minor structures (fractures) were those observed on at least two directions. They are oriented in one of the two main directions: NE-SW (N040 to N060) and NNW-SSE (N345 to N360). The lineament result showed those that already existed on the reference map and the newly updated lineaments. Spatial relationships between mapped lineaments and areas of current and historical mining exploration were examined by overall lineament density. Mining sites correlate with areas of high lineament density particularly around the Ngovayang massif within the Paleoproterozoic Nyong unit.

This study stresses the usefulness of remote sensing data and methods in field campaign, improvement of old geological maps and mining prospecting in areas with an equatorial climate.

Fracturing and karst uvala systems affecting Liassic limestones in the Agourai plateau of the Middle Atlas, Morocco

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Abstract

Karst phenomena are well studied in the alpine peri-mediterranean chains and are associated to the climate changes in this area from Cretaceous periods until Plio-Quaternary epoch. In Morocco, many dolines are described in the Middle Atlas, particularly in the Ifrane area, where the main karstic depressions are important lakes, offering natural parks and ecological reserves. Despite the importance of karst systems in the alignment and drainage of groundwater systems, the functioning of the aquifer systems of the Agourai plateau is still unknown. This area constitutes the continuity towards the West of the tabular plateau of the Ifrane-El Hajeb area, which has been the subject of important geological, hydrogeological and geomorphological studies. This study analyses the fracture network at different scales in the Lower Jurassic limestones outcropping in the Agourai plateau, Middle Atlas, and their relationship with karst structures. Belonging to the Sub-Tabular Middle Atlas belt, called "Causses Moyen-Atlasiques". This area underwent a polyphased tectonic evolution, involving karst depressions aligned NE-SW parallel to the main faults. The approach is based on the fracturing analysis and the determination of relationships between tectonic events and the main karstic structures development, corresponding to aligned dolines, forming important uvala systems. We analyse the karst distribution along the main faults affecting Liassic carbonates and we describe some karst sedimentary fill. Satellite image analysis and aeromagnetic data from the Agourai plateau show a NE-SW orientation for the main lineaments. These structures are responsible of Liassic aquifer recharging. Fracture analysis in the borders of the polje revealed the presence of brecciated limestone units, with dips of bedding oriented towards the center of the sub-circular depressions. In some sites along the edges of the polje, vertical tension gashes, filled with reddish detrital sediments appear. The walls of the gashes are coated with calcite indicating an intense rainwater circulation, responsible of the dissolution phenomena which allowed the formation of these karsts. The Liassic carbonate formation, is affected by different geological phenomena, corresponding to karstification, brecciation and mainly intense fracturing. The Agourai plateau is affected by a main fault system oriented NE-SW, delimiting different blocks, elongated in the same direction. The intense fracturing affecting these Liassic limestones is related to extensional syn-rifting episodes, or associated to sedimentary brecciation following temporary emersions. Indeed, the study of fracturing in these carbonate formations revealed three directions: NE-SW, NW-SE and E-W. This fracturing was associated to the main phases of deformation that affected the Middle Atlas during the Tertiary and Quaternary periods. In the mid part of Agourai plateau, the karstic depressions have shaped his morphostructures. The main connected dolines determine an uvala that can even be called karst polje extended in the NE-SW direction, parallel to the major regional faults. In these doline edges, an intense fracturing and an important brecciation have been developed. This fact has determined the ruiniform limestones, characteristic of the karst landscape.

Insights into the birth of the East African Rift System from the tectonothermal evolution of the Turkana Depression

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Abstract

The East African Rift System (EARS) is characterised by two extensive regions of crustal uplift and volcanic construction centred on the Ethiopian Dome in the north and East African Dome to the south. These high plateaux (average elevations of ~3,000 m and ~2,500 m respectively) are separated by the Turkana Depression (TD), a broad region of subdued topography (~ 500 m) in northern Kenya. Here, the EARS is expressed by a wide zone of rifting (~300 km) and thinned crust (~20 km), in marked contrast to the narrow rift trends (~50 km) and thicker crust (~35-40 km) of the surrounding Domes. The topographic segmentation of the EARS into discrete plateaux led to the idea that these were the surface manifestations of upwelling mantle plumes. Under this model, Neogene-Recent active rifting began in the extended crust over the domes and propagated passively into the TD, forming an accommodation zone in the otherwise undisturbed basement. In striking contrast to this picture, the TD displays a complex rifting history beginning as early as the Cretaceous. The region is partly underlain by ~NW-SE trending Cretaceous-early Paleogene Anza and South Sudan rift structures extending discontinuously from the Kenyan coast to South Sudan. Moreover, Turkana hosts the earliest manifestations of EARS-related volcanism (Eocene) and perhaps rift basin formation (late Paleogene?), as suggested by seismic reflection data¹. However, despite its principal role in the chronology of EARS evolution, the morphotectonic evolution of the TD remains poorly understood.

Apatite fission track, apatite (U-Th-Sm)/He, and zircon (U-Th)/He data from Precambrian basement and Late Cretaceous-Paleogene sedimentary rocks in the TD reveal a polyphase tectonothermal evolution of the upper Turkana crust spanning Cretaceous-Recent times. Thermal history modelling shows that the ~200 km wide, NW-SE trending belt of basement rocks adjacent to the TD are dominated by a regionally-extensive Cretaceous to early Paleogene cooling event, corresponding to Anza-South Sudan syn-rift sedimentation. Turkana basement rocks also record Cretaceous denudational cooling, suggesting this area initially acted as a basement high between the rift systems and provided an axial source of sediment. However, in the Late Cretaceous-early Paleogene, parts of Turkana began to subside, in places accommodating substantial thicknesses of infill. This marked an important period of crustal thinning that may have facilitated the subsequent Eocene commencement of major volcanism in Turkana. Afterwards, rift basin formation became widespread throughout much of the TD, marking the onset of EARS extension in East Africa.

Corroboration of the existence of Paleogene aged rift basins in Turkana, predating those elsewhere in the EARS, suggests a unique geological framework existed there at that time. The anomalously thinned crust of the TD, at least in part a product of its Cretaceous-early Paleogene rifting history, likely influenced the earliest manifestation of EARS extension being focused there. The TD region may have been inherently weaker than the thicker crust of the Ethiopian and East African Domes and thus more adept to accommodate strain at the onset of rifting.

references

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Contribution of the SENTINEL-2A MSI imagery to geological mapping and mineral exploration of northeastern part of Saghro massif (eastern Anti-Atlas, Morocco)

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Abstract

The analysis of remote sensing data is widely used for geological mapping and become very useful especially in arid and semi-arid regions. In this work, Sentinel-2A MSI data geological survey data were used to map geological units of northeastern part of Saghro massif. This massif situated in the northeastern part of the Anti-Atlas belt, which known by its arid climate and historical mining. Geologically, it is composed of low-grade metasedimentary sequences of the Saghro Group of Cryoginian (basement) and intruded late by calc-alkalin plutons of Ediacarian, which is unconformably overlain by volcanic and volcanosedimentary successions “Ouarzazate supergroup” of Ediacaran. On the northern side, it is covered by early Paleozoic sequences. These Precambrian basement is mainly affected by Pan-African and Variscan orogenies. However, the Paleozoic cover rocks are especially affected by both Variscan and Alpine orogenies but this last one is still very discrete.

For achieving this mentioned purpose, two approaches have been adopted. In first time, unsupervised classification and band ratios were carried out on Sentinel 2A image acquired on 29 May 2017, mainly to appreciate the potential of this sensor for discriminating geological units of study area. In the second time, lineaments automatic extraction was carried out on the first component issue of principal component analysis (PCA) and converted to fractures network.

As a results, the map obtained (at 1:25,000 scale) in this study shows a high accuracy of geological delimitation units of Saghro massif in comparison to the previously geological map (at 1:50,000 scale). However, the typological analysis of fractures system allowed to highlight three main directions E-W (N70-N90), NW-SE (N100-N150) and NE-SW (N40-N70) and others less frequent as results to the Pan-African and Variscan and Alpine deformations. The most Saghro deposits are only vein-type deposits and related automatically to this fractures network. Thus, lineaments automatic extraction and geological delimitation units via Sentinel-2A might be sincerely a good tool of mining exploration at regional scale.

Apport de la teledetection spatiale a la reconnaissance morpho-structurale de la region d'oumejrane (Anti-Atlas Oriental, Maroc)

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Abstract

L'objectif de la présente étude consiste à développer une approche méthodologique opérationnelle utilisant une base de connaissances géoscientifiques et des données spectrales provenant du capteur Landsat, afin de cartographier les différents facies et surtout mettre en évidence les réseaux de fracturation susceptibles de contenir des minéralisations. La région ciblée par cette étude est celle de Taghbalt Maider qui fait partie du district minier d'Oumjrane. Ce dernier se situe dans la partie méridionale de l'Anti-Atlas oriental, à 50 Km au SE de la ville d'Alnif. Il est caractérisé par des minéralisations à Cu, Pb, Zn et Ba, qui sont encaissées essentiellement dans des terrains sédimentaires de nature grésopélitiques de la formation supérieure du groupe de 2^{ème} Baní (Ordovicien supérieur). Ces terrains sont affectés par des déformations cassantes ayant développé des failles qui abritent les minéralisations filoniennes. L'approche méthodologique adoptée est fondée sur l'utilisation des images spatiales Landsat (2010-2011). Elle se base particulièrement sur l'analyse des caractéristiques radiométriques, morpho-structurales et texturales des formations géologiques existantes. L'analyse d'images satellites de la région d'étude a permis de reconnaître quatre familles de fractures d'importance régionale. Ces failles, d'orientation moyenne N00, N75, N85 et N90, ont toutes contribué, ensemble ou séparément à la structuration de l'anti atlas oriental. Le traitement numérique des images satellites montre que les linéaments qui ont une direction compris entre 45°-90° sont plus nombreux. Elles se situent dans leur globalité dans la partie nord-ouest du secteur d'étude.

Gondwana correlations across Atlantic Ocean: Eastern Brazil and Western Africa

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Abstract

New detailed geological mapping of the Eastern Brazil, carried out in a joint program UERJ-CPRM, together with many geochronological and isotopic data of the basement rocks brought out new insights on the correlation across South Atlantic. Major tectonic pieces involved into Western Gondwana puzzle are: preserved Archean nucleus, Archean terranes reworked by the Rhyacian Orogeny, Juvenile Rhyacian terranes, Paleo to Mesoproterozoic intracratonic magmatism and sag to rift basins, Reworked Paleoproterozoic terranes during Panafrican-Brasiliano orogeny, Tonian to Ediacaran rift to passive margins, Tonian to Cryogenian intra-oceanic to immature magmatic arcs, Ediacaran Cordilleran magmatic arcs, sin- collision Ediacaran magmatic rocks and Cambrian post-collision bimodal magmatism.

Major orogenic systems are Araçuaí-Ribeira-West Congo belts and Dom Feliciano- Kaoko-Damara belts developed between São-Francisco, Congo and Kalahari cratons. Correlation of the major ties are still in debate, but a comprehensive tectonic model is presented (Heilbron et al., 2017, Peixoto et al., 2017, Lobato et al., 2016, Valeriano et al., 2016, Bruno et al., 2017). Our model supported by paleomagnetic data (D'Agrella et al., 2017) propose diachronic amalgamation of these cratonic blocks with respective passive margins and magmatic arc terranes (both cordilleran and intra-oceanic) at ca. 620-595 Ma, 595-565 Ma and 535-510 Ma. A profuse tectono-magmatic Cambro-Ordovician event marks the transition to platform stage with intracratonic basins.

Gondwana break-up studies in South Atlantic were done in the scope of many joint projects involving UERJ-Petrobras. Data suggests that structural and lithospheric inheritance together with focused magmatism in the so-called pre-rift stage play a role in the Late Cretaceous break-up event, controlling geometry, salt deposition and magmatism abundance in the marginal basins. Dike swarms (Guedes et al, 2016; Almeida et al., 2013) in both sides of the Atlantic mark main tectonic episodes and the local stress field. Late Cretaceous to Eocene alkaline intraplate magmatism and renew tectonism reworked the Atlantic marginal basins and their onshore basement shoulders resulting on the formation of an intracontinental rift system.

This long and complex geological history leaves important structures (weak zones) that have been reactivated many times, including during Neotectonic deformation.

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New model for the crustal and tectonic evolution of SW Ghana: implications for the assembly of the West African Craton and Precambrian tectonics

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Abstract

The Palaeoproterozoic juvenile granite-greenstone terranes of the West African Craton (WAC) offer a unique opportunity to investigate orogenic processes active in the early Earth. The dominant crustal architecture, strain patterns and metamorphism are attributed to the Eburnean Orogeny (ca. 2150 - 2070 Ma). This study uses a multi-disciplinary, multi-scale approach to examine the crustal and tectonic evolution of the NE-striking Sefwi Greenstone Belt and adjacent metasedimentary domains of SW Ghana, in the southeast portion of the WAC. ϵ_{Hf} data indicates that the radiogenic Palaeoproterozoic continental crust exposed in Sefwi Belt was derived from a mafic proto-crust extracted from the depleted mantle between 2260 and 2650 Ma. Major and trace element analysis reveal the coeval production of TTG-like and calc-alkaline magmas, derived from both partial melting of mafic crust at contrasting depths, as well as a LILE-enriched mantle source, emplaced between ca. 2159 and 2135 Ma, with inherited zircon ages between 2270 and 2250 Ma. Significantly younger muscovite-bearing leucogranites, emplaced between ca. 2092 and 2081 Ma reveal distinct crustal origins. This magmatic evolution bears a number of similarities to Neoproterozoic terranes, associated with a nascent subduction setting. Combined geochemical, geochronological and isotopic evidence suggest juvenile crust formation occurred in an intra-oceanic subduction setting, with late emplacement of shallow crust-derived magma, interpreted as the product of collision and suturing of two crustal blocks.

Evidence of this suturing event is preserved in the relatively understudied tectono-metamorphic history of SW Ghana. A regional, bedding-parallel foliation (S1), axial planar to isoclinal F1 folds, and top-to-the-NNW thrust faults represent the oldest observed structures. We present petrological constraints derived from migmatitic and subsolidus amphibolite facies metapelite and amphibolite rocks, which reveal peak D1 conditions of 10.0–11.5 kbar, 580–650 °C (HP-MT). Such conditions preserve the highest metamorphic pressures in southern Ghana. D1 is interpreted as a collision-related crustal thickening event. Consequent to D1, partial melting in the thickened crust generated the aforementioned leucogranites, representing the final episode of magmatism in the study area. Emplacement of the leucogranites is spatially restricted to the NW margin of the Sefwi Belt and the interpreted suture zone. Overprinting D1 structures, D2 deformation generated E-W constrictional folds, sinistral reactivation of major NE-striking shear zones and normal NNE-striking detachments, attributed to simple shear dominated ENE-WSW transtension. This oblique orogenic extension resulted in the exhumation of mid-crustal and lower-crustal rocks, juxtaposed against low-grade metamorphic domains, reminiscent of transtension and exhumation of UHP rocks in the Early Devonian Scandinavian Caledonides (Dewey, 1988; Krabbendam & Dewey, 1998). The timing of D2 is constrained by in-situ monazite SHRIMP U-Pb ages of ca. 2073 Ma, post-dating a similar metamorphic history in NW Ghana by ~60 m.y. suggesting a diachronous metamorphic history for the WAC. Subsequent E-W shortening (D3) resulted in localised greenschist facies metamorphism and dextral reactivation of shear zones bounding the Sefwi Belt.

We present a new explanatory model for the assembly of southern Ghana highlighting the Neoproterozoic-like magmatic evolution and its tectono-metamorphic similarities and discrepancies relative to modern collisional orogens, suggesting a transitional Palaeoproterozoic tectonic regime.

Mboutou Double Ring structure: possible impact scar

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Abstract

In northern Cameroon, an isolate and shallow depression called the Mboutou Double Ring is located above the Mayo Tiel, northward from Baschéo near the border with the Nigeria. The feature is 47 km distant from Garoua city and centred at lat 9° 43' 41.7969" N; long 13 ° 21' 49.7649" E geographical coordinates, with about 6 km in diameter. It presents roughly two concentric rings surrounding a central peak of 1 km in diameter. It could be classified morphologically as an annular depression with a central dome. The relief is rather monotonous, dominantly expressed with flatness and isolated massifs known as Hosséré, that is the case of Hosséré Mboutou. The altitude range is between 295 and 550 m. This structure is situated on the Cameroon Volcanic Line which still active. The sampling outcrops consists mainly of blocks or boulders of granites and gabbro which are intersected by leucocratic dykes of various sizes. Thin sections of four samples have been observed on optical microscope. Mbo4 and Mbo6 samples show strong fracturing in quartz and planar microstructures. Fractures extend the length of the individual cristals, it may possibly be Planar Fractures PFs or Planar Deformation Features PDFs resulting from transient shock wave throughout the target. Mbo3 and Mbo7 show heterogeneous glass.

Interpretation of geomorphological pattern is made easy by remote sensing with satellite imagery data. The petrographic analyses of thin sections show shocked minerals, most of them being crushed into microcrystals. The crater appears to be a unique local structure superimposed upon regional deformed Precambrian rocks. This study constrained by remote sensing and petrographic surveys support the hypothesis of meteoritic impact origin. Mboutou Double Ring morphology appears to be a complex impact crater.

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**Tectonics
and
structural
geology**

Analyse structurale et microtectonique dans les formations carbonatées et gréseuses du Viséen du Massif Central Marocain

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Abstract

Le Massif Central hercynien marocain (MCHM) a fait l'objet de nombreuses études géologiques, et continue à susciter l'intérêt des géologues, vu la diversité des âges et affleurements qu'il offre et la richesse de ses paysages, depuis les bordures des chaînes alpines atlasiques jusqu'au littoral Atlantique. La partie Est de ce massif constitue un segment de la chaîne hercynienne marocaine, à séries paléozoïques allochtones, s'étalant de l'Ordovicien jusqu'au Namurien. Le front de ces nappes est formé par les formations carbonatées dévono-carbonifères mises en place dans un contexte de bassin d'avant-pays en compression, pendant le Viséen supérieur et le Namurien-Westphalien. Ces formations s'alignent suivant une direction NNE-SSW. Les formations paléozoïques de toute cette région sont structurées en anticlinaux et synclinaux à orientation NE-SW issus de la phase majeure de l'orogénèse hercynienne, dite phase namuro-westphalienne. Les séries viséennes allochtones de la partie Est du massif central marocain, affleurant le long du front de la nappe du Jebel Bou Khemis, entre Mrirt et Amghasse, ont fait l'objet d'une étude structurale et microtectonique, visant à mettre en évidence la relation entre le plissement et la fracturation. Les stations microtectoniques étudiées ont été relevées dans plusieurs plis et dans différentes parties du même pli (flancs longs et courts et dans la charnière) pour d'une part, étudier la relation entre la géométrie du pli et la fracturation, et d'autre part, pour montrer le contrôle du faciès et son importance dans la genèse de la fracturation. Les familles des fractures sub-verticales paraissent antérieures aux fractures sub-horizontales. Elles semblent correspondre aux premières déformations cassantes accompagnant les premières phases de raccourcissement pendant le Layer parallel shortening (LPS), les fractures horizontales se sont développées par accommodation du pli lors de l'extension verticale et l'amplification de la charnière. Ces familles de fractures sont postérieures à la phase majeure de plissement ayant généré des plis synschisteux à schistosité pénétrative orientée NE-SW. Ces fractures accompagnent à des phases ultimes de plissement ou elles sont contemporaines des dernières phases cassantes ayant affecté la chaîne hercynienne marocaine. Les mêmes familles de fractures macroscopiques ont été détectées par étude microtectonique de lames minces orientées, confectionnées dans les faciès carbonatés. Il s'agit de microdéformations (microfractures et microcisaillements) permettant de confirmer la présence d'une déformation pénétrative dans ces faciès.

Interprétation géodynamique des données morphostructurales du volcanisme du Hoggar

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Abstract

Le Hoggar est le siège d'une importante activité magmatique qui se manifeste de l'Eocène au Quaternaire (Dautria, 1988, Liégeois et al., 2005, Azzouni et al., 2007), au cours de laquelle se mettent en place d'importants volumes de laves tholéitiques, alcalines et hyperalcalines, saturées et sous-saturées. Ce volcanisme comprend plusieurs necks, dômes, filons, plateaux, lambeaux basaltiques ainsi que des produits pyroclastiques variés. Il se localise le long des grands accidents d'échelle lithosphérique qui séparent le plus souvent les terranes qui composent le Hoggar central.

Par ailleurs, des études en cours utilisant des données géophysiques (Bendaoud et al., 2016, Ben El Khaznadji et al., 2016 et Boubekri et al., 2016) démontrent l'influence de grands cisaillements, dont celui du linéament de l'Oued Amded et de ses satellites NE-SW, sur la mise en place du volcanisme Cénozoïque du Hoggar.

Le présent travail s'est intéressé aux différentes provinces de ce volcanisme situées dans les terranes de la Tefedest, Laouni, Azrou N'Fad et Egéré-Aleksod. Ces terranes appartiennent à un ensemble appelé LATEA, qui correspond essentiellement à un micro-continent Archéo-paléoprotozoïque démembré par de grands accidents au cours du Panafricain.

L'étude consiste, en suivant la méthodologie de Nkono et al. (2007), à faire une cartographie de la distribution des structures volcaniques, des failles et des linéaments qui les accompagnent en utilisant des images satellitales de moyenne résolution, telles que les Landsat 7 ETM et les modèles numériques de terrains (DEMs Digital Elevation Models ; SRTM : Shuttle Radar Topography Mission). Cela permet de contraindre le champ des contraintes et le jeu des failles au moment de la mise en place du volcanisme étudié.

Nous avons fait une cartographie détaillée des appareils volcaniques ; puis nous avons fait un traitement numérique permettant la réalisation de rosaces des directions préférentielles de leur distribution. Le même travail a été réalisé sur les linéaments.

Les résultats obtenus convergent et suggèrent une relation directe entre la distribution des structures volcaniques et les directions linéamentaires. Ces linéaments se disposent en conformité avec un modèle de Riedel. Les structures volcaniques se disposent préférentiellement dans la direction T, transtensive définie par le modèle.

Etude des cisaillements majeurs de la région de Tin Tarabine (Hoggar Central, Algérie): Apport de l'imagerie satellitaire

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Abstract

L'Orogenèse panafricaine correspond au Hoggar, à des accrétions d'arcs insulaires océaniques juvéniles et à des terranes continentaux plus anciens archéens et/ou paléoproterozoïques. Ils ont subi pendant les périodes du Tonien et Cryogénien une compression E-W finale et générale suite à la collision survenue au cours de l'Ediacarien. Au cours de cette phase finale, des mouvements horizontaux majeurs de terranes le long des zones de méga-cisaillement, principalement N-S, ont eu lieu dans cette région coincée entre le craton ouest africain et le métacraton saharien.

La région de Tin Tarabine est une région clef pour étudier cette période, elle se situe dans le Hoggar central, à la jonction des terranes archéo-éburnéens d'Azrou N'Fad et Egéré- Aleksod, d'histoire précambrienne polycyclique, et le terrane de Sérouenout qui est juvénile (panafricain). Ainsi, des études antérieures ont mis en évidence une importante déformation post-collisionnelle, correspondant à une tectonique décrochante essentiellement transpressive, matérialisée par de grands cisaillements subméridiens dont les plus importants correspondent à des limites de terranes. Ce travail consiste, grâce à des traitements d'images satellitaires, à réaliser une carte de la trajectoire de la foliation, de délimiter les lithologies et de tracer les linéaments comme première étape de l'étude de la déformation de cette région.

Pour ce faire, nous avons procédé à des traitements d'images satellitaires Landsat 8 OLI. Ainsi, après avoir créé une mosaïque, les traitements effectués sont les suivants: rehaussement spectral (ETM4 ETM3 ETM2, ETM7 ETM5 ETM3 et ETM7 ETM6 ETM5), analyse en composantes principales (CP3762 CP3524 CP1362 et CP224 CP257 CP267), rapports de bandes (4/3 7/6 5/4), (7/6 5/4 3/2) et (7/6 5/4 4/3) et filtres directionnels (F45° F90° F0°) et (F45° F135° F0°) en matrice 3x3.

Cartographie des failles bordières du bassin de la Mitidja

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Abstract

Le bassin de la Mitidja se situe au nord de l'Algérie qui est à la frontière active de deux plaques accommodant la convergence de l'Afrique et de l'Eurasie. Avec une structure mal connue et des failles sismogènes qui ne sont pas toutes identifiées. Notre étude est essentiellement basé sur la cartographie se veut une contribution à une meilleure connaissance de la géologie de la région algéroise afin de mieux appréhender son évolution récente avec les risques sismique quelle présente.

Ce travail a consisté à utiliser trois outils différents pour la cartographie des failles qui délimitent le bassin de la Mitidja : le traitement d'images satellitales (Landsat 8 et Sentinel 2); des travaux de terrain (même si ils furent limités) et le traitement de données gravimétriques.

Les résultats nous paraissent être très intéressants:

- l'intégration des résultats obtenus par les traitements d'images satellitales au sein d'un SIG permet une cartographie extrêmement précise aussi bien des failles majeures qui bordent le bassin de la Mitidja que les failles plus réduites qui les recoupent et les décalent;
- les mesures sur le terrain nous a permis de faire des vérifications sur la localisation de certaines de ces failles et de déterminer leur nature et leur jeu apparent;
- le traitement des données gravimétriques a permis de confirmer l'existence de certaines failles qui pouvaient être ambiguës, telles que les failles N-S qui recoupent le bassin et l'Atlas Blidéen. Il permet également de retrouver la forme du bassin et la localisation des failles majeures qui le bordent et d'observer que le bassin se poursuit légèrement sous la mer vers le NE.

L'inversion de ces données qui aboutie à une coupe horizontale à 3 km du contraste de densités, permet de voir la forme compartimentée du Bassin de la Mitidja et confirme la plupart des observations citées plus haut.

Les différents technique ont apportés des arguments qui montrent que les outils utilisés, le traitement d'images satellitales et de données géophysiques déjà disponibles peuvent donner des résultats qui non seulement sont loin d'être négligeables mais sont même parfois remarquables

Analyse des rhéologie, dynamique et hétérogénéité pour la caractérisation des systèmes naturels et la mise en évidence d'un bassin extensif en Pull-apart dans la localité de Santchou (lignes de structures N030 et N058-N073 du Cameroun)

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Abstract

La localité de Santchou, située entre 5°10' et 5°30' latitude Nord et 9°45' et 10°10' longitude Est est traversée par deux principales lignes de structure orientées N030 et N058-N073 à l'origine de grandes complexités géodynamiques et géomorphologiques. A travers les campagnes de mesures et l'analyse des rhéologie, dynamique et hétérogénéité des structures et des systèmes naturels, on observe une cinématique principale composée de failles en transtension dans la direction SSW-NNE et une cinématique minimale composée de failles en transcompression dans la direction WNW-ESE; d'où la formation d'un bassin extensif en pull-apart.

Apport des images satellites Landsat 8 OLI et Sentinel 2 à la caractérisation de la déformation hercynienne dans les monts d'Ougarta (Sud-Ouest Algérien)

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Abstract

La chaîne d'Ougarta est située à l'aplomb de la zone de suture entre le domaine panafricain de l'Afrique de l'Ouest et le craton Ouest-Africain. Actuellement elle appartient à la partie Nord-Ouest de la plateforme saharienne. Elle est divisée en deux faisceaux, la Saoura dans le Nord-Est et la Daoura dans le Sud-Ouest. Ces deux derniers sont séparés par l'Erg Er Raoui.

C'est une région fortement plissée et notre étude a pour but de caractériser les déformations hercyniennes dans cette région, en associant les mesures de terrain, les travaux antérieurs et le traitement de données multispectrales des capteurs Landsat 8 OLI et Sentinel 2. Pour cette dernière partie, la procédure consiste à réaliser des filtres directionnels selon quatre directions, avec des matrices en 3×3 et 7×7 , des compositions colorées, des néobandes obtenues de l'analyse en composantes principales et des rapports de bandes, qui permettent de délimiter les lithologies reconnues sur le terrain et les structures associées aux grandes shear-zones panafricaines ainsi que les structures plissées qui leur sont associées. Il apparaît ainsi que pendant les phases de compression hercyniennes et plus tardives, les plissements ont été guidés par de grandes shear-zone panafricain qui sont majoritairement orientées NW-SE, E-W et NE-SW.

Tectonic signatures of Post-Gondwana break-up in the West Congo Belt (D.R. Congo): first results from low-temperature thermochronology

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Abstract

Low-temperature thermochronology is the principal method to investigate tectonic movements in the upper crust, and to place them into an absolute timeframe. The method has been used numerous times to investigate passive margins around the South Atlantic, with mainly a focus on the South American continent. On the African margins studies have also been conducted in different countries (South Africa, Namibia, Cameroon, ...). This study is the first to conduct thermochronologic research on the western margin of the D.R. Congo. The geology in the region is dominated by the West Congo Belt, which is the eastern part of the Araçuaí – West Congo orogen (AWCO). Currently the western Araçuaí counterpart lies on the South American continent (Brazil). The AWCO was a confined orogen that was enclosed by the São Francisco – Congo craton, that had formed as a result of the Brasiliano – Pan African orogeny (latest Neoproterozoic). The AWCO was separated, rifted and became two individual passive margins during the Early Cretaceous (~130 Ma). We acquired samples on two E-W and two N-S profiles in the Central Congo province, consisting both of archive samples from the Royal Museum for Central Africa (Tervuren, Belgium) and newly obtained samples from a field campaign in 2016. The samples are analysed with the apatite fission track (AFT) and the apatite (U-Th-Sm)/He (AHe) combined methods. Tectonic reactivation will be mostly visible in the E-W profiles, while the N-S profiles could yield information concerning current hypotheses involving transform faults related to the opening of the South Atlantic.

Kinematic evolution of two gravity-driven deep-water fold-and-thrust belts: the Orange Basin and the Lamu Basin case-studies

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Abstract

Recent advances in seismic processing and acquisition have revealed the presence of many deep-water fold-and-thrust belts (DWFTBs), often developing along continental passive margins. These kinds of tectonic features have been intensively studied, due to their resource interest.

The African continental passive margins host several gravity-driven DWFTBs (Morley et al., 2011). Here we used previously unpublished 2D seismic reflection profiles in order to study and compare the kinematic evolution of two case-studies: the Orange Basin (S. Africa west margin) and the Lamu Basin (Kenya and S. Somalia).

The Orange Basin (OB) resulted from Late Jurassic to Early Cretaceous rifting and subsequent drifting of the African and South American Plates. It comprises a series of Upper Jurassic syn-rift sequences overlaid by Lower Cretaceous to Present post-rift passive margin deposits. The Cenozoic megasequence is affected by extensional faults up-dip, genetically linked to the development of imbricate thrusts down-dip (Paton et al., 2008). The Lamu Basin (LB) formed in the Late Paleozoic, during the early phases of Gondwana breakup, and developed passively in Mesozoic time after the Jurassic separation of Madagascar from Africa. Cruciani et al. (2017) recognized a margin-scale fold-and-thrust belt, active from Late Cretaceous until Early Miocene times.

The two DWFTBs are significantly different in terms of width, structure, dip of detachment and mechanics. The OB compressional domain extends for about 15 km, above an oceanward dipping detachment (probably driven by gravity gliding) at a depth between 2-3 km. The shortening (6 km) is accommodated by four main thrust faults and the related anticlines wavelength has an almost constant value of 3 km. The LB, in turn, has a wider compressional domain which varies from 180 km, at the north-central part, to less than 50 km, at the southern part; it developed above a landward dipping basal detachment (driven by gravity spreading) at a depth between 6-7 km. Shortening (up to 50 km) is accommodated by imbricate thrust faults in the outermost sectors and by double-verging structures and detachment faults in the innermost sectors. The structures wavelengths progressively increase landward.

Despite the differences in the total amount of shortening, the percentage of shortening is similar, being 24 % in the OB and between 17,5 and 21,7 % in the LB. Also shortening distribution along dip shows a similar trend in both case-studies; maximum shortening is achieved down-dip and decreases toward the hinterland. For the OB is almost linear, while for the LB case-study it is not. The LB accommodated up to 97 % of shortening during Paleocene, with a shortening rate between 1 and 5 mm/yr. The OB was active during the Cenozoic with a shortening rate of, at least, 1mm/yr.

The two case-studies, besides their common classification as Type 1a DWFTBs (i.e. near field systems detached above shale), reveal significant geometrical and mechanical differences, but rather similar kinematics.

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Relationship between fracturing and folding in fault related fold: a case study from central Tunisia

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Abstract

Fracture network properties in a fault related fold in central Tunisia are described, analysed, and combined with fold geometry to bring out relationship between fracture network and folding process. In this paper, a quantitative study of fracture network was established. The adopted methodology consist to collect geological data from field then modeling folds with Rampe EM software. Fracturing station covering 1m² collected from two limbs and hinge then rotated throw the axial plane to have an idea about their distribution before folding process. Results of kinematic modeling show that fold structure is a backthrust fold with two detachment levels, the first level is Triassic evaporates and the second one is the hauterivian barremian shale and gypsum. Fracturing parameters show a mixed origin: fractures initiated with the first compressive phase and characterize one limb; fracture initiated before compressive phase and that are rotated throw the stress direction.

Faulting and fracturing in the Lower Jurassic limestones in the Tabular Middle Atlas, Morocco: hydrogeological implications

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Abstract

The Tabular Middle Atlas is affected by a main fault system oriented NE-SW, inherited from Paleozoic epoch, delimiting different blocks, elongated in the same direction. The intense fracturation affecting the Liassic limestones is related to extensional syn-rifting episodes, during Triassic and Lower Jurassic or associated to sedimentary brecciation following temporary emersions or to post-depositional periods caused by shortening phases during Tertiary and Quaternary. The NE-SW fault system has controlled Triassic and Lower Jurassic sedimentation, the Plio-Quaternary alkaline volcanic activity and is still playing an important role in the seismic activity in the area of Azrou-Ifrane-El Hajeb plateau. This area has been the subject of important geological, hydrogeological and geomorphological studies, but the knowledge of fracture network and its relationship with karst systems and groundwater circulation aquifers is still unknown. This area underwent a Mesozoic polyphased tectonic evolution, involving karst depressions aligned NE-SW parallel to the main inherited faults forming the important lakes in the region. Our approach is based on the fracturing analysis and the determination of relationships between tectonic events and the main tectonic structures development, corresponding to main faults and important fractures that control the water flow in this plateau. Indeed, the study of fracturation at different scales in these Liassic carbonate formations revealed four directions: NE-SW, NW-SE, N-S and E-W. This fracturation was associated to the main deformation phases that affected the Middle Atlas during the Tertiary and Quaternary periods. The relative chronology of these fracture families is well established, the NW-SE set seems to be the later one and is controlling the water flow from the tabular Middle Atlas formations toward the Saiss Neogene basin. The different fracture sets have determined the ruiniform limestones, characteristic of the karst landscape, but the important volcanic activity in this area has added important fracturation surrounding the main volcanic craters occurring especially between Azrou-Ifrane and Timahdit. The studied microtectonic stations chosen in the perimeter of craters and South of Timahdit, in the folded part of the Middle Atlas, allow us to understand regional fracture sets, local fractures linked to the volcanic activity and the fracture sets associated to folding. The Liassic carbonate formation seems to be affected by different geological phenomena, corresponding to karstification, brecciation and mainly intense fracturation associated to polyphased tectonic events from Triassic-Lower Jurassic rifting to Plio-Quaternary shortening phases.

Observation of Soft Sediment Deformation Structure in the Neoproterozoic Kansuki Formation (Katangan Supergroup, Democratic Republic of Congo)

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Abstract

Soft Sediment Deformation Structure (SSDS) in the Neoproterozoic Katangan Supergroup is poorly documented. These structures were identified in the Mwashya Subgroup (Cailteux et al., 2007) and recently in the diamictite of the Nguba Group (Mambwe et al., 2017) but their origin were not debated. Newly observation made in the Central part of the Lufilian arc at Tenke Fungurume Mining district make an evidence of the SSDS within the Kansuki Formation. This host formation consist by a succession of the carbonate platform interlayered by the pyroclastites and mafic veins. Three sedimentology significance of the SSDS are defined in the Roan Group throughout the Kansuki Formation: (1) an evidence of subaerial exposure of the carbonate platform indicate by the tepee structures, (2) a sedimentary origin induced by a rapid deposition and an overloading. They triggered the small-scale of load structures and the succession of load and flame structures, (3) and the seismicity in accordance within the volcanic and magmatic activities related to the expansion of the paleorift Katangan basin. It triggered the load structure with attached pseudonodule, ball-and-pillow and boudinage like structures with water escaper. The described SSDS occurred in different beds of the Kansuki Formation and showing a temporal and spatial extension.

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Nature of Pan-African Central Africa Orogenic Belt exposed in the southern Ouaddaï Massif, South of the Sahara Metacraton

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Abstract

The aim of this work is to discuss the significance of the enigmatic Saharan metacraton based on structural, metamorphic and geochronological data along its southern margin in the southern part of the Ouaddaï Massif, located in the Central Africa Orogenic Belt (CAOB), north of the Congo Craton. This region is dominated by metasediments (metapelite, metagreywacke, quartzite and marble) alternating with metabasites and intruded by intermediate to felsic plutons (granodiorite, monzogranite, biotite-granite and leucogranite). Metasediments display a NE-SW trending S_0/S_{1-2} foliation bearing a L_{1-2} lineation weakly dipping ($10-30^\circ$) towards the NW and associated with centimeter to hectometer scales homoaxial F_1 and F_2 isoclinal folds delineating hook type interferences pattern. The S_0/S_{1-2} foliation is also affected by open F_3 folds outlined by alternating shallow dips ($3-39^\circ$) towards NW or SE and marked by the development of a faint axial planar S_3 schistosity variably dipping ($10-79^\circ$) to the NW. These rocks are affected by greenschist facies metamorphism as illustrated by a chlorite-epidote-actinolite paragenesis in metapelites and metabasites. Thermodynamic modelling (pseudosection and phengite-biotite multi-equilibrium) yield PT conditions of around 4 kbars for less than 400°C . Three quartzites samples contain zircons with inherited cores pointing to Archean (ca. 2,6 Ga et ca. 3,0 Ga), Paleoproterozoic (ca. 1,9 Ga et ca. 2,0 Ga), and Pre-neoproterozoic (ca. 1,0 Ga et ca. 1,1 Ga) sources. All of these cores display an Archean Hf model age of ca. 3,8 Ga or ca. 2,7 Ga. Metamorphic rims yield a concordant age of $602 \pm 3,2$ Ma. A biotite leucogranite and a biotite granite yield U-Pb zircon concordant ages of $635 \pm 2,5$ Ma and $612 \pm 8,2$ Ma. These magmatic zircon are characterized by a ϵHf close to zero departing from the trend of inherited cores of the quartzite and precluding a petrogenetic link between these rocks. The amphibolites correspond to basalts with a geochemical signature typical of arc or back-arc magmas and are characterized by a ϵNd spreading from +5 to +7 pointing to a juvenile mantle source. Two magmatic series are identified in the plutonic rocks. Granodiorite and monzogranite with a meta-aluminous, alkaline A-type signature and ϵNd spreading from -21 to -18 are interpreted to reflect an origin by partial melting of an old mafic crust. Mica-leucogranites with a hyperaluminous and calc-alkaline S-type signature with ϵNd of -10 and an Archean Nd model age of ca.3,41 Ga are attributed to partial melting of the metasediments. The biotite granites are interpreted to reflect a mixture between these two magmatic series but are characterized by crustal-dominated signatures with ϵNd spreading from -11 to -6. Isotopic data confirm that the Ouaddaï Massif is made of rocks dominated by an Archean to Paleoproterozoic model age reworked during the Pan-African Orogeny, which might appear at first sight consistent with the metacraton model (Abdelsalam and al., 2002; Liégeois et al., 2013). However, deposition of the protoliths of metasedimentary rocks and emplacement of magmatic rocks are all dated in the Neoproterozoic and no pre-Neoproterozoic basement has been identified. Accordingly, as an alternative to the Metacraton model, we propose that at least for the Ouaddai Massif, reworking proceeded first by erosion of the Archean-Paleoproterozoic craton and second by deformation and metamorphism during the Pan-African orogeny.

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The phases of alpine deformation in the Beni Khettab region, (Internal domain of the basement of small Kabylie-Algeria)

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Abstract

The NE of Beni Khettab region (NW of small Kabylie basement) is constituted by Jebel Sidi Ali, one of the internal nuclei of the chain of Maghrebids, its petrographic study shows the upper unit of base materialized by gneiss plagioclastics, micaschists surmounted by white marbles. This unit is separated from the lower unit consisting of leptynites by a late Hercynian mylonitic band (Bouillin, 1982 and Djellit, 1987) (Peucat et al, 1991)) and the ensemble is surmounted by a series of satin shale to past Paleozoic sandstone (Djellit, 1987). The whole of small Kabylie basement was intruded posteriorly by Hercynian granites (Peucat et al, 1996).

The southern part of the region shows basal and ultrabasic rocks (alpine volcano-sedimentary complex of Tabellout) (Bouillin et al 1977).

The structural study in the area has shown NW-SE reverse faults, these faults are overlapping and creased (sub-vertical at the surface and dipping to the NE at depth). These faults pack with them brecciated doleritic elements torn from the mafic and ultramafic rocks of Tabellout, these intensely deformed rocks played the role of tablecloth during the overlap of the Kabyle basement on the flyschs.

The southern contract that separates the satin shales from the granite body is marked by sigmoidal elements showing a sinistral deco-overlap towards the SW, this same deformation is underlined by the sigmoidal elements resulting from the satined shales, these different observations of ground are supported by the stereographic projection.

This study allowed us to highlight three principal deformation directions related to the alpine orogeny, the first NW-SE direction, it is related to a shortening movement that took place between the AlKaPeCa block and Africa and the overlap of the inner domain of the Kabyle pedestal on the outer domain. The second is represented by a sinistral deco-overlap towards the SW, it is related to the readjustment of the chain. While the third direction of deformation is later, it shows northback thrusting.

These different structural elements resulting from the different levels of the Kabyle basement and the different deformation directions argue in favor of a polyphase basement that records the Hercynian and Alpine phases (Durand Delga 1969 and Bouillin 1982, 1984).

oral

04

**Stratigraphy,
Sedimentology
& Paleontology**

Le mississippien de la formation de Jbel Hassi Nebech, (Anti-Atlas Oriental, Maroc): faciès sédimentaires et reconstitution de paleoenvironnements

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Abstract

La Formation de Jbel Hassi Nebech affleure à l'Est de l'Anti-Atlas marocain. Elle est située au Sud-Est du Bassin de Tafilalet à moins de 10 km de la route nationale N13 joignant Taouz et Rissani. L'étude biostratigraphique basée sur les foraminifères, algues et pseudo-algues lui donne un âge du Brigantien. Le but de cette étude est d'identifier les différents faciès et microfaciès sédimentaires constituant cette formation et de reconstituer les environnements de dépôt correspondants. La Formation de Jbel Hassi Nebech montre une épaisseur d'environ 170 m. Elle est composée de faciès très variés : (1) calcaire bioclastique à crinoïdes, (2) mud-mound à crinoïdes et à polypiers solitaires, (3) argilites noires, (4) conglomérat à galets de démantèlement de mud-mound, (5) tempestites calcaires, (6) calcaire gris fin.

L'étude microscopique des lames minces montre les microfaciès suivants : calcaires packstones /wackestones bioclastiques à foraminifères algues et pseudoalgues, calcaires grainstones bioclastiques à crinoïdes, calcaires floodstones/rudestones bioclastiques, calcaires grainstones oolithiques bioclastiques, calcaires mudstones pelloïdales bioclastiques.

Ces faciès et microfaciès sédimentaires montrent des variations latérale et verticale indiquant une translation des aires de dépôts dans le temps et dans l'espace. Cette étude sédimentologique nous permet de distinguer trois types d'environnements de dépôts: (A) un littoral à dépôts siliciclastiques, (B) une plate-forme à dépôts de tempestites calcaires, calcaires bioclastiques et bioconstruits, (C) un bassin à argilites noires.

La prédominance de tempestites calcaires, l'absence de barrière récifale et la dominance des espèces spécifiques de paléoprofondeur montrent qu'il s'agit d'une plate-forme de type rampe peu profonde soumise à l'action de vagues violentes. L'estimation de la paléobathymétrie de la rampe de Jbel Hassi Nebech au cours du Brigantien est basée sur la présence d'espèces indicatrices de paléoprofondeur. Les microfaciès nous ont permis également de distinguer des environnements de rampe interne, médiane et externe. La biodiversité très importante et le développement des microfossiles carbonatés montrent que cette plate-forme a évolué sous un climat tropical, chaud et humide.

Seismic attributes in the interpretation of channel geometries and infilling lithologies: the case of the Congo Basin

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Abstract

Seismic attributes are commonly used in the oil & gas industry to improve the interpretability of seismic data. In this study, we applied this technique to geological features like channelized systems and faults visible in a high-resolution “Pre-Stack Time Migrated” (PSTM) 3D seismic volume collected across the lower Congo Basin. Throughout the application of seismic attributes for example, Root Mean Square (RMS), Spectral Decomposition and Coherence, the visualization of such geological structures was enhanced allowing to considerably improve their interpretation. The study region of the lower Congo Basin is characterised by turbidity systems within the Miocene deposits of the Malembo Formation. The area is also intersected by extensional tectonics. The geological framework is the Angolan Passive Continental Margin, in which the channel systems of Zaire River and the wide fan of the Congo Basin develop with a length of about 800 Km westward and a width of more than 400 Km from Gabon to Angolan margins.

The seismic attribute technique permits to enhance and better observe local signal variations, highlighting changes in amplitude, phase and frequency, that are respectively sensitive to contrasts of acoustic impedance, reflectors continuity/discontinuity and different local frequency contents. The attributes were computed along 7 horizons, each with an area of 375 Km² and 60 milliseconds of equidistance in TWT from each other to investigate about 550 m of the 3D volume (considering a mean velocity of 2800 m/s). Among them, the RMS amplitude allowed to infer possible variation of lithologies along the channels in accordance with the acoustic impedance contrasts, in particular from the channel fill and the levees. Coherence attribute enhanced the discontinuities therefore allowing to better identify channels geometries, fractures and faults. Combining coherence with other attributes, it was also possible to display how the extensional tectonics affected the area by disrupting the channel features. The identification of those complex channels patterns was also aided by the Spectral Decomposition attribute, by introducing a chromatics visualization that emphasize their visualization otherwise not so clear in the standard seismic sections. Lateral changes of seismic facies and thickness variations were strongly enhanced by Red Green and Blue (RGB) colour blending which allows to investigate “maps” of the inner channels geometries.

With the application of attributes on the seismic lines and time-slices or horizons, it was therefore possible to make an analysis of channels characteristics like width, length and variations with increasing depth, calculating “Sinuosity Index” variation ranging from straight ($I_s=1$) to meandering channels ($I_s>1.5$). The results highlighted in this work, through the identification of morphologic, sedimentary and structural elements are fundamental in the characterization of the study area to help further processes of seismic interpretation and to improve the geological knowledge of this region.

Sequence stratigraphy and paleoenvironment reconstruction of Paleogene deposits of Faidh section in Central Tunisia

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Abstract

The integration of the various lithostratigraphic, biostratigraphic and mineralogic results, of Paleogene deposits of Faidh section, allowed us to characterize six major discontinuities, which involve to distinguish five depositional sequences of 2nd order. Some discontinuities are classified as tectonic order attested by the presence of polygenic conglomerates, indicating gaps, while others are rather eustatic.

An attempt of correlation between the present chart and the global chart, allow to establish a new insight about the geodynamic of the basin. It evolve that the Triassic movement can be regarded as a local factor, which is responsible of some hiatus.

The cycle TA2 can be correlate to the series of the Paleocene and Ypresian, Pal.1 (limited by D1 and D2) coincide with the new cycle TA2.1. The cycle Pal.2 that is limited by discontinuities D2 and D3 is correlated to TA2.2 of the global chart. Moreover, the cycle Pal.3 correspond to TA 3.1. Further the cycle Pal. 4, which is limited by discontinuities D4 and D5, correspond to TA 3.2. Discontinuities D5 and D6 underline the cycle Pal 5 which correspond to TB. 1. Therefore, the cycle TA4 presented in the global chart of seem to be eroded or is not deposit. It can be related to a tectonic event (unconformity), recorded in surface and also in subsurface.

This new subdivision can be emphasize the passive activity of the Triassic movement, probably in two time, during the Paleogene The structuration into horst and graben initiated also on Triassic movement and persisted until Early Eocene, which create different deposits areas, and it was responsible for systematic hiatus or slight unconformities. These geometries are not obvious to characterize in marine sedimentation. Halokinetic movement, volcanism on offshore and onshore and almost sea level changes and climatic events are the main factor in basin geodynamic. The principal paleogeographic sketches during time related to the conjugation of main factors; tectonic, sea level changes and accessory climate and halokinetic events.

The result lead us to preconize that the two new cycles can be related to the ascensional movement of the Triassic. The geodynamic evolution is established throughout knowledge about depositional constraints and the tectonic framework. Most hiatus are locally bounded either by uniform conglomerate or by heterogenetic, indicating tectonic activity

Biostratigraphy, palaeoenvironment and palaeobathymetry characterization of Miocene sequences, Niger Delta, Nigeria

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Abstract

A biostratigraphical study was carried out on cutting samples recovered from Utona-1l and Olure-1b exploratory wells within the range of 1100m – 1750 m and 1350m – 2250 m depth respectively.

Twenty and twenty five samples were retrieved from Utona-1 and Olure-1b wells respectively and were analyzed for their lithofacies, fauna and flora contents

The lithofacies are argillaceous sandstone, sandy mudstone and mudstone. Biostratigraphic characterization of the wells was evaluated using foraminiferal and palynomorphs assemblages' distributions. The foraminifera recovery in Utona-1 well was poor with the absence of benthonic and planktonic diagnostic species, hence making the age and zonation determination impossible. In Olure – 1b well, fairly abundant and diverse foraminiferal assemblages were recovered. A biozone of N7 – N4 was established based on the regular occurrence of *Globigerinoides trilobus immaturus*, which were recorded at 1476 m depth thus confirming that the well section cannot be older than early Miocene of N4 planktonic zone. Olure-1b well was zoned based on the planktonic index species, N8 Zone or younger was established which has been correlated with the F9300 fauna zone. This was based on the Last Downhole Occurrence (LDO) of *Globigerinoides obliquus obliquus* (1739 m) which co- occurred with *Quinqueloculina microcostata*, *Q. lamarckiana*, *Amphistegina lessonii*, *Brizalina interjuncta*, *Heterolepa floridana*, *Lenticulina inornata*, *Valvulineria* spp. and *Rotralia* spp.

The low abundance of foraminifera assemblages in the Utona-1 sequence suggested deltaic and inner neritic environment. This was evident with the sparse abundance of benthonic fauna such as *Quinqueloculina larmackiana*, *Q. microcostata*, *Amphistegina lessonii* and *Quinqueloculina* spp. Palynomorphs assemblages recorded in Utona-1 well include abundant land derived forms which include *Zonocostiatites ramonae*, *Laevigatosporites* spp., *Acrostichum aureum*, *Monoporites annulatus*, *Verrucatosporites* sp., *Stritricolpites catatumbus*, *Sapotaceaedaepollenites* sp., and *Pteris* spp. with few occurrences of dinoflagellate cysts such as *Polyspheridium zoharyi*, *Multispinula quanta*, *Odontochitina* sp., and *Leiosphaeridia* sp. In Olure-1 well, palynomorphs recorded include all the forms that characterized Utona-1 well which co-occurred with *Verrutricolporites rotundisporus*, *Sapotaceae*, *Psilatricolporites crassus* with an influx of *Pediastrum* sp. The established biozonations for Utona-1 well are Zones P800 – P700 and Subzones P820 – P780.

The palaeoenvironmental trend in the wells shows transgressive - regressive signatures that characterized a paralic sequence in the Agbada Formation. This is evident in the recovered faunal and floral distributions in both wells, thus suggests that Utona-1 and Olure-1 wells penetrated Agbada Formation and was dated early to middle Miocene.

Palynostratigraphy of the Moatize – Minjova Basin in the N'Condèzi region: preliminary results

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Abstract

Karoo sedimentary rocks are well represented in Mozambique in various sedimentary basins, located along the Zambezi River valley in Tete Province, Central-West Mozambique. The Moatize-Minjova Basin is one of these basins which sedimentary successions are regarded as the key stratigraphic sections for the Lower Karoo Supergroup in Mozambique, including from base to the top the Vúzi, Moatize and Matinde formations. This basin is also important due to its world-class coal resources and reserves present in the Moatize Formation. However, the palynology from the Lower Karoo successions in Mozambique has not been comprehensively studied and only few published papers are known (Pereira et al., 2016; Götz et al., 2017). In this work we present preliminary palynological data obtained from an extended stratigraphic section (ca. 1000 m thick), in borehole A1TM-058 drilled for coal exploration in the N'Condèzi region, of the Moatize-Minjova Basin. The entire borehole consists of interbedded shales, carbonaceous shales, coals seams and sandstones. This borehole is one of the deepest drilled in this region and penetrated at the base the Mesoproterozoic gabbros and anorthosites of the Tete Suite making the basement rocks. Therefore, the core of the borehole may represent all the stratigraphic units of the Lower Karoo in the Moatize-Minjova Basin. Shales and carbonaceous shales of the first 100 m at the top of the borehole, yielded well-preserved palynomorphs characterized by pollen grain as *Guttulapollenites hannonicus*, *Lueckisporites virkkiae* and *Weylandites lucifer*, *Polypodiisporites* spp. and verrucated monolet spores. This palynological assemblage let to refer the succession to Lopingian age.

Due to this unique condition, the extended section preserve in the core of this borehole, offers a rare opportunity to know not only the age of the stratigraphic units of the Lower Karoo in this basin, but also may provide an important record of the environmental and climatic changes that occurred during the time span of the Lower Karoo. These studies may provide a better understanding of the palaeoenvironments of the coal facies and time constraint the end of the Late Palaeozoic glaciation in this region.

A first assessment of organic maturation using Palynomorphs Darkness Index (PDI) of the Moatize – Minjova Basin, Mozambique

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Abstract

Palynomorph Darkness Index (PDI) is a new quantitative method to establish the thermal maturity of organic matter. PDI is calculated from measurement of the red, green and blue (RGB) intensities of light transmitted through palynomorphs, using standard palynological microscopes and digital cameras. This is based on the integration of red, green and blue intensities to produce a single greyscale value that is then converted to a newly-defined PDI. In the present study, the palynomorphs were digitally imaged using Olympus BX51 microscope, equipped with a 5 Megapixel digital colour camera, and software image acquisition CELL[^]A. Images were collected at a constant illumination setting using a 60X magnification objective. The background colour was used to calculate the pollen grain's adjusted gray scale as described by Goodhue and Clayton (2010).

In this study, PDI values were calculated on sporomorphs (e.g. unornamented spore and central body of bisaccate/monosaccate pollen grain) yielded from DW123 and DW132 boreholes of the Moatize-Minjova Coal Basin of Lopingian (Late Permian) age. Ten measurements of ca. 16 µm² area were performed for each sporomorph selected.

The PDI values were correlated with vitrinite reflectance (VR) data which range from ca. 1.3 to 1.6% Ro, corresponding to the boundary between the oil and wet gas windows (Fernandes et al., 2015). PDI values showed a positive linear correlation with vitrinite reflectance, and are consistent with the increase value of PDI with maturity observed by Goodhue and Clayton (2017) using samples with VR values at the early oil window. This study demonstrates that the use of PDI could be an alternative tool for evaluate the organic maturation of sediments, and used in thermal basin modelling studies with applications in hydrocarbon exploration and for general geological studies of sedimentary basins.

The middle-upper Eocene vertebrate record from Tarfaya–Laâyoune–Dakhla Atlantic Basin (Morocco) and their implications.

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Abstract

Several palaeontological field campaigns in Ad-Dakhla and Boujdour area in the Tarfaya–Laâyoune–Ad-Dakhla Basin have resulted in the discovery of rich Bartonian and Priabonian vertebrate assemblages. These faunae are mainly dominated by marine taxa, including selachians, bony fishes, turtles, crocodiles, palaeophiid snakes, pelagornithid seabirds, proboscidiens, archaeocete whales and sirenians. All this material comes from two areas in the Moroccan Sahara desert: the Aridal Formation at Gueran, ca. 150 km southeast of the city of Boujdour, and the Samlat Formation in Ad-Dakhla area. At Gueran, all fossils come from a single meter-thick sandstone unit. Archaeocete whales are especially well represented by skeletons and hundreds of vertebrae referred to at least eight species of Protocetidae and Basilosauridae. Fauna from Gueran also includes abundant selachian teeth, a few remains of bony fishes, and rare fragments of turtle shells, fragments of jaws, vertebrae and osteoderms of crocodiles, Palaeophiid snake vertebrae, seabird remains and fragments of proboscidian teeth. The presence of both protocetid and basilosaurid whales indicates a probable Bartonian age for the locality, because basilosaurids are unknown during the Lutetian, and a single protocetid is known from early Priabonian. This age is consistent with the Bartonian age suggested by the assemblage of sharks and rays. At Ad-Dakhla area, fossils are known from stratigraphic sections along 30 km of Atlantic Ocean coastline, south and southwest of Ad-Dakhla, in southern Morocco. The outcrops are located in three areas, which are from North to South, El Argoub, Porto Rico, and Garitas. At Garitas, vertebrate remains come from three levels called A1, B1 and B2. The lower fossiliferous layer A1 of lithostratigraphic 1 (Unit1), that includes some 22 m of rhythmically-bedded, chert-rich marine siltstones and marls, has provided selachian teeth, palaeophiid snake vertebrae, sternebra of a small protocetid and several cheek teeth of the large protocetid *Pappocetus lugardi*. Protocetids are usually Bartonian in age and their occurrence in coastal strata deserves to be highlighted since they are better known from the inland locality of Gueran. Unit 1 strata are overlain by 1–1.5 m of vertebrate-bearing conglomeratic sandstone (B1), another 4–8 m of rhythmically-bedded siltstone and marl, and a second 3–6 m unit of vertebrate-bearing muddy sandstone (B2) which constitutes lithostratigraphic 2 (Unit2). Bonebed B1 has yielded abundant and diversified selachians and archaeocete whales, as well as remains of sirenians, proboscideans, actinopterygians, turtles, palaeophiid snakes, crocodiles and pelagornithid seabirds. The cetaceans from bed B1 represent at least five species. The only identifiable cetacean found in Bonebed B2 is *Basilosaurus* sp. Dugongid sirenians identified as cf. *Eosiren* sp. are the most common mammals in bed B2. A late Eocene Priabonian age was assigned to the Unit 2 and to both B1 and B2 bonebeds, based on the selachian fauna. This age is confirmed by the archaeocete assemblage from Bonebed 1, similar to those identified in the Priabonian Formation of Wadi Al Hitan in Egypt. This sequence also produced planktonic foraminifera, which made it possible to propose dating at three different levels of the sequence. Two planktonic foraminifera assemblages respectively confirm the Bartonian and Priabonian ages of lithostratigraphic 1 and lithostratigraphic 2. While the third assemblage of the level located at the base of the lithostratigraphic unit 3 indicates Early Oligocene age. The presence of similar planktonic foraminifera assemblage indicates the first undisputed characterization the marine Early Oligocene (the Rupelian) in this basin. At Porto Rico, Bonebed B2 includes a well-preserved dentary of a new protosirenid sirenian similar in molar size to *Protosiren smithae*, but with a distinctive symphyseal conformation. A rich earliest Oligocene fauna of continental mammals is known at Porto Rico and El Argoub.

New sedimentological interpretation of late Visean carbonate rump deposits from Bou Balghatene area, central Morocco

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Abstract

The Bou Balghatene Formation crops out at the East of central Morocco. It is located at less than 43km to the north of Mrirt city. It is accessible through the secondary road S331 connecting Meknes to Mrirt. The overthrust structure shows a verging towards the NW. The new biostratigraphic data based on microfossils (foraminifers, algae and pseudo-algae) shows that the Bou Balghatene Formation has a Late Brigantian in age. The aims of this paper are to identify the different sedimentary facies and microfacies of this Formation and to specify their depositional environments.

The Late Brigantian outcrops of Bou Balghatene area, showing an actual thickness above 213m, are composed of very diversified facies: (1) metric olistholite, (2) channelized polygenic conglomerates, (3) bioclastic sandy limestone, (4) calcareous tempstites, often truncated by their base and/or top, (5) oolitic limestones (6) bioclastic limestones with *Gigantoproductus* (rudstone, grainstone, packstone, wackestone and mudstone), (7) siltstones, (8) shales with nodules. These facies show a laterally and vertically variations indicating translations on time and space of depositional environments. They also show three types of depositional environments: (1) littoral with silicoclastics deposits, (2) platform with storm deposits, bioclastic limestones and bioconstructions, (3) basin with shales.

The predominance of storm deposits, the absence of reef barrier and the dominance of specific species of paleobathymetry show that this carbonate platform corresponding to a carbonate ramp with shallow marine depth subject to the action of storm waves. The paleobathymetric estimating of the Bou Balghatene rump is based on the presence or absence of some foraminifers (*Pseudoammodiscus* sp., *Archaediscus* sp., *Tetrataxis* sp. and *Globoendothyra* sp.), algae and pseudo-algae (*Koninckopora* sp., *Ungdarella uralica* sp., *Saccamminopsis* sp. *Frustulata* sp.) according to Pille's model carbonate rump (2008).

The microfacies analysis allows identifying an internal, middle and external environments rump. This carbonate ramp was been alimented by a hinterland situated to the East and South-East during the Brigantian. The very important biodiversity and the development of the carbonates microfossils testify that it was evolved under a tropical climate, warm and humid. The depositional model thus proposed to Bou Balghatene area is similar to the Berkhli (1999) and Tourab et al. (2017) models.

Analyse pétrographique et sédimentologique de l'Aptien d'Ain Mimoun, flanc nord de l'anticlinal de Khenchela (Nord Est Algérie)

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Abstract

L'anticlinal de Khenchela est une structure de direction Atlasique (N50°E–N60°E), ébauchée lors du plissement majeur de la fin de l'Eocène moyen (Lutétien supérieur). Les formations de cet anticlinal ont hérité l'effet de deux tectoniques superposées: (a) les accidents liés au plissement principal, déformés postérieurement par divers rejeux; (b) les accidents tardifs associés à d'autres phénomènes tectoniques majeurs, en particulier les décrochements.

Les dépôts aptiens d'Ain Mimoun présentent un inventaire pétrographique varié, ils sont de diverses et multiples natures lithologiques à contenu faunistique riche et diversifié.

Les analyses pétrographique et sédimentologique du profil étudié, montrent que le dernier cycle sédimentaire de l'Aptien est incomplet (probablement érodé). Ce dernier se termine par une émergence et se sépare du premier cycle de l'Albien par des sédiments de plage indiquant le début d'une phase de transgression. La présence d'une inconformité entre ces deux cycles confirme les données géologiques concernant la lacune stratigraphique de l'Albien inférieur; qui selon la présente étude peut être liée à une exondation temporaire.

La synthèse des cortèges sédimentaires et le découpage séquentiel des dépôts aptiens mettent en évidence 6 séquences de 4^{ème} ordre de type transgressif / régressif, correspondant à des cycles de 3^{ème} ordre [sensu Vail]. Les propriétés de ces séquences ont permis le démembrement de l'Aptien en trois subdivisions stratigraphiques essentielles (Aptien inférieur, Aptien moyen, Aptien supérieur). L'intercalation de niveaux détritiques dans les faciès carbonatés, beaucoup plus épais, peut être justifiée par des événements de décharges épisodiques de matériaux silico-clastiques. L'arrêt de ces décharges détritiques, vers la fin de l'Aptien moyen, coïncide avec l'apparition "brusque" des dolomies secondaires massives qui peut être alors interprétée par la survenue d'un événement géologique majeur, probablement d'ordre tectono-sédimentaire.

Les propriétés lithologiques et les caractères sédimentologiques dégagés au niveau des associations des microfaciès suggèrent un environnement de dépôt de plate forme carbonatée (carbonate shelf), ouverte, peu profonde, d'environnement chaud influencée par des événements de décharges épisodiques de matériel silico-clastique.

L'association des faciès milite en faveur d'un modèle de sédimentation en "Rampe Etendue" peu profonde à faible pente. La tendance globale d'approfondissement de cette rampe est vers le NNE, la source probable de provenance du matériel silico-clastique étant située vers le SSW.

Lithostratigraphy and geochemical studies of Cretaceous-Tertiary lithofacies from Nigerian three Inland basins.

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Abstract

A total of nine selected ditch samples retrieved from Chad (Kanadi-1, Albarka-1 and Tuma-1), four samples from Sokoto (Dange-1) and four samples from Dahomey (Seme-1) Basins were subjected to lithologic and inorganic geochemical studies with the aim of determining the provenance and tectonic setting as well as depositional environment.

This entails detailed lithostratigraphic description, Inductively Coupled Plasma Emission Spectrometry (ICP-ES) and Mass Spectrometry (ICP-MS) through Lithium Metaborate fusion method was carried out on seventeen ditch samples.

The lithologies of the study wells from Chad, Sokoto and Dahomey Basins comprise of mudstone, dark shale, brownish sandstone and light brownish shale; mudstone and dark brownish shale and clay, dark brownish shale, siltstone respectively. The geochemical result showed an abundance of SiO_2 with an average of 75.05 %, Al_2O_3 average of 12.51 % (sandstone), values of 18.10 % to 10.12 % and 5.51 % to 16.17 % (shale). Fe_2O_3 abundance range from 2.12 % to 8.56 % while the other major elements have very low concentration. The high SiO_2 content indicated a quartz rich adjoining source rock while low values of ratio $\text{K}_2\text{O}/\text{Al}_2\text{O}_3$ and $\text{Na}_2\text{O}/\text{Al}_2\text{O}_3$, coupled with high average values (<70%) of Plagioclase Index of Alteration (PIA), Chemical Index of Alteration (CIA) and Chemical Index of Weathering (CIW) indicated intense weathering condition and humid climate at the source area. The sediments classification includes greywacke, arkose, litharenite and quartz arenite. A-K-F plot indicated transitional marine environment. Discrimination function plots revealed felsic igneous, quartzose sedimentary and intermediate igneous provenances. The plot of La-Th-Sc showed deposits of passive margin setting. Chondrite normalized REE plot showed an enrichment of light REE with strong negative Eu anomaly which is an indication of a felsic source.

However, these inland basins consist of marine deposits with plutonic igneous rock as the main source rocks couple with low grade metamorphic and quartzose recycled rocks deposited in transitional marine environment under intense weathering in a tropical, humid climatic condition.

poster

04

**Stratigraphy,
Sedimentology
& Paleontology**

Guinea-Bissau geological map edition, scale 1:400,000

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Abstract

The recent edition of the Geological Map of the Republic of Guinea Bissau (GB) scale 1:400,000 updates the 1968 Teixeira map published during the Portuguese colonial rule and the Mamedov (1980) unpublished map related to the URSS foreign aid after the independence of GB.

The Geological Map is available through the local geological survey (DGGM in Bissau) since 2015 and at the Portuguese geological survey (LNEG) since 2017. The map was printed in 2013 by LNEG, where the final geological interpretation and the ArcGis digital edition were made. Most field and lab work was conducted by the IICT (Tropical Sciences Research Institute, Lisbon), currently part of the University of Lisbon. A large team from the DGGM was also involved in drilling and fieldwork related to the map. Works from other authors were taken in consideration, especially those from the BRGM (geological maps of Gabu and Bafata, scale 1:100,000 and research regarding the Farim area phosphates), Portuguese and URSS geologists for the Boé region, data from 1400 selected water boreholes all over the country, and UN sponsored works on the Bijagos archipelago.

Besides the geological data presented on most geological maps (unit limits, lithostratigraphy, cross section and legend) this edition was printed front and back to include other sorts of data, as a way to make it useful to anyone interested in facts about the country, including school communities and the local population. This option was also followed because publishing a map of GB is a very rare occasion, as less than one general map is printed per decade, due to lack of interest, low funding, scarcity of mineral resources, political and governance instability. GB is also one of the least visited countries by tourists, even as it is one of the safest countries to visit in Africa.

Data included: Geology 1:400,000 and Geological cross section; Legend; Location of the main outcrops; List and location of 57 mineral occurrences; “Vendus” (pans or temporary lakes); 346 boreholes (location in the map and log on the back); Bathymetric chart showing the continental shelf and pinpointing the Bijagos Delta; Satellite image showing the sedimentary transport; Geomorphological sketch map with a small abstract; Hypsometric map; Geological cross section of the Mesocenozoic basin; Lithostratigraphic column as followed in hydrocarbon exploration; Map of the administrative divisions; Cartographic division; References; Photos of outcrops.

For this edition a new base map was created, as no modern raster base existed. The 1:50,000 scale colonial cartography covers GB with 72 maps of remarkable quality but clearly outdated, as they were produced from 1953 to 1966. These maps were converted from raster to vector, adapted to the 1:400,000 scale and updated through imagery, field knowledge and the 2009 Census of population, as the road network and the rural settlements changed after the 1963-1974 colonial war when large areas of the country were abandoned by the population. Even with the colors of geology and all the technical symbols, the detailed topography of this map that includes contour lines and nearly 2000 spot heights will help any traveler in GB.

Quelques traits caractéristiques du passage Carbonifère-Trias dans le bassin d'Illizi (Sud-Est Algérien)

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Abstract

Les terrains carbonifères affleurent largement dans la plateforme saharienne notamment dans sa partie nord ouest où les coupes du carbonifère constituent une référence à l'échelle régionale.

Ailleurs, il est surtout connu grâce aux forages pétroliers qui le traversent souvent dans sa totalité. Les sondages étudiés montrent une différence nette sur le plan sédimentologique où les sédiments deltaïques du Carbonifère sont recouverts en discordance par des dépôts fluviaux du Trias.

La présence de l'espèce palynologique *Camerosporites secatus* attribuée au Trias au dessus du Carbonifère ayant fourni des palynomorphes riches en *Vallatisporites* sp, *Vallatisporites verricosus*, *Densosporites variamarginatus*, *Spelaeotriletes cf arenaceus* et *Gongonisphaeridium* du Viséen inférieur montre que le Trias s'est déposé directement sur le Carbonifère.

L'étude des diagraphies de spectrométrie montre aussi une nette dispersion du rapport Th/K au passage Carbonifère-Trias.

Cette étude permet de cerner avec plus de précision la limite et l'emplacement de la discordance hercynienne.

Geochemistry of shales from the Paleoproterozoic (~ 2.1 Ga) Wa-Lawra Belt, northwestern Ghana: implications for provenance and source area weathering

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Abstract

The Wa-Lawra belt, located in northwestern Ghana, marks the eastern side of the larger Paleoproterozoic Bromo greenstone belt which extends further northwards into Burkina Faso, as part of the Bromo belt. It is a N-S trending belt divided into two parts, a western and an eastern part, by the crustal scale Jirapa shear zone which is a huge structure that exhibits sinistral characteristics. The western part comprises mostly of shales, volcanoclastics and volcano-sedimentary rocks, as well as basalts and granitoids; the eastern half consist mostly of granite, paragneiss and orthogneiss, rhyolite and granotoids.

Major (SiO_2 , Al_2O_3 , Fe_2O_3 , CaO, MgO, Na_2O , K_2O , TiO_2 , MnO, P_2O_5), trace (Ba, Rb, Sr, Sc, V, Cr, Co, Ni, Th, U, Zr, Hf, Nb, Ta, Y) and rare earth element (La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu) whole-rock geochemical study was carried out on the shales from the western part of the Wa-Lawra Belt, to determine the provenance and source area weathering conditions. The major element analysis was carried out by the Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES) method and trace elements, including rare earth elements (REEs), by the Inductively Coupled Plasma-Mass Spectroscopy (ICP-MS) method.

The geochemical characteristics of the studied shales show that they are immature in nature and first cycle in origin, with little or no recycled component. Compared to average early Proterozoic upper continental crust, the Birimian sedimentary rocks show depletion in the alkalis and alkaline earth elements and the high field strength elements, and enriched in transition metals. Chondrite-normalized REE patterns are characterized by fractionated LREE (average $\text{LaN}/\text{SmN} = 2.81$), small negative europium anomaly (average $\text{Eu}/\text{Eu}^* = 0.80$) and fairly flat HREE (average $\text{GdN}/\text{YbN} = 1.5$).

Major element geochemistry indicate that the shales were subjected to potassium metasomatism after deposition. Pre-metasomatized Chemical Index of Alteration and Plagioclase Index of Alteration calculations indicate that weak to moderate degree of chemical weathering took place at the sediment source area.

Co-Th-La-Sc systematics reveal mixing between mafic and felsic sources for the shales. Eu/Eu^* and Th/U values, together with other trace element characteristics indicate that the shales were mainly derived from juvenile rocks. Model calculations based on the REEs suggest that the source materials are composed of about 49% basalt, 16% TTG and 35% granite. The shales were most likely derived from nearby mafic volcanic rocks and their associated granitoids in the Birimian greenstone belts. The geochemical characteristics of the shales further suggest that deposition took place in an Oceanic Island Arc settings.

New ichnological evidence of Xiphosurans from the Middle Jurassic Imilchil Formation (Central High Atlas, Morocco): palaeoenvironmental, palaeoecological and palaeobiogeographical implications

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Abstract

Xiphosurans (limulacea, limulids) from Mesozoic deposits are extremely rare in the fossil record of the African continent. Here we report new findings of xiphosuran traces, including the ichnogenera *Kouphichnium* (repichnia) and *Selenichnites* (fodinichnia), which have been discovered in Middle Jurassic strata of the Imilchil area (Central High Atlas, Morocco). The Xiphosuran traces are preserved on upper and lower bed surfaces of sandy limestone and marls in the middle and the uppermost parts of the Imilchil Formation (late Bajocian-early Bathonian) outcropping in the Lakes Plateau and Aït Ali Ou Ikkou Synclines. The *Selenichnites* traces, measuring up to 30 cm in width co-occur with theropod and small tridactyl bird-like footprints (repichnia) with slender digits.

The reported *Kouphichnium* is the first record from Mesozoic deposits of Morocco, while both ichnotaxa, *Kouphichnium* and *Selenichnites*, are considered here as the second occurrence in Mesozoic strata of Africa. They are interpreted to reflect different behaviour of horseshoe crab; i.e. *Selenichnites* is the result of burrowing activity when searching for food in the sediment, and *Kouphichnium* is a regular locomotion trace left on the sediment surface, occasionally leaving impression of the telson.

Combination of sedimentological data and ichnological analysis indicates a shallow-water subtidal palaeoenvironment preceding the Bathonian regression of the Atlas domain. Palaeobiogeographically, the discoveries indicate the presence of xiphosurans at the Southern margin of the Tethys. Furthermore, they enlarge our knowledge of, previously scarcely documented, limulid distribution in Gondwana during the Mesozoic.

Foraminiferal contribution in biostratigraphy and paleoenvironmental interpretations of lower Eocene phosphatic series of Sra Ouertaine basin, Northwestern Tunisia

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Abstract

Biostratigraphy, sedimentology and statistical analyses of paleoecological preferences of benthic foraminifera were carried out on the phosphatic succession of Sra Ouertaine and Dyr El Kef sections (Northwestern Tunisia).

Based on the abundance and stratigraphic distribution of the planktonic foraminiferal species, five planktonic zones have been recognized. From the base to the top: *Acarinina sibaiaensis* zone E1, *Pseudohastigerina wilcoxensis* zone E2, *Morozovella marginodentata* zone E3, *Morozovella formosa* zones E4 and the *Morozovella subbotinae* zone E5. For the first time a Early Ypresian age is attributed to this phosphatic serie.

The Multivariate statistical analyzes based on a wide range of diversity indices (RS specific richness, Shannon-Weaver index HS, dominance index D, Fisher α index and equitability E) allow the reconstruction of paleoenvironmental conditions. The benthic foraminifer's assemblages show that Dyr El Kef phosphatic series characterize an external platform (paleodepth between 150 and 200 m). Despite the eutrophic conditions the palaeoenvironment was oxygenated and stable possibly subject to upwelling of minimum oxygen current.

For the Sra Ouertaine section the environment evolved from an initially outer neritic platform (150m) with an ecosystem diversified to inner platform. The ecosystem is unsettled with a paleodepth less than 100m. Upper Paleocene and earliest Eocene environmental conditions are similar to those of Dyr El Kef. All species of benthic foraminifera present in both sections indicate a warm marine deposits possibly influenced by lower Eocene thermal episodes.

Biostratigraphic zonation of the Oligo- Miocene Series of Cap Negro, Northern Tunisia

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Abstract

A multidisciplinary approach based on micropaleontology, biostratigraphy and sedimentological facies has been applied to the study of the Oligocene- lower Miocene series of the Cap Negro cross sections in Northern Tunisia in order to establish a biostratigraphic and chronostratigraphic zonation of the Numidian flysch in the Mogods chain.

This study was carried out on samples from the predominantly marly series of Sidi Mechreg section and the flyschoid series of Cap Negro. In this area, deposits proved to be very rich in foraminifers and ostracods.

Based on the abundance and stratigraphic distribution of planktonic foraminiferal's species in the different lithological units, a fine biozonation was established in this area and compared with the general scheme of the Cenozoic chart. Seven planktonic zones are recognized: five zones in Oligocene and two in lower Miocene (Aquitanian).

Micropaleontological analysis shows the occurrence of about 200 species of microfossils in these formations (benthic, planktonic foraminifers and ostracods). In Cap Negro section, only agglutinated foraminiferal's assemblages are recognized. Analysis of agglutinated foraminifera revealed a unique and diverse Oligocene –Miocene fauna that is described for the first time in Tunisia.

The benthic foraminifera of Sidi Mechreg show an upper bathyal depositional environment, with a paleobathymetry included between 200- 500 m. While Cap Negro section was deposited at middle to lower bathyal and probably abyssal paleodepths.

oral

05

Isotope Geology

L'âge (isotopique U-Pb) Néoprotérozoïque-Cambrien des galets de granites du conglomérat Dévonien inférieur d'Imouzzer Kandar (NW du Moyen Atlas, Maroc)

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Abstract

Dans la boutonnière d'Imouzzer Kandar (NW du Moyen Atlas, Maroc), la série paléozoïque est constituée de terrains ordovico-siluro-dévonien formant des olistolites emballés dans un matériel détritique tournaisien-viséen. Le Dévonien inférieur montre des conglomérats de l'Emsien inférieur (Charrière, 1990; Richter et al., 2016) contenant des galets (peu ou pas déformés) de roches détritiques (grés, quartzites, etc.) et de roches magmatiques incluant des granites. Ceux-ci peu déformés et métamorphisés ont été investigués par des datations U-Pb sur zircons¹, extraits de quatre échantillons.

Les données obtenues respectivement le n° d'échantillon, l'âge ²⁰⁶Pb/²³⁸U, le mswd, l'âge ²⁰⁷Pb/²³⁵U, le mswd, le nombre sont:

IM13, 558 ± 10 Ma, 3.67, 554 ± 6 Ma, 1.43, n=12

IM2, 502 ± 4 Ma, 2.60, 501 ± 4 Ma, 3.42, n=34

IM10, 500 ± 6 Ma, 3, 496 ± 5 Ma, 2.23, n=27

IM 18, 489 ± 5 Ma, 4.83, 492 ± 6 Ma, 4.70.

Les massifs granitiques non affleurant, peu ou pas déformés, origines de ces galets granitiques ne devraient pas être très loin (vu l'état arrondis des galets). Ils devraient être en relation avec des massifs granitiques ibériques et/ou du NE canadien qui sont proposés comme source de ces galets granitiques. Par ailleurs, aucun massif granitique d'âge cambrien n'est connu à l'affleurement dans cette partie africaine (Meseta marocaine) NW du Gondwana. Ces nouvelles données permettent une nouvelle discussion sur le cadre géodynamique néo-protérozoïque-paléozoïque inférieur de cette partie du Gondwana.

1: Analyses au Centre d'Instrumentation Scientifique de l'Université de Granada.

remerciements

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The contribution of paleo-Congo fluxes, associated with collapse of the African surface, to rapid Cenozoic seawater $^{87}\text{Sr}/^{86}\text{Sr}$ changes

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Abstract

Rapid increase of $^{87}\text{Sr}/^{86}\text{Sr}$ in seawater over the last 40 million years is attributed mostly to exhumation of the Himalayas following collision and orogeny between India and Eurasia. These processes eroded abundant rocks with elevated radiogenic Sr isotope ratios (0.73-0.77), the detritus of which shed into the Indian Ocean to form the Bengal fan (~10 million km³). By contrast, across subSaharan Africa an elevated peneplanation surface known as the African Surface developed during the Kalahari Epeirogeny between 120 and 80 Ma, after which intense chemical weathering created a hardcap cover of duricrusts that protects this plateau from any significant exhumation of crystalline basement. However, across the Congo Basin, thick sequences (100-1000 m) of poorly consolidated Jurassic-Cretaceous red-beds underlying the duricrusts initiated extensive subterranean erosion and collapse of the African Surface and its carapace of duricrusts during the Cenozoic. This rapid erosion across the Congo Basin is matched against the onset of accelerated offshore sedimentation of the Congo fan (~1 million km³) along the Atlantic margin during the Eocene-Oligocene transition, at ca. 34 Ma, following a long period (55 Ma) of very subdued sedimentation. Because the source terrains for the red-beds are mostly recycled from a vast system of Precambrian mountain belts, including abundant metamorphic rocks and granitoids with elevated Sr isotope ratios (0.71-0.86), as evidenced by U-Pb detrital zircons provenance analysis, we propose that the sudden discharge of the Congo Basin (> 50 million tonnes/yr) triggered significant changes in the Sr composition of the oceans.

We present new Sr isotope analyses to test the effects of such large scale erosion processes on ocean chemistry: Kalahari calcretes $^{87}\text{Sr}/^{86}\text{Sr}$ = 0.71-0.73 (0.714 in average); red sandstones $^{87}\text{Sr}/^{86}\text{Sr}$ = 0.73-0.75 (0.739 in average); boulders of silcrete/calcrete $^{87}\text{Sr}/^{86}\text{Sr}$ = 0.73-0.74 (0.733 in average); and dilute acid leach experiments from these endmember rock samples have $^{87}\text{Sr}/^{86}\text{Sr}$ = 0.72-0.73 (0.727 in average). Our results support interpretation of considerable dissolved Sr fluxes from the paleo-Congo River, and our modelling reveals that over the last 34 Ma these Sr fluxes at times surpassed those from the Ganges-Brahmaputra.

Sea-level and epeirogenic fluctuations of southern Africa disentangled based on Sr isotope stratigraphy of Cretaceous-Cenozoic marine terraces in the Eastern Cape, South Africa

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Abstract

Sea level along the coasts of southern Africa has fluctuated by several hundreds of meters over the past 100 million years (Ma), as evidenced by dated marine sequences. But in current models, the amplitude and timing of these fluctuations vary considerably because of inconsistent corrections applied to the observed paleo-sea levels when linked to epeirogenic movements during the opening of the Indian and South Atlantic Oceans and emplacement of multiple Large Igneous Provinces flanking the continent.

To solve this debate we use Strontium (Sr) isotope stratigraphy in Upper Cretaceous to Quaternary marine terraces preserved at different elevations along the southern coast of South Africa. These sequences are close to present-day sea level (psl) along the southwest coast, between Hermanus and Plettenberg Bay (De Hoopvlei Formation; Mio-Pleistocene) and along the east coast, between Port Edwards and Richards Bay (Uloa Formation; Mio-Pleistocene); whereas in the southeast the terraces are superimposed between 140 and 350 m above psl near Addo (Alexandria Formation; Mio-Pleistocene), e'Kalikeni (Bathurst Formation; Eocene), and East London (Needs Camp; Campanian-Maastrichian).

We sampled different fossils (shark teeth, oysters, corals, stromatolites) and bioclastic limestones. Measured $87\text{Sr}/86\text{Sr}$ reveal two distinct populations in the south-eastern terraces: at 0.709043-0.709144 and 0.707781-0.708425, which correspond respectively to 5.2-0.6 Ma and 36-20 Ma on the global marine $87\text{Sr}/86\text{Sr}$ curve, yet these are not consistent with present established biostratigraphy. Some of the variability is due to the possible influence of radiogenic freshwater and/or the effect of diagenesis. The samples are thus analysed further using SIMS (GFZ Potsdam, Germany), laser ablation ICP-MS and clumped isotopes (University of California at Davis and Los Angeles, USA) in order to determine the carbonate mineral heterogeneities, precipitation temperatures and the paleo-salinities. We will report on this new data, which better constrains when and why the south-eastern tip of the continental margin subsided and uplifted episodically. This in turn will enable a more robust sea-level curve for southern Africa, and provide an improved benchmark for global models of late Cenozoic sea-level changes.

Contribution hydrogéochimique dans la caractérisation des nappes phréatiques de la région de Chichaoua - Imin'Tanout, Maroc

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Abstract

La zone d'étude fait partie du piémont du haut Atlas occidental et la plaine d'Ouled BOUSBAA. La compilation des données géologiques, des données de forages et les coupes géologiques montre que sur le pan hydrogéologique la zone est formée par un système multicouche; une nappe libre dans les formations quaternaire Eocène et Turonien à l'affleurement et une nappe captive dans les formations Cénomano-Turonienne; localisée au niveau des deux bassins synclinaux, le premier dit d'OULAD BOUSBAA et le second est nommé le bassin de IDOUIRANE. Une ligne de partage des eaux souterraines est matérialisée par l'anticlinal de Marmouta qui sépare les deux structures synclinales. Afin de déterminer les différentes origines et comprendre les circulations des eaux souterraines dans cette zone complexe nous avons opté pour une approche géochimique multi traceur (isotopes $\delta^2\text{H}$ et $\delta^{18}\text{O}$). Les valeurs de $\delta^{18}\text{O}$ varient entre -7.60 et -4.25 alors que celles de $\delta^2\text{H}$ oscillent -53.07 et -27.03. L'analyse des échantillons indique que les eaux présentent une variation des signatures isotopiques en $\delta^{18}\text{O}$ et $\delta^2\text{H}$, et ce à la fois entre les deux aquifères étudiés. L'interprétation de la courbe $\delta^{18}\text{O}$ versus $\delta^2\text{H}$ a permis la distinction de deux groupes d'échantillons. Le premier enrichi en isotopes lourds ($\delta^{18}\text{O}$ et $\delta^2\text{H}$ les plus élevés) et donc ayant subi une évaporation. Et le second a $\delta^{18}\text{O}$ et $\delta^2\text{H}$ plus faibles et donc les eaux n'ont pas subi au processus d'évaporation. Le premier groupe est celui de la nappe libre et le deuxième est celui de la nappe captive.

Carbon isotope analysis of carbonate rocks from Nigerian schist Belts: implication for their age of deposition

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Abstract

Belts of metamorphosed volcano-sedimentary rocks infolded with granitic gneisses are a common component of the Nigerian basement, where they are referred to as schist belts. While precise U-Pb ages have been reported for the granitic gneisses in Nigeria, ranging from Archean to Neoproterozoic, the age of the schist belts remains unconstrained. Field observations and stable isotope analyses of marbles hosted in these schist belts have been carried out in an attempt to better constrain the age of deposition of carbonate units of Obajana (Lokoja-Igarra schist belt) and Muro (Toto-Muro schist belt) of central Nigeria. In Obajana and Muro, carbonates form lenses or intercalated sheets within a sequence of banded iron formation, mica schist and quartzite. The carbonate mineralogy varies from ferroan calcite to calcite and ferroan calcite to dolomite, respectively.

Results obtained from gas-source mass-spectrometric analysis of Obajana samples revealed a $\delta^{13}\text{C}$ range of 3.4-5.0 ‰ and $\delta^{18}\text{O}$ range of -5.4 to -7.2 ‰. For Muro samples, $\delta^{13}\text{C}$ values ranged from -1.0 to -2.9 ‰ and $\delta^{18}\text{O}$ values from -9.2 to -11.2 ‰.

In the Precambrian, excursions to highly positive $\delta^{13}\text{C}$ values have been recorded only in the Paleoproterozoic (Lomagundi carbon isotope excursion; ca. 2.2 to 2.06 Ga) and Neoproterozoic successions. The highly positive carbon isotope values in Obajana samples suggest their deposition in the Paleoproterozoic or Neoproterozoic. Unfractionated carbon isotope values of Muro carbonates close to 0 ‰ may suggest deposition at a different time in Earth's history relative to Obajana samples.

Copper isotopic record in soils and tree rings near a copper smelter, Copperbelt, Zambia

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Abstract

The copper (Cu) content and isotopic composition were studied in soils and in pine tree rings at locations close to and far from the Cu smelter, located at Kitwe, Zambia. The soil in the remote area contained 25 - 75 mg kg⁻¹ Cu, whereas the soil close to the smelter contained 207 - 44,000 mg kg⁻¹ Cu. The $\delta\delta^{65}\text{Cu}$ at the remote area and close to the smelter varied in the range -0.40 to -0.11 ‰, and -0.44 to 0.01 ‰ respectively. The $\delta\delta^{65}\text{Cu}$ of the surface soil at both profiles (-0.44 to -0.40 ‰) is similar to the isotopic composition of the concentrates processed in the smelter (-0.75 to -0.45 ‰), i.e. both locations are affected by Cu ore dust. The increase in the $\delta\delta^{65}\text{Cu}$ in the direction towards the centre of the profile is caused by the oxidative dissolution of Cu(I) from ore minerals during which heavier Cu is released. In deeper parts of the profile, there is a slight decrease of $\delta\delta^{65}\text{Cu}$ because of easier mobilisation of the lighter isotope. The tree rings at the two locations differ in the total contents and isotopic composition. At the less contaminated site, the Cu contents equal 0.4 to 1.1 mg kg⁻¹ while, at the polluted site, the Cu contents vary in the range 3 to 47 mg kg⁻¹. Whereas, at the less contaminated location, the tree rings are substantially enriched in lighter Cu ($\delta\delta^{65}\text{Cu} = -0.76$ to -2.2 ‰), at locations close to the smelter, the tree rings have an isotopic composition (-0.31 to -0.88 ‰) similar to that of the contaminated soil or processed ore. The isotopic composition of the tree rings close to the smelter are affected particularly by interception of dust containing Cu ore. The $\delta^{13}\text{C}$ in tree rings demonstrate interconnection of acidification and Cu mobility. This study was supported by the Czech Science Foundation project (GAČR 16-13142S).

poster

05

Isotope Geology

The Shared groundwaters Resources in the Saharan Sedimentary basin (North-Western Sahara Aquifer System (Algeria-Tunisia-Libya): The use of Environmental Isotopes

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Abstract

The North-Western Sahara Basin (NWSAS) comprises two main aquifers: the deep “Continental Intercalaire” (CI), and the “Complexe Terminal” (CT). With a surface area of approximately 1 000 000 km², the CI extends across three countries, Algeria, Tunisia and Libya and constitutes one of the largest groundwater systems in the world. This resource is generally considered as being “fossil”, i.e. inherited from previous climatic conditions, more humid than at present, with a very limited modern recharge. This basin supplied an estimated volume of 2.2 billion m³ fresh water for domestic water supply, agriculture and other industrial purposes. Groundwater withdrawals from the NWSAS increased from about 14 m³/s in 1950 to 82 m³/s in 2000, resulting in decreases in the natural water flows.

Over the last two decades, isotopic investigations have been carried out (¹⁸O, ¹⁴C, ³⁶Cl) and rare gas (He, Ne, Ar, Kr, Xe) to assess the groundwater resource potential in the Sahara of Algeria, Tunisia and Libya. The compilation of isotopic data indicate that waters from CT and CI aquifers are characterized by depleted oxygen-18 and deuterium isotope contents as compared to that of the modern rainfall. This would suggest that the modern rainfall is not recharging these groundwaters. Although some sources for active recharge cannot be neglected. Different studies have shown that the NWSAS is recharged by infiltration of surface runoff around the periphery of the domain, particularly around the Saharan Atlas, the Dahar, Tadmait and Tinrhert as well as in the Great Occidental basin during years of exceptional rainfall.

The main objective of the present study, is to gather all these data and to examine how they may be interpreted in terms of groundwater residence time, recharge rate, evaporation losses can help the water managers of the three involved countries to develop or refine appropriate models. This should facilitate the implementation of a trans-boundary integrated management of the shared resources.

Stable isotopes in carbonate minerals: calibration of internal laboratory standards

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Abstract

Research based on stable isotopes is one of the most important scientific fields in Earth Sciences. Isotope ratios of light stable isotopes such as carbon and oxygen in carbonate minerals provide very useful information about geological processes.

The intercomparison of isotope ratios obtained in different laboratories worldwide is only achieved by using Stable Isotope International Standards available in IAEA (Europe) and NIST (USA). International Standards are also suitable for use in calibration of analytical instrumentation, for testing analytical methods, and for use as quality control samples. The international standards mostly used for analysis of $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ in carbonates are NBS-19 ($\delta^{13}\text{C} = +1.95\text{‰}$; $\delta^{18}\text{O} = -2.2\text{‰}$) and NBS-18 ($\delta^{13}\text{C} = -5.01\text{‰}$; $\delta^{18}\text{O} = -23\text{‰}$).

However, the high cost and the limited supply of these international standards, along with the lack of international standards for a larger range of $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values that can satisfy different carbonate sources, led some stable isotope laboratories to calibrate their own standards (internal laboratory or in-house standards) to fulfil their needs. The accuracy of internal laboratory standards is verified against the internationally known reference materials.

For this purpose, we have studied calcite and dolomite samples from different origins as potential internal laboratory standards. After confirming their purity by X-Ray Diffraction (XRD) and Electron Microprobe Analysis, the isotope ratios $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ of calcite and dolomite samples were measured, against International Standards, by Isotope Ratio Mass Spectrometer equipped with Dual-Inlet (IRMS-DI), at the Laboratory of Stable Isotopes (LIE) of the Faculty of Sciences, University of Lisbon.

The carbonate samples analysed for in-house standardisation in the LIE were: calcite from Cala, Spain ($\delta^{13}\text{C} = -10.71\text{‰}$, $\delta^{18}\text{O} = 12.53\text{‰}$) and Neves Corvo, Portugal ($\delta^{13}\text{C} = -0.34\text{‰}$, $\delta^{18}\text{O} = 0.73\text{‰}$); and dolomite from a Moroccan mine ($\delta^{13}\text{C} = 2.14\text{‰}$, $\delta^{18}\text{O} = 29.30\text{‰}$). Precisions better than 0.1 ‰ were obtained for both isotopes ratios.

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U-Pb detrital data from two metasedimentary successions on the Central Malagasy basement and its Neoproterozoic tectonic evolution

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Abstract

The East African Orogen (EAO) involves a collection of Neoproterozoic microcontinents and arc terranes wedged between cratonic units during the Gondwana supercontinent assembly, extending from the Arabian Peninsula along eastern Africa to Antarctica^[1;2;3]. The Malagasy basement preserves a record of the Neoproterozoic timing and style of amalgamation of Indian Dharwar craton with the Congo/Tanzania/Bangweulu blocks during the final closure of the Mozambique Ocean^[2;4;5]. The central Madagascar highlands are comprised of a number of Precambrian units. The oldest blocks, the Antongil and Masora cratons, consist of Mesoarchaeoan ortho- and para- gneiss cores in addition to Neoproterozoic granitic and metasedimentary rocks^[6]. The largest unit is the Antananarivo Block that consists of Neoproterozoic to Proterozoic granulite- to upper-amphibolite facies orthogneiss and paragneiss^[4;7;8]. To the south and west, it is overlain by siliciclastic metasedimentary successions, two of them form the focus of this research. The Itremo sub-domain consists of greenschist- to amphibolite- facies metasedimentary rocks^[9], predominantly quartzite with minor layers of dolomitic marble and metaconglomerate, overlying the Antananarivo basement. The Ikalamavony sub-domain is located to the west and is comprised of meta-wackes, calc-silicate and subvolcanic intermediate layers, that partially overlies the Itremo sub-domain. We performed U-Pb LA-ICP-MS analysis on detrital zircon from four samples of these successions to constrain age and provenance of the Itremo-Ikalamavony Domain. The three Itremo sub-domain samples show major populations of detrital zircon with ages of ca. 2.7-2.6 Ga, ca. 2.5-2.4 Ga, ca. 2.2 Ga and ca. 2.1-1.9 Ga, and minor populations of ca. 3.3 Ga, ca. 3.1-2.9 Ga, ca. 2.8 Ga, ca. 2.5 Ga and ca. 1.8-1.7 Ga. The youngest detrital zircon is 1783 ± 26 Ma. This succession is cross cut by the ca. 850-700 Ma magmatic rocks of the Imorona-Itsindro Suite^[10]. The samples from the psammitic gneiss of the Ikalamavony sub-domain show very distinct results. The major detrital zircon population is ca. 0.85 to 0.70 Ga, with minor Neoproterozoic to Paleoproterozoic populations (ca. 2.7-2.4 Ga, ca. 2.2-2.0 Ga and ca. 1.9 Ga) and ca. 1.0 Ga. The youngest detrital zircon is 709 ± 11 Ma. Both units show metamorphic rims with ages between ca. 600-500 Ma, and are intruded by late to post tectonic magmatic rocks of the Ambalavao Suite, a post-collisional magmatic suite that was emplaced after the Gondwana amalgamation events. The Ikalamavony sub-domain has been interpreted as a ca. 1.80-0.98 Ga metavolcanoclastic sequence intruded by igneous rocks from the Stenian-Tonian Dabolava Arc^[11]. This age range is not compatible with the data here obtained on the psammitic gneiss from the Ikalamavony district region. In accordance with field evidence we interpret this volcanosedimentary unit of ca. 700 Ma as coeval with the Imorona-Itsindro Suite, considered a continental magmatic arc and could be part of the Molo Group^[12;13]. This would be the main source for the Ikalamavony basin that might be a fore- or a back-arc. On the other hand, the underlying sedimentary layers of the Itremo sub-domain present sources older than the Mesoproterozoic. The contrasting sources, sedimentary environment, lithological units and the tectonized contact between the Itremo and Ikalamavony layers indicate that the former was a distinct and older basin.

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**Earth's mineral
resources and
sustainable
development**

Mineral and lithology mapping of the lead-zinc deposit Gamsberg, Aggeneys, South Africa using thermal infrared hyperspectral imaging airborne data

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Abstract

There is still an ongoing demand for mineral resources to supply the high tech industries with raw materials. Therefore existing or new exploration methods have to be enhanced or have to be developed to reduce costs and to increase efficiencies in prospection, exploration and exploitation processes. Therefore a thermal infrared (TIR) hyperspectral imaging (HSI) airborne survey has been carried out in July/August 2015 to test modern HSI systems on their potential to address the above given tasks. The area of interest is the Gamsberg near the Aggeneys ore deposits, South Africa. TIR Airborne data from 7.7 to 11.4 μm wavelength range with a spatial resolution of 2.5 meter per pixel have been acquired. In addition a high resolution digital elevation model (1 m spatial resolution) was derived from Lidar data used for orthorectification and atmospheric correction.

This study presents the results of mapping metasediments and metavolcanics consisting mainly of schists, different quartzites, conglomerates surrounded by gneiss and granitic-gneiss in context to the lead-zinc mineralization of Gamsberg. The lithostratigraphic units belong to the Nousees Mafic Gneiss Formation, Gams Iron Formation including amphibole rocks, Pella Quartzite Formation, Namies Schist and Haramoep Gneiss of the Bushmanland Group with an age of approximate 1.5 Ga. The mineralization is bound to the Gams Formations.

All flight lines have been radiometrically calibrated, orthorectified and atmospherically corrected. A separation of temperature and emissivity based on the normalized emissivity method has been performed. Finally the single lines have been mosaicked to the final data set. The mineral mapping is based on a multi range spectral feature fit to separate the diagnostic mineral features. To minimize ambiguities selection rules such as the number of spectral features and their wavelength positions per spectrum are applied and compared with existing spectral reference libraries. The resulting mineral maps are used for a following spectral characterization and identification of the different lithological units and the mineralization zone. The derived maps are discussed in context of the geology and mineralization. For the latter the lead-zinc mineralization zone has been clearly detected by identifying the spatial distribution of gossans as an indicator dominated by a significant hematite appearance. This study demonstrates how TIR HSI analyses derived maps provide detailed spatial mineral distribution information to improve exploration and mining activities.

Characteristics and self-heating behavior of Moatize coals, Moatize Coal Basin (MCB), Mozambique

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Abstract

Mozambique has a great potential in terms of coal deposits, the most important being the deposits from Moatize Coal Basin (MCB) located in Tete Province, Moatize District. The coals of the MCB have an Early-Middle Permian age, and belong to the Moatize Formation of the Karoo Supergroup, that spans in age from the Upper Carboniferous to the Lower Jurassic. The MCB has estimates reserves of about 2.5 billion tons, with thick coal seams allowing the open-pit exploitation. It is well known throughout the world that Moatize basin is a world-class deposit for both coking and thermal coal. However, recently, occurrences of spontaneous combustion are being registered in both in situ coal seams and stockpiles of washed products (coking coal and thermal coal). Spontaneous combustion is a consequence of self-heating, and it is a global issue affecting environment, economy and human health.

In this study, petrographic and chemical properties (in terms of major and trace elements) of samples of raw coal (in situ layers), coking coal and thermal coal were studied to analyse the changes on petrographic composition and to evaluate the propensity to self-heating. Moreover, the effects of a Lower Jurassic igneous intrusion at the final phase of the Karoo Supergroup were also investigated". The petrographic analysis was performed using a Leica DM4000 microscope, equipped with the software "Discus-Fossil" from Technisches Büro Hilgers and included the determination of vitrinite reflectance and maceral analysis according to standard procedures, and following the ICCP nomenclature. The chemical composition of samples on major and trace elements was determined by inductively coupled plasma-mass spectrometry (ICP-MS).

Several aspects revealed by microscopic characterization occur that are related to the coal reactivity and potential to self-heating leading later to spontaneous combustion. These include vitrinite reflectance, oxidation rims, micropores and cracks mainly on in situ coals, and also some signs of weathering (oxidized framboidal form of pyrite), and oxidation on thermal coals.

Samples affected by igneous intrusion show signs of intense thermal alterations, among them: fractures, devolatilization vacuoles, vitrinite particles with high reflectance, natural coke with fine to medium mosaic texture.

The chemical composition in terms of trace elements is variable, especially with respect to Ba, Sr, Zr, Ce, which are the most abundant elements. These show an increase in concentration with the approximation of the combustion foci, creating a clear separation between affected and unaffected samples. However, all elements, except Zn, have concentration below the Clark values defined for hard coals pointing out no risk of toxicity and environmental and human health concerns. Regarding the concentration of major oxides, no significant variations were detected, with the exception of the CaO that shows an anomaly in the samples affected by the igneous intrusion, due to an enrichment on calcium emanated by the intrusion.

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A review of peat deposit in Rwanda: potential and development

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Abstract

The peat deposits in Rwanda are distributed over an area of 50,000 ha and were formed about the end of last glaciations period. However Akanyaru peat is 20,000 years old and contains peat of glacial and postglacial period. The recent studies show that Rwanda has 155 million tone of dry peat which can be used to generate electrical energy and this deposit is sufficient to meet country's vast energy requirements for 30 years. Hence, it was felt necessary to map prospective locations of peat and their energy potential. The result of the study and assessment of peat to power in Rwanda shows that the average in-situ ash content, in-situ moisture content and in-situ bulk density of the collected peat samples are 36% wt, 70.8%wt and 1112 kg/m³ respectively. Their average thickness ranges from 0.9 to 7.8 m. In Finland, peat was used as fuel in 1996 and produce 10% of total installed capacity. Rwanda has the same operational peat power plant in Gishoma; Rusizi District generating 15MW connected to the national electrical grid. A peat-fuelled power plant is under construction and is expected to generate 80 MW .This plant, once completed, is expected to connect 50% more household into national grid before the end of 2018.Thus, this effort along with other projects will increase electrical power from 208 MW to 563 MW in 2018. Peat deposit is expected to generate 500 Mega watt electrical powers during 30 years. Although an effort was done to use peat as fuel, the power plant is still vulnerable to the lack of good quality of dry peat to operate and thus efforts are on to develop suitable technology for exploitation.

Mineral chemistry, oxygen isotopes and petrogenesis of gem-bearing pegmatite around Awo Mining District, southwestern Nigeria

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Abstract

Gem and rare-earth elements-bearing pegmatites could be formed from melt fractionation or assimilation of crustal materials by magmatic melt. Despite the mining activities in Awo district, southwestern Nigeria, details of the genetic evolution of the pegmatite using mineral chemistry and stable isotopes has not been adequately undertaken. The aim of this study is to determine the source, degree of fractionation and other processes leading to the formation and evolution of the pegmatite.

Pegmatite and host rocks were subjected to petrographic analysis. Polished sections and grain mounts of forty one mineral separates were selected for Electron Probe Microanalysis (EPMA) to determine the mineral chemistry. Major, trace and rare-earth elements data of the pegmatite and twenty five host rocks were obtained using X-ray fluorescence (XRF) and Inductively Coupled Plasma Mass Spectrometric (ICP-MS) techniques. The pegmatite, host rocks and mineral separates including gemstones were selected for O-isotope studies using the conventional and laser fluorination method at the Department of Geological Sciences Laboratories, University of Cape Town, South Africa.

The pegmatite of Awo district intrudes muscovite schist, diorite and granodiorite. The essential minerals in the pegmatite are albite, oligoclase, microcline, perthite, quartz, muscovite and biotite. Accessory minerals include beryl (sodic-rich), garnet (almandine and spessartine), tourmaline (schorl and liddicoatite), titanite and tantalite. The pegmatite is peraluminous with mean A/CNK of 1.53 and associated with S-type granite in orogenic tectonic setting. The Na, K and Si in the pegmatite fractionated from low temperature granitic melt into water-rich phase, within which rare elements diffused. Geochemical trends in the pegmatite and the host rocks are similar but pegmatite were more enriched in total alkali than host rocks. Plots of K_2O vs Na_2O , TiO_2 vs SiO_2 and Na_2O/Al_2O_3 vs K_2O/Al_2O_3 suggests moderate degree of albitisation and alkali fractionation controlling Ta-Nb enrichment. Mean elemental ratios of K/Ba (320.4), K/Cs (14573.4), K/Rb (342.5), Mg/Li (278.3), Rb/Sr (19.2), Nb/Ta (15.3) and Rb/Cs (44.2) indicate low to moderate melt fractionation and marginal mineralization, while incompatible elements, such as Ba, Hf, Sr, Th, U, Nb, Sn, Rb, Be, Cs and Ga were derived from both fractionation and assimilation of crustal materials. The oxygen isotope ($\delta^{18}O$) values of the pegmatite (8.6-13.0 ‰), host rocks (7.4-10.1 ‰) and gemstones (9.2-11.9 ‰), suggests that the pegmatite evolved from fractionation of a primary magmatic melt, contaminated by assimilated high $\delta^{18}O$ (>10.0 ‰) crustal materials during the pegmatite intrusion.

Characterization and quantification of iron mineralization in Northern Cape South Africa using hyperspectral imaging data

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Abstract

The Northern Cape Province of South Africa is well known for its giant mineral deposits. Iron mineralization in Banded Iron Formations (BIF) between Prieska and Kuruman and the significant Iron deposits bound to conglomeratic, reworked BIF near Postmasburg are discussed in detail. A hyperspectral flight campaign was carried out in the Northern Cape to spectrally describe the mineralogical/geological surface characteristics of main mineral deposits and their geological settings. The hyperspectral imaging data were simultaneously acquired by three sensors covering the visible light, the near infrared and shortwave infrared (VNIR-SWIR, 0.4-2.5 μm) and the long wave infrared (LWIR, 7.8-11.4 μm) with a spatial resolution of 2.5 m. In addition LIDAR data were acquired to create surface and terrain models with a spatial resolution of 1 m for orthorectification of the hyperspectral data and detailed tectonic studies.

The mineral identification was done in VNIR-SWIR and LWIR separately by a multi feature extraction approach combined with a spectral unmixing approach to derive the dominant mineral components. The results of the VNIR-SWIR and LWIR mineral identifications were cross validated where applicable. A further step was the synergetic information extraction from the spectrally derived mineral paragenesis by a context driven assessment of the results and a correlation with the geological setting to characterize and identify deposits. The results are thematically discussed together with ground truth data, geological maps and multispectral analysis.

These investigations demonstrate the potential of spectrally high resolution data sets, and are seen as preparatory studies in the framework of the recent developments for future satellite based hyperspectral remote sensing missions. Diagnostic spectral features, as the shape of the spectral data and the wavelength positions or frequencies (wave numbers) of the absorption features allow the identification of the materials, whereas the depth of the corresponding bands correlates with percentage of the specific material. This accounts for the possibility of quantification, which is not feasible using medium resolution multi spectral data such as provided by Sentinel and Landsat only. When applying spectral analytical models with additional geodata, semi- automatic algorithms allow to identify and even to quantify the various materials down to a sub pixel level. These new models go far beyond the state of the art classification methods. Hyperspectral data acquisition of the Earth' surface from different airborne platforms and two satellite systems with limited operational use do already exist, and a new German hyperspectral spaceborne system called EnMAP, is scheduled for 2020, and for the Copernicus Program a hyperspectral sensor is under discussion. For the first time the acquisition of operational hyperspectral data sets, continuously and with moderate spatial and temporal resolution, are feasible and will provide an end-user friendly processing and a value added product chain.

Application of remote-sensing and surface geophysics for groundwater prospecting in a hard rock terrain, (Tata region, SE of Morocco)

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Abstract

Remote sensing and geophysical investigations were carried out in the Tata region (Eastern Anti-Atlas Chain of Morocco) to delineate potential zones for future groundwater exploration. The study area is underlain by the Limestones, Schist and a complex series of metamorphic rocks covered by Adoudounian limestone. A lineaments map shows that the majority of lineaments have E-W and NE-SW directions. Lateral resistivity profiles were used to confirm the presence of these lineaments in 90% of cases. The application of Total Comptage indicate a discernable anomaly at three stations and where the high yield of drilling confirm the efficiency of this proposed methodology.

Finally, the identification of geomorphological significance of each mapped lineament gave an excellent explanation of the relationship between lineament distribution and groundwater in fractured limestone. The distance between the lineaments and the river network, which play an important role in the recharge of the fractured formations, was inversely related to the likely presence of groundwater. The results of this study show the importance of using an integrated methodology for groundwater prospecting in the hard rock terrains.

Genesis of the sediment-hosted Cu-Ag deposit of Tizert (Igherm inlier, Anti-Atlas Copperbelt, Morocco)

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Abstract

The Anti-Atlas Belt in Morocco comprises large Proterozoic basement inliers consolidated during the Eburnean and the Panafrican orogenies, and a Late Ediacaran to Paleozoic sedimentary cover weakly folded during the Hercynian orogenesis. The terminal Neoproterozoic to Lower Cambrian cover includes important copper orebodies, with up to 200 occurrences, some of which are currently mined. These orebodies are hosted by Upper Neoproterozoic volcanic and volcanoclastic formations, or by terminal Neoproterozoic clastic and carbonaceous sedimentary formations.

The Tizert deposit is the largest sediment-hosted copper deposit in the Anti-Atlas Copperbelt. The deposit is hosted by the Late-Ediacaran-Early Cambrian Adoudou Formation, which represents the oldest volcano-sedimentary complex unconformably covering the Proterozoic basement. The Adoudou Formation was deposited during a major marine transgression, and has been subdivided into two members that correspond respectively to the Basal Series and the Lower Limestone. The Basal Series was deposited in wide subsiding zones controlled by extensional normal faults bounded by basement cored topographic highs. The upper Lower Limestone was deposited across both the depressions and the paleohighs and sealed the Tizert basin.

Most of the copper mineralization is present as disseminated and stratabound Cu-sulphides hosted by the uppermost siliciclastic horizons of the Basal Series. The ore grade zones are well developed along basin margins adjacent to the basement paleohighs. These mineralized zones display a lateral sulphide zoning with central bornite-chalcocite zones grading outward to intermediate chalcopyrite and external pyrite zones. There is also a vertical sulphide zoning with evolution from bornite and chalcocite dominant mineralized rocks at the bottom to chalcopyrite and pyrite dominant mineralized rocks at the top of the lithostratigraphic succession. A late diagenetic age for this mineralization is indicated by the geometry of the mineralized zones that transgress bedding at a low angle, the sequential replacement of sulphides by other sulphide minerals, and the possible involvement of mobile hydrocarbons as reductants.

A second style of mineralization is represented by sulphide filled fractures and veins present in the Basal Series, as well as in the basement and the overlying dolomites. The location of better-mineralized zones of this style of mineralization near fractures and faults indicates it was epigenetic; it may have occurred during Late Hercynian shortening.

The similarity of the paragenetic sequences between the disseminated and the vein-hosted mineralization suggest that they may be related to the same mineralizing event. It is believed that the high heat flow associated with a thermal subsidence-dominated regime initiated intrabasinal convective circulation. Saline brines originated from evaporite dissolution, moved downward and leached metals from the underlying Precambrian basement. The oxidized metal-rich fluids moved upward to the Basal Series where their interaction with mobile hydrocarbon-bearing sediments allowed deposition of metals. The late diagenetic disseminated mineralization was rapidly followed by the Late Carboniferous compression and the onset of the vein-style mineralization.

Compositional features and industrial assessment of talcose rocks of Itagunmodi-Igun area, Southwestern Nigeria

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Abstract

Talcose rocks from Itagunmodi and Igun areas within the Ilesa Schist Belt, southwestern Nigeria, were studied to determine their compositional affinities and industrial properties. The talcose bodies occurred as lensoid enclaves closely associated with amphibolites and quartz-mica schists. Petrographic and X-ray diffraction-aided mineralogical studies reveal that the talcose rocks are of the talc-chlorite schist variety composed predominantly of talc (average 73.63 %), subordinate chlorite (average 16.08 %) and accessory lizardite (average 6.5 %). Total whole rock characterization of the samples using Lithium Fusion digestion revealed high mean concentrations of SiO₂ (57.53 %), MgO (24.84 %) and Fe₂O₃ (7.73 %) with significant enrichment of Ni, Co and Cr; and low values of Ba, Rb, Sr, V, Cu and Pb. The talc-chlorite schists plotted in the peridotitic komatiite field of the Al₂O₃-(FeO+TiO₂)-MgO diagram. Water Absorption Capacity ranges from 6.25-8.20 %, Loss on Ignition is 4.8-6.1 % while Linear Shrinkage is 1.25-1.70 % and firing colour is brown to dark-brown. The overall compositional features of the talcose rocks of the area, which were hitherto uncharacterized, show their suitability as raw materials for paint, coloured pottery, ceramic insulation, textile, rubber and plastic manufacture with varying beneficiation requirements. Their high trace element content however, makes them unsuitable for use in pharmaceutical and cosmetic applications.

Distribution of the pegmatite fields in Mozambique: localization, characterization and mineralizations

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Abstract

Pegmatite fields in Mozambique are distributed north of parallel 19° 30' S and occur in all administrative provinces of the north-eastern and north-western regions of the country. According to the present knowledge, actually the most important pegmatite field is the one at Alto Ligonha region, in the centre of the Zambézia Province, described as extending along 170 km, from Mocubela, in the south, up to Alto Ligonha, in the north (Marques, 1989).

This pegmatite field and others adjacent form the Alto Ligonha District which, together with the South District, constitutes the Zambezian Pegmatite Province (Leal Gomes et al., 2016).

Generally, the pegmatite bodies that occur in Zambézia and Nampula Provinces belong to one of the two following groups: i) group with homogeneous chemical composition and mineralogy, and ii) zoned type, showing more or less developed zoning.

Geochemically, the pegmatites of the Alto Ligonha District present a LCT (Li, Cs, Ta) feature, with extensive hydrothermal replacement and are lithium mica-bearing, as well as ore minerals enriched in tantalum-bearing. In the adjoining South District, pegmatites present still preserved LCT primary paragenesis, with spodumene and petalite as traces of high temperature and tapiolite > tantalite > microlite as dominant ores (Dias et al., 2008 in Leal Gomes et al., 2016).

The Alto Ligonha Pegmatite Field is followed towards NE by the heterogeneous sodalithic pegmatites with amazonite and by the group of heterogeneous pegmatites with tourmaline, located in Monapo and Nacala-a-Velha Districts in Nampula Province (Marques, 1989).

In Cabo Delgado Province fairly investigated pegmatites occur in Mueda region and in Niassa Province the most known are the rare elements bearing that occur in Metarica and Marrupa regions. In Marrupa the pegmatites are of NYF (Nb, Y, F)-type.

The Marirongoè Pegmatite Field is the most known and famous existing in Tete Province. In fact, it looks to be one of the most complete NYF type pegmatite fields, showing peculiar paragenesis with columbite, topaz, noble beryl (aquamarine and heliodor varieties), metamict minerals (monazite, xenotime, euxenite-polycrase, samarskite), amazonite, and others (Marques et al., 2011). Tete still presents pegmatite fields spread along Zumbo, Zâmbuè, Chioco, Cazula, Moatize, and Changara administrative Districts.

One of the most recent discovered fields extends between Catandica and Guro Districts in Manica Province, with heterogeneous pegmatites distributed in Palaeoproterozoic and Mesozoic terrains. This group produces giga-tourmalines of elbaitic type.

Finally, the Inchope-Doerói Aplite-Pegmatite Field is situated in the western extreme of the Sofala Province, continuing in the neighbouring Manica Province. It is constituted by pegmatites mineralized in cassiterite and tantalite, the unique ones occurring in Mozambique. Tin mineralization also occurs in aplites and greisen zones in gneisses (Direcção dos Serviços de Geologia e Minas, 1974).

Characterization, beneficiation and blending of Cafumpe clays (Mozambique) to ceramic applications

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Abstract

The present work aims to assess the potential of Cafumpe clays deposit (district of Gondola, Manica province, Mozambique) as raw material for ceramic industry. This study is focused on a finer characterization of fundamental and technological properties which will support proposals for a more developed application of these clays to ceramic and related industries, with upgraded added value. The area under study is covered by sheet number 1932/1933 of the geologic map of Mozambique, 1:250000, compiled by GTK Consortium and published (2004) by the National Directorate of Geology of Mozambique. The clays of Cafumpe constitute a residual deposit, resulting from the alteration of gneisses and biotitic metagranites (Mount Chissui Gneiss, belonging to Chimoio Group, Bárue complex, of mesoproterozoic age).

12 samples were selected as representative of the different levels occurring in the clay deposit, ensuring adequate representativeness of vertical and lateral variability. Several analyses were carried out: grain size distribution (wet sieving and sedimentation), mineralogical composition (X-ray diffraction), geochemical (major and minor elements) analyses (X-ray fluorescence), abrasivity, plasticity, cation exchange capacity and exchangeable cations, specific surface area, expandability, cationic exchange capacity (and the respective Exchange cations) and thermal tests (DTA and DTG). All these analyses had been carried in accordance with the protocols and norms followed in the Departments of Geosciences and in the Department of Materials Engineering of the University of Aveiro. The obtained results were object of statistical treatment, using Cluster and Principal Components analysis.

The results revealed that the studied clays are very plastic, despite containing reasonable amounts of quartz, and clay mineralogical association consists predominantly of kaolinite, accompanied by illite and in some samples smectite, usually very discrete, as well as by other accessory minerals, such as iron oxides and hydroxides (goethite, hematite, magnetite-maghemite). There is an almost total absence of feldspars, pointing to a deep kaolinization process. The results of the chemical analysis showed the presence of very high amounts of silica, aluminium and iron, with high values of the "Weathering Index" (CIA).

Thus, we can conclude that these clays can be considered as excellent raw material for the production of ceramic bricks; but for the production of tiles (and ceramic floors) they would require a prior (granulometric) classification and beneficiation focused on iron minerals and smectite contents as well as on thermal properties as well as blending tests with other ceramic raw materials, such as feldspars.

Mapping bauxite indices using Landsat ETM+ imageries constrained with environmental factors in Fouban area (West Cameroon Highlands)

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Abstract

The current study uses a GIS-based mapping approach to investigate the relationship between bauxite indices and other environmental factors in the Fouban area (West Cameroon Highlands). The approach proceeds in two steps. (i) The first step deals with encrusted bauxitic surfaces mapping using on the one hand brightness and textural attributes of the Landsat ETM+ imageries for digital classification, and on the other hand additional data from band ratios. (ii) The second step involves characterization of encrusted laterites using macroscopic, microscopic, mineral and geochemical investigations, to better address the issues related to their bauxite nature. Thus, in the Fouban area, two categories of encrusted bauxitic surfaces have been identified: (a) the discontinuous encrusted bauxitic surfaces covering a total area of 11.13 km², and (b) the continuous encrusted bauxitic surfaces overlapping 2.41 km². The field observations portray the discontinuous encrusted bauxitic surfaces with 5.5 m thick bauxitic mantle subdivided into 1.5 m thick discontinuous duricrust lying on 4.0 m thick continuous duricrust. The continuous encrusted bauxitic surfaces are 4.1 m thick bauxitic duricrust. Mineralogical analysis showed that the Fouban bauxites exhibit: 78% to 86 % of gibbsite, 7 % to 22 % of goethite and less than 7 % of kaolinite. Geochemically, Al is the most abundant chemical element with content varying from 45.6 % to 58.7 wt.% of Al₂O₃; followed by Fe with content varying from 12.9 % to 20.1 wt.% of Fe₂O₃ and Si with content varying from 1.0 % to 3.7 wt.% of SiO₂. Chemical element mobility stated with enrichment factor (EF) allows differentiating three categories of chemical elements in the Fouban bauxites: strongly depleted elements with EF < 1 (Si, Ca, Mg, K, Na, Cu, Mn, Zn); strictly enriched elements with EF > 1 (Al, Fe, Cr); and elements with irregular depletion and enrichment behavior with EF ± 1 (Nb, Sr, V, Zr). Based on the mass-transport function (M), chemical elements decrease as follows: Sr > Nb > Cr > Al > Zr > V > Zn > Fe > Cu > Si > Ca > K = Na > Mg > Mn. The Fouban encrusted bauxites are classified as laterite and iron-rich high grade ortho-bauxites with 45.6–58.7 wt.% of Al₂O₃ and 1.0–3.7 wt.% of SiO₂, with bauxite reserves estimated to 75.8 million tons. The mapping approach has shown to be suitable for delineating encrusted bauxitic surfaces within loose laterites in tropical regions.

Estimation of the iron potential in the metamorphic formations from the Zambé area (Southern Cameroon): constraints from petrographic and magnetic investigation

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Abstract

The basement rocks of the cratonic domains are particularly interesting because they very frequently contain mineralization. Petrography and magnetic investigation were carrying on metamorphic rocks from Zambé area in order to evaluate their iron potential. Base on their petrography study and concentration in iron or not, the both petrography unit of Zambé area can devised in two groups: (i) the iron-poor rocks consist of garnet amphibolite (GA), hornblende-garnet gneiss (HGG), quartzite (Qzt) and garnetite (Gt). (ii) rocks rich in iron, include ferriferous amphibolites, hornblende ferriferous gneiss, hornblende-garnet ferriferous gneiss. It is important to note that the iron oxide is magnetite, which sometimes reaches 30% in the second petrography group. The magnetic data confirms the existence of these two groups and distinguish two sectors of variation of magnetic susceptibility. The first sector (0 to 999.9×10^{-3} SI), materialize the sterile zone while the second sector (1000 to 2000×10^{-3} SI), indicates the mineralized zone. The interpretation of the susceptibility maps shows that the zones of high mineralization are situated between 0 and 10m and between 30.5 and 78.5m. Base on the standard commercial standards for iron ores, the results of this study show that the study area can be exploited for the production of iron.

Late orogenic Kalana gold deposit: petrography, metallogeny and fluid inclusions study (Southern Mali)

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Abstract

Kalana gold deposit occurs within greenschist facies metamorphosed Paleoproterozoic (2210-2100 Ma) metavolcanosedimentary series of southern Mali (Baoulé Mossi domain of WAC). These Birimian formations are intruded by several small dioritic bodies (2000 Ma); andesitic and tonalitic dykes exhibiting a volcanic arc setting signatures. The sulfide and gold mineralizations are hosted by quartz veins that intersect the major Eburnean sub meridian and steeply dipping schistosity. The quartz veins form two distinct groups. The first includes shallow dipping thicker veins oriented NS, NE-SW or EW. The second corresponds to subvertical thin quartz veins oriented NE. Structural features suggest that the two vein groups are genetically related. Group-1 veins formed during displacement of shallowly dipping reverse faults (thrusts). During subsequent deformation, further fault movement triggered the formation of micro-shear zones within the veins and parallel to their orientation, and creation of subvertical tension gashes filled by Group-2 quartz veins. In both vein sets, a late déformation is marked by an intense shearing and fracturing. These structures are consistent with a nearly EW regional shortening and progressive deformation evolving from ductile regime to a more brittle one. In these quartz veins gold occurs as: i) small inclusions in a primary arsenopyrite; ii) free nuggets associated to galena, sphalerite, chalcopyrite, bismuth sulfides and native bismuth in late fractures affecting the quartz lodes.

Both groups of vein show three types of fluid inclusions among which are: H₂O-CO₂-NaCl type; H₂O-NaCl type and H₂O-CH₄-NaCl type. The specific distribution of these fluids allows determining an earlier H₂O-CO₂-NaCl fluid. The second type of fluids results from the post-entrapment modification of the type1 during the semi-ductile deformation that underwent Kalana quartz veins. The last CH₄ rich fluid could originate from dehydration of sediments and the economic gold as free nuggets is associated to that phase.

Kalana deposit is clearly of mesothermal and late-orogenic type.

Contribution of environmental isotopes and geochemistry to the assessment of Santiago Island hydrogeology (Republic of Cape Verde): an overview

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Abstract

At Santiago Island, like in most semi-arid and arid regions, surface waters are either seasonal or non-existent and groundwater becomes the perennial source of water supply. Santiago Island is characterized by scarce hydrological resources due to low and irregular precipitation, between 190 and 320 mm/year at low altitudes and in the highest mountains (Pico da Antónia or Serra Malagueta), respectively. The semi-arid to arid climate of Santiago Island, leads to prolonged drought periods. In fact, this situation is responsible for quasi-periodic and sometimes catastrophic dryness.

Under the R&D Project “HYDROARID – Evaluation of the Hydrogeological Potential and Sea Water Intrusion Monitoring in Semi-Arid Zones Using a Multitechnique approach: application to the Santiago and Maio Islands (Cabo Verde)”, two fieldwork campaigns were carried out at Santiago Island, and groundwater samples were collected for ^{18}O , 2H and 3H determinations. Chemical analyses (major species) were also performed in these samples. Electrical conductivity, pH and temperature were obtained in situ. The sampling was performed along two transects of the island, from the high mountain areas, located in the central part, to the coastline.

Overexploitation of coastal aquifers and pollution are among the main problems related to groundwater resources assessment and management in Santiago Island. Brackish groundwater for agriculture and human supply (e.g. Praia Baixo, Montenegro, and Charco) are being provided to numerous parts of the Island, as the only type of available water. Solute and isotope data obtained in different groundwater systems were used in the identification of groundwater resources degradation. In order to understand the influence of the anthropogenic activities on the water quality and the main origin of the salts in groundwater, a statistical approach (e.g. Principal Components Analyses - PCA) was performed on the physico-chemical data. The results obtained indicate water-rock interaction mechanisms as the major process responsible for the groundwater quality (mainly Ca-HCO₃-type), reflecting the lithological composition. Anthropogenic contamination was identified in several areas. Isotopic techniques combined with geochemistry provided comprehensive information on groundwater recharge, as well as on the identification of salinization mechanisms (e.g. seawater intrusion, salt dissolution, and marine aerosols) of the groundwater systems. Moreover, the isotopic pattern presented by some of the groundwater samples can be related to direct infiltration of irrigation waters undergoing significant evaporation, during the dry periods. On the other hand, within this group of waters, the influence of marine aerosol cannot be excluded since the isotopic enrichment is also followed by an increase in the Cl⁻ and Na⁺ content. It was concluded that effective management of the groundwater resources at Santiago Island requires future detailed studies on the assessment of available water resources through a multi- and interdisciplinary approach including further isotopic, chemical and geophysical surveys, as powerful tools for the investigation both of modern hydrological processes and to reconstruct palaeohydrology. Otherwise, the estimation of the amount of recharge is fundamental for the sustainable management of groundwater resources at Santiago Island.

Prospection géochimique des minéralisations de cuivre dans la Boutonnière de Bou Azzer, Anti Atlas Central du Maroc

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Abstract:

Au cours des travaux d'exploration menés par la compagnie d'exploration minérale Managem, nous avons utilisés la méthode de prospection lithogéochimique sur le district minier de Bleida dans la partie Est de la Boutonnière de Bou Azzer au Maroc où sont exploités des gisements de cuivre sous forme d'amas sulfurés et/ou disséminés oxydés et des gisements de minéralisation d'Or portés par une série volcano-sédimentaire d'âge panafricain (protérozoïque supérieur).

Après des tests préliminaires d'échantillonnage et de représentativité, plus de 3000 échantillons rocheux ont été prélevés dans des zones à indice de cuivre et qui sont préjugées potentiels. Ces échantillons ont été analysés par spectrométrie d'émission atomique (SEA) pour 34 éléments majeurs et traces, les données analytiques ont été traitées à l'aide de méthodes statistiques afin de définir les fonds, seuils et teneurs de coupures anormales. Des zonalités géochimiques ont été bien circonscrites dans le terrain et mises en évidence à différents niveaux : zonalité spatiale en surface ; fonction de la nature lithologique et de l'état structural de l'encaissant et zonalité intra corps minéralisé. L'élaboration des cartes géochimiques, confirme que les halos géochimiques des éléments accompagnateurs de la minéralisation peuvent s'étendre sur des centaines de mètres autour des corps minéralisés, elle s'amplifie en fonction de la densité de la fissuration et des failles. Sur la lumière des ces résultats, il apparaît donc que la méthode lithogéochimique peut être adoptée pour la découverte de nouveaux corps minéralisés cachés dans le cadre d'une prospection tactique dans le domaine de l'Anti Atlas marocain.

The geodynamic and geothermal activity of the thermal waters of the Prérif, South Rif Thrust: contribution for the sustainable development of the region of Fès-Meknes, Morocco

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Abstract

Morocco is characterized by a remarkable potential for low-enthalpy geothermal resources, having more than 120 thermo-mineral springs with outlet temperatures ranging from 25 °C to 54 °C [1; 2]. These systems are being exploited just for balneotherapy uses, being located in different Moroccan geodynamic domains (Rif, Meseto-Atlas and Anti Atlas). They constitute the surface expression of highly developed hydrothermal systems, especially in the region of Fès-Meknes along the South Rif Thrust. Unfortunately, they do not contribute in an integrated way to the sustainable development of the region and many investigations are still necessary to achieve an integral use of these renewable energy resources. Such hydrothermal systems are often characterized by deep structures and geological formations allowing groundwater circulation and/or an anomalous source of heat, i.e. a relatively large geothermal flow ($> 35 \text{ °C} \cdot \text{km}^{-1}$) [3]. The region of Fès-Meknes combines these two conditions. This work is an integrated geological and hydrogeochemical study carried out in the Fès-Meknes region in order to have a better understanding of the conceptual model of the thermo-mineral waters near the South Rif Thrust.

The geochemical results highlight a significant diversity of physico-chemical compositions, salinity and outlet temperatures. This hydrochemical diversity seems to be related to: (1) the degree of water-rock interaction processes and the heterogeneity of the lithological nature of the hosting geological formations (evaporites, limestones, marls, sandstones, granites, etc.); and (2) mixing processes between cold shallow immature waters and deep thermal waters, both in the reservoirs and during their rise to the surface. Equilibrium temperatures obtained by chemical geothermometers range from 50 to 150 °C. Assuming a geothermal gradient of $42 \text{ °C} \cdot \text{km}^{-1}$ [2] and an average infiltration water temperature of 20 °C [4], theoretical maximum reservoir depths between 714 and 3045 m are obtained.

A close relationship between the occurrence of thermo-mineral waters and the intersection of E-W thrusts of the Rif Belt and NE-SW faults were also confirmed, highlighting their relevance as preferential pathways for groundwater flow and the transfer of heat to the surface. Consequently, they constitute priority areas for future drilling of boreholes for geothermal purposes.

This work provides new insights into the conceptual hydrogeological model of the thermo-mineral waters along the South Rif Thrust, suggesting the existence of a significant geothermal potential besides direct geothermal purposes.

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Caractérisation minéralogique et géochimique des métaux précieux (Au, Ag) du gisement polymétallique d'Amensif (Haut Atlas occidental, Maroc).

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Abstract

Le gîte polymétallique à Cu, Zn, Pb, Ag, Au d'Amensif, filonien, à pour coordonnées (X: 223361,4122 ; Y : 60488,38454). Il s'inscrit dans le massif paléozoïque du Haut-Atlas occidental. La minéralisation est encaissée essentiellement dans des formations métavolcano-sédimentaires (schistes, métatuffs, carbonates) d'âge cambrien inférieur.

Les analyses chimiques (ICP-AES) des passes de carottes minéralisées révèlent, outre les métaux de base, la présence de teneurs notables en Au et Ag. L'étude minéralogique a permis de mettre en évidence quatre stades de minéralisation:

- stade (1) précoce à pyrite et arsénopyrite massives dans une gangue principalement à quartz ;
- Stade (2), marqué par une bréchification des dépôts précédents et la mise en place de la chalcoppyrite, avec une deuxième génération d'arsénopyrite dans des veines de carbonates ;
- Stade (3), représenté par une minéralisation à sphalérite et galène à exsolutions (cuivre gris et chalcoppyrite disease) avec une gangue à carbonates;
- Stade (4) supergène à bornite et la covellite ;

Le traitement statistique des données chimiques, permet de noter l'existence de corrélations significatives d'une part entre Ag vs (Cu, Pb) et d'autre part entre Au et As.

Les analyses au MEB et à la microsonde ont permis d'identifier plusieurs phases minérales porteuses de Ag : la Freibergite, la Schirmerite et la Matildite ainsi que la Tétrédrite et la galène. Par ailleurs, malgré ces investigations minéralogiques les phases porteuses de l'or restent à préciser. Toutefois, le coefficient de corrélation Au-Ag ($R^2 = 0.25$; analyses sur passes de carottes minéralisées) renvoie à l'existence de l'amalgame Au-Ag.

First GIS-based geological map of the Kivu (DR Congo): methodology and preliminary results

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Abstract

In contrast with neighboring regions, the geology of the eastern Democratic Republic of Congo (DRC) is still poorly known today. Recently however, a compilation effort of existing archive data records has been initiated as a collaboration between the Université Officielle de Bukavu (UOB) (DRC) and the Royal Museum for Central Africa (RMCA) (Tervuren, Belgium). This work is part of the ongoing GEOKIVU project developed with the support of the Belgian Development Cooperation. GEOKIVU aims at enriching regional and local knowledge in various fields, including the Earth Sciences, by stimulating access to existing documentary resources in African partner institutions, and especially at the RMCA.

In a first phase of the geological works, a methodological approach was conceived based on an inventory of existing relevant data and documents and a priority target area was defined ranging between 1°S to 5°S and from 26.5°E to 29.5°E. In this intra-plate zone, several Proterozoic to Cenozoic geological assemblages have been described in the field by various authors, the oldest of which date back to the first part of the 20th century (Salée, 1940, Kun et al., 1957, SOMINKI, etc.).

All the available archive records have been scanned, georeferenced and imported in a GIS environment for manual digitizing. The latter procedure allows to correct for the geometric and geographical errors that were inherent to cartography at that time. It relies mainly on the geomorphological expression of geological features, and in particular on structural features and magmatic intrusions that are identifiable on satellite data and digital terrain models (SRTM-1, TanDEM-X). The historic field records also contain valuable descriptions that allow to further evaluate, adapt, modify, and even refute the uncertain geological contours represented on these old maps.

The expertise available at the RMCA and the UOB enables to propose a new – up to date chrono- and lithostratigraphic interpretation based on the regional knowledge of the geological assemblages developed in adjacent areas with a similar geological build up, notably in Rwanda and Burundi. The ongoing work will result in the first regional GIS-based geological map of the Kivu at the scale of 1: 500,000.

Gestion intégrée et durable des eaux souterraines par la modélisation géostatistique: cas du Haouz (Maroc)

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Abstract

L'eau souterraine est une ressource vitale à la vie. Elle fait l'objet d'une attention accrue des acteurs économiques et politiques de par le monde, ce qui assure le caractère stratégique d'une gestion intégrée et durable de ces ressources. Cependant, la dégradation des eaux dans le monde, tant en qualité qu'en quantité, menace toutes les composantes de l'écosystème et a une incidence directe sur la vie humaine. C'est le cas aussi au Maroc où la situation est particulièrement alarmante ; et où il est donc urgent de revoir la gestion durable et intégrée de ces eaux souterraines.

Cependant, les données relatives à l'étude des eaux souterraines sont issues des campagnes de mesures in situ, dont le coût de production est non négligeable. De ce fait, ces données sont, non seulement, spatialement limitées en un réseau de points géoréférencés (puits et forages), mais en plus, les mesures y sont effectuées de manière discontinue dans le temps. Cela permet certes de réduire les coûts induits par ces mesures mais présente un frein majeur à l'étude des eaux souterraines. Il est donc impératif de procéder à l'interpolation des données disponibles en utilisant la méthode adéquate afin de combler les lacunes spatiales et temporelles.

C'est dans cette optique que s'insèrent les deux volets, de ce travail de recherche, basés sur la modélisation géostatistique. Le premier vise à produire des cartes régionalisées de conductivité électrique de la nappe du Haouz en utilisant l'interpolation spatiale permettant ainsi l'estimation des valeurs de la conductivité électrique non mesurées. Le deuxième, a pour but l'interpolation temporelle des séries piézométriques du réseau de surveillance permettant d'étudier la variation dans le temps du niveau de la nappe en fonction du temps. A cet effet, une transformation logarithmique pour la normalité des données en entrée a été réalisée. Ensuite, plusieurs variogrammes et semi-variogrammes expérimentaux ont été élaborés prenant en compte l'aspect isotrope et anisotrope. Finalement, une modélisation variographique a été effectuée et plusieurs modèles mathématiques ont été ajustés pour représenter au mieux la réalité. La validation croisée a été une étape incontournable dans cette méthodologie afin d'évaluer la précision et la performance de chaque modèle. Ce travail touche directement la prise de décision économique et politique de la gestion durable des ressources en eau au Maroc.

Methodology for selecting areas of potential metallic mineral interest in Angola

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Abstract

LNEG, together with IGME (Geological Survey of Spain), is involved in a large project in Southern Angola (PLANAGEO). The project has several execution phases and so far the one that has been completed are the airborne radiometric and magnetic surveys. Geological mapping at 1:250 000 scale is in the final stage and a geochemical survey has yet to begin. Initially, the selection of regional potential areas for mineral exploration was to follow the above mentioned surveys and mapping. The proposed methodology to select potential areas of metallic minerals interest has two philosophies: 1) Minerals supply for the internal market for the industrialization of the country and 2) minerals for the external market. Angola has the potential to be a supplier of strategic and critical metals for the European economy and during the timeframe of the project this choice looks more realistic. Therefore, the focus was given to the latter in the context of the PLANAGEO project. Old exploration reports, Mineral Catalogue of Angola, unpublished thesis and other publications were studied and compiled by the consortium to build a mineral database. The choice of the areas was based on the knowledge of the location of the known mineral deposits with higher potential, the geological potential of the host formations, the new airborne geophysical survey already carried out together with the existence of infrastructures such as roads and possible transport routes by river or sea. As a result, remote areas with difficult access were discarded. The minerals were chosen by importance in the past economy of the country and by the demands of today's international markets. New mineral or mining concessions of exploration companies were not taken in consideration by decision of the Angolan authorities. According to the contract, the scale of work is 1:100 000 and 1:50 000 and based in the new preliminary geological maps at 1:250 000 scale, the mineral occurrences and previous mining. Continuous adjustments are carried out to the selected areas with input of information from the on-going geological mapping.

Groundwater level dynamics in a fractured aquifer system in Mekelle Outlier, Ethiopia: preliminary results

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Abstract

Water remains essential for life and agricultural production. A safe, adequate and accessible water supply is a prerequisite for socio-economic development. Groundwater is a globally as well as locally an important, valuable and, frequently, renewable resource. But it should be well-managed. Initially, Mekelle City (in northern Ethiopia, East Africa) is supplied since 1998 with water mainly from Aynalem well field, which is situated about 5 km south east of the City. It was reported that the groundwater level in the Aynalem well field is declining with time. This paper provides an overview of groundwater occurrence and of the main issues affecting its quantity and quality with a main focus to its dynamics in terms of groundwater level. To understand the causes and to have better insights in the situation, a four year project was launched in 2016. In the framework of this project, a groundwater monitoring network using five data loggers was established to understand the effect of abstraction and temporal dynamics of the groundwater level. To complement the results from the data loggers, intensive geological mapping, manual groundwater level measurement and water sampling and analysis were carried out. Preliminary analysis of previous and recent data shows that there is considerable decline in groundwater level in boreholes drilled to the shallow aquifer (less than about 100 m deep) while boreholes drilled to a deep aquifer (more than 100 m deep) do not show considerable decline. Some boreholes drilled to the shallow aquifer were already abandoned while those drilled to the deep aquifer are still operational without showing significant decline in water level. Field observations confirmed that as a result of groundwater abstraction and subsequent lowering of the groundwater level in swampy areas, the Aynalem stream, grazing lands and few springs were found to have dried up. The observations testify the strong relationship between abstraction and piezometric head. Climate changes and the continuing trend of population migration to the City are leading to water shortages. This situation needs further in-depth investigation from ecological and sustainability perspectives. Looking for other alternative water supply sources for the City is strongly recommended.

Assessment of mechanical properties of ceramics sugar jars pieces from Aveiro production

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Abstract

Ceramics sugar jars pieces are from the morphological point of view conical containers of fired clay with a hole in the vertex, which were used to sugar cane pulp maturation into sugar cake. These ceramic materials were produced in Aveiro given the existence of raw material in abundance and of very good quality. Also, this occurrence of geological deposits exploited for red clays allowed the local development of strong pottery production centre, transforming the city of Aveiro into one of the major Portuguese cultural heritage sites very rich in traditional ceramic tiles and other ceramic products. After local manufacture the ceramic sugar jars pieces were exported as sugar production devices for Madeira island, Cape Verde archipelago and later, for Brazil.

Prosperity in sugar production (since the 15th century) resulted in a continuous increase of this manufacture of ceramics sugar jars pieces, reaching large-scale production. Due to the absence of natural stone for the construction of the city buildings, the rejected/surplus ceramics were used as building material on the walls. Recently, following old house demolitions in the city of Aveiro, whole walls have been discovered with these ceramic materials, many of which were practically intact, which allowed the development of a project for its study.

This work presents the results obtained from analysis of geometric, physical and chemical characteristics of various ceramics sugar jars pieces and other types of ceramics allowing to comparatively analyze the characteristics of these different materials. Mineralogical analysis were carried out by X-Ray diffraction, using a Panalytical X'Pert-Pro MPD, $K\alpha$ Cu ($\lambda = 1,5405 \text{ \AA}$) radiation on random-oriented powders; chemical composition was assessed by X-Ray Fluorescence using a Panalytical Axios PW4400/40 X-Ray Fluorescence spectrometer for major and trace elements; Lost on Ignition (LOI) was also determined. Compressive strength was determined by using a Shimadzu AG-IC with load cell of 5 kN.

In general terms, it was possible to conclude that the chemical and mineralogical behavior of ceramics was similar, pointing to local production using only local raw materials. Quartz is present in all samples. The phyllosilicates are not present in any sample of the sugar ceramics, but are present in all the remaining ceramic samples. The presence/absence of phyllosilicates is an indicator of the heating process temperature, higher on the case of the sugar ceramic than on the other ceramic materials. The compressive strength analysis of the ceramics sugar jars pieces shows higher values (mean 9.5 MPa) than other ceramics (mean 8.0 MPa), reflecting the higher firing temperatures and being in accordance with the remaining tests.

Evaluation of the BK16 kimberlite pipe located within the Orapa Kimberlite Field, Botswana

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Abstract

BK16 is one of the known diamondiferous kimberlites of the Orapa Kimberlite Field (“OKF”) in Botswana and is currently being evaluated for its economic potential. Of the 83 known kimberlites of the OKF four are currently mined: Orapa mine (AK01, Debswana), Karowe mine (AK06, Lucara Diamond Corporation), Damtshaa mine (BK01, BK09, BK12 and BK15, Debswana) and Lethlakane Mine (DK01 & DK02, Debswana). The mining of the latter is restricted to the tailing dumps. BK11 and BK16 (Tsodilo Resources) are at an evaluation stage. Since the discovery of the Orapa kimberlites in 1967 this field has produced over 350 million carats of diamonds. The Karowe mine has recently produced some famous diamonds like the 1,109 carat ‘Lesedi La Rona’ and the 813 carat ‘Constellation’. OKF lies on the northwest side of the Zimbabwe Craton and the basement is overlain by south dipping rocks of the Karoo Supergroup. AK01 (the Orapa Diamond Mine) was dated at 93.1 Ma and it is presumed that all the kimberlite intrusions of the OKF are of similar post-Karoo age.

The diamondiferous BK16 kimberlite pipe, which is overlain by 25 m of Kalahari Group sediments and at the pre-Kalahari surface measures approximately 6 hectares in size, and is known to contain rare and valuable Type IIa diamonds. A geological model is worked out based on 3,050 meters of core drilling, a high resolution ground magnetic survey and a detailed gravity survey. This has identified five kimberlite phases that make up the BK16 kimberlite pipe. The data from the 20 drill core holes and 27 historical boreholes were combined and incorporated into a three-dimensional geological model. Of the five kimberlite phases, VK2 and VK3, are the most significant volumetrically. The Kalahari overburden consists of calcrete, silcrete and loose sand at the surface. The country rock of the kimberlite is made up of Carboniferous to Triassic Karoo sediments and basalts of the Jurassic Stormberg Lava Group. At depth it comprises Archaean basement.

Some 2,000 tons of kimberlite has been extracted using 24-inch diameter drill holes and these are presently being treated through a 10 tonne per hour dense media separation plant and X-ray recovery unit to assess the grade of the kimberlite and the value of the recovered diamonds.

Delineating mineralised zones in Tegna, Northcentral Nigeria, using integrated geological datasets

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Abstract

The integration of geological datasets in mineral resources exploration promotes faster evaluation, better turnover of prospective regional data, improves geological interpretation at very much reduced cost. Nigeria recently invested in the acquisition of several geoscientific datasets, which are currently gaining traction in their application in solving geological problems. This study utilised these sets of data to undertake geological mapping and geochemical evaluation of the Tegna area in North central Nigeria, in order to delineate possible mineralised zones.

Geochemical, Geophysical (airborne radiometric and aeromagnetic) and Remotely Sensed (ASTER and SRTM) data were used for this study. This was followed up by extensive mapping and sampling of two identified target areas to validate the information obtained from the remotely sensed images. The radiometric data were used to generate a ternary image to delineate various geological boundaries. Subsurface structures were delineated by applying various derivatives to the aeromagnetic data. The SRTM was used to delineate surface structures while the ASTER data was used to map areas of possible hydrothermal alterations. Additional geochemical data were obtained by analysing rock and soils samples using inductively coupled plasma mass spectrometry (ICP-MS), while mineralogical data were obtained from X-ray diffraction (XRD) analyses. The results obtained were statistically and geochemically interpreted.

The identified lithological units were granitic, metasedimentary and mylonitic rocks. The lineaments extracted were mostly trending in the NE-SW with few trending in the E-W and NW-SE directions around areas that have been sheared and faulted. The interpreted datasets revealed two possible mineralised areas through hydrothermal alteration contrasting, with the metasedimentary rocks showing argillic and porphyritic alterations. The hydrothermal alteration in the area appeared related to the intensive shearing and fracturing of the host rocks especially in the schistose rocks units. The alteration was further confirmed by the presence of minerals such as smectite, vermiculite, kaolinite, illite and goethite in the analysed soil samples from the area. The interpreted elemental results from the soil and rock analysis revealed the occurrence of anomalous concentrations of Au, Ag, Pb, Cu, Ni and REE in the two target areas. The prepared geochemical maps showed anomalous concentration for the identified metals trends in a NNE-SSW direction, with higher concentrations of Au in Target area A than in B.

Geochemical exploration for gold mineralisation in parts of Osu Town, Southwestern Nigeria

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Abstract

Commercial gold exploitation in Nigeria has mostly been attributed to the Northwestern part of the country. However, there have been reports of artisanal mining activities for gold in other parts, especially in the southwestern part of Nigeria, but these gold deposits have not been understood in terms of their style of occurrence, nature and extent. Therefore, this study aimed to understand the occurrence mode of these gold deposits, associated elements and minerals, as well as the determination of lateral and vertical extent of the identified anomalies around selected artisanal mining sites in Osu town, Southwestern Nigeria.

Three active artisanal gold mining sites in Orogo, Amuta and Itagunmodi were selected for this study. Geological mapping of the areas was undertaken and soil samples were collected at defined intervals in vertical profiles of the identified mining pits and, horizontally, along profile lines defined away from the existing mining pits. A total of 51 soil samples were collected, 12 from the mining pits to a depth of 13 m, and 39 samples were taken along horizontal profile lines. All samples were air dried, pulverised, sieved to <75 µm and chemically analysed using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). In addition, the mining pit samples were further analyzed for mineralogical composition using X-Ray Diffraction (XRD) and gold content were also determined through Fire Assay technique and solutions analysed by flame atomic absorption spectrometry (FAAS). The data obtained were subjected to statistical analysis to ascertain geochemical relationships.

Geological mapping revealed that the Orogo area was within quartz-schist rocks while both Amuta and Itagunmodi areas are underlain by amphibole-schist rocks. The FAAS analysis showed Au concentration ranging from 4.0-11.0 ppb while ICP-MS analysis showed Au concentrations that ranged from 12.9-78.8 ppb for samples collected along the various profiles. Pearson's correlation and R-mode factor analysis showed significant relationship between Au and Mo, Pb, Zn, Ni, As, Sb, Co and Se suggesting that these metal(loid)s may serve as pathfinder elements for further Au exploration within the study area, and formed contemporaneously by the same hydrothermal event responsible for the gold mineralization. Predominant minerals in the analysed soils were quartz (34.15 % – 84.91 %), kaolinite (10.42 % – 38.39 %) and hematite (0 % – 27.46 %). The presence of kaolinite in the weathered horizons may also be an indication of the in-situ hydrothermal alteration of potassic feldspars of the host rocks.

Gold mineralisation was observed to extend beyond the current artisanal workings, indicating that the area could support larger gold exploitations, according to the distribution of the highest Au concentrations.

Hydrothermal alteration uses for exploration of copper mineralization in the Neoproterozoic glacial Mwale Formation (Katangan Supergroup, African Copperbelt)

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Abstract

The Katangan Supergroup has the majority of its Copper-Cobalt mineralization contained inside the Roan Group, these are the classic type of ore body for the African Copperbelt. In recent years, several copper only deposit and occurrences were discovered in the the Nguba Group, mainly in the Mwale Formation or Grand Conglomérat such as Kamoa-Kakula (Schmandt et al. 2013) and Shanika (Mambwe et al. 2017) both in the Congo Copperbelt and Fisthie (Hendrickson et al. 2015) in the Zambia Copperbelt.

In the Tenke Fungurume Mining District (TFMD), exploration conducted along the Neoproterozoic glacial Mwale Formation identified some anomalic copper occurrence in the Kamakonde area. The copper mineralization is found in the glaciogenic (diamictite) and the glaciofluvial beds (greywacke, sandstone) of the Mwale Formation, in the overlain shale of the Kaponda Formation and the dolomite of the Kakontwe Formation. The mineralization consist of pyrite and chalcopyrite rims on the diamictite's clasts and a dissemination of euhedral pyrite crystals in the matrix. Replacement of the sulphides by an assemblage of malachite, chrysocolla and azurite associated with multiple generations of dolomite-chlorite-pyrite-chalcopyrite-bornite veins is also commonly seen.

The particular characteristic of the glacial Mwale Formation in the African Copperbelt are the relationship between the hydrothermal alteration and the copper mineralization. Tectonic control of the mineralization coupled with a magnesian alteration are associated to the copper mineralization at Kamakonde and Shanika synclinal (TFMD) and at Fisthie (Zambia) while the potassic and silicification alteration is described at Kamoa-Kakula. These two hydrothermal alteration type indicates two different genetic process and mineralization in the same units. These alterations could be used for specific targets generation in the exploration in the Neoproterozoic diamictite along the African Copperbelt.

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U cycle and crustal growth-differentiation: the example of the magmatic/Na-metasomatic U mineralization associated with ductile to brittle deformation of the Pan-African A-type Zabili syntectonic pluton (Mayo-Kebbi, SW Chad)

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Abstract

Uranium is an incompatible element that is also highly mobile as exavalent uranyl ion (UO₂²⁺ under oxidizing conditions (Cuney, 2009). Accordingly, it is a perfect tracer of magmatic-hydrothermal processes involved in crustal growth and differentiation. In this contribution, we describe the characteristics of U mineralization hosted by the A-type Zabili syntectonic pluton exposed in the Mayo-Kebbi massif and discuss its implication in terms of formation and evolution of the Neoproterozoic crust. Located in southwestern Chad, the Mayo-Kebbi massif exposes a Neoproterozoic juvenile crustal segment that has been tectonically accreted onto the Central Africa Orogenic Belt and reworked during the Pan-African orogeny. It comprises a syntectonic high-K calc-alkaline magmatic suite including the Zabili A-type granite that has been interpreted as a highly differentiated magma generated by partial melting of a Neoproterozoic juvenile protolith containing traces of an older continental basement and that have been affected by fractional crystallization (Isseini et al., 2012). Syn- to post-magmatic ductile to brittle deformation of the Zabili pluton is associated with metasomatism and locally with the deposition of uranium mineralization. Primary magmatic U-bearing minerals are zircon, monazite, and probably uranothorite. Late-magmatic deformation is marked by the development of R' antithetic shear zones characterized by high-temperature dynamic recrystallization of K-feldspar and plagioclase linked with transformation in albite along deformation bands and grain boundaries. Quartz, amphibole and biotite, filling space in between feldspar phenocrysts are replaced by secondary albite, calcite and epidote that are also affected by intracrystalline deformation. This high-temperature ductile deformation-metasomatic event is associated with the crystallization of U-bearing minerals represented by hydrothermal monazite, uraninite (pseudomorphosed in ekanite at high temperature), brannerite, and U-silicates such as coffinite. U-Th-Pb dating of these monazite grains, yields an age of 599±4 Ma. Cooling of the granite and late-tectonic deformation below the ductile/brittle transition is expressed by cataclastic zones and veins associated with the precipitation of albite, epidote, calcite, chlorite, apatite, zircon, and iron-oxides. Brittle deformation is also associated with remobilization of U-bearing minerals and with the crystallization of pechblende (altered in uranophane under supergene conditions) in hydrothermal veins. These data suggest that uranium mineralization in the syntectonic Zabili A-type granite is related to a superposition of processes starting with (1) ductile deformation and metasomatic alteration implying the interaction between magmatic minerals with a Na-rich fluid, potentially magmatic in origin, coeval with the deposition of uranium oxides, followed by (2) brittle deformation coeval with the deposition of secondary hydrated uranium silicates. The U mineralization hosted by the A-type Zabili pluton illustrates the U cycle in the framework of Neoproterozoic crustal growth and differentiation. Uranium has been extracted from an enriched mantle pointing to the impact of crustal recycling on the U cycle. Uranium concentration is then associated with partial melting, fractional crystallisation and mobilization in hydrothermal fluids from late magmatic ductile deformation to brittle deformation.

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South Africa's geothermal energy hotspots inferred from subsurface temperature and geology

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Abstract

South Africa intends to mitigate its carbon emissions by developing renewable energy from solar, wind and hydro, and investigating alternative energy sources such as natural gas and nuclear. Low-enthalpy geothermal energy is becoming increasingly popular around the world, largely as a result of technological advances that have enabled energy to be harnessed from relatively low temperature sources. However, geothermal energy does not form part of South Africa's future renewable energy scenario. This omission may be related to insufficient regional analysis of potentially viable geothermal zones across the country. We considered existing subsurface temperature and heat flow measurements and performed solute-based hydrochemical geothermometry to determine potentially anomalous geothermal gradients that could signify underlying low-enthalpy geothermal energy resources. We correlated these findings against hydro/geological and tectonic controls to find prospective target regions for investigating geothermal energy development. Our results show a significant link between tectonic features, including those on-craton, and the development of geothermal potential regions. In addition, potential regions in South Africa share similarities with other locations that have successfully harnessed low-enthalpy geothermal energy. South Africa may therefore have a realistic chance of developing geothermal energy, but will still need additional research and development, including new temperature measurements, and structural, hydrogeological and economic investigations.

Assessing the reactivation potential of pre-existing fractures in the southern Karoo, South Africa: evaluating the potential for sustainable exploration across its Critical Zone

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Abstract

Understanding the kinematics of pre-existing fractures under the present-day stress field is an indispensable prerequisite for hydraulically increasing fracture-induced rock permeability, i.e. through hydraulic stimulation, which forms the basis of economically viable exploitation of resources such as natural gas and geothermal energy. Predicting the likelihood of reactivating pre-existing fractures in a target reservoir at particular fluid injection pressures requires detailed knowledge of the orientations and magnitudes of the prevailing stresses as well as pore fluid pressures. In the absence of actual in-situ stress measurements, e.g. derived from boreholes, as is mostly the case in previously underexplored “frontier areas”, such predictions are often difficult. In this study, the potential of reactivating pre-existing fractures in a likely exploration region of the southern Karoo of South Africa was investigated. The orientations of the present-day in-situ stresses were assessed from surrounding earthquake focal mechanisms, implying c. NW-SE oriented maximum horizontal stress and a stress regime changing between strike-slip and normal faulting. A comparison with paleo-stress axes derived from inverted fault-slip data suggests that the stress field very likely did not experience any significant reorientation since Cretaceous times. Maximum possible in-situ stress magnitudes are estimated by assuming that these are limited by frictional strength on pre-existing planes and subsequently, slip and dilation tendency calculations were performed, assuming hydrostatic pore fluid pressures of c. 32 MPa at targeted reservoir depth. The results suggest that prevalent E-W and NW-SE oriented sub-vertical fractures are likely to be reactivated at wellhead pressures exceeding hydrostatic pore fluid pressures by as little as 2-5 MPa, while less prevalent sub-horizontal and moderately inclined fractures require higher wellhead pressures that are still technically feasible. Importantly, actual in-situ stress measurements are essential to test these theoretical considerations and to guide the design of safe and effective exploration linked to fracture manipulation, such as shale gas recovery.

Geological Assessment of metallic mineral potentials of Ikomu (Sheet 220), Southwestern Nigeria

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Abstract

The increased global demand for metals and the continuous decline in the currently exploited reserves has led to aggressive and intensive search for these metals all over the world, especially in unexplored areas and with no previous mining history. Nigeria had witnessed intense interest in the recent past in exploring for mineral reserves, especially metals. This study is aimed at assessing the geological and geochemical characteristics of soil and rocks in part of Ikomu Sheet 220, South-Western Nigeria, in order to evaluate their potentials for Au and REE mineralizations.

Detailed lithological field mapping of the study area was undertaken with representative rock samples obtained for petrographic and geochemical studies. Ninety-three soils samples were collected from the area and chemically analysed by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). The elemental results were then plotted as geochemical maps using ArcGIS and also interpreted using statistics and various geochemical plots.

Geological mapping revealed the lithologies of the area to be garnet-biotite-gneiss, granite gneiss, quartzite, talc schist, cordierite-staurolite-garnet-mica-schist, staurolite-garnet-biotite-schist, amphibolite (foliated and massive varieties), syenite, medium-grained-granite, porphyritic granite and pegmatite. Elemental results (ppm) in the soil showed the following range of concentration: Au (bdl-0.006), Cu (9.7-1829.9), Pb (4.9-178.8), Zn (17.3-100.7), Ni (8.00-296.80), Mn (298.0-10,000.0), As (0.4- 25.6), V (54.00-900.0) and Cr (34.00-1121.4). The results also revealed that the area was enriched in LREE and depleted in HREE. The plotted geochemical maps on the geology map indicated that the Au, Cu, Pb, Ni, Mn, As, V and Cr were enriched in soil underlain by porphyritic granite, syenite, cordierite-staurolite-garnet-mica-schist and foliated amphibolite. Correlation and R-mode factor analysis partitioned the metals into Ag-Zn-Sc-Y-La-Nd-Er, Cu-Ni-Mn-V-Cr-Sc-C, U-Th-Sn and Cu-Ni-Mn-V-Cr-Sc, Y-La-Nd-Er, Pb-As-U-Ce suites and reflective of the underlying geology.

poster

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**Earth's mineral
resources and
sustainable
development**

Problematic of the artisanal mining exploitation and their impacts on the environment in walikale (north kivu. DR Congo)

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Abstract

The artisanal mining exploitation in democratic Republic of Congo is adjusted by the article 26 of the mining Code that arranges: “without prejudice of arrangements of the article 27, only the major physical people of Congolese nationality can acquire and can detain the cards of artisanal operator and trader’s cards “. otherwise, the article 109 of the IV title of the mining code institutes the artisanal exploitation zone in these terms: “When the technical and economic factors that characterize some lodgings of gold, diamond or all other mineral substance don’t permit to assure an industrial or semi-industrial exploitation of it, but permit an artisanal exploitation, such lodgings are erected, in the limits of a determined geographical area, in artisanal exploitation zone.

The institution of an artisanal exploitation zone is made by way of decree of the minister after opinion of the direction of the Mines and the governor of the province concerned, but an activity without control However, it includes enormous inconveniences notably on the human health but also the one of the environment and the natural resources. She also has some consequences on a social level. It is necessary to note indeed that the artisanal mining exploitation contributes to the deforestation, to the deterioration of soils, to the pollution of air by the dust and the monoxide of carbonic, of soil and water by the used oils of the motors and the chemicals

In conclusion: This exploitation is considered like source of financing of the groups armed, it is the basis of the insecurity in the East of the RDC

Nécessité d'exploitation du Pétrole dans le parc National de Virunga et du Gaz méthane du lac Kivu face aux impératifs de la protection de l'environnement a l'Est de la RDC

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Abstract

Les découvertes d'énormes ressources d'hydrocarbures à l'Est de la RD Congo (pétrole et gaz méthane) ont suscité une attention particulière par rapport aux multiples enjeux et défis qui en sont inaliénablement liés. Partant du contexte géologique qui a été favorable à ces énormes accumulations, l'Est de la RD Congo jouit de ce fait de tous les avantages de son essor suite à ces potentialités dont une fois exploitées constituera la clé du développement de cette partie du pays et incontestablement de la RD Congo.

Une grande réserve du pétrole se trouvant au Cœur du Parc National de Virunga qui est un patrimoine mondial et aussi signale d'énorme quantité du Méthane se trouvant dans le lac Kivu. Plusieurs compagnies d'explorations pétrolière et entreprises furent installées dans plusieurs pays frontaliers parmi lesquels le Rwanda pour le gaz méthane et l'Uganda pour le pétrole aussi en RDC la société SOKO pour le britannique dans le parc de National de Virunga. Néanmoins d'énormes débats sur les conditions d'exploitation de ces ressources suscitent l'attention de plus d'une personne. Ces débats s'articulent sur des questionnements relatifs d'une part à la protection de l'environnement pour l'exploitation du pétrole et à l'impérieuse urgence d'exploitation du gaz méthane quant aux risques de son inexploitation par rapport aux villes riveraines du lac Kivu.

Au-delà de tout, la contribution de ces audacieuses entreprises d'exploitations de ces ressources par rapport aux principaux enjeux de développement demeure une des attentes les plus ressenties. Car longtemps, cette partie de la RD Congo a vu ses ressources être exploitées mais des apports signifiants par rapport au développement sont très moindres.

La possibilité d'améliorer les conditions sociales et la croissance économique est la forte demande en énergie dans la region qui constitue pourtant une nécessité a l'Est de la RD Congo. Globalement, la nécessité s'impose de lancer l'exploitation à l'Est de la RD Congo, cependant des réflexions liées aux enjeux environnementaux devront être entreprises, car ces ressources doivent contribuer au développement de la région et non alimenter des conflits armés.

Comme une grande exploitation exigerait un aménagement des ouvrages et matériels dans un environnement censé être protégé eu égard de ses réserve patrimoine, et de la biodiversité,...

Etant donné que l'exploitation pour le cas du pétrole se ferait dans le parc, des mesures salvatrices de l'écologie devraient être envisagées. L'importance d'une synergie d'action dans la protection de l'environnement s'avère cruciale et de méthodes innovatrices pour la conservation de l'environnement serait à la base de la préservation de ce milieu qui serait en voie de disparition.

Tous les défis doivent être adressés aux autorités nationales, aux chercheurs du monde dans ce domaines et surtout aux sociétés concernées afin que l'exploitation de ces hydrocarbures pose un minimum d'impacts sur l'environnement en maximisant les bénéfices aux aspects environnementaux, écologiques, biodiversités, économiques et sociaux pour le bien de la population.

REE-U-Th-As enrichment in iron (hydr-)oxides from supergene ore deposits of the High Atlas and Anti-Atlas (Morocco)

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Abstract

Morocco hosts a wide range of supergene deposits principally located in the High Atlas and Anti-Atlas. The interest of mining these ores lies in their relatively high metal, including Rare Earth Elements (REE) content, and their rather easy extraction process related to their softened host rocks and near-surface distribution. The weathering of hypogene ores generates the formation of supergene profiles composed of, from base to top, the i) hypogene zone, ii) cementation zone, iii) oxidized zone, and iv) leached zone (or gossan). We focus here on the enrichment in particular elements of iron (hydr-)oxides such as goethite. Goethite is the most common and stable iron oxyhydroxide under atmospheric conditions, and is thus widely observed in the gossan of supergene deposits. Several copper deposits from the districts of Bou Arfa (Oriental High Atlas) and Akka (Eastern Anti-Atlas, Kerdous and Ighrem inliers) are considered.

Twenty-six samples of goethite were analyzed to assess their concentrations in major and trace elements (including REE). The contents of major and trace elements in goethite are mostly depending on the nature of the host rocks (carbonates, shales, ...) and the type of the mineralized veins (Cu, Pb, Zn, ...) of the deposit, whereas the REE patterns show particular features related to the nature of the samples. Well-crystallized samples show higher values in LREE, whereas poorly crystalline powdery goethite is enriched in MREE. In comparison to the Post-Archean Australian Shale (PAAS), most samples present fractionated patterns, with slightly negative Ce anomalies and an enrichment in MREE and HREE.

Another important feature of iron (hydr-)oxides of both Bou Arfa and Akka districts is their high U and As content. The concentration of U and REE in iron (hydr-)oxides is a typical supergene trend. Enrichment in U and associated depletion in Th are related to a selective U vs Th mobilization during weathering processes. Soluble and mobile U is preferentially leached and accumulated in neoformed minerals, while immobile Th is retained in weathering-resistant minerals. The high REE and U contents in goethite are related to the large specific surface, the numerous cation exchange sites, the subsequent important adsorption capacity under acidic conditions, but also to the coprecipitation of minerals at the interface between iron (hydr-)oxides and fluids. Enrichment in As is related to the adsorption of this element by goethite, in the form of arsenate or FeAsO_4 , in oxic environments. The fractionation of REE patterns reflects the precipitation of goethite from relatively acidic fluids, where LREE are more soluble than HREE, whereas the lack of fractionation is a consequence of neutral pH conditions, possibly related to a neutralization by carbonate host rock. The slightly negative Ce anomaly of most samples indicates that Fe (hydr-)oxides formed in an oxidizing environment. The rapid oxidation and subsequent precipitation of this element indeed triggers its decoupling from the other REEs that remain in solution.

Geopolitical concerns arising from artisan mining in some parts of Nigeria and Cameroon

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Abstract

Artisanal and illegal mining of solid minerals pervade the entire country leaving behind their effects on the environment. Most of these artisanal and illegal miners (men, women and children) are rural and poor, operating without legal mining title. Their activities include mining of gemstones like tourmaline, beryl, amethyst, aquamarine and garnet and precious minerals like diamond and gold. Other minerals like columbite, tantalite, copper, lead, zinc and cassiterite are also widely mined. Mining of river sands, digging of burrow pits, removal of topsoil, sand and laterite for building purposes are also carried out. Other activities include removal of vegetation and cleaning of dams to produce dam sands. This array of activities lead to uncoordinated and unregulated mining which usually result in haphazard extraction of the minerals and eventual destruction of the environment, generating huge socio-political and socio-economic concerns. Evidences of such destruction are observed in the form of soil erosion, change in topography, water pollution and dumps of overburden material. The resultant effects of abandoned pits and other mining sites that becomes flooded during the raining season pose health dangers to the citizens. All these impact negatively on and degrade the environment. In this paper, mining communities and sites were visited, questionnaires were administered and local were interviewed where possible. Findings indicated that aside the attitude of some miners of not fulfilling their side of agreement with their host communities and the fact that community leaders are corrupt, there seem to be minimal geopolitical concerns arising from the activities of artisanal mining.

Use of structural geology as a guide in mineral exploration and selective mining process in orogenic gold deposits: Twangiza Mine Case

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Abstract

Twangiza Mine is located in the eastern part of the Democratic Republic of Congo and consists of a gold mine deposit. The Twangiza Mine lays in Itombwe Supergroup which is a Neoproterozoic belt overlaying the Kibaran belt of Mesoproterozoic age. The Twangiza Mine is formed of black shale intruded by granitoid sills. The granitoid sills have been metasomatised to albitite formations. The Twangiza mine's formations have been deformed during the Pan-African orogenic event (ca. 550 - 520 Ma) and underwent a regional low grade metamorphism. These formations have been folded into an N-S trending anticline axial plane.

The anticline axial zone constituted a suitable pathway and trap of gold during the mineralizing hydrothermal fluid flow. Gold mineralization is therefore localized along the nearly N-S trending anticline axial plane. The mineralization occurs in the form of mineralized quartz veins and massive sulphide veins formed in the dilation zone between different lithological layers, in cleavage planes and in different fractures formed during the tectonic process. The albitite sills are commonly more mineralized than the black shale host rocks probably due to their lithological property which are more brittle, and their chemical properties which might have played a role of trap of the gold mineralization. The deposit have been later on deformed, probably after the mineralization event, as attested by local faults displacing the ore body and the deposit formations of few centimetres.

In orogenic gold deposits the discontinuities, resulting often from tectonic stresses, commonly play the role of pathways for the mineralizing fluids flow. The structural geology study will help to identify and to characterize the different types of discontinuities, but also to identify which type of structures are mineralized and which are not. The mineralization within the Twangiza area is mostly controlled by the structures, especially the main anticline axial plane and the associated parasitic folds. Therefore, the best understanding of the structural geology helps to locate the position of an ore body.

During ore exploration works, a careful geological mapping is conducted in order to identify the different structures, especially anticline axial planes, and associated lithological formations. The exploration targets are then planned according to the relevant structures.

The selective mining process during the mine production phase is also conducted based on the relevant mineralized structures. For instance, mineral alteration close to the anticline axial planes is carefully considered while alterations beyond the axial plane is seriously investigated before being mined as it may be barren or of low grade. The grade control drilling have also to be planned according to the relevant structures, such as the drillholes spacing. For the more complex and relevant structures areas a small drillholes spacing is applied while a big spacing is considered for less relevant structures areas.

Le kaolin du gisement de Guenfouda, Maroc Nord-Oriental : caractérisations minéralogique et géochimiques - valorisation industrielle

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Abstract

Le gisement de kaolin de Guenfouda est situé sur le flanc nord du bassin de Jerada (NE du Maroc) daté du Viséen supérieur. L'étude minéralogique montre que la roche-mère de cette argile blanche est une rhyolite ou une rhyodacite. La roche-mère, a été fracturée postérieurement à son dépôt, puis affectée par une altération hydrothermale par circulation de paléofluides d'une température inférieur à 300°C. L'objectif de ce travail est de caractériser l'argile de ce gisement pour une valorisation industrielle.

La caractérisation est faite par différentes méthodes d'analyse, la diffraction des rayons X, la fluorescence X, la spectrométrie infrarouge (FTIR) et le microscope électronique à balayage (MEB). L'analyse par diffraction aux rayons X sur roche totale montre que ce kaolin est composé de kaolinite, d'illite, de pyrophyllite, de chlorite, de micas, d'apatite, de jarosite, de pyrrhotite et de quartz. Les analyses qualitative et semi-quantitative des diffractogrammes de la fraction argileuse (méthode de lames orientées) montrent que cette argile est composée par des pourcentages varie entre 7.5 et 93.94 d'illite, 5 % à 65.79 % de pyrophyllite, 4.5 % à 87.5 de kaolinite et 16.13 % de chlorite. L'analse par la fluorescence X montre que la roche total contient 28.85 % de Al_2O_3 , 0.56 % de Fe_2O_3 , 0.88 % de TiO_2 , 3.24 % de K_2O et 0.25 % de Na_2O . Le spectre d'infrarouge présente une fréquence à 693 cm^{-1} correspond à la liaison Si-O de la kaolinite, la fréquence à 798 cm^{-1} confirme la présence de quartz, la fréquence à 3404 cm^{-1} correspond à l'eau interfoliaire de l'halloysite. Ces résultats sont en accord avec ceux de la DRX. Ils confirment la présence de kaolinite, illite, micas et le quartz dans l'argile étudiée. Les analyses EDAX montrent que cette argile contient l'oxygène, le silicium, l'aluminium, le titan et le potassium. Le cœur de la carrière est riche en titan et dépourvu de potassium alors que la périphérie est plutôt à potassium et sans titan.

La comparaison de la composition géochimique et minéralogique du kaolin de Guenfouda avec les normes industrielles de matériaux utilisés dans divers produits, montre que le kaolin de Guenfouda pourrait être utilisé dans la céramique, la peinture, le papier et les réfractaires.

Challenges in rural water supply in Nasarawa State, Nigeria: a case study of coverage and effectiveness

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Abstract

Effective and sustainable rural water supply remains a challenge globally. This paper takes a look at both Government and non Government rural water supply schemes in Nasarawa state. It examines the following key issues: coverage, effectiveness and sustainability of boreholes in rural communities. Challenges identified include: poor coverage and sustainability as well as duplication of projects. It was discovered that since 1980's, several projects were initiated and completed, however there is a lot of duplication so that some communities have upto 8 independent borehole based water supply schemes, while others don't have a single water supply scheme. Reasons identified include: (i) politics where communities that provide massive support for the Government of the day during elections benefit continuously from several interventions; (ii) decision makers are ill educated regarding the coverage of such projects as locations and spread of such rural communities is not well documented; and (iii) communities that are privileged or opportune to be on major road networks (accessibility) are better captured, while the existence of rural areas in the hinterland are not known and hence not captured. Another reason for duplicity is sustainability; where such schemes 'fail' new schemes are put in place rather than examining the reason for the failure. A solution to these challenges is proposed: a detailed map of the State to include the following: (i) communities with existing or otherwise water supply schemes; (ii) accessibility to such communities; and (iii) potential water sources (both surface and ground water). Secondly, decision makers from both Government and non – Governmental Agencies need to be educated on these challenges. A pilot map for rural communities in Lafia and Keffi Local Governments Areas of the state were produced to demonstrate this and presented to the state Ministry for Water Resources and Rural Development for consideration.

Les phases de déformations alpines dans la région des Beni Khettab, (domaine interne du socle de Petite Kabylie-Algérie)

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Abstract

Le NE de la région des Beni Khettab (NW du socle de la Petite Kabylie) est constituée par le Djebel Sidi Ali, un des noyaux interne de la chaîne des Maghrébides, son étude pétrographique fait apparaître l'unité supérieure de socle matérialisée par des gneiss plagioclasiques, des micaschistes surmontés par des marbres blancs. Cette unité est séparée de l'unité inférieure constituée de leptynites par une bande mylonitique (Bouillin, 1982 et Djellit, 1987) d'âge tardi-hercynien (Peucat et al, 1991) et l'ensemble est surmontée par une série de schiste satinée à passées gréseuse d'âge paléozoïque (Djellit, 1987).L'ensemble du socle de Petite Kabylie a été intrudé postérieurement par des granites d'âge Hercyniens (Peucat et al, 1996).

Le sud de la région de Petite Kabylie fait apparaître des roches basiques et ultrabasiques (complexe volcano-sédimentaire de Tabellout) d'âge alpin (Bouillin et al 1977).

L'étude structurale a montrée que la région est traversée par des failles inverses de direction NW-SE, ces failles sont chevauchantes et plissées (sub-verticales en surface et plonge vers le NE en profondeur). Ces failles emballent avec elles des éléments bréchiques doléritiques arraché des roches basiques et ultrabasiques de Tabellout, ce roches intensément déformées ont joué le rôle de semelle de nappe lors du chevauchement du socle Kabyle sur les flyschs.

Le contract sud qui sépare les schistes satinées du corps granitique est jalonné par des éléments sigmoïdes montrant un décro-chevauchement senestre vers le SW, cette même déformation est soulignée par les éléments sigmoïdes issus des schistes satinés, ces différentes observations de terrain sont confortées par la projection stéréographique.

Cette étude nous permis de mettre en évidence trois directions de déformation principales liées à l'orogénèse alpine, la première de direction NW-SE, elle est liée à un mouvement de raccourcissement qui a eu lieu entre le bloc AlKaPeCa et l'Afrique et le chevauchement du domaine interne du socle Kabyle sur le domaine externe. La seconde est représentée par un décro-chevauchement senestre vers le SW, elle est liée au réajustement de la chaîne. Alors que la troisième direction de déformation est plus tardive, elle montre un rétro-charriage vers le nord.

Ces différents éléments structuraux issus des différents niveaux du socle Kabyle et les différentes directions de déformations plaide en faveur d'un socle polyphasé qui enregistre les phases hercyniennes et alpines (Durand Delga 1969 et Bouillin 1982, 1984).

Preliminary results of the Kodieran and Koulekoundrill holes (Guinee): petrographic study and mineral chemistry

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Abstract

Lithostratigraphic and petrographic studies of drill core samples from the Kodieran and Koulekounboreholes (Guinee) revealed various lithologies, including sedimentary rocks (mainly siliciclastic) intercalated with volcanic horizons (pyroclastic deposits and rhyolitic, dacitic, and andesitic flows), and local dolerites.

Preliminary analyses show that the mineralization occurs as sulphides and electrum, which appear in two forms:

1. Disseminated, mainly in sandstones and dacites, but also present in the other facies.
2. In veins, associated with quartz or calcite.

The alteration assemblage consists of variable replacement degrees of feldspars by sericite, and alteration of mafic minerals to chlorite. This style of alteration is compatible with porphyry and epithermal (both high and low sulphidation) mineralization styles.

Four stages of mineralisation were recognized: the first one is mainly represented by the crystallization of pyrite, followed by the second one, consisting of epitaxial overgrowths and replacements of pyrite by arsenopyrite. In a third next stage, vugs in pyrite and arsenopyrite were filled with chalcopyrite, sphalerite and electrum. The fourth event is the crystallization of pyrrhotite along veins.

The defined mineralisation stages suggest a change of the sulphidation state of the mineralising fluid from intermediate to low. Observed changes in the proportion of arsenic in arsenopyrite may indicate changes both in the temperature and the sulphidation state of the mineralizing fluid, for instance, higher concentration of As in the fluids are related with higher temperatures and lower sulphidation states.

Methods of remote sensing for assessing groundwater exploitation in the Maghreb region

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Abstract

Since a few years, the use of remote sensing data for environmental challenges increases exponentially. The earth observation Copernicus programme with its Sentinel missions contributes highly to this expansion, as it allows both a facilitated access to such data, making them free and open available, and a very regular revisiting time along with a coverage and a resolution that opens up the floor to all sorts of monitoring applications. Such capability is of particular interest in the Maghreb region, where access to in-situ information for monitoring groundwater resources is not always granted. We present here the case study of an agricultural area in the region of Kairouan, Tunisia, where most of the water used for irrigation comes from the underlying aquifer. As only a few fields are equipped with water meters, the authorities experience some difficulty to assess the real amount of water pumped for agricultural use. That's where remote sensing methods come in, in order to support the estimation of the volume of water pumped from the aquifer and to warn about potential overexploitation of water resources. More specifically, we use for this region two different approaches. The first approach consists in estimating ground water use through the identification of the different crop types and their evapotranspiration, both being highly correlated to their corresponding water demand. For this, we perform land use classification on optical data of the Sentinel 2 Copernicus mission. Time-series of Sentinel 2 are used to better distinguish the different cultures from each other. The water volume is then calculated using the FAO (Food and Agriculture Organisation) approach, combining land use classification results with climatological data. The second approach consists in analysing time series of RADAR data from the Sentinel 1 Copernicus mission. In particular, advanced RADAR interferometry (InSAR) techniques, like the Persistent Scatterer Interferometry (PSI) or Small Baseline Subset (SBAS), offer the possibility to measure surface deformation with large coverage and high precision in the range of mm. We prefer here the use of the SBAS approach, better adapted to ground motion monitoring in rural areas. The observed deformation pattern for the region of Kairouan shows an important land subsidence, evidence for ground water decrease and overexploitation. The area of subsidence is highly correlated with the location of the agricultural area. The high rate of subsidence (up to 100mm/year) is explained by the situation of this area above alluvial deposits. A discharge of the underlying aquifer feeds back to the surface. A synergetic use of RADAR and optical data allows to better assess the current state of the aquifer and possibly make some previsions and scenarios for the future.

Ni-Cr mineralization in the regolith of serpentinite at Lutshatsha and Nkonko deposit (Congo Craton, Democratic Republic of Congo): exploration and grade distribution

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Abstract

The Archean Congo craton in the Central part of Africa is exposed in Democratic Republic of Congo (DRC), Angola, Central Africa Republic, Gabon and Cameroon. It is known as the Kasai-Congo craton block in DRC and is constituted of several magmatic and metamorphic complexes such as the granitic and migmatitic complex of Dibaya, the gabbro-noritic and gabbro - charnockitic complexes, the Haute Luanyi gneiss, the Sandoa-Kapanga gneiss complex, including serpentine dykes. These dykes are respectively oriented E-W and ENE-WSW and correspond to the Lutshatsha and Nkonko Ni-Cr deposits. Drill cores data (lithology, grade) reveal that both the Lutshatsha and Nkonko deposits exhibit characteristics typical of Nickel laterite deposits. Therefore, the fresh serpentinite (up 500m-thick) is overlain by the regolith zone (~37 m-thick). The grade distribution in the saprolith zone indicates very low concentrations of Ni-Cr (<0.5 %) in the saprock layer (~14 m-thick) whereas higher grades are found in the saprolite (~10 m-thick, 1 -4 % of Ni and < 3 % of Cr). Nickel stills show very low grade (<0.5 %) in the pedolith zone (~13 m-thick) contrasting with Cr (>4 %). The regolith zone along the serpentinite dykes in the Kasai-Congo craton block constitutes the best exploration target in reference of Lutshatsha and Nkonko Ni-Cr deposits. These results from this pioneering work sufficiently highlight the interest of this target in a more intensive exploration program.

Gypsum hosted in the Kundelungu Group (Democratic Republic of Congo): lithology, mineralogy and tectonic control

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Abstract

The Katagan Supergroup in the central part of Africa forms the Lufilian Panafrican fold belt hosting Cu-Co and Cu-Pb-Zn mineralization's in sedimentary rocks. Inside the Congo copper-belt in the Katagan foreland, several gypsum occurrences were mentioned, mainly along the Pande valley from the Bianco Plateau. The rocks (shale, sandstone, conglomerate) from this area constitute the lithology of the Bianco Subgroup [1-3]. In this study, we present the result of field work done in this region at Kapiri I and II gypsum occurrences. The gypsum is hosted by the karst developed in massive sandy limestone at Kapiri I. The gypsum is colorless to blackish. The black color is due to the presence of black clay originating from the weathering of the host rock and embedded along the cleavage during the crystal growth. At Kapiri II site located roughly 300 m to the north of Kapiri I gypsum occurs in open spaces resulting from faulting and jointing and in breccias, constituting the matrix. The color of the gypsum varies from colorless to white yellowish. Brown to yellowish clay material from the weathering of the shale occurred in the cleavage as observed at Kapiri I.

Gypsum crystals are generally prismatic to elongate in habit and usually show frequent twinning at Kapiri (I-II). Their size varies from millimeter to metric (up 1.2 m-height) relatively to the size of both the enclosing karst and fractures. High angle of bedding plan (50°-90°) and extensive fracturing observed in the lithological succession of laminated shale and silty shale at Kapiri II are an evidence of the tectonic implication in the crystallization process at least indirectly.

The precipitation of the gypsum in the Kundelungu Group post-dates the deposition of the Katangan rocks and the Lufilian orogeny. The occurrence of gypsum is controlled by the circulation of meteoric water through fractures and karst openings due to the dissolution of carbonate rocks and faulting related to Lufilian or post-Lufilian event. The Pande valley is interpreted as a result of a major erosional event affecting the Bianco Plateau. It allows in same area an exposure of the underlying rocks from Ngule Subgroup bearing Cu mineralization (e.g. Mutobo area ~ at 10km East of Kapiri). The precipitation of gypsum is attributed to the mixture of Ca⁺⁺ containing water from the dissolution of carbonate beds with sulfate (SO₄⁻) containing water from the alteration of sulfide minerals

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Les formations ferrifères de la région de Berrahal (massif de l'Edough, NE Algérien) : un exemple de gîtes de fer métamorphisés.

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Abstract

Les anciens gisements de magnétite ± hématite de Berrahal affleurent dans la partie sud du massif de l'Edough (NE Algérien). Les corps minéralisés apparaissent sous la forme de couches stratiformes lenticulaires de fer métamorphisés héritées des faciès carbonaté et silicaté d'anciennes formations ferrifères (Henni, 2006) d'âge pré-permien, probablement précambriennes (Caby et al. 2001) avec une composition globale calcitique ou calco-silicatée et sont encaissés dans des schistes à disthène-staurotide-grenat. Les principaux minéraux des corps minéralisés sont : magnétite, hématite, sidérite, quartz, calcite, fayalite, hédénbergite et grenat (almandin).

Trois types de faciès peuvent être distingués sur la base d'observations pétrographiques et géochimiques : Le premier faciès nommé Mc correspond à un minéral carbonaté. Ce minéral est caractérisé par une gangue carbonatée avec des rubanements alternés de calcite et de calcite + magnétite. La sidérite est sporadiquement présente. Le quartz est également présent. Le second faciès, nommé Ms, est un minéral silicaté caractérisé par une gangue de silicates tels que fayalite et hédénbergite. L'amphibole est présente et apparaît sous forme d'hornblende ferro-édénitique à hastingsitique, tandis que le grenat est présent sous forme d'almandin. Le troisième faciès, nommé Mi, est considéré comme un faciès intermédiaire en raison de sa teneur en silice inférieure à celle de Ms. La gangue est constituée d'olivine principalement, avec quelques bandes calcitiques intercalées. La calcite et la fayalite apparaissent en équilibre.

Les minéraux précoces sont affectés par un métamorphisme Mn^{+2} exprimé par une linéation $N130-140$ à la surface des corps minéralisés, et une foliation Sn^{+2} concordante avec celle des schistes encaissants.

Les similitudes pétrographiques et géochimiques suggèrent que l'étendue régionale de la minéralisation est héritée de protolithes de nature sédimentaire ou volcano-sédimentaire d'âge précambriens transformés par un métamorphisme isochimique antérieur à Mn^{+2} (Henni & Guy, 2012).

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07

**Weathering,
Climate
and Surface
Processes**

Contribution of clay minerals in paleoenvironmental reconstructions: case of Jbel Boukhmis Formation (Central Morocco)

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Abstract

The Jbel Boukhmis Formation crops out in the East of central Morocco, at the North of Mrirt city. It lies in angular unconformity on the Devonian series. The overthrust structure shows a verging towards NW. The new biostratigraphic data shows that this Formation has a Brigantian age. The sediments of Jbel Boukhmis Formation are diversified, they show depositional carbonates environments of a shallow carbonate ramp. The analysis of microfacies carbonates indicates internal, middle and external environments ramp. The qualitative and semi-quantitative analysis of different diffractograms reveals that the clay minerals are composed essentially of simple minerals such as kaolinite (0-44 %), illite (41-100 %), chlorite (0-31 %), vermiculite (0-28 %) and mixed layer clay minerals such as illite-chlorite and illite-vermiculite type (<21 %). The aim of this paper is to determinate the contribution of these clay minerals to the paleoenvironmental reconstructions.

The kaolinite, illite and chlorite are present along of the Jbel Boukhmis Formation, they show dependence with sedimentary facies which is on relation with accommodation changes. They have an authigenic origin. The percentages of kaolinite increase towards coastal facies and decrease towards shelf marine deposits. The percentages of illite increase towards the shelf marine deposits and decrease towards coastal deposits. The ratio of I/K shows a dependence with lithology. It increases towards offshore deposits, which indicates an open environment more far than shore. The chlorite shows a low and badly formed peak at 14 Å°, this chlorite disappears towards sea environment. The vermiculite appears only towards the sea and missing along the other environments deposits. This can be explained by an instable authigenic chlorite, which can transform into vermiculite towards sea by degradation process, by washing of Mg²⁺ cations that exists between the interlayer spaces of the chlorite. The appearance of some mixed layer clay minerals such as illite-chlorite or illite-vermiculite is explained by the increasing of degradation process. The predominance of kaolinite along of Jbel Boukhmis Formation shows a shallow burial depth and testifies a warm and humid climate that prevailed in Morocco during the Brigantian. The appearance or the disappearance of the transformed clay minerals towards shelf marine environments where occur the exchanges of the ions between the clay minerals and their deposits environments. The ratio I₀₀₂/I₀₀₁ of the illite is superior to 0.3, which testifies an aluminous character of the illites. The representation of the illite crystallinity (Kübler's index) as a function of the I₀₀₂/I₀₀₁ ratio of the illites on the Esquevin diagram shows diagenetic to anchizonal domains.

These data show the major effect of the detrital contribution and the intense effect of weathering in the studied area. The distribution of clay minerals proves that the carbonate platform of Jbel Boukhmis evolved under the influence of a tropical climate during the Brigantian. The origin of these alumina silicates is mainly the alteration, in a hot and humid climate, of the silicate minerals of a hinterland that feeds this carbonate platform. The covering of the sedimentary series does not exceed 4 km.

REE and Fe crystalchemistry in topsoils of Fogo Island (Cape Verde)

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Abstract

Fogo is the fourth biggest island of the Cape Verde archipelago, with an area of approximately 476 km², corresponding essentially to a volcanic cone with a maximum altitude of 2829 m. The slopes of the volcano are mainly covered by layers of basic lava flows and pyroclasts. The volcanic rocks of Fogo include intrusive carbonatites, nephelinites and associated lavas (pre-caldera formation), as well as lavas of different historical eruptions (post-caldera formation).

In this work, the surficial layer (0-20 cm) of soils (topsoils) developed on diverse geological/geographical contexts of this island were studied: five soils developed in the pre-caldera formation - one carbonatite, three nephelinites and one limburgite; 13 soils developed in post-caldera formation - nine lavas and pyroclasts from historical eruptions, two pre-historic pyroclasts (prior to 1721) and two deposits (lahar or slope). The analytical methods used were: instrumental neutron activation analysis, using the Portuguese Reactor (CTN, Bobadela) as neutrons source, to obtain the concentration of Fe and rare earth elements (REE), and ⁵⁷Fe Mössbauer spectroscopy for identifying the Fe-containing phases in the soils, as well as the Fe²⁺/Fe³⁺ ratio in these phases.

The specific objectives of this work are: (a) the distribution of REE in the whole sample ($\varphi < 2$ mm) of topsoils; and (b) the iron speciation and its correlation with the REE behavior. This study is also a contribution to the characterization of georeferenced topsoils of Fogo Island.

The REE concentrations of topsoils are generally higher in the pre-caldera formation than in the post-caldera formation, particularly the light REE. Positive Eu anomalies are observed in some of the most recent topsoils, mainly in those developed on lavas and pyroclasts of 1951 and 1995 eruptions, suggesting the existence of hydrothermal processes involving hot fluids where the concentration of Eu²⁺ is high. In fact, Eu³⁺ can be reduced and Eu²⁺, which is more mobile than Eu³⁺. On the other hand, the older soils (of the pre-caldera) present a higher degree of Fe oxidation, which can be explained by a higher degree of weathering, as expected. It should be noted that in the post-caldera formation, the most recent soils show a high degree of oxidation which can be explained by a faster oxidation/weathering of the outer layers of the lavas, due to a higher glass proportion in these materials. The existence of high-temperature hydrothermal fluids, which gave rise to the Eu positive anomaly, may also explain the presence of jarosite, identified by Mössbauer spectroscopy in topsoils of recent volcanic conduits (Marques et al., 2014).

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Trace and major elements distribution in topsoils from Fogo and Brava islands (Cape Verde)

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Abstract

Fogo and Brava islands (Cape Verde archipelago) are located in the Atlantic ocean and are characterized by a rugged topography due to the recent volcanic activity. The archipelago litology is mainly composed of basic and ultrabasic volcanic rocks (basalts, nephelinites, tephrites) and phonolites. Carbonatites and sedimentary formations also occur. In this work, georeferenced samples of topsoils (0-20 cm) of Fogo (135) and Brava (43) islands were studied, aiming the geochemical patterns and the identification of similarities/dissimilarities between the two islands, and/or within the same island. The concentration major, minor and trace elements were obtained by instrumental neutron activation analysis (INAA).

Multivariate statistical analysis methods were applied to 178 topsoils samples and 30 chemical elements concentration as variables. Cluster analysis (hierarchical method and non-hierarchical) showed the existence of two outliers from Brava Island (one extrusive carbonatite and one phonolitic pyroclasts). The application of the principal components analysis (PCA) showed that most of the topsoils developed in the Brava Island are distinguished from those of Fogo essentially due to higher levels of rare earth elements (REE), Th, Zr, Mn, Cs, Hf, Rb, K, and lower concentrations of Sc, Cr and Co. Also a set of soils from both islands with high levels of REE could be distinguished.

The results obtained for the topsoils developed on the so-called pre-caldera formation of Fogo Island showed that there are significant differences in the chemical composition of the samples collected even in the same geological formation (geological map by Machado and Assunção, 1965). These results can not be explained by factors like the degree of weathering, since incipient modifications occurred in the parent rocks since their atmospheric exposure in this semi-arid climate. Instead they may reveal a diversity in the nature of the parent rocks/geological formations not yet published.

In Brava Island, topsoils develop on phonolitic volcanism (Upper Unit, Madeira et al., 2010) present significant chemical contents variations. This is the case of topsoils located in the eastern part of the island with higher concentrations of K and Rb and lower Sc, Fe, Cr and Co. Topsoils developed on the Middle Unit - pyroxenites/ijolites, carbonatites - and on sediments with contribution of these materials could be differentiated by PCA mainly due to high REE, Mn and Zn concentrations. The REE patterns show significant variations in the Eu and Ce anomalies in topsoils of both islands, certainly related to the nature of the parent rock in the semi-arid climate of Cape Verde.

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Mineralogical and geochemical characterization of the weathering mantle developed on the mineralized schists of the Lom series in the Bétaré-Oya section of the Cameroon shear zone (East Cameroon)

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Abstract

This study aims at documenting and explaining mobilization and redistribution of chemical elements in relation with minerals during lateritic weathering of mineralized schist belonging to the Lom series, a section of the Cameroon Shear zone (CSZ) located at the East region. This is in order to address issues on: (i) processes involved in lateritic weathering of schists in humid tropical conditions; and (ii) chemical elements mobility during weathering, so as to trace the occurrence of minerals and chemical elements in weathering products. For this purpose, two representative weathering profiles were selected in two slope units (upper slope and downslope). The upper slope weathering profile differentiates from bottom to top: a whitish red saprolite, a thick (>5 m thick) graveled mineral horizon, a clayey-sandy mineral horizon overlapped by a loose clayey mineral horizon at topsoil. In downslope, the weathering profile exhibits from bottom to top: a gleyic saprolite; a pseudo-gleyic mineral horizon, a thin (<1m thick) graveled mineral horizon and a loose clayey mineral horizon. The Al_2O_3 -CaO+Na₂O-K₂O diagram associated with the chemical index of alteration (CIA) show complete weathering of plagioclase prior to K-feldspars with moderate weathering intensity not exceeding 90%. The SiO_2 - Al_2O_3 - Fe_2O_3 diagram indicates relatively low kaolinization process affecting the weathering profiles with the index of laterization (IOL) not exceeding 50%. Minerals association in these weathering profiles are in decreasing content: quartz (40 % - 69 %); kaolinite (12 % - 21 %); feldspars (1 % - 9 %); hematite (0 % - 11 %); goethite (4 % - 10 %); chlorite (0 % - 10 %); muscovite (1 % - 11.9 %); halloysite (2 % - 8 %); corundum (2 % - 5 %); graphite (1 % - 3 %) and diaspore (0 % - 3 %). Accumulation-exportation rates allow grouping chemical elements into three categories: enriched, depleted and elements with complex behavior. In both weathering profiles, Pb, U, Sb, Mo and Sn are enriched. But, in the upper slope, elements depleted are: Ca, Mg, K, Na, Mn, P, Ni, Co, Zn, Cu, Ba, Li, Rb and Cs; while Al, Fe, Ti, Si, Cr, Sc, Y, Th, Zr, V, As, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu portray complex behaviors. Contrarily, the downslope depleted elements are: Ca, Mg, K, Na, Mn and P; while Si, Al, Fe, Ti, Cr, Ni, Co, Zn, Sc, Cu, Ba, Y, As, Th, Zr, Li, Rb, Cs, V, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu evidenced complex behaviors. The REEs normalization using Chondrite and Schist respectively allows differentiating in these weathering profiles positive Eu, Ce and Tm anomalies. The REEs fractionation is also noticeable in both weathering profiles with the light REEs (LREEs) enrichment in the upper slope and the heavy REEs (HREEs) in downslope. Al_2O_3 , Fe_2O_3 , CaO, MgO, K₂O, Na₂O, MnO and P₂O₅ oxides are positively correlated with most of the traces and REEs (Tm, Yb, Cu, Pb, Mo, U, Eu, Gd, Dy, Ho, Er, Lu, Zn, La, Pr, Nd, Sm, As), pointing to the fact that they may be incorporated into newly formed clay minerals and oxides.

The Holocene paleoclimate reconstruction in the Adamawa plateau (Central Cameroon) inferred from the geochemistry and mineralogy of the Lake Fonjak sediments

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Abstract

In the aim of improving the understanding of paleoclimate variations in the transitional zone between the sahelian and sub-equatorial rainforest belts, paleoclimate conditions of the Adamawa plateau (Central Cameroon) were reconstructed from geochemical and mineralogical records coupled with radiocarbon dating of lacustrine sediments since 11500 cal yr BP. The Lake Fonjak depositional sequence consists, from the bottom to the top, of a greenish grey mud overlapped with a volcanic ash layer which is covered by alternating dark and light grey mud layers; this sequence is capped by peat. A correlation between the age-depth model and lithofacies of this depositional sequence suggests Late Pleistocene to Early Holocene sediments at the base, and Late Holocene sediments at the top. These Holocene sediments exhibit in XRD data various minerals assemblages with relative content varying from 15 % to 44% for quartz; 22 % to 37 % for kaolinite; 12 % to 37 % for micas; 6 % to 18 % for serpentine; 1 % to 11 % for feldspars and 5 % to 7 % for gibbsite. As far as detrital minerals are concerned, they are: quartz, orthoclase, siderite, vivianite, hornblende, plagioclase and opaque minerals. Major elements in these sediments can be grouped into two categories: elements with complex behavior (SiO_2 , Al_2O_3 , Fe_2O_3 , TiO_2 , MnO, MgO, Na_2O , K_2O and CaO) and elements with increasing contents upward (P_2O_5). Three categories among trace elements were differentiated: elements with increasing contents (Ni, Zn, Sr, Cu and Rb), element with decreasing content (Co) and elements with complex behavior, alternatively increasing and decreasing content (V, Sc, U, Th and Zr). REE can also be divided into two categories: REE with stable contents (La and Ce) and REE with complex behavior (Nd, Pr, Sm, Gd, Dy, Eu, Er, Yb, Tb, Ho, Tm and Lu). The geochemical classification of these sediments shows that they are Fe-shales deposited under anoxic conditions and deriving from highly weathered igneous mafic rocks probably andesite as suggested by some characteristic indexes and diagrams. This sedimentation happened within three distinguished paleoclimatic phases: 11500 – 4000 cal yr BP, 4000 – 2400 cal yr BP, and 2400 cal yr BP to present, predominantly humid and marked either by the slowdown of rainfall or by the reinforcement of precipitation.

Soil chemical and physical properties contributions in the dynamics of soil quality in the southern Cameroon plateau in a shifting agricultural landscape

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Abstract

A study was conducted on soils identified under 8 land cover types in the southern Cameroon: bare soil with burned vegetation (FR₁), bare soil with unburned vegetation (FR), *Chromolaena odorata* fallow (JC), bush ligneous fallow (JR), secondary forest (FS), primary forest (FC), *Gilbertiodendron dewevei* forest (FG), and raffia forest (RA). The aim of this work was to assess the contributions of soil chemical and physical indicators into global soil quality index (IQSg). Topsoil samples (0 – 20 cm) were analysed for chemical and physical parameters and based on these data IQSg was computed for each class of soil. Statistical analyses, particularly analyses of variance and principal component analysis were used to compare the contributions of soil quality indicators and to select those that contributed most in IQSg, respectively. It appears that under FR₁, FC, FG and RA, where IQSg is relatively high, main contributors are the chemical parameters, estimated at 75 %, 63 %, 72 % and 78 %, respectively. Under FR, where IQSg remains high, chemical contributions are predominant (65 %) over physical (35 %) ones. On the contrary, under fallows, where IQSg is relatively low, these two types of contributions are nearly equivalent (52 % and 48 %, respectively). Thus, the main indicators which help to assess IQSg at low cost, contributing significantly to global soil quality and representative in this landscape are: OM (organic matter), pH_w, and C/N ratio. These differences in contributions are mainly due to the type of agricultural practices, quality and quantity of OM brought by different land cover types and the topographical position of some soils.

Preferential precipitation of magnesite over calcite during mineral carbonation of platinum tailings: a possible consequence of the inhibition effect induced by the Mg cation activity in solution.

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Abstract

Carbon sequestration experiments on platinum tailings were conducted under a supercritical (100 °C and 100 bars) CO₂ conditions on concentrated orthopyroxene and plagioclase extracts concentrated from the ore-bearing orthopyroxenite found in the Rustenburg Layered Suite within the Bushveld Igneous Complex. Analyses were done using an inductively coupled plasma optical emission spectrometry on both the fluid resultant samples that were reacted for 13 days and control. When these samples were compared to the control samples, an increase in Mg and Ca cations liberated from the dissolved crystal surfaces of the pyroxene and feldspar was observed. The extraction of Mg and Ca from the mineral structure resulted in a saturation of the cations in experiments where the solution was not seeded with sodium bicarbonate.

Notably, the saturation limit of Mg in NaHCO₃-absent experiments was the same for a plagioclase dominant sample, while the saturation of Ca was comparatively 4 times higher in the plagioclase dominant sample. However, the cations were depleted in experiments that were seeded with the NaHCO₃, resulting in the fluid sample extract having a concentration lower than those observed in the control experiment. Magnesite was the only secondary carbonate mineral that was produced, specifically in samples seeded with the salt. While calcium carbonate was anticipated in plagioclase dominant samples, the system appeared not to have kinetically favoured calcite precipitation despite the relatively high amounts of Ca cations being liberated from the dissolving mineral. Some workers attribute the deficiency in calcite precipitation to be an effect of the (rate limiting) phase transformation from an amorphous phase to calcite, which in turn is possibly affected by the activity of Mg in the solution. That is, the higher the Mg/Ca ratio, the greater the precipitation inhibition effect.

This is consistent with the observations made during experiments seeded with sodium bicarbonate, where the system was expected to precipitate calcite since Ca cations were depleted from the solution, thus precipitation of the cation should have occurred. In addition, the precipitation of magnesite points toward a system that was favourable to the precipitation of carbonate minerals. Despite these conditions, the calcite phase was not precipitated above detectable analytical limits for techniques such as X-ray diffraction, scanning electron microscope and Raman spectroscopy. Moreover, there was no other detectable secondary mineral (notwithstanding the secondary vermiculite) that significantly sequestered the calcium cation, further suggesting that the calcium was not liberated from the amorphous phase in order to precipitate calcite. The implications of this phenomenon are important to consider in future mineral carbonation capture process design.

The geochemistry of sediments from the Moatize - Minjova Basin, Mozambique: implication to source area weathering and provenance

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Abstract

The stratigraphic record of the Karoo basins of South-Central Africa, represents a fundamental part for the understanding of the geological evolution of the South edge of the supercontinent Pangaea during the Late Palaeozoic-Early Mesozoic times. In Mozambique, the Moatize - Minjova Basin (Tete Province) consists entirely of rocks of the Karoo age. The stratigraphic succession of the Moatize - Minjova Basin is represented, from base to the top, by: the Vúzi Formation (Late Carboniferous), the Moatize Formation (Cisularian) and the Matinde Formation (Cisuralian-Guadalupian). These formations have been correlated with the glaciogenic deposits of the Dwyka Group (Vúzi Formation) and Ecca Group (Moatize and Matinde formations) of the Main Karoo basin in South Africa. However, recent palynostratigraphic data does not support this interpretation. In order to better understand the geological evolution of the Moatize - Minjova Basin, a geochemical provenance study was carried out in siliclastic sediments of the Vúzi and Moatize formations.

Geochemistry of major elements in the mudrocks from the Vúzi and Moatize formations is characterized by large variations of the $\text{SiO}_2/\text{Al}_2\text{O}_3$, $\text{K}_2\text{O}/\text{Na}_2\text{O}$ and $\text{K}_2\text{O}/\text{Al}_2\text{O}_3$ ratios, similar values of Ti/Al , and low contents of MnO_2 (< 0.1 %). In both formations, most of the mudrocks exhibit enrichment in LILE and variable $(\text{Cr}+\text{V}+\text{Ni})/\text{Al}_2\text{O}_3$ ratio. In addition, their content in trace elements does not correlate with TOC. The chondrite-normalized REE patterns of the mudrocks of both formations are characterized by an enrichment in LREE and a flattened HREE pattern. The Eu/Eu^* ratio ranges between 0.56 to 0.90. The critical geochemical ratios of provenance (e.g. La/Sc , Th/Sc , La/Co , Cr/Th , Eu/Eu^*) suggest that source area(s) are dominated by rocks with felsic composition with minor mafic contribution. Moreover, compositional variations (felsic vs. mafic) observed on the source area are not linked with variations observed in the stratigraphy of the studied succession. Significantly, the mudrocks of the Vúzi formation exhibit a high Chemical Alteration Index ($\text{CIA} > 85$) and Plagioclase Index Alteration ($\text{PIA} > 85$) values, and low values of the Index of Compositional Variability (ICV). The mudrocks of the Moatize Formation exhibit identical values of CIA, PIA and CIW. Collectively, these data point to conditions of intense chemical weathering associated with the source area(s) of the sediments of the Vúzi and Moatize formations, which is not compatible with the glaciogenic sedimentation described for Dwyka Group. The pattern of distribution of major and traces elements, critical ratios of provenance, CIA, PIA and ICV, suggest a striking geochemical similarity between Vúzi and Moatize Formations, which is consistent with recent palynostratigraphic data indicating that both rock units have the same age (Cisuralian to Lopingian).

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Impacts of climate change on livelihood activities of coastal farming communities: a case study from SW-Nigeria

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Abstract

Coastal areas have been centres of human activity as a result of the rich variety of ecosystems and habitats which provides a range of goods and services critical to human sustenance and well-being, particularly food production, raw materials, and transportation options. However, the coastal areas are also at the receiving end of impacts coming both from the sea and from the land (climate change), which has been found to threaten livelihoods along coastal regions. In coastal areas, varied socio-economic impacts are experienced at levels of individual, household and whole community. Hence, this study aims to investigate the effect/impact of climate change on livelihood activities of farmers in coastal area of Igbokoda in Ekiti state, SW-Nigeria.

Purposive and random sampling methods were used to select 240 respondents while data were collected through interview schedule and analysed using both descriptive and inferential statistics. In this study, 45.8 % of the respondents fall within the age bracket of less than 50 years; 56.3 % were male, and the majority (81.3 %) were married; 19.5 % had higher education while 35.0 % had no formal education. Fishing, fish processing, farming, water transportation service and trading were the most predominant occupations in the study area. However, 2/3 of the respondents combined different occupations to enhance living standards.

From the data evaluation, decline in soil fertility (91.3 %) was observed, while flooding (57.9 %), erosion (53.8 %) and rainfall (52.9 %) were pointed out as increasing over time. Reduction in soil quality, loss of farmland and reduced soil water quality were perceived as the top three worsened environmental problems over the past 30 years. In addition, most of the respondents reported decline in food crop productivity (91.7 %), cash crop production (89.2 %), access to snail (87.9 %) and access to bush meat (85.8 %), while decline in quality of fish (85.8 %), income generation (79.6 %) and fish species (75.8 %) were also observed. These are clear indications that the livelihood, local economy and well-being of the coastal communities are under the threat of climate changes.

By and large, in terms of coping mechanism, the respondents usually employed a combination of strategies, as no single strategy is enough to effectively adjust to climate change impacts. However, on the scale of 3 adjusting feeding pattern (1.18) and alternating livelihood activities (1.17) were mostly employed by the respondents as coping strategies. The overall study revealed negative impacts of the climate changes on livelihood activities of coastal dweller in the study area. Therefore, there is the need to promote adaptive capacity to combat such negative impacts.

Physico-chemical characterization of some soils of the region of Meknes (Morocco)

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Abstract

In northern central Morocco, the region of Meknes is a very large area of plains and plateaus. It is an agricultural region par excellence where most of the land is cultivated. The majority of the soils of the Saïs derive from lake limestones and tawny sands which rest on tortonian marl interbedded with sandstones and conglomerates. The physicochemical analysis of the three soil types in the Meknes region (on two depths: 0-30 cm and 30-60 cm) made it possible to highlight the domination of the sandy fraction in the soil of Boufekrane. Bouassal is sandy-clay, whereas the soil of Oualili has a silty-clayey texture. Of the three types mentioned above, Boufekrane soil is very poor in organic matter, while Bouassal and Oualili soils are rich in organic matter. The soil of Oualili is basic and Bouassal is neutral show contents of total limestone raised in depth against that of Boufekrane is slightly acidic and poor in total limestone. The Bouassal and Oualili soils are characterized by significant assimilable potassium levels in the two studied depths, whereas the Boufekrane soil is poor in K_2O at the level of the superficial part and having an average depth content. However, the soil of Bouassal has a very high phosphorus content, whereas the soils of Boufekrane and Oualili are very poor in P_2O_5 .

Suitability of ASTER and SRTM DEMS, and satellite imagery in detailed geomorphological mapping in Dzanani area of Makhado Municipality, Limpopo Province, South Africa

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Abstract

Detailed geomorphological mapping is important for monitoring environmental phenomena, it is therefore crucial that the methods employed for mapping are accurate. Earlier approaches of geomorphological mapping relied on field surveys and delineating boundaries on aerial photographs. These methods are deemed costly and tedious, and research on applications of landform classification are usually focused on solving a specific problem and are not focused on detailed geomorphological mapping. This study sought to assess the suitability of SRTM and ASTER DEMs in combination with satellite imagery for detailed geomorphological mapping. The main objective of this study was to prepare a detailed geomorphological map using the traditional technique of field survey and aerial photo interpretation, which served as a standard map for the comparisons. The similar approach of demarcating landform boundaries was implemented to segment the DEMs into landforms classes. The `r.slope.aspect` command in GRASS GIS was used to compute morphometry in a single step. The D8 flow accumulation algorithm was used to delineate drainage channels from the DEMs, while the topographic position index (TPI) demarcated the slope positions into valleys, ridges and flat areas. The 30m ASTER and SRTM DEMs are the high resolution available DEMs and were used in this study. 90m resolution SRTM DEM was used to assess whether the different results obtained would be attributed to DEM resolution. QGIS 2.14.22 Essen was used to generate the landform maps from the DEMs. ENVI 4.4 was used for the processing of the satellite imagery to extract terrain characteristics of surface materials and land cover and land use (LCLU). Linear spectral unmixing in ENVI was used to extract soil spectra from the generated regions of interest. Supervised classification was used to segment the Landsat 8 image into LCLU. Soil spectra were extracted from surfaces with an NDVI value of less than 0.2. Resultant geomorphological units' maps from the DEMs when compared with those produced from field survey and aerial photo interpretation show that the automated classification technique has advantages in terms of its efficiency and reproducibility, but distinct limitations are apparent. Vertical accuracy of the DEMs were positively correlated with field data. Elevation error was minimal for each DEM and the DEMs could be easily used for landform classification. The slope angles measured in the field differed greatly with the slope angles estimated from DEMs. The kappa coefficient for 30m SRTM was 0.23, 30 m ASTER 0.14, and 90m SRTM 0.5. The DEMs generally have similar landform patterns compared to the photo interpretation from a visual perspective. DEMs, with an exception for the 90m SRTM DEM, perform poorly in the low lying areas, while greater similarities are apparent in the high areas.

poster

07

**Weathering,
Climate
and Surface
Processes**

Importance of rocks and their weathering products on groundwater quality in Central-East Cameroon

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Abstract

The present work highlights the influence of lithology on water quality in Méiganga and its surroundings. The main geological formations in this region include gneiss, granite and amphibolite. The soils developed on these rocks are of ABC type, which are acidic to slightly acidic. Electrical conductivity (EC), organic matter, total nitrogen, nitrate-nitrogen, sulfate, chloride, phosphorus and exchangeable base values were low to very low in the soil samples. Groundwater samples were investigated for their physicochemical characteristics. The wide ranges of EC values (15.1–436 $\mu\text{S}/\text{cm}$) and total dissolved solids (9–249 mg/L) revealed the heterogeneous distribution of hydrochemical processes within the groundwater of the area. The relative abundance of major dissolved species (mg/L) was $\text{Ca}^{2+} > \text{Na}^+ > \text{Mg}^{2+} > \text{K}^+$ for cations and $\text{HCO}_3^- \gg \text{NO}_3^- > \text{Cl}^- > \text{SO}_4^{2-}$ for anions. All the groundwater samples were soft, with total hardness values (2.54–136.65 mg/L) below the maximum permissible limits of the World Health Organization (WHO) guideline. The majority of water samples (67%) were classified as mixed CaMg- HCO_3 type. Alkaline earth metal contents dominated those of alkali metals in 66.66 % of samples. Thus, for the studied groundwater, Mg^{2+} and Ca^{2+} ion adsorption by clay minerals was almost nonexistent; this implies their release into the solution, which accounts for their high concentrations compared to alkali metals. Ion geochemistry revealed that water-rock interactions (silicate weathering) and ion exchange processes regulated the groundwater chemistry. One water sample points towards the evaporation domain of this diagram, indicating that groundwater probably does not originate from a deeper system. Kaolinite is the most stable secondary phase in the waters in the study area, in accordance with the geochemical process of monosiallization, which predominated in the humid tropical zone.

Vendus. A landform of Guinea-Bissau

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Abstract

The Republic of Guinea-Bissau (GB) presents some remarkable geomorphological features such as temporary lakes locally called vendus, meandering rivers, boual / bowal plateaus (hard and dry laterite and bauxite flat surfaces), laterite on successive planation surfaces, collapsed Fe-duricrusts, slope deposits, and finally the Bijagos delta.

Vendus are well represented in the 1953 to 1966 old colonial topographic maps scale 1:50,000 and others were identified during fieldwork conducted as part of the edition of the Geological Map of Guinea-Bissau scale 1:400,000 (LNEG and DGGM, as geological surveys of Portugal and GB). These seasonal lakes only occur in the eastern part of the country and the name vendu, a word from the fulbe (fula) dialect, was adopted as this is the main ethnic group on that area.

Temporary pools where cattle and other animals drink and people go fishing are reported in many countries of Africa and they present some resemblance to vendus but only apparently. The vendus are peculiar landforms and do not present all the characteristics that pertain to most depressions or pans described by other authors, like dambos, claypans, saltpans, cuvettes, mares, and so on. The vendus in GB were briefly referred to by portuguese authors in the middle of the twentieth century as temporary lakes occurring on depressions formed on iron duricrusts, with a muddy bottom impermeabilizing it. The terms “wendous” or “vendous” have been used by Y.Boulvert for the Bové country and the Fouta Djalon and by P.Michel for Senegal, present some similarities to these vendus.

Field work was conducted on 33 of the 71 vendus known in GB. They only occur in eastern GB, on thin Cenozoic formations over a Paleozoic or Neoproterozoic basement and their distribution follows a pattern, evidencing the tendency for positioning on N30°-40°E lineaments. Only 20 % of the vendus include outcrops. Vendus form essentially in areas of low relief or no relief at all, generally planations, with evidence of widespread laterites in the vicinity, although frequently only lateritic gravel is observed on excavation and sampling. They occur as flat concavities on the landscape with nearly no vegetation, as generally only high grass grows up, contrasting strongly with the surrounding savana forest. Vendus present no termite mounds probably due to the 3 to 4 months long water that fills them during the rainy season. The border of the vendus is well marked by a small step less than 1 m high and the interior is flat, exception made to a very small area up to 1 m deeper that keeps water longer into the dry season. The vendu density, although irregular, goes from about 7.2 to 15 per 1000 km² and their size is bracketed from 0.1 to 188 ha; for the 45 vendus larger than 6 ha the average area is 31 ha.

The main genetic processes probably involved in vendu formation include cracking and weathering along discontinuities and iron dissolution, suggesting a pseudo-karstic process. Another condition is the prevalence of a tropical or sub-tropical monsoon type climate. The current reduction of precipitation in the region may already be leading to the reduction of the area of some vendus.

Hydrogeochemical evolution and stable isotope characteristics of groundwater and surface water in Lake Bosumtwi, Ghana

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Abstract

The Lake Bosumtwi area, Ghana, is an important geological site with the largest, young and well-preserved complex meteorite impact crater. This crater is one of 170 meteorite impact craters currently known on earth and also one of only four known impact craters associated with a tektite strewn field. It displays a pronounced rim and is almost completely filled by an 8 km wide and a 78 m deep lake, Bosumtwi, and represents the only significant natural lake in Ghana and the West African sub region.

Hydrochemical data and stable isotopes of $\delta^{18}\text{O}$ and δD were used to relate groundwater to surface water in the lake and to identify probable recharge areas and the mechanisms of groundwater flow in aquifers around the lake.

Q-mode hierarchical cluster analyses (HCA) of the data uniquely classifies the lake water chemically and isotopically from the groundwater of the area, suggesting either the nonexistence of hydraulic connection between these system, or where it exists, it favours the lake to a limited extent. This baseline study also revealed that recharge to the aquifers occurs on hill tops where the water is characteristically acidic with low level of mineralization, suggesting short residence time and rapid recharge. Ionic concentration increased with deeper circulation and longer contact with host rock minerals and the groundwater evolved to more mineralized water.

There are not much plausible isotopic variations in the groundwater of the study area. This indicate that the aquifers are recharged by recent meteoric water that has undergone evaporative enrichment as the study revealed that the rate of evaporative loss of water that infiltrates the unsaturated zone is in the range of 45-51 %. The lake water is significantly enriched, indicative of severe evaporation over the open lake surface that resulted in an evaporative loss of ~82 %. Estimated likely source rainwater suggests that the lake water is dominated by heavy rainfall events.

Tracing the metal dynamics in semi-arid soils near mine tailings using stable Cu and Pb isotopes

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Abstract

Wind-blown dust from mine tailings enriched in metals constitutes an important source of pollution for soils, especially in dry environments. Here, we studied the dynamics of Cu and Pb in eight soil profiles (Luvisols, Chernozems), located at various distances from the tailings dams near a closed Cu-Pb-(Zn)-Ag mine at Kombat (Namibia). Tailings, soils, and bedrocks were analysed for bulk Cu and Pb concentrations, for their chemical fractionation using the sequential extraction procedure, and the isotopic compositions of Cu ($\delta^{65}\text{Cu}$) and Pb ($^{206}\text{Pb}/^{207}\text{Pb}$, $^{208}\text{Pb}/^{206}\text{Pb}$). The tailings were mainly composed of carbonates, and contained up to 4790 mg Cu/kg and 1900 mg Pb/kg. Copper concentrations in uncontaminated soils were relatively low (21.9-54.1 mg/kg), whereas soils near the tailings exhibited significantly higher Cu levels (44.5757 mg/kg). Similarly, Pb concentrations in uncontaminated and contaminated soils were in the range 18.6-34.6 and 38.5-815 mg/kg, respectively. In both soil types, the Cu and Pb concentrations were significantly correlated with the total Mn ($R^2 = 0.84$ and 0.85 , respectively). Manganese oxides (occurring also as pedogenic nodules) were assumed to affect the metal distribution in soils to a higher degree than the Fe oxides. The sequential extraction indicated that Cu occurs in soils in more “labile” forms (exchangeable fraction); whereas, Pb is more tightly retained in the soils (reducible fraction). The PHREEQC-2 speciation calculations, performed with leachates from the tailings materials, also confirmed that Pb, to a greater extent, formed positively charged complexes that can be more efficiently immobilized by soil constituents than are Cu species (mainly neutral carbonate complexes). The Cu and Pb distributions in the soils indicated their vertical migration in the soil profiles in both irrigated and non-irrigated areas. The basement rocks yielded negative $\delta^{65}\text{Cu}$ values (-0.368 to -1.062‰) and highly variable $^{206}\text{Pb}/^{207}\text{Pb}$ values (1.158-1.124). The tailings materials, which are the major source of contamination in the area, had positive $\delta^{65}\text{Cu}$ values (+0.144 to +0.820‰), and $^{206}\text{Pb}/^{207}\text{Pb}$ clustered around the value of 1.150. Whereas Luvisols were mostly characterized by an increase in Cu concentration, and changing $\delta^{65}\text{Cu}$ values as a function of depth; Chernozems mostly yielded uniform Cu concentrations and isotope compositions in all soil horizons, clearly contrasting with the isotopically lighter composition of the carbonate bedrocks. The isotope multitracing, using a combination of Cu and Pb isotope systems, revealed that the Pb composition of the soils is a result of a simple mixing between end-members; whereas the Cu isotopic composition of the soils resulted not only from a combination of the two contrasting signatures (tailings vs. bedrock), but was also highly affected by other biogeochemical processes (e.g., sorption). The role of these biogeochemical processes was even more pronounced in uncontaminated soils, where the influence of the Cu isotope signature of the tailings materials was suppressed. This study was supported by the Czech Science Foundation project (GAČR 16-13142S).

Morphologic characterization and coastal management in Mozambique

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Abstract

The present communion intends to understand the morphodynamic processes to improve the use and utilization of the coastal territory. In order to achieve this general objective, the following specific objectives were outlined: characterization of the physical and socioeconomic characteristics of the study area to relate morphodynamic and land use and the contribution to coastal management in Mozambique. The study was carried out over a 7 km stretch, 3 km on Vilanculos beach divided into two tourist and recreational areas, 2km in Tofo and 2 km in Závora. In order to reach the objectives, the following methods and techniques were used: bibliographical and documentary review, indirect observation, statistical, field work that included direct observation and sampling of sediments for granulometric analysis on the beach face, semi-structured interview with local goers for over then ten years, field work and cartography that allowed the georeferencing of Google Earth satellite images of coastline in the years 2005, 2011 and 2016 using ArcGIS software. The results of the laboratory reveal that the beaches are composed mainly by sediments of average granulometry and vary in relation to other granulometric categories. The statistical analysis revealed that the sediments of Tofo beach are more calibrated, confirming the soft floor and the walking pleasant sensation, and poorly calibrated the ones of Vilanculos in the recreational part. Regarding morphodynamic, the results reveal that, in general, the coast is retreating due to the reduction of continental sediments brought to the coast by the rivers and by the intensity of the waves. However, the intensity of the wave differs in the three beaches. It is intense in the exposed beaches or near the promontories, in the case of Tofo beach, and less intense in the beaches sheltered by islands (Bazaruto archipelago) in the Vilanculos tourist area. Regarding the management of the territory, it was observed that the tourist building structures are concentrated in the tourist area of Vilanculos beach, the most stable, followed by Tofo which, although exposed, has an extensive berth that protects it from the erosive action of the waves, the beach of Závora also exposed but without shoulders to face erosion problem. However, in the three beaches, there were cases of touristic projects that threaten the sustainability of the coastal environment, such as the buildings within the partial protection area (Vilanculos tourist area), the area of the riparian area (Vilanculos recreation area) and buildings constructed on frontal dunes system (Závora). This study is expected to contribute to the understanding of morphodynamic and improve management in the coastal domain in Mozambique.

oral

08

Geophysics

Electromagnetic gravimetric and electrical prospecting of the discontinuous and karstic reservoir of the Middle Atlas Causes and Saïs basin junction

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Abstract

Fractured and karstic aquifers represent an important groundwater stock in Morocco. However, they remain poorly exploited. Those of the Middle Atlas Causes and their junction with the Saïs basin present the most important example in the northern Morocco. In these complex areas, fracturing plays a very important role in the structuring of reservoirs, in water supply and in groundwater circulation. The study of fracture networks is therefore essential for the best exploitation of water resources.

In order to define the geometry of the reservoir, we carried out in the "Bittit" spring area on the junction zone, three geophysical surveys: an electrical survey by Electrical Resistivity Tomography, a potential field prospecting by microgravimetry and an electromagnetic survey by VLF (Very Low Frequency).

Several processing, corrections and inversions were carried out on the collected data; the analysis of the geophysical results showed their convergence. Finally, a drilling was carried out to identify the lithologies in order to interpret the geophysical results. Two families of sub-vertical faults oriented NE-SW and NW-SE have been identified and mapped. The 2D and 3D modeling of the results showed the dislocation of the liasic blocks by the detected faults thus forming a mini-Graben structure. These results correlate well with the fracturing analysis carried out in the field, on cartographic inventories and SPOT satellite images.

Finally, we have identified the fractured areas and establish a 3D representation of the spatial distribution of these structures, showing preferential flow zones. This study allowed us to propose a local hydrogeological model, and to show the usefulness of the coupling of electrical tomography, microgravimetry and VLF in the imaging of complex and fractured zones.

Acknowledgments

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Basement configuration and lineaments mapping from aeromagnetic data of Gongola arm of Upper Benue trough, Northeastern Nigeria and its implication on petroleum potential

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Abstract

High Resolution Aeromagnetic Data (HRAM) acquired over the Gongola arm of the Upper Benue Trough, northeastern Nigeria were filtered, enhanced, transformed and analyzed in terms of rock distribution, basement structures, basement topography and sedimentary thickness for the purpose of evaluating the petroleum potential of the Gongola Basin. Cultural noise were filtered out using Butterworth low and high pass filters. Upward continuation technique was employed to enhance deeper magnetic signatures by eliminating short wavelength signals which often correspond to shallow and noisy magnetic effects. The data were further reduced to pole at low latitude to simplify magnetic anomalies and focus anomaly peaks over corresponding sources. Analytic signal and vertical / horizontal derivative filters were applied to enhance rock boundaries and linear structures respectively. Euler deconvolution depth weighting technique was adopted to determine depth to basement rocks beneath the sedimentary piles. The processed data indicate that residual magnetic intensity and magnetic susceptibility of rocks across the study area range from – 172 nT to + 200 nT and 300 to 26000 respectively. Most of the extracted lineaments trend in ENE – WSW with subordinate E – W while few trend in WNW – ESE direction. Three dimensional (3D) located Euler Deconvolution depth solutions indicate sediment thickness over the basin ranging from approximately 50 m to over 5 km with undulating basement topography. High petroleum potential prospect is expected over the western part of the study area which presents thickness is in excess of 2 km and in most places over 5 km. This part presents significant sedimentary thickness which is adequate to generate geothermal gradient and pressure for maturation and preservation of hydrocarbon from source rocks where they exist.

The ultimate recoverable oil resources using the Monte Carlo simulation techniques from 'OWA' Marginal Field, onshore Niger Delta, Nigeria

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Abstract

Four (4) deviated wells and 3D seismic volume (362 inlines and 401 traces) were interpreted for the evaluation of the field. The petrophysical evaluations were interpreted using the Power Log software and the seismic, Geographix and Petrel software. Stochastic reserves estimation were done using Monte Carlo sampling techniques and subjected to uncertainty quantification using the Crystal Ball software by varying distributions and measuring sensitivity impact on the overall reserves. Production profile was predicted based on some assumptions and history matching which resulted in the overall Expected Ultimate Recovery (EUR). The development of the field was further considered by running the cashflow analysis and establishing the economic indications.

The petrophysical analysis shows reservoirs to be within the unconsolidated continental Benin Formation denoted as 'Intra-Benin' sands, an unconventional reservoir as supposed the normal reservoir rocks within the Agbada Formation. This indicated high porosity (0.28), water resistivity (70hms.m), and water saturation and also inferred Heavy Oil (low API). Nine (9) hydrocarbon sands were identified but only three (3), (B1, D and E), representing shallow, mid and deep reservoirs were further evaluated. 1P and 2P reserve estimates were 4.8 MMBO and 5.7 MMBO for B1; 15.2 MMMscf and 16.4 MMMscf for D; 8.4 MMMscf and 8.8 MMMscf for E respectively. The Monte Carlo Simulation of 1,000,000 trials with mainly triangular distribution assumption generated P10, P50, P90 were 6.5 MMBO, 5.6 MMBO and 4.4 MMBO for B1; 17.5 MMMscf, 13.7 MMMscf and 10.8 MMMscf for D; 10.4 MMMscf, 8 MMMscf and 6.1 MMMscf for E respectively. The sensitivity analysis and coefficient of variability of about 15%, 19% and 20% for B1, D and E respectively indicated that there is a very low level uncertainty of reserve estimation based on the distributions of input parameters. The one-well scenario was only able to produce 50% of EUR (2,842,369) while the two-well scenario gave up to 80% EUR (4,699,390) before abandonment rate for a field life of about 15 years. The cashflow analysis showed an attractive marginal project with positive Net Present Value for the \$50/bbl base oil price scenario and the contractor's take was estimated to be about 22% of the total share. The greatest effect on the NPV was seen from the Petroleum Profit Tax and the oil price in the sensitivity analysis which is negative and positive respectively.

Seismic and gravity modeling of grabens of central West Tunisia

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Abstract

The Geophysical prospecting in this area is based on seismic and gravimetric methods has shown the lateral evolution of facies and evidenced the structure of the NW grabens. In addition, the data set was found to have a good understanding of the structural geology of the region. Our study area is part of the northwestern Tunisia, whose geological evolution is strongly marked by the behavior of the whole Alpine chain of North Africa and the Western Mediterranean. The lithostratigraphic correlations established between outcrops and seismic data, allowed to better understand the structural complexity and the role of the various tectonic accidents that contributed to the current configuration, highlighted by the presence of grabens. The NW-SE, NNW-SSE to NS and NE-SW to EW fault directions played a major role in the genesis of the folds and the opening of the NW-SE grabens. The seismic line L1 made possible to evidence the NW-SE compression which resulted by prevailing unconformities widely identifiable on its lithostratigraphic column. These unconformities, representing reverse faults, were interpreted as an overlap on the L1 seismic profile. Gravity data with a negative anomaly also corroborate the seismic interpretation, confirming the structure of Kalaa Khesba graben, composed of Mio-Plio-Quaternary series.

poster

08

Geophysics

Geophysical modelling and inversion of Ambam-Mvangan-Sangmellima (South-Cameroon) gravity anomaly, constraints from spectral analysis.

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Abstract

Modelling and inversion of residual Bouguer gravity data in the southern Cameroon are interpreted to better understand the organization of principal shallower structures in the northern edge of the Congo Craton. The Bouguer anomalies map is characterized by an elongated NE-SW trending positive gravity anomaly associated to the formations of Ntem Units. Three sections defined along the anomaly crossing Ambam, Mvagan and Oveng-Sangmellima localities respectively shows two domains of densities for each. In the first section, densities of domain I (2-6 km) vary between 2.64-2.70 g/cm³ while that of domain II (up to 6 km) vary between 2.71-2.86 g/cm³. In the second section, domain I (3-5km) shows the variation of densities comprises between 2.50-2.65 g/cm³ whereas the densities of domain II (up to 5 km) vary from 2.66 to 2.98 g/cm³. In the third section, domain I (4-6 km) present the densities from 2.50 to 2.70 g/cm³ while in the domain II (up to 6 km), densities vary between 2.71-2.94 g/cm³. 2-D spectral analysis done on these profiles shows three majors discontinuities for the shallower structures: the first discontinuity situated at an average depth of 1.20 km, the second at 3.00 km and the last at 10.40 km. Results from this study define the top of the anomaly at 3 km about with a mean density of 2.85 g/cm³.

Mapping the subsurface structure of the suevite deposit in the North of the Bosumtwi impact crater using electrical resistivity and seismic refraction tomographies

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Abstract

Electrical resistivity imaging and seismic refraction methods have been used to map the subsurface structure of the suevites in the north of the Bosumtwi impact crater in Ghana. Seven electrical resistivity tomography and two seismic refraction profiles were surveyed. The lengths of the profiles varied between 160 and 600 m. The multi-electrode system was combined with roll along techniques for resistivity data collection using gradient array. Roll along was also executed for the seismic refraction survey where two geophones were overlapped to extend survey length. The data was acquired in 2D where electrodes separation of 4 m was the same as the geophone spacing, whilst the shooting interval was 8 m. The data was processed with Res2Dinv and ReflexW for the resistivity and seismic refraction respectively. Electrical resistivity and seismic refraction tomography identified the suevite deposits which were observed within 12 m depth. The resistivity of northern Busumtwi suevites varies between and the P-wave velocity ranges from The results also showed that the subsurface is made up of either two or three layers: Unconsolidated top soil, clayey soil, and fractured clastone. The deepest depth of investigation was about 26 m. The results of the seismic velocities and the electrical resistivities of the northern Busumtwi suevites compare very well with those found for suevites at Ries impact crater Germany and other impact craters.

Aerospectrometric survey interpretation in Cabo Delgado, Mozambique: new inputs in surface geology

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Abstract

Airborne geophysical surveys are usually used to investigate large areas with difficult access, as is the case of the African environment. From the methods that can be applied in airborne surveys, gamma ray spectrometry can be used to improve the knowledge on surface geology and tectonics, by highlighting the concentrations in radioactive isotopes of U, Th and K in the earth's shallowest 30 to 50 cm. Either through the use of simple concentration maps of U, Th or K, or U/Th and Th/K ratios different facies and lithotypes can be differentiated. Techniques that use the ternary combination of the radiometric channels using the colour patterns RGB and CMY can also enhance the perception of large geological and geochemical domains, which in turn can be delimited. Small alterations in the concentration of U, Th and K, often reflecting different facies of the same lithotype can be detected in smaller areas. Different types of discontinuities can also be identified. Therefore, smaller scale investigations can be done after the interpretation of airborne gamma ray spectrometry. This study uses airborne spectrometric data to investigate the geology and structure of Block 5 in the Cabo Delgado Province, North of Mozambique, from 11°S to 13° S and from 38°E to 40°E, covering an area of about 5000 km². The airborne data were acquired at the same time as magnetic data, with flight lines spacing 300 m and at an height of 150 m. Following all the necessary correction procedures, these spectrometric data were processed using Geosoft Oasis Montaj and krigging method was Minimum Curvature. Several improvements were made to the 1:1,000,000 scale geological map. Five large geological blocks were defined inside Block 5, with similar radiometric signature but with different characteristics that were not detected by geological mapping at this scale. A larger elliptic area, corresponding to the conglomerate and quartz feldspar sandstones of the Maconde Formation with low K, U and Th values, dividing blocks of granites and gneisses from the Chiure Supergroup with high U, Th and K values. There can also be identified the conglomeratic sandstone, ferruginous and red sand of the Mikiddani Formation from the Rovuma Basin, with medium values of U and Th and low K caused by leachate, granites, gneisses and migmatites of the Nampula Super Group. Blocks (M), (N), (ML), (X) and (FR) covering these geological formations were defined and radiometric signatures were assigned to the major identified blocks, giving an important input to the magnetic interpretation and geological knowledge of this large area.

Aeromagnetic survey and interpretation in Cabo Delgado, Mozambique: inputs in geology and tectonics

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Abstract

In African context, airborne geophysical surveys are useful due to the large areas to investigate, some of them very difficult to assess. From the methods that can be applied in airborne surveys, magnetics can be used to improve the knowledge on geology and tectonics, by highlighting the deep magnetic domains and discontinuities. This study uses airborne magnetic data to investigate the geology and structure of Block 5 in the Cabo Delgado Province, North of Mozambique, from 11°S to 13° S and from 38°E to 40°E, covering an area of about 5000 km². The airborne data were acquired at the same time as spectrometric data, with flight lines spacing 300 m at an height of 150 m. Following all the necessary correction procedures, these magnetic data were processed using Geosoft Oasis Montaj and krigging method was Bi-directional Line Gridding. Filters were used to obtain maps comprising magnetic field anomaly, first vertical derivative, reduction to the pole and analytical signal. To estimate the depths of the sources of the anomalies, Euler Deconvolution solutions maps were produced and provided interesting results. The interpretation of these maps adds several improvements to the 1:1,000,000 scale geological map. Five large geological blocks were defined inside Block 5, depicting similar radiometric signature, with different characteristics that were not detected by geological mapping at this scale. A larger elliptic area, corresponding to a magnetic domain that corresponds to the conglomerate and quartz feldspar sandstones of the Maconde Formation, dividing blocks of granites and gneisses from the Chiure Supergroup. There can also be identified the conglomeratic sandstone, ferruginous and red sand of the Mikiddani Formation from the Rovuma Basin, and granites, gneisses and migmatites of the Nampula Super Group. Magnetic signatures were assigned to the major blocks identified, giving an important input to the magnetic interpretation and geological and tectonic knowledge of this large area. Five magnetic block domains (M), (N), (ML), (X) and (FR), coincident with the magnetic and spectrometric surveys and covering these geological formations were defined. Their delimitation was also made according to the lineaments defined by all the magnetic maps, namely the first derivative maps. The evidence of deformation phases affecting the Block 5 study area were summarized. The complexity of the faults, joints, shear zones and folds shown by the first derivative of the anomalous magnetic field is indicative of the intense tectonic activity that affected the northern and northeastern Mozambique. According with the Euler solutions. In the area under investigation and based on the interpretation of aeromagnetic data, different types of structural anomalies were mapped, namely: contacts, vertical dikes, sills, cylinders and spheres.

oral

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Ocean Sciences

Recent evolution of Bazaruto island coast

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Abstract

Bazaruto Island, located NE of Vilankulos is the largest of five islands which form the archipelago with the same name (Rebêlo et al., 2012, *Cooperação entre Portugal e Moçambique na Área das Geociências*: 65-72). This archipelago sits in the continuation of the southern coastline, and, at the present high-sea-level stand, is separated from the continent by a shallow complex deltaic system that engulfs the sand coming from the south, filling the bay that spreads from Vilanculos to Inhassoro.

Bazaruto is one of the barrier islands (Cooper & Pilkey, 2002: *JCR Sl36*:164–172; Armitage et al., 2006: *Geomorphology*, 82:295-308) that are part of a very extensive costal barrier system, spreading from South Africa coast to the Zambezi delta. Several dune pulses, from the oldest, dated from approximately 126 Ky (Armitage et al., 2006), to the present inland sand migration, have been described. Southeast prevailing winds are responsible for major dune morphology and, since Bazaruto is mainly built by dunes, are also responsible for the island morphology. Large superimposed parabolic dunes and complex transverses dunes dominate the landscape. The dunes in the western part of the island are stabilized by vegetation, but recent coastal processes are responsible for dune destabilization and for the extensive mobile dune fields facing the Indian Ocean.

Different scale of analysis should be used to understand the island evolution. The large scale approach is important to understand the role of the older sand pulses in the context of the island major relief units and the recent oceanic coastline and morphology evolution. However, a small scale analysis is crucial to comprehend the Holocene variations and the recent evolution of the western side of the island.

Although sand is present in impressive quantities, at present conditions of high sea level coastal morphology reveals that beach and dune erosion is the dominant process in Bazaruto shore (Armitage et al., 2006). Submerged beachrocks and consolidated dunes alignments, alongside with headlands and zeta bays, are good evidences of coastal retreat. However, geological evidence shows that, even during the Holocene, coastal processes were significantly different, and that accretion processes were dominant. Prior to that accretionary phase, the island shape was significantly different and most of the present low-lying sandy areas of the western side of the island, facing the bay, were submerged. Sand spits and small-scale coastal barrier systems, anchored on the older dunes headlands, lead to the creation of sheltered areas allowing the deposition of tidal flats and mangrove plains. Beachrock formation also occurred, which largely contributed to maintain the old coastline position, which shows actually a retreating behaviour.

Looking to beachrock successions, analysing coastal morphologies and explaining present erosion evidence, coupled with OSL dates (unpublished data) of the recent dunes, paleo-tidal flats and beachrocks, will help to understand the Holocene evolution of Bazaruto.

Coastal geology processes and Holocene coastline evolution analysis will be presented in terms of its importance to proper land use management, aspect particularly relevant in this type of environment and where evidences of recent changes are known to occur.

oral

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**Geoparks,
Geotourism
and Geoethics
for Promoting
Earth Heritage
in Africa**

St. Vincent, Cape Verde: geology and tourism in the ruins of an Ocean Island Stratovolcano

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Abstract

In 1851, the book “A Guide to the Cape de Verd Islands” by John Rendall, Esq., HBM Consul, Porto Grande, St. Vincent, put the archipelago on the tourist and cultural map of Africa. In 1932, J. Bebianos seminal “Geologia do Arquipélago de Cabo Verde” (Geology of the of the Cape Verde Archipelago) was the first systematic description, with maps, of all the islands; St. Vincent island was the first to be described. In 1963, A. Serralheiro started the modern geology of Cape Verde, writing a paper on the geology of St. Vincent. It is understandable that St. Vincent deserves to be now revisited. To remind: the island is an intraplate, deeply eroded statovolcano, with a collapse caldera whose lowered floor exposes the Old Volcanic Complex (basalts, syenites, carbonatites, phonolites...). Three topics will be discussed here.

History – The knowledge of the effort made by the predecessors is an important factor in the development of the identity of a people. The period before Bebiano is dominated by the Germanic pioneers: A. Stuedel in 1863, G. Doelter in 1982, I. Friedlaender and W. Bergt in 1912. Two of the rare Stuedel drawings are now presented. The period after Bebiano is marked by the 1963-1975 “Missão Geológica de Cabo Verde” (A. Serralheiro, L. Celestino Silva...). After the Independence, the international cooperation was strengthened.

Geodiversity, geoheritage, geotourism – An in-depth knowledge about geodiversity gives an informed background for the inventory of geological heritage, with important economic consequence for geotourism: 1) beautiful landscapes (Monte Verde, Madeiral...), 2) pleasant white sandy beaches (Baía das Gatas, Palha Carga...), 3) attractive rocks and minerals (nepheline syenites, phonolites, carbonatites...).

Education – The geodiversity of St. Vincent is a good opportunity for helping both students and the public in general to strengthen a rational attachment to nature and to homeland. However, there is a prerequisite: politicians and authorities need to be educated, particularly as far as geoconservationism and environmental topics are concerned. An inspiring case study was presented in 2007 by the Cape Verdean researcher Vera Alfama in her MSc thesis on the Fogo island.

The geotourist place of St. Vincent in the Archipelago is tentatively defined.

Geoheritage of São Tomé and Príncipe Archipelago

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Abstract

São Tomé and Príncipe (STP) archipelago is recognized by its remarkable biodiversity, with numerous endemic species, which led to the establishment of protected natural reserves (“Obo National Park”) and the announcement of Príncipe Island as a UNESCO World Biosphere Reserve in 2012. However, both islands also present noteworthy geological and geomorphological features that should be classified as geosites.

STP Islands are part of a major volcanic alignment known as the Cameroon Volcanic Line (CVL), a prominent 1,600 km-long intra-plate NE-SW volcanic alignment, extending through the oceanic and the continental African lithosphere.

São Tomé Island (857 km²) is mainly composed of volcanic rocks of the basalt-trachyte-phonolite series, with basaltic rocks prevailing. The island has four main stratigraphic units: Cabras Islet Volcanic Formation (~13 Ma), Mizambú (6-8Ma), Ribeira Afonso (2.5-5 Ma) and São Tomé (< 1.5 Ma) Volcanic Complexes.

Príncipe Island (139 km²) consists of basaltic to thephritic and phonolitic rocks, being the later predominant. The oldest rocks are palagonite breccias (~31 Ma) probably testifying to a submarine phase. An Older Series (19-24 Ma) of alkali basalts and hawaiites, cut by NW-NE trending dykes and a Younger Series (3.5-5.5 Ma) of nephelinite and basanite lavas occur on the northern part of the Island, while predominantly phonolitic plugs (5-7 Ma) and associated phonolitic to trachyphonolitic lava flows constitute the south of Príncipe.

Field work for the production of the Geological Map of São Tomé Island allowed the identification of several sites of geological and/or geomorphological interest. Along with the towering volcanic plugs, which are iconic landscapes on these islands, there are other geological features that deserve to be highlighted as geosites due to their scenic, scientific, didactic or cultural value. In addition to the geosites already mentioned by other authors on São Tomé Island, we will focus on sites displaying: a) well-preserved testimonies of submarine volcanism, including submarine tuffs, hyaloclastite and pillow lava outcrops; b) recent cinder cones exhibiting well-preserved morphology and rhythmically bedded pyroclastic layers; c) spectacular columnar jointing on basalt flows from São Tomé and on phonolites from Príncipe Island; d) phonolite structures in Príncipe Island and d) sedimentary landscapes such as black and white sand beaches along the coasts of both Islands.

The preservation of STP's geological heritage must be planned in order to identify, select and characterize geosites, followed by the implementation of measures for its classification, protection and conservation by local authorities (namely the DGRNE). The preservation of the geological heritage, besides its intrinsic value, will also contribute to the growing touristic industry.

Some steps have already been taken, such as two collaboration actions between LNEG and high-school teachers from STP, to raise awareness on geoheritage amongst the younger population.

Bases de données et les NTIC pour l'Inventaire, la promotion et la protection du géopatrimoine Algérien

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Abstract

L'Algérie avec ses 2.381.741 km² de superficie est le plus grand pays d'Afrique. Elle renferme une grande variété de sites géologiques et géomorphologiques de très grande valeur. Il est important d'assurer leur pérennité pour en profiter scientifiquement, économiquement et culturellement. Ces sites, qui doivent être préservés pour les générations futures, peuvent être un moteur économique avec le développement du géotourisme, de l'artisanat et de la petite entreprise.

Par ailleurs, la création et la gestion de bases de données géoscientifiques, et l'utilisation des nouvelles technologies de l'information et de la communication (NTIC), sont devenues des outils précieux pour la recherche fondamentale ou appliquée, telles que la géologie minière ou la gestion des risques naturels. Elles le sont tout autant pour la préservation du patrimoine géologique. Ce travail présente deux outils que nous avons élaborés à cet effet.

GeoAl@ est une application qui gère une base de données regroupant une description complète et détaillée des géosites algériens. Son but est l'inventaire du géopatrimoine. La base de donnée peut être visualisée et complétée sur un ordinateur, une tablette ou un site web dédié. Elle permet de localiser les géosites sur une image satellitale, sur laquelle on peut superposer différentes cartes thématiques (géologiques, topographiques). On peut également y attacher des fichiers tels que des photos, des articles scientifiques ou des rapports. Chaque géosite est décrit en détail et ses qualités évaluées suivant des critères très précis. Cette application est en train d'être adoptée par le Service Géologique de l'Algérie (ASGA).

Le deuxième outil est un site web utilisant les techniques de la veille informationnelle qui permet de se tenir au courant en continu d'informations pertinentes en rapport avec un thème précis. Il a été conçu pour retrouver semi-automatiquement les photographies à différentes époques de géosites pour visualiser l'évolution de leur état de conservation. Il comprend également un module de veille qui s'intéresse à toute information, relative à ces géosites, sous différentes formes écrites (articles, livres). Il permet ainsi de surveiller un site et de nourrir la base de données GéoAl.

L'objectif des solutions proposées est de mobiliser la communauté géoscientifique, les autorités locales et nationales, la société civile ; et surtout, la population locale, vivant aux alentours de ces géosites, pour la préservation de ce patrimoine et sa valorisation. Idéalement, avec l'aide des pouvoirs publics, cela devrait se traduire par la protection des sites ; et la promotion du géotourisme comme moyen de développement durable.

Assessment proposal to establish the first geo-park in Egypt at Abu-Roash Area, Cairo

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Abstract

Egypt is known as cradle of civilization due to its ancient history and archeological sites, but Egypt possess also a cradle of Geo-sites, which qualify it to be listed as one of the most important Geo-heritage sites all over the country. Geology and landscape in Abu-Roash area is considered as one of the most important geological places (geo-sites) inside Cairo which help us to know and understand geology and geologic processes, so the area is used mainly for geological education purposes, also the area contain an archeological sites; pyramid complex, tombs, and Coptic monastery which give the area unique importance.

Abu-Roash area is located inside Cairo 9 km north of the Giza Pyramids, which make the accessibility to the area easy and safe, the geology of Abu-Roash constitutes a complex Cretaceous sedimentary succession mass with showing outstanding tectonic features (Syrian Arc system event), these features are considered as a Geo-heritage, which will be the main designation of 'Geo-parks' establishing.

The research is dealing with the numerous geo-sites found in the area, and its geologic and archeological importance, the relation between geo-sites and archeology, also the research proposed a detailed maps for these sites depicting Geo-routes and the hazardous places surrounding Abu-Roash area.

The research is proposing a new proposal not applied in Egypt before, establishing a Geo-park, to promote this unique geo-heritage from hazardous factors and anthropogenic effects, also it will offer geo-educational opportunities to the general public and to the scientific community, enhancement of Geo-tourism which will be linked easily with the Ancient Egyptian tourism, it will also provide a significant economic benefit to Abu-Roash residential area.

Finally, the research recommend that The United Nations Educational, Scientific and Cultural Organizations promote conservation of geological and geo-morphological heritage to list this area for its importance under the umbrella of geo-parks.

Nile basin as a transnational Global Geopark.

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Abstract

The Nile, by its length, is the longest river in the world at 6,853 km long, covering an area of around 3 million km². It was born from the meeting of two rivers: the White Nile and the Blue Nile. Its first feeder is at Lake Victoria in Uganda, the second at Lake Tana in Ethiopia.

The Nile river as its drainage basin covers eleven countries, namely, Tanzania, Uganda, Rwanda, Burundi, the Democratic Republic of the Congo, Kenya, Ethiopia, Eritrea, South Sudan, Republic of the Sudan and Egypt, in particular, the Nile is the primary water source of Egypt and Sudan.

The Nile River has the extraordinary chance of crossing many countries, it had the advantage of being a useful and practical way to get from one end of the country to the other, there are wonderful treasures to be found in the constantly changing shapes, colours, landscapes and rocks of the areas surrounding and the cultures of the community the Nile river.

Despite an abundance of truly amazing cultural, geological, biodiversity and archaeological features, these greatest sights, combined with the coming impacts of climate change and subject to political interactions.

On the ground it is fascinating to travel across the Nile Valley to the point where the irrigated fertile valley changes abruptly into barren, inhospitable desert...etc. The need for cooperative sustainable management of the trans-boundary water, and related, resources of the Basin has never been more compelling.

So the proposal of establishing “Nile Basin geopark” will be as a transnational geopark to address the region’s brewing water conflict, reduce poverty and promote economic integration. Leaving economies stronger rather than weaker, and try to reduce ongoing conflict over the Nile.

The proposed geopark has the potential to reduce a number of problems in the basin, and continues to fuel conversations, geotourism and peace. All of these competing projects combined with the region’s already over.

Potentialités géotouristiques de la région d'Imouzzer Marmoucha (Moyen Atlas, Maroc)

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Abstract

La région d'Imouzzer Marmoucha se situe dans le Moyen Atlas plissé qui est une chaîne constituée par quatre rides anticlinales étroites à matériel carbonaté du Jurassique inférieur, encadrant des synclinaux larges à remplissage marno-calcaire du Jurassique moyen et du Crétacé. Cette région recèle des géosites présentant différents phénomènes qui illustrent bien l'histoire géologique et géomorphologique de la région :

- Sites à valeur structurale : La région se situe dans la zone du passage de l'Accident Sud Moyen Atlasique (ASMA). Cet accident majeur a joué à différentes périodes notamment son jeu syn-sédimentaire au cours du Jurassique moyen. Cette activité tectonique est à l'origine de discordances angulaires et progressives (Feddan, 1988). Ces géosites ont des valeurs scientifique, pédagogique et esthétique.
- Sites à valeur paléontologique : La région est caractérisée par la présence de nombreux gisements fossilifères (Ammonites, Brachiopodes, ...) dont l'étude a permis de préciser la stratigraphie régionale (Benshili, 1989). Cependant le plus célèbre est celui du squelette du 1^{er} dinosaure sauropode découvert au Maroc dans la région d'El Mers (De Lapparent, 1955) qui se trouve à une dizaine de kilomètre à l'ouest d'Imouzzer Marmoucha. Depuis, d'autres gisements d'ossements, notamment celui d'Aït Bazza, et d'empreintes de pas de dinosaures ont été découverts dans la région.
- Sites à valeur minéralogique : Le site d'Aït Moussa est un site unique au Moyen Atlas par la présence d'indices d'hydrocarbures. Il s'agit d'une alternance de marnes (roche mère) et de calcaires (roche réservoir), affectés par plusieurs générations de fractures à travers desquelles il y a expulsion du bitume (Assaoud, 1994). Un deuxième site correspondant à un gisement exploité de calcite pure associé aux carbonates jurassiques à Serghina au niveau de la troisième ride.
- Sites à valeur hydrologique : la région revêt un grand intérêt hydrologique et hydrogéologique. Les eaux souterraines génèrent une multitude de sources permanentes. Les plus importantes sont Aïn Skhounat (thermale) et Aïn Tataw (fraiche). Les eaux de cette dernière donnent lieu à la célèbre cascade d'Imouzzer Marmoucha.

Cette richesse géopatrimoniale peut contribuer au développement régional par la promotion du géotourisme en intégrant les différents géosites aux circuits touristiques existants.

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poster

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**Geoparks,
Geotourism
and Geoethics
for Promoting
Earth Heritage
in Africa**

The Tichoukt massif: a geotouristic play in the Folded Middle Atlas (Morocco)

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Abstract

The Middle Atlas Mountains have rich geomorphologic landscapes and remarkable geological sites, little known by the general public. In this work, we propose an approximately 60 km long geological trail, including several geosites mostly staggered in the sinuous valleys of the Atchane and Guigou rivers, between Boulemane, Skoura and El Mers.

These geosites reflect the geological, geomorphological and environmental history of the region with a strong aesthetic value and give a particular scientific and geotouristic interest to the proposed geotrail. The Boulemane panorama gives the opportunity to observe a case-study of geomorphology linked to a knee fold that corresponds to the SW peri-anticline of the majestic Tichoukt chain. The geotrail then offers several geosites in the Middle Jurassic regressive sedimentary series of the Skoura Syncline. The NE extremity of the Tichoukt shows the thrusting of the fold crest onto the inverted flank of the Skoura Syncline (Alpine tectonic). The SE flank of the Tichoukt fold is affected by a Middle Jurassic uplift related to faulting and diapiric activity. The geotrail ends at El Mers, the site where the sauropod dinosaur was first discovered in Morocco. This geoheritage has been never used into the traditional tourist trail; it deserves to be valued in the context of projects aimed at developing a sustainable eco-geotourism, and the knowledge of the culture of the Amazigh people in these harsh mountainous areas.

oral

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**Geohazards,
Natural and
human-induced
environmental
hazards and
disasters**

Characteristics of landslides causing road failures in Ethiopia

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Abstract

Ethiopia is undertaking massive infrastructural development (roads, railways, power lines, etc.) that pass through hilly/mountainous terrains of the highlands as well as through geologically complex settings of the rift valley and its escarpments. Landslides are among major geohazards challenging the road sector; hampering traffic movements and incurring huge mitigation costs. In order to evaluate the causes and failure characteristics of landslides, research has been on-going in the last years which involved: (a) inventory of 65 road sections which have been damaged by landslides of various types and sizes, (b) evaluation of the failure characteristics (types and sizes), (c) detailed geological and geotechnical investigation of representative sites, and (d) assessment of the performances of the landslide mitigation measures implemented in different parts of Ethiopia. Results of the study revealed that the major types of landslides causing road failures include: debris/earth slides with limited debris/earth flows, rockslides, and rockfalls. Over 90% of the landslides were debris/earth slides which involved failure of soil masses with depth of failures at the interface with the underlying rocks of different types (volcanic rocks, shales, tillites and phylites). Though repeated maintenances have been carried out to mitigate the problems, the engineering measures implemented could not achieve the intended purpose for 80% of the road sections. In almost 90% of the sites, the mitigation measures implemented had contributed to further instability of the slopes. In 45% of the sites, road maintenance has been carried out up to 4 times in 5 years. This research has shown that: (a) so far little attention is given to understand the geological and geotechnical conditions of the routes starting the feasibility study, (b) the causes and failure mechanisms of landslides are not clearly understood in all phases of road development (feasibility to detailed design, construction and maintenance), (c) there is lack of knowledge/capacity in the study, design and construction of appropriate engineering solutions to landslides, and (d) there is no coordinated research and capacity building on landslide processes and their mitigation measures in the country. There is, therefore, a strong need to give due attention to landslides and their mitigation options through collaborative research, capacity building and learning in order to reduce costs and ensure the safety of roads and other infrastructures in Ethiopia and in similar countries in Africa.

Hydrochemical assessment of impacts of artisanal mining on groundwater quality of Awo and Ede areas, southwestern Nigeria

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Abstract

Pegmatites around Awo, in southwestern Nigeria, were found to contain economic minerals such as beryl, tourmaline, tantalite, columbite and clay. Artisanal mining activities have been carried out in the area to exploit these mineral resources. Artisanal mining is a major contributor to environmental pollution including groundwater contamination. Thus, groundwater quality is usually at risk in areas where artisanal mining activities are being carried out. The restoration of the contaminated water to its natural composition is a difficult and very expensive, hence regular monitoring of water sources is necessary. Few studies have been carried out to assess the impacts of artisanal mining on the groundwater quality in Nigeria. This study therefore aims at assessing the possible impacts of the artisanal mining of pegmatites of Awo area on the groundwater quality of the mining district and its possible dispersal across neighbouring areas like Ede.

Fifty-nine (59) groundwater samples from the mining district and its environs were collected and analysed. Major anions and heavy metals concentrations were determined using Atomic Absorption Spectrophotometry, while major anion concentrations were determined using Colorimetry and Titrimetry. Physical parameters (Temperature (°C), pH, EC (µS/cm) and TDS (ppm)) were measured in-situ using a Portable pH/EC/TDS/Temperature HI9813-6 meter.

The groundwater has modified its chemistry from the weathered materials derived from the underlying bedrocks. Concentration of the cations in the study area is in the order of Na⁺>K⁺>Ca²⁺>Mg, while that of anions is HCO₃⁻→Cl⁻→NO₃⁻→SO₄²⁻→PO₄³⁻→CO₃⁻. Most heavy metals were negligible. The average values of pH (6.47), EC (0.41 µS/cm), TDS (277.29 ppm), and average ionic concentrations in mg/L {Ca²⁺ (13.56), Mg²⁺ (10.89), Na⁺ (23.59), K⁺ (27.15), HCO₃⁻ (41.82), Cl⁻ (32.91), NO₃⁻ (11.98), SO₄²⁻ (1.05), Fe²⁺ (0.01), Mn (0.06), Zn (0.04); CO₃⁻, Cu, Cd, Pb, Co, Cr (0)} of the groundwater samples from the mining districts in Awo area and its environs showed no significant difference from the average concentrations of samples from the other parts of the study area with average values of pH (6.51), EC (0.47 µS/cm) TDS (322.79 ppm), and average ionic concentrations in mg/L {Ca²⁺ (16.98), Mg²⁺ (10.72), Na⁺ (25.60), K⁺ (20.58), HCO₃⁻ (73.15), Cl⁻ (44.75), NO₃⁻ (6.48), SO₄²⁻ (0.85), Fe²⁺ (0.14), Mn (0.08), Zn (0.01); CO₃⁻, Cu, Cd, Pb, Co, Cr (0)}. However, bicarbonate ion got significantly introduced into the groundwater system during transportation due to ion dissociation resulting from CO₂ charge-recharge to produce bicarbonate ions. Most ion concentrations show that the groundwater of Ede and Awo is low mineralized, chemically potable, within WHO standards and suitable for irrigation. Artisanal mining has not impacted the groundwater.

Mercury remobilization from highly polluted topsoils during simulation of wildfires in semi-arid areas

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Abstract

Anthropogenic activities play an important role in the distribution and cycling of mercury (Hg). This research was focused on organic-rich topsoils highly polluted by the Tsumeb copper smelter, which processes Hg-rich concentrates (up to 20.0 ppm, bound mainly in sulfides) in the northern part of semi-arid Namibia. Total Hg concentrations in topsoils near the smelter attained 7.6 ppm. To understand the potential remobilization of Hg from polluted topsoil samples during wildfires, laboratory thermodesorption experiments in the temperature range 75-670 °C have been performed. In oxygen-rich atmosphere the Hg release occurred at temperatures higher than 100 °C and exhibited a sharp peak at 340 °C. This observation indicates a local increase of temperature during the residual biomass burning, which causes the complete Hg release. This was also supported by TG-DTA measurements, which showed a massive mass loss at 350 °C. To eliminate spontaneous burning and uncontrollable temperature increase during thermodesorption, the same experiments in nitrogen atmosphere were performed; the obtained results were identical with those obtained under the oxygen-rich conditions. This behavior means that all the Hg can be mobilized under the low temperature conditions (ca. 350 °C), well corresponding to mean temperatures during bushfires. Moreover, these results confirm that the remobilized Hg was bound in the topsoil organic matter and not in the sulfides windblown directly from the concentrate processing facilities. Experiments confirm a major role of wildfires in Hg cycling and indicate that the amounts of Hg, which could be potentially remobilized by bushfires from mining- and smelter-polluted areas in semi-arid Africa could be predicted.

This study was supported by the Czech Science Foundation project (GAČR 16-13142S) and student project from the Granting Agency of the Charles University (GAUK 1598218).

Reduction risk and seismic activity at Nyiragongo and Nyamulagira volcanoes in the western brach of the east african rift/DRC

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Abstract

About 50 to 60 volcanoes erupt every year worldwide. Large eruptions endanger lives, human settlements and livelihoods of the almost 500 million people estimated to live near active volcanoes in 2000. That number will increase in the future as today more than 60 large cities are located near potentially active volcanoes, threatened by volcanic eruption. Volcanoes with high activity are located predominantly in developing countries, particularly in Latin America, the Caribbean, parts of Asia and in the southwest Pacific.

In these countries, despite the improvements in many national civil defense agencies. Capacities to manage volcanic emergencies, eruptions are becoming increasingly risky because of rising population density and intense interweaving of infrastructure in the areas surrounding volcanoes. An activity of glow visibility was been noted at Nyamulagira volcano from June 22nd 2014.

After few days, the NASA organization noted this situation by his satellite detection and published on his Web site the apparition of a new lava lake in the crater of Nyamulagira. We can note that, Nyamulagira volcano (in his known history) logged again in his crater a lave lake from 1921 to 1938 (Mavonga et al, 2010).Here are analyzed the seismic parameters before and after this new event at mount Nyamulagira, and we found that this event was been preceded by Volcanic tremors (12 hours about), for this reasons, a revised assessment of seismic and volcanic hazard is urgently needed. In this subject, we describe effort to gather data and derive models of geological processes that can be used to monitoring volcanoes and assess the earthquake hazard, plan the settlement of displaced people and to build back better.

Fate of copper smelter-derived dusts in soils from subtropical and semi-arid areas

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Abstract

Soils near non-ferrous metal smelters are often highly polluted by metal(loid)s. Compared to temperate soils, (sub)tropical and semi-arid soils are particularly affected by this type of contamination, because they generally exhibit low organic matter contents and contain low-activity clays and less reactive Fe-oxides.

Laboratory pot experiments using wetted soils (Oxisol, Luvisol, Chernozem, Arenosol, representing soils typical for subtropical and semi-arid areas) were performed with polyamide experimental bags with Cu-smelter flue dusts inserted in the topmost part of the soil column. We monitored the loss in flue dust mass and the soil pore-water chemistry during dust incubation in soil over 1008 hours of the experiment. In addition, the distribution and availability of the contaminants (As, Cd, Co, Cu, Pb, Sb, Zn) in the soil after the fly ash incubation were evaluated using bulk chemical analyses and single extractions. In addition, we also performed a 1-year in situ incubation of flue dust in Luvisol and Chernozem.

Smelter fly ashes were highly reactive in the studied soils (mass loss up to 56 % after 1 year of exposure). Whereas metals were released from the dust samples in lower amounts and were relatively efficiently retained in soils, arsenic and antimony were released to a greater extent and were found to be highly mobile especially due to prevalent As(III) form. The HRTEM and SEM observations indicated that newly formed Ca-, Pb- and Ca-Pb arsenates [such as mimetite, $Pb_5(AsO_4)_3Cl$] partly controlled the release of As and other contaminants. The smelter dust incubation experiments indicated that the assumption of the vulnerability of (sub)tropical and semi-arid soils with respect to smelter-related contaminants is justified, especially under the low pH conditions, where retention mechanisms for metals are limited.

This study was supported by the Czech Science Foundation project (GAČR 16-13142S).

Heavy metals and rare earth elements (REEs) in the phosphates from Oum El Khceb mine (southern Tunisia): environmental and economic implications

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Abstract

The sedimentary phosphates of marine origin mark the Paleocene-Eocene period in the region of the Gafsa Basin, as elsewhere in northern Africa. The studied sector of Oum El Khceb in southern Tunisia is considered an important economic area with high phosphate production. Outcrops of the studied site are characterized by a sequence of phosphate within carbonate formations, and mainly composed by carbonate-fluorapatite, calcite, gypsum, heulandite and quartz. The various analyzes showed that the phosphates are of significant economic value due to its high P₂O₅ content reaching 29% in some layers, and with chemical yields up to 90 %. In addition, the chemical analyses revealed that the study site is of potential interest for rare earth elements (REEs) (Σ189-523 mg kg⁻¹), in particular for light-REEs. However, these phosphate rocks are also enriched in heavy and toxic metals including Cd (21-72 mg kg⁻¹), Cr (200-300 mg kg⁻¹), Ni (12-40 mg kg⁻¹), U (23-51 mg kg⁻¹), V (44-124 mg kg⁻¹), Zn (115-589 mg kg⁻¹), which are known by their adverse effects to both human and environment healthy states. This aspect may hinder the use of these phosphates in agriculture if no adequate refinement/removal of the toxic metals were performed. Also, when exposed on surface to the hydro-weathering agents and processes, these phosphates may become potential sources of finest particles mobilization reaching other environmental compartments (e.g. surface and groundwaters).

Therefore, in this study were applied a selective and sequential-chemical extraction (SSCE) procedure in order to evaluate the availability of these toxic elements. While the REEs, Cr, P, U and V were not easily available, since they are mainly associated with crystalline resistant phases (e.g. silicates and Fe-oxides), the Ni and Cd were highly associated with the oxidizable phases (e.g. organic matter). A considerable proportion of Cd (20-30 %) was also extracted in the first sequential steps by using ammonium acetate. Zinc was more associated with Fe-oxyhydroxides (either amorphous or crystalline) and with oxidizable phases, but no significant differences on the extraction amounts between each step were observed. In view of these results, the high toxicity of Cd and its great availability in the analyzed samples makes it a potential threat for human health and the environment, whereby more detailed studies of this element in these phosphates should be considered.

Understanding Polycyclic Aromatic Hydrocarbons (PAHs) occurrences in groundwater and stream around Upper Cretaceous Mamu Coal from Okaba-Odagbo, Kogi State, North-central Nigeria

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Abstract

The concentrations of Polycyclic Aromatic Hydrocarbons (PAHs) and Carcinogenic PAHs (cPAHs) in water samples from groundwater and stream around Mamu Coal in Ankpa were determined. Samples from the study area were analyzed using Gas Chromatography-Mass Spectrometry (GC-MS).

The total concentrations of the 15 PAHs [acenaphthalene, acenaphthene, fluorene, phenanthrene, pyrene, benz(a)anthracene, benzo(b)fluoranthene, chrysene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd) pyrene, dibenz(a,h)anthracene, 1-methylnaphthalene and 2-methylnaphthalene] detected around the mining site were in the range of 16.82-17.28 µg/l, while that of cPAHs fall between 10.13-10.23 µg/l. These accounted for 59.20-60.70 % of the total PAHs from the mine ponds; while that of the 15 detected PAHs from Omaji-oda stream was 16.93 µg/l with cPAHs of 10.20µg/l representing 60.25 % of total PAHs of the samples.

These values were much higher than the standards by WHO (2.00 µg/l), Standard Organization of Nigeria (SON) (7.00 µg/l) and European Union (0.10 µg/l) for PAHs in water. The high molecular weight (HMW) PAHs make up the largest proportion of the PAHs while the low molecular weight (LMW) PAHs shows the lowest concentration. Hence, the high concentration of HMW-PAHs makes it difficult for degradation to take place due to their affinity for particulate matter which decreases their bioavailability. Using diagnostic ratios of low molecular weight/high molecular weight (LMW/HMW) PAHs, phenanthrene/anthracene (Phe/Ant) and benz(a)anthracene/chrysene (B(a)A/Chry), the source is established to be pyrogenic which is linked to coal mining activities which may be due to possible continuous erosion and drains from the coal mine field (acid mine drainage). This may account for increase in the level of PAHs and cPAHs concentration in the groundwater and stream.

In conclusion, continuous erosion, acid mine drainage from the coal mine field into the groundwater and stream could heighten the levels of the PAHs/ cPAH in the study area. A suggestion is therefore made for immediate remediation action of the site.

Naturally occurring radioactivity in Paleozoic Enticho Sandstone aquifer, Adigrat area, North Ethiopia

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Abstract

Elevated level of naturally occurring radioactivity in groundwater from Paleozoic sandstone aquifers in the Middle East and Arabian Peninsula were reported. Radium radionuclides in particular are found in higher concentrations in sandstone aquifers the region. Sandstone aquifers consisting of reworked materials from the Arabian Nubia Shield (ANS) are particularly intended to be involved. This pilot study aims to test the hypothesis on Paleozoic Enticho Sandstone aquifer in northern Ethiopia. Samples were collected from eight wells supplying drinking water to the Adigrat town and the surrounding villages in northern Ethiopia and analyzed for radionuclides. Their corresponding health risk was assessed through annual effective dose estimation for an adult and infant age (< 1 year) group of the population. The results were evaluated for their compliance with WHO (2017) legal limits. In addition, five sandstone rocks were geochemically analyzed to consider the source of radioactivity in the aquifer materials. Heavy mineral separation was conducted on the sandstone samples analyzed. The bulk samples and the light fractions were geochemically analyzed for the major and trace element chemical compositions with ICP-MS and ICP-AES methods.

The activity concentration values of Ra-228 in the groundwater were found to be above the legal limit (100 mBq/L) in five wells, with a range of 20 to 790 mBq/L. The uranium concentration in the groundwater was well below 30 µg/L in all groundwater. The estimated annual effective dose for an adult age due to intake of combined (Ra-228 and Ra-226) has shown 50 % of the collected groundwater samples are above the legal limit of 0.1 mSv/year. For an infant age, the mean annual effective dose due to Ra-228 intake was 1.89 mSv/year, which is nearly 19 times the WHO guideline level of a drinking water. The effective dose due to Ra-226 intake value ranges from 0.02 to 0.57 mSv/year. The combined annual effective dose, was found to be 21.7 times the WHO guideline level.

The geochemical analyses result of the bulk and light mineral fractions was examined to check the association of relevant chemical parameters (Th, U, Zr and TiO₂) with the heavy minerals in the sandstone. The results revealed that Th and U, which are the prominent source of radioactivity in groundwater were found in the light mineral fractions with 57.9 % and 58.8 % respectively. Based on the observed analyses, regarding groundwater radioactivity, one could argue that light mineral fractions in the Enticho Sandstone aquifer contribute significantly than anticipated. Further research is recommended to assess the potential source/s of Th and U in the light fractions.

Comparative study on the heavy metals behaviour in phosphates from the Kalaa Khasba and Oum el Khceb deposits (Tunisia) through the use of sequential selective chemical extractions (SSCE)

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Abstract

Tunisia is one of the largest phosphate producers in the world, and some of these typical phosphorite deposits occur in areas, such as Gafsa-Metlaoui region (SE Tunisia) and Kalaa Khasba (NW of Tunisia). The Gafsa basin is one of the biggest deposits of phosphates under exploitation and is very well characterized in terms of geological features. Therefore, previous studies carried out in the Gafsa-Metlaoui and Oum El Khceb (OUM) deposits, allowed the identification of sedimentological facies, depositional environment, diagenetic aspects, and the geochemical characterization of the region. On the other hand, the Kalaa Khasba (KKH) is a smaller deposit and is no longer in operation, since 1993. Analyses carried out in these phosphates deposits showed that they are of significant economic value due to their high content of P_2O_5 (reaching 29 % in some layers) and chemical yields up to 90%. However, data also demonstrate that these phosphates are enriched in several potential toxic elements, such as Cd, Ni, U and Zn, which concentrations can be about 3 times higher than the world mean concentrations for phosphates[1]. However, when comparing with the shales world average concentrations[2], Cd can reach concentrations of 206 and 240 times, U 44 and 17 times, Ni 1.1 to 1.2 times, and Zn 2.9 and 6.2 times in the phosphates of KKH and OUM, respectively. Anyway, in general, the mean concentrations of these heavy metals in both KKH and OUM deposits do not differ much, and the main differences are found between layers of the same deposit sequence. As the main use of these phosphates is devoted to fertilizers production, the availability and mobility of their heavy metal contents is of great concern either for environmental or human health issues. Therefore, sequential selective chemical extractions (SSCE) were applied to phosphate samples collected from both KKH and OUM deposits, in order to investigate the main support-phases of the highlighted heavy metals. In KKH phosphate samples, Cd is mainly associated with residual phases (more resistant dissolution phases) and also Mn-oxides. However, about 10 to 20 % of Cd is highly available, since it is extracted from the first sequential extraction steps (easily dissolved phases). Nickel is a very available metal in these samples, since about 40 % is extracted from the exchangeable fraction and about 70 % account for the first two sequential steps (i.e. bound to exchangeable and Mn-oxides phases). Zinc shows a quite similar behaviour as Ni, with a high percentage of this element associated to Mn-oxides. Although a great fraction of Zn is bound in residual resistant phases (30-40 %), while the exchangeable fractions account for about 20%, but in some cases can reach 35 %. The SSCE results of samples collected from OUM deposit showed some differences on the representativeness of different support-phases for these metals. Thus, Cd is mainly associated with oxidizable phases (i.e. organic matter), which in average is about 40% of the total Cd extracted, but in some samples can reach 50%. As in KKH samples, there is a significant amount of Cd extracted from the exchangeable and acid soluble phases (20-30 % and, in some cases, 35 % of extraction). Nickel is also highly extractable from organic matter (40-50 %) and is very weakly associated to residual resistant fractions (only 5-10%), while the exchangeable and acid soluble phases represent 10 to 20 %. The Fe-oxyhydroxides (either amorphous or crystalline) are the most important support-phases of Zn (about 40% in average). The extraction from the most available and the most resistant support-phases corresponds to approximately 20 % for each. The results from both studied deposits showed quite differences in the main support-phases of the studied heavy metals and, thus, distinct availabilities. However, the great amounts extracted in the first sequential steps of the SSCE (the most highly soluble phases) poses some potential threats for the environment and human health, due the main use of these phosphates for agricultural purposes.

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poster

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**Geohazards,
Natural and
human-induced
environmental
hazards and
disasters**

Peri-Urban crop and livestock farming for food security and livelihood sustainability in the Nairobi Metropolitan Region Kenya

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Abstract

One of the challenges of the millennia in Africa and Kenya is to eradicate poverty and food security as well articulated in the sustainable development goals (SDGs) and this can be obtained by linking agriculture and food security to investment. Some of the areas requiring constant investigation include the effects of the physical environmental conditions of food security, strategies towards agricultural sustainability, behavioural indicators to food deficits, coping strategies by gender and farming types. Agriculture in Kenya contributes 75 percent of the rural livelihoods and innovations are required to feed the 9.9 million undernourished people between 2014 and 2016. The urban and peri-urban poor are most affected by food (in)security due to inability to afford food leading to several coping mechanisms.

The Nairobi metropolitan region is continually re-defining its boundaries and has now extended to Kajiado and Machakos counties This study examines how plant resources are selected, cultivated and marketed within the two adjacent counties to Nairobi County to support food security in urban and peri-urban areas now and in the near future. This research used mixed methods approach and was carried out in Machakos and Kajiado Counties of Kenya due to their proximity to the City of Nairobi. Sampling of market farms around the main markets (in urban and peri-urban areas) was done in these counties. The various crop and livestock farms found in the region were identified and classified. Questionnaire was administered to traders, farmers and county government officials regarding specific aspects of the research. Specifically, this research process transcended different disciplines making it highly trans-disciplinary in nature with active diverse and relevant academic and non-academic partners, who are key generators and users of data and information gathered. The research employed methodological polytheism, in that, it acknowledged the strengths of embracing a pluralistic approach by employing a variety of methods as no one set of tools is categorically better than the other, therefore, this research made several moves back and forth between theory (re)construction and data analysis. It is committed to a holistic inquiry as assesses the interplay between human agency, systemic structures, and tensions while at the same time acknowledging the reflexivity of the process. It was also aimed at achieving social change in the food security spectrum, thus the relevant partners both academic and non-academic will be co-opted. The aim of the paper for presentation is analysis of food insecurity variables in two peri-urban counties of Kenya. We aim to determine whether the SDG of good health and wellbeing is possible or even attainable from the selected counties which supply the highest food and livestock products to the capital city of Nairobi.

Paleo flooding events in the Limpopo River floodplain, Mozambique

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Abstract

Sediment stratigraphic records of magnetic susceptibility (χ) and saturation isothermal remanent magnetization (SIRM) in Lake Magandane and Lake Soane were used to investigate paleo flooding events occurring in the Limpopo River floodplain. Chronological models were established using ¹⁴C dating of the terrestrial gastropod *Melanooides tuberculata*. χ indicates the ability of grains to be magnetized and is affected by concentration, shape, size and mineralogy that is interpreted to be the result of changes in grain size (Šroubek et al., 2007). SIRM is associated with the concentration of ferrimagnetic particles and is affected by sediment source (cf. Siteo et al., 2015; Thompson and Oldfield, 1986). Therefore, high values of χ and SIRM are interpreted to represent sediment deposited in high energy environment connected to flooding events (Siteo et al., 2015). The data indicate that at least seven high and nine low magnitude flooding events have affected this floodplain during the last c. 1100 years. The high magnitude flooding events are dated to c. AD 1250, 1300, 1370, 1580, 1855, 1920, 1970 and 2000, while low magnitude events are dated to c. AD 940, 980, 1040, 1100, 1300, 1665, 1755 and 1945. Written sources indicate that the Limpopo River floodplain has been affected by at least eight flooding events during the last 62 years, while our records only revealed two events. This suggests that only major events were picked up from our proxy-data. Furthermore, the above identified flooding events do not always co-occur between different sites, which might be associated with dating uncertainties, spatial distribution of sediments during flooding events depending on local or upstream precipitation, topography, geomorphology (especially the distance to the contemporary river meandering channel). This shows the need to apply a multi-core approach targeting several sites in order to identify as many flooding events as possible. These should in the ideal case be spread both upstream and downstream, as well in east-west direction.

Although minor differences regarding dating and duration, Lake Magandane and Lake Soane records revealed at least three of the four high magnitude flooding events retrieved from grain-size, χ and SIRM in the Coassane Oxbow (Siteo et al., 2015). These are dated to the AD 1260 ± 60, 1385 ± 75, 1500 ± 75 and 2000. Differences in age and duration can be attributed to dating uncertainties, but the above mentioned factors for flooding non co-appearance among sites should be considered. Our records are also in agreement with a tree ring carbon isotope record from upstream the Limpopo River basin, in the Northern Province (Woodborne et al., 2015; 2016), which displayed peaks of flooding events at c. AD 1075 and AD 1270.

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Impact of the oil exploitation on the Albertine Block: case of the Virunga National Park at the East of DR Congo

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Abstract

The recent discovery of the hydrocarbons resources in the Eastern Congo (oil and methane gas) opened the world to deepen the research of the oil reserves in the national park of Virunga while the gas also found in Kivu Lake.

More of the exploration activities are did in several borders countries, the gas methane exploitation in Rwanda and oil in Uganda.

The possibility to improve the social conditions and the economic growth in the region cannot be appreciated while by the way the demand in energy fuel in the region continues to grow. However, the discoveries have been made in the most ecologically areas of some various regions of the country whereas is exploitation causes negative impacts on fauna, flora and the human ecosystems, therefore the destruction of the environment.

In Uganda, the oil exploration and activities of the production are visible in the Albertine graben mostly nearby national parks and their relative effects on fauna cannot be underestimated according to the testimonies of the land populations. The exploitation activities of the gas methane of the Kivu Lake in Rwanda also have the negative impacts on the environment. In DR Congo the same project is under examination in order to reduce the demands in energy of many cities of the region among them Goma, Gisenyi and Bukavu.

The environmental impacts of the oil and gas methane extraction can cause several damages on the environment like the destruction of the atmosphere, the contamination of the lakes and rivers waters, the destruction of the ecosystems of animal shelters, the pollution of waters, the changes of climates, the ecological damages, falls of oil, intensification of the greenhouse effect, acidic rain.

The importance of a synergy between the protection of the environment and the economic operators of this sector according to the exploitation of the hydrocarbons put a challenge in the past of our days and can continue in the future. These challenges must be addressed to the national authorities so that the exploitations of the hydrocarbons and gas put a minimum of impacts on the environment while maximizing the profits to the biophysical, economic and social aspects of environment in which such activities are undertaken.

Overview of hazardous elements present in incrustations resulting from the 2014-15 eruption of Fogo volcano, Cape Verde

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Abstract

The last eruption of the Fogo volcano (Cape Verde) occurred between November 23, 2014 and February 7, 2015, producing extensive lava flow fields (a'a and pahoehoe), that destroyed houses and agriculture (mainly vine and fruit plantations). Furthermore, the hot volcanic gases (pure or resulting from their interaction with surroundings) emitted through vents and fissures for a long time, transport volatile species that are released to the atmosphere or deposited by cooling and condensation or sublimation - fumarole incrustations. Minor and trace elements carried by minerals on these materials, can be hazardous to health, depending mainly on its nature, concentration and speciation. Therefore, the chemical characterization of incrustations and altered rocks were undertaken to identify possible harmful elements.

Two techniques were used: X-ray fluorescence spectrometry with wavelength dispersive system (XRF-WDS), performed at the laboratory to obtain a semi-quantitative analysis, and energy dispersive X-ray fluorescence (EDXRF) used at the European Synchrotron Radiation Facility (ESRF) in Grenoble, France. The high brilliance of synchrotron X-rays, allows for remarkably low limits of detection for most chemical elements, thus enabling the analysis of trace and sub-trace species hosted by a mineral.

A large span of minor and trace elements, some of them potentially toxic, were identified - Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Mn, Fe, Ni, Cu, Zn, Ga, As, Se, Br, Rb, Sr, Y, Zr, Nb, Mo, Ba, Ce, Pt, Hg, Tl, Pb, Bi, U. The crystal structure of the carrier mineral phase strongly constrains the range and content of elements that may be hosted in the various structural sites available, however the presence of some heavy metals, e.g. Hg, Tl, Bi, U, plays a major environmental concern as local populations use sulphur and white materials as treatment for some diseases. The crystal structure of common sulphur is built up by the packing of S₈ molecules restraining the diadochic replacements to Se and As in solid solution. Results to be presented will show the identified phases and detected concentrations of hazardous heavy elements. The highest content obtained for Se by XRF-WDS, was 1000 ppm. The white materials are mainly sulphates (anhydrite, bassanite, gypsum, thenardite) incorporating As, Ba, Pt, Hg, Pb, Bi and U, while the toxic metal Tl (highest content, 2000 ppm) is carried by ralstonite, an hydrated aluminum fluoride. The presence of these geohazardous elements was also noticed following the 1995 eruption of the same volcano endangering the local population.

Intensification of coastal occupation of Bukavu city: analysis of vulnerabilities facing mass movement

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Abstract

In developing countries in general, and particularly in the Democratic Republic of Congo (DRC), the urbanization rate and population growth, associated with poor adequate policies, is one of the causalities that explain the increasing vulnerabilities. According to UNEP (2011), in DRC, the population is mainly rural. However, the country has shown a demographic growth rate of 4, 6 % per year (from 2005 to 2015), which is superior to the demographic growth in rural area and to the national average, respectively from 1, 8 % and 2, 8 %. Bukavu is located in the eastern part of DRC close to the Lake Kivu and Ruzizi River where many natural hazards such as earthquake, landslides, occur and have effects on people activities. The population density and the socioeconomic level are among the factors that influence the landuse. Hence, the combination of permanent and active mass movement with vulnerabilities is crucial to the risks that people can undergo in the city.

For this, two main zones are investigated. The first one is located in the Lake Kivu coastal zone where some researches (Dewitte, 2017) have shown that the landslide is shallow: it means the susceptibility to landslide is low; while the landslide in Ruzizi River coastal zone is deep: it means the susceptibility to landslide is high. In the direct approach, through field observations, we are going to identify different environmental and physical parameters that explain this complexity in the coastal zone of Bukavu.

In addition to this, a diagnostic survey will be done to understand the perceptions of different actors in regard of the space organization, natural hazard knowledge, risk representation and risk management. In indirect approach, a diachronic analysis by mapping and statistical method (qualitative analysis) will be made. This will provide an understanding of population vulnerabilities in regard of the mass movement dynamic in the coastal zone of Bukavu. This study will help to understand the relation between vulnerabilities and mass movements in the context of urban growth, informal buildings and demographic pressure in the coastal zone of Bukavu.

Geoenvironmental maps in African context: its importance to land use planning in coastal cities

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Abstract

Geoenvironmental maps covering a set of sensitive features can be determinant for the basic well-fare of the populations living in the suburbs of large cities. In African cities where environmental problems can be an obstacle to achieve a minimal quality of life, the information provided by these maps can be a useful tool to land use planning to mitigate these problems. Several subjects are used, such as geology, groundwater and soil quality, land cover and groundwater access to local populations. A good knowledge on these subjects is fundamental to predict future problems, to ensure that the cities are correctly developed and to correct or mitigate the actual problems. Furthermore, in coastal cities, the protection of groundwater resources and their sustainable management, require the understanding of the coastal area geodynamics and hydrogeology. In Beira city, Mozambique, this is not exception. Beira city is located below the mean sea level on the mouth of the Pungwé River and has environmental problems related with the overcrowded suburbs which increase its vulnerability to environmental problems. In order to assess and futurely prevent the origin of some problems related with above mentioned issues in the city urban planning, a set of interdisciplinary methodologies was used as part of a regional geoenvironmental study of the Beira region, with special focus in the Beira city. Firstly, it involved the detailed analysis of LANDSAT and ASTER multispectral satellite images, aerial photography and existing topographic maps of several ages. The images were used to check the accretionary regime of the Pungwe River and changes in coast line as well as land cover mapping based on Corine Land Cover (CLC) classes adapted for tropical regions. Regarding water and soils, sampling surveys were planned and carried out with a representative remote sensing distribution of the samples origin. On the field, several works were conducted: i) regional geological surveys to identify and characterise the geological units and updating of the Beira Geological Map at 1/50.000 scale, ii) field validation of the classes obtained through the analysis and processing of the satellite images, iii) soil, streamline and channel sediments sampling surveys for a geochemical characterization of the inorganic and organic compounds iv) groundwater sampling survey for hydrogeochemical, microbiological and organic inorganic compounds contamination and v) ground geophysical prospecting with frequency electromagnetics (FDEM) Geonics EM34 in environmentally critical areas or requiring additional information. Using these methodologies, important information regarding land use planning was produced to be used by legal entities, in critical issues like groundwater supply to suburbs of Beira, prediction of future problems in coastline sustainable management, or to identify major contaminants in soils and waters in critical areas.

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Geosciences Education in Africa

Using social media sites to promote the role of geo-education, geo-tourism and geo-ethics in Egypt

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Abstract

In the world of today, media has become almost as necessary as life essentials. It is true that media is playing an outstanding role in strengthening the society, and recently it plays an important role in educate people in all ages. The media has a strong social and cultural impact upon society. Because of its inherent ability to reach large number of public, it is widely used to convey message to build public opinion and awareness, the information revolution mass media has become such a massive part of our lives, media denotes an item specifically designed to reach a large audience or viewers from this point the idea of applying the concept of Geo-education and encouraging people for geo-tourism was the main target for this article.

A group on facebook was established to provide people with a combination of understanding, attitudes, and abilities that they will need throughout their lives. Understanding, knowledge, appreciation to the earth.

Monitoring the effect of people and number of members through time to see the outcomes of a geo-education, a geologic trip was done after 5 month of establishing the group to make a successful geo-education results, in this trip an application of geo-ethics was applied to provide a community for geo-educators.

An obvious increase of members and interact after the first trip detected in the group, which make a good achieve to the main group goal.

Finally, social media is very powerful tool in achieving a learning aims regardless the kind of community, where this group was one of our steps toward the main goal of providing all people with a well-rounded geo-education.

poster

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**Geosciences
Education
in Africa**

Aerial photography from Niassa Province in Mozambique

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Abstract

“Centro de Informação Geoespacial do Exército” (CIGeoE) has stored several boxes with aerial photos of the 60s from Mozambique. These aerial photos are not organized or inventoried and is an unexplored source of information collected during the Portuguese military occupation in that country. CIGeoE was contacted and promptly available the photos and collaborate for its classification to which Department of Geosciences of the University of Aveiro (DGeoUA) appreciates.

The aerial photographs in question, some of them in poor condition of conservation, are positive proofs on black and white photographic paper, with an approximate scale of 1/40000 and have image overlap in about 60%, thus enabling coverage and stereoscopic study of the areas and the possibility of photointerpretation using the relief.

Taking in advantage the presence of the Mozambican student in the master's course degree of Geomaterials and Geological Resources at the University of Aveiro, it was made an inventory, treatment and classification of almost 2000 aerial photographs. The photographs are mostly from Niassa Province and a few from Cabo Delgado. Many more remained without treatment.

The organization and classification involved the following tasks: (1) a raster scan of each photo in a resolution of 600dpi on TIFF format. (2) after scanning, each photo was georeferenced. For georeferencing was used the Google Earth platform, free available on the Internet, which, together with knowledge of Mozambique's geography, was able to georeferenced at least four points on each photo. The points used were features identified on the ground such as connection points of rivers, topographic higher sites, location of buildings/monuments in villages, etc. (3) after georeferencing, ArcGIS (version 10.5) was used for projection and location on the ground and maps. (4) taking advantage of this collected information, layers with geological and geomorphological maps available in the literature, of different scales, were added.

With this work the following objectives were achieved: (1) to start the inventory, organization and classification of a part of the aerial photographs from Mozambique. (2) georeferencing aerial photographs using Google Maps and ArcGIS. (3) contribute to the consolidation of the geographic and geological knowledge of Mozambique, in particular of the Province of Niassa.

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**Integrated
approaches
in Geology
(Medical Geology,
Geophysics and
Geochemistry)**

Cape Verde geophagic clays (from Santiago, Boavista and Fogo islands)

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Abstract

A Cape Verde is a country where the use of clays with healing purposes is well known. People consume clay materials, namely by ingestion, in order to treat gastrointestinal disorders (e.g. diarrhea and nausea) or as a supply on their diet. Geophagy (the practice of eating soil or other geological substances) can be harmful for health, namely when Potential Toxic Elements (PTEs) are present in high concentrations. Moreover, when soils are ingested as a way for supply mineral deficiencies, may occur the opposite effect, since the absorption of certain nutrients can be inhibit, due to the excess of others. Considering this, the mineralogical and geochemical composition, as well as the technological properties of samples from three islands of Cape Verde archipelago (Santiago, Boavista and Fogo), were studied in order to understand the behaviour of the clay materials that are being used by the locals to this end. Fraction under 63 microns was obtained through wet sieving and under 2 microns through sedimentation, according to Stokes law. All tests were performed on fraction under 63 microns, with exception of SEM/EDAX that was performed only on fraction under 2 microns. Mineralogical analysis was carried out by X-Ray diffraction, using a Panalytical X'Pert-Pro MPD, $K\alpha\text{Cu}$ ($\lambda = 1,5405 \text{ \AA}$) radiation on random-oriented powders (fine fraction) and oriented aggregates (clay fraction). The oriented aggregates were treated with glycerol and heated up to 500 oC. Chemical composition was assessed by X-Ray Fluorescence using a Panalytical Axios PW4400/40 X-Ray Fluorescence spectrometer for major and trace elements. Loss On Ignition (LOI) was also determined. The cation exchange capacity (CEC) was determined using ammonium acetate ($\text{CH}_3\text{COOHNH}_4$) as saturation solution. A HANNA HI 9126 equipment was used to assess pH. Abrasiveness was determined with an Einlehner AT 1000. Atterberg limits were assessed using a Casagrande shell to obtain the Liquid Limit and rolls in a glass plate were performed and measured to obtain the Plastic Limit. Expandability was performed according to the LNEC E 200 from 1967 specification. Viscosity was accessed with Haake Viscotester iQ, Thermo Scientific; Rotor: CC25DIN/Ti. Specific Surface Area was assessed through BET, measured with a Gemini II 2370 equipment and specific heat was determined with a DSC-50 Shimadzu. Some interesting results were obtained, namely concerning mineralogy and chemistry. All samples revealed adequate composition, being rich in phyllosilicates, namely smectite, well known as good for ingestion purposes, due to its absorption capacity (Santiago is a pure smectite clay). In terms of chemistry, high contents on silica, iron, magnesium, potassium and calcium were detected; some PTEs are also present. Concerning remaining properties, high expandability (up to 89% on Santiago), high/medium values for CEC, sorption capacity, specific surface area and plasticity as well as fine to medium grain size and low abrasiveness are all suitable for geophagic purposes. Thus, all studied clays display physical and chemical properties that could justify their use as geophagic clays, particularly for the healing of gastrointestinal affections, essentially based on their high sorption capacities (mainly those from Santiago: 89 % and Boavista: CB4 with 23 %). Bioavailability tests of some chemical elements present in these samples are advisable before use.

Geochemical characterisation of lead in urban soils and sediments of Nigeria: a case from Southwestern Nigeria

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ABSTRACT

The presence of Heavy Metals (HM) in soils, sediments and dusts are good indicators of contaminations of urban environment. Lead (Pb) is of grave concern amongst other HM because of its toxic impact on the environment and human health. Previous studies on HM have focused on the determination of concentrations and spatial distribution in various Nigerian cities. However, the geochemical fate and nature of Pb in Nigeria's environmental media is relatively unknown. This study was therefore designed to quantify and characterize Pb in soils and sediments from Southwestern Nigeria.

A total of ninety composite soils, 56 sediments, and 10 representative rock samples were collected randomly from two mega-cities in southwestern Nigeria (Ibadan and Lagos). Soil and sediment samples were air-dried, screened, pulverised and sieved through 63 µm nylon mesh. The sieved fractions and pulverised rock samples were digested using standard methods and analyzed for elemental components using ICP-MS. The chemical fractionations of Pb in the samples were determined by sequential analysis. Lead isotopes compositions of the samples were determined using quadrupole-based ICP-MS. Mineralogical analyses of rocks and other samples were determined using X-Ray Diffraction.

The concentration (ppm) of Pb in soils and sediments for Lagos were: 21.0-1963.0 and 23.0-830.0; while in Ibadan soils and sediments were: 13.0-470.0 and 17.0-3288.0; respectively. Chemical fractionation (%) of Pb were: organic-sulphide (42.78-82.45); reducible (8.23-27.20); carbonate (9.00-43.60) and exchangeable (0.01-0.23) phases, respectively. Lead isotopes (ppm) showed that ²⁰⁴Pb ranged 1.72-47.41; ²⁰⁶Pb, 30.69-779.68; ²⁰⁷Pb, 27.00-664.46 and ²⁰⁸Pb, 65.67-1642.27 in Ibadan samples while that of Lagos were: ²⁰⁴Pb, 1.43 - 31.00; ²⁰⁶Pb, 25.26 - 509.74; ²⁰⁷Pb, 21.96-446.22 and ²⁰⁸Pb, 52.61-1089.93. Ibadan and Lagos rocks Pb isotopes (ppm) were: ²⁰⁴Pb, (0.02-0.07 and 0.03-0.06); ²⁰⁶Pb, (0.56-2.33 and 0.56-1.21); ²⁰⁷Pb, (0.38-1.56 and 0.47-1.01) and ²⁰⁸Pb, (1.19-4.13 and 1.22-2.57), respectively. Quartz, microcline, k-feldspar, plagioclase and kaolinite were the preponderant minerals in powdered rocks, soils and sediments. An enrichment of radiogenic Pb (²⁰⁶Pb, ²⁰⁷Pb and ²⁰⁸Pb) were observed in soils and sediments relative to their local background values, an indication of anthropogenic origin of Pb. The plots (²⁰⁸Pb/²⁰⁷Pb)/(²⁰⁶Pb/²⁰⁷Pb) revealed that over 80% of Pb in the environmental media was derived from anthropogenic sources. The LIRs of soils and sediments were characterised by lower ²⁰⁸Pb/²⁰⁶Pb ratios while the bedrocks had higher ²⁰⁸Pb/²⁰⁶Pb.

Delineating soil productivity using geophysical parameters and permeability: case study at Cocoa Research Institute, Ibadan, Nigeria

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Abstract

Evaluating the physical properties of agricultural soils in ascertaining its productivity is an indirect approach of determining nutrient available for plant uptake, which is cost effective and efficient in demarcating site specific management zone. This study arose from differential growth rate observed on some kola trees at Cocoa Research Institute of Nigeria with a focus on testing the effectiveness of physical parameters and soil permeability in delineating soil productivity areas in the farm. The farm covers an area of 6,300 m² which has been in existence for six years.

Seasonal assessments of the kola farm were conducted using apparent Electrical Conductivity (ECa), Volumetric Water Content (VWC), thermal properties and soil permeability at the root zone (0.3 m) to delineate soil's management sections within the farm. A sum of twenty-one lines were occupied at kola farm consisting of 700 ECa/VWC data points at both seasons on a non-saline soil using Allied resistivity earth meter (ECa) and VG-meter-200 soil moisture meter (VWC) in the north-south direction. KD2PRO was used in ascertaining the thermal properties and 67 stations were occupied at both seasons; and permeability test was conducted on ten disturbed soil samples selected from the regions of high to low ECa with the aid of ELE permeameter. ECa, VWC and thermal maps were generated using ARCGIS software.

Strong correlation existed between ECa and VWC, and regions of high ECa/VWC were characterized by soils of low thermal diffusivity, high specific heat, high thermal conductivity and weak to moderate correlations were observed between these thermal properties and ECa/VWC. Soil permeability (k) studies around kola plot revealed that soils from high ECa section have low permeability (0.000145 to 0.00043 cm/sec) were classified to be silty clay with moderately slow to moderate infiltration rate; soil of medium permeability (0.000543 cm/sec) is suggestive of moderate rate of infiltration while electrically less conductive soils (low ECa) were characterized with high permeability (0.000546 to 0.005964 cm/sec) indicating moderate/moderately rapid/rapid infiltration associated with nutrient leaching and water depletion, categorized as silty clay/fine sand.

The use of soil physical parameters in delineating the management zones has helped in mapping out sections of healthy kola trees growth to be zones of high EC/VWC, low permeability and vice versa.

Characterization of Rammed-earth and coating materials of Badii Palace (Marrakech, Morocco)

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Abstract

The city of Marrakech contains some of the most prestigious monuments of Islamic art: Agdal and Koutoubia (12th century), the Saadian Tombs (16th century), Badii Palace (16th century). During the last few decades, interdisciplinary research and new technologies have been introduced in damage diagnosis and monument preservation activities. This study is based on the characterization of 18 representative samples collected from different parts of the Badii Palace and investigated for their particle size distribution, chemical and mineralogical characteristics in order to assess the technique and the provenance of the earth utilized by Saadian (16th century) in the construction and to identify suitable materials for restoration. In order to not damage certain parts of the monument, micro-sampling was performed according to the protocol adopted by the conservation of historic monuments of Marrakech. The samples can be classified into three categories: rammed-earth samples (seven samples labeled Pis), coating samples (six samples labeled Rev) and local raw materials (five samples labeled Mar).

The mineralogical analysis was performed by X-ray diffraction (XRD), using a X'Pert-Pro MPDPhilips/PANalytical X-ray diffractometer ($\text{CuK}\alpha$; $\lambda = 1.5405 \text{ \AA}$), on powdered bulk sediment and on the <2 mm fraction. Chemical analysis of < 63 μm fraction was assessed by X-ray fluorescence spectroscopy (XRF) using a Panalytical Axios spectrometer equipped with Rh tube, the used gas being Argon/Methane, and used data processing program were IQ+. Multivariate statistical analysis were performed on the obtained data, using Cluster Analysis, Principal Components and Discriminant Analysis. The results show clear differences in compositions between the rammed-earth and coating materials; this suggests a different origin for these two types of materials. The analyzed samples collected from well-preserved places of the wall show a perfect compatibility between the coating material and that of the corresponding rammed-earth. However, in many parts of the wall where the original coated materials have deteriorated by natural weathering and by the corrosive action of polluted atmospheres, the incompatibility of these two types of materials is evidenced. The composition of coating material currently used for the repairing shows the same incompatibility with the substrate, it may show the same degradation problems. Finally, for both types of materials (rammed-earth and coating), we can conclude that the raw earth material was extracted from 2 different deposits, but both around the city area.

Potential health risk via dietary exposure to potential harmful elements in Kadoma Zimbabwe

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Abstract

In the Sanyati catchment area of Zimbabwe certain diseases were noted to be more prevalent in the mining areas compared to non-mining areas. The diseases with higher prevalence in the mining areas include chronic heart failure, chronic renal failure, cancers and still births. Several postulates can be advanced to explain the co-factors that account for the aetiology and prevalence of these diseases. One possible explanation hinges on the accumulation of PHEs in staple food, as a co-factor. This study estimated daily intakes (EDIs) of twenty potential harmful elements (As, Be, Sb, Cd, Cr, Cu, Pb, Hg, Ni, Se, Ag, Zn, Co, Sn, Te, Pd, Pt, Au, Tl, and Bi) in nine vegetables (viscose, cabbage, pumpkin leaves, okra, tomato, carrot, peas, onion and covo), commonly consumed by people around Kadoma, Zimbabwe one of the areas with the highest mining activities. The daily intakes were determined to assess the potential health risks. All samples were analysed using Inductively Coupled Plasma – Mass Spectrometer (ICP-MS). Be, Te, Pd, Pt, and Bi were not detected in the vegetables. The rest of the potential harmful elements (PHEs) were detected in the vegetables. Based on the maximum acceptable limits set by the Joint FAO/WHO Food Standards Programme Codex Committee on Contaminants in Foods Zn, Pb, Cr, As and Ag are the elements with a high risk. Pumpkin leaves and tomatoes appear to have more risk than the other vegetables

Subsurface mapping and reservoir estimation of Enena Field, Offshore Niger Delta

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Abstract

An integrated approach using well log data, seismic, sequence stratigraphy and geological information was employed for the mapping and evaluation of the Enena field in order to estimate the reservoir properties, fluid distribution, and economics as well as to construct a 3D modeling of the field.

The sequence stratigraphic study of the field using the Gamma Ray (GR) log was employed. The integration of petrophysical, structural and stratigraphic data was carried out and an algorithm through Gaussian random function simulation for static modeling was developed. The resultant static model was then used for volumetric distribution of the field. Two (2) cases were studied differently because of unavailable neutron data from the Oil Company and the seismic volume was of poor resolution with missing portions.

The GR log shows a coarsening upward sequence (which is indicative of a high stand systems tract), and a prograding complex. Four reservoirs were identified namely, the S30, T40, U50 and V60 reservoirs with a STOOIP of 51.3, 15.1, 0.0 and 17.1 MBO respectively and recoverable reserves of 18, 5.3, 0.0 and 6.0 MBO assuming a primary recovery factor of 0.35 and 33.5, 9.8 and 11.1 MBO as well as a 2P recoverable reserve of 0.65 were utilized. The GIIP was estimated as 28, 8, 0.0 and 9.0 BCF of gas and the recoverable reserves shows a P1 of 18.2, 5.2, 0.0 and 5.85 MBO at a recoverable reserve of 0.65 and a 2P of 22.4, 6.4, 0.0 and 7.2 MBO at a recoverable reserve of 0.8 was estimated for the four reservoirs. STOOIP and GIIP was not calculated for the U50 reservoir and zero value was assigned because, despite the thick / good sand package as seen on the GR log, the reservoir was found to be water wet. Out of the four reservoirs, the S30 reservoir is found volumetrically the most significant both in the oil and gas case respectively, the individual sands and their sub-units are separated by thick to thin shales.

This study revealed that the natural driving mechanism of the Enena field is the water drive and could be recommended for marginal field operators based on existing guidelines for bidding.

Geological mapping and geophysical investigation of associated sulphide mineralization around Baban-Tsauni area, North-Central Nigeria

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Abstract

Understanding the structural setting and ore body geometry had been a major challenge in mineral exploration. This study focuses on delineating structural setting and lithological association playing host to the reported lead and associated sulphide mineralization around Babban Tsauni area, north-central part of Nigeria. The area is underlain by basement rock comprising migmatitic gneisses, granitic intrusions, quartzite with few intrusions of pegmatites and aplites.

The airborne magnetic and radiometric dataset of the area was compiled and subjected to various enhancement techniques and derivatives computations, to enhance subtle structural and lithological information for effective interpretation. Geological ground truthing helps identify lithology characterized from airborne radiometric; while ground magnetic studies with higher resolution was employed to decipher the local structures.

Interpretation of the aeromagnetic data shows that the structural setting was characterized by NE-SW primary structure and other secondary structures trending almost N-S, NNW-SSE and some few WNW-ESE. Since the mineralization was structurally controlled, the mineralizing fluids are interpreted to have been emplaced in the much younger secondary structure in the NW-SE and the WNW-ESE trends. The mineralization as evaluated from the radiometric data was suspected to be related to regions of high thorium concentration which are gneissic in composition. Also, two large intrusives (granitic) were mapped out from the magnetic, radiometric and ground truthing and suspected to be of similar origin but giving varying radiometric signatures due to depth of burial as interpreted from the magnetic data. The ground magnetic survey picked more of the local structures which are mainly in the NW-SE and NNW-SSE, which was in agreement with the horizontal gradient derivative of the aeromagnetic data.

Thus, integration of airborne radiometric, aeromagnetic, geological ground truthing and ground magnetic studies have helped in identifying some possible structures which play host to the associated sulphide mineralization within the study area.

Geochemical characterization and heavy metals sorption of clay-shale materials from Anambra Basin, SE-Nigeria as landfill liners

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Abstract

Challenges of solid waste management and associated environmental contamination problems due to increasing population growth and urbanization warrant the need for disposal of wastes in properly engineered landfills. However, geochemical characteristics and sorption behaviour of liner materials in such landfills are critical for attenuation and removal of contaminant metals from leachates. Hence, this study was designed to determine the mineralogical, geochemical and sorption properties of some clay-shale samples to determine their suitability as land-fill liner materials, as replacements for expensive, imported synthetic liners in a typical developing country, like Nigeria.

Three clay and four (4) shale samples were analysed for bulk chemical composition using the Atomic Adsorption Spectrometer (AAS) while the cation exchange capacities (CEC) were determined using Ammonium Acetate method. The mineralogical compositions were determined using X-ray diffraction (XRD) technique while batch adsorption studies were carried out in order to investigate the effects of contact time and initial concentrations on the adsorption of Cu, Zn and Pb by the clay-shale materials. The adsorption isotherms were evaluated using Langmuir and Freundlich models.

The results of the bulk chemical composition revealed high content of SiO₂ (45.5-58.0 %) and Al₂O₃ (14.5-32.8 %), suggesting that the clay-shale materials are rich in quartz, feldspar and mica group. However, the clay materials have higher CEC of 6.98-7.62 meq/100g compared to the shale materials with CEC of 4.90-5.73 meq/100g. The mineralogical composition was consistent with the CEC as clay materials exhibited relatively higher content of kaolinite, while shale materials have traces of smectite (0.7-4.1 %). The sorption tests revealed that increase in metals (Cu, Zn and Pb) concentrations from 25 mg/l to 100 mg/l and from 250 mg/l to 500 mg/l resulted in about 5-10 % reduction in adsorption capacity of the clay and shale materials. However, all the metals exhibited 94-98 % removal within four (4) hours of reaction time suggesting effective sorption. In addition, the sorption data fitted well with the Freundlich adsorption isotherm model with correlation of R² > 0.99 compared to that of Langmuir model with R² < 0.50.

Nonetheless, higher sorption capacity as estimated by the K_f-parameters of the Freundlich for the clay materials was consistent with higher kaolinite content and CEC compared to the shale materials. The overall evaluation revealed that the clay/shale materials can serve as cheap sorbents for removal of contaminant heavy metals from aqueous leachates in landfills while the study underlies the application of local naturally occurring clay-shales as alternative cheap liner materials compare to expensive imported synthetic liners in developing countries.

Radiometric signature of the Bosumtwi impact crater: new insights of the K anomaly

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Abstract

Geophysical methods have been used to characterize geological structures potentially resulting from a meteoritic impact, particularly for highly eroded structures or those buried under sediments. Gravimetry, magnetism and 2D electric methods have been used for decades, but airborne radiometric data has been rarely used. Radiometric data are commonly used for geological mapping in mineral exploration - particularly in tropical regions where outcrop conditions are poor. Maps of K, Th, and U surface concentrations, at different scales, are derived from airborne radiometric data obtained by measuring the natural activities of ⁴⁰K, ²³²Th, and ²³⁸U. To date, K-Th-U radiometric signatures of only two impact structures have been described - Bosumtwi in Ghana [1] and Serra da Cangalha in Brazil [2]. In both cases the structures are characterized by annular high-K anomaly, and Serra da Cangalha is also marked by annular low-Th and low-U anomalies. Bosumtwi is a complex impact structure of 10.5 km diameter and 1.07 Ma age. The structure shows a double-ring K anomaly. The first anomaly, 10 – 12 km from the center, more or less corresponds to the crater rim section (ring I). The second one has a diameter of about 18 km (ring II) [3]. We report here the combined results of field observations and initial analyses of a series of measurements of K-Th-U concentrations obtained with a handheld spectrometer at the Bosumtwi impact structure. Forty-six sites were visited around the structure along several radial profiles extending from the rim, across the ejecta layer (from ring I to ring II) and beyond ring II. The measurements reveal that the relatively high-levels of K, up to 3.5 wt%, generally correspond to outcrops of brecciated metasediments (shales, slates, meta-tuffs) sometimes including impact melt. On average, the K concentration on the granite measured by the FPGRS is ~1.3 wt%. In the literature the concentrations of K range from 1.3 to 1.5 wt%. K-rich regions are often associated with steep or rough topography (rim, or abrupt termination of the ejecta blanket [4]). Low-K content outside the crater and its ejecta are associated with a thick and well developed lateritic cover that occurs throughout the environs of the impact structure. A smooth topography, with a thin lateritic layer (1 m thick) occurs over K-rich metasediments in the ejecta blanket between the two rings. From these observations we propose a new hypothesis to explain the double-annular K anomaly. The impact occurred into metasediments covered by a thick (10 – 20 m) lateritic cover. The initially K-rich ejecta layer and rim (composed of metasediments) was subjected to erosion and alteration. The rough topography of the rim and ejecta front have been continuously eroded since impact time and new fresh K-rich metasediments are continuously exposed to the surface, whereas a lateritic cover has started to develop on the main part of the ejecta layer in a flat area separating the two rings. If this hypothesis is confirmed by further analysis, the Bosumtwi impact structure may be used as a natural laboratory to study regolith formation since 1 Ma.

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Organic geochemical evaluation of shale intervals within Bokh formation, Ogaden Basin, Ethiopia

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Abstract

The Ogaden basin is the largest sedimentary basin in Ethiopia and has been a target for hydrocarbon exploration in the last few decades. The basin has been explored before but the exploration strategies were based on regional geological information, basin evaluation, and biostratigraphy of the basin with little information about the hydrocarbon potential. On the contrary this study utilizes organic geochemical parameters in determining the hydrocarbon source potential of the associated shales from the subsurface samples within the basin. Fifteen (15) representative core cutting shales samples were collected from Calub-2 and Calub-3 wells, within the Bokh Formation, at different depths; 3280 to 3595 m and 3320 to 3585 m respectively. The samples were subjected to detailed sedimentological description and subsequent Total organic carbon and Rock-Eval analyses. Result of total organic carbon (TOC) for Calub-2 ranges from 0.76 – 0.83 wt% (av. 0.59 wt %) while the TOC for Calub-3 ranges from 0.68 – 0.86 wt% (av. 0.77 wt %) indicating poor source rock. The genetic potential (GP) for Calub-2 ranges from 0.17 - 0.5 mg/rock (av. 0.345 mg/rock) while GP for Calub-3 ranges from 0.09 – 0.25 mg/rock (av. 0.17 mg/rock) which is lower than the minimal 2 mg/g rock GP required for the potential source rock. The hydrogen index (HI) values of the shales range from 13 – 32 mgHC/gTOC (av. 21.5 mgHC/gTOC) and 8 – 21 mgHC/gTOC (av. 14.5 mgHC/gTOC) for Calub-2 and Calub-3 respectively indicating gas prone source rock. The cross plot of TOC vs. S₂ (on Langford and Bordenove) and HI vs. OI (on the Van Krevelen) diagram shows that the shales are mainly type IV and inert with no potential to generate hydrocarbons mainly crude oil. The overall Tmax and production index (PI) values range from 388 to 453°C and 0.28 to 0.46 respectively indicating thermally immature to matured shales. It can be deduced that the shale units of the Bokh Formation in Ogaden basin have little or no potential to generate hydrocarbons. This is mainly associated with poor source of organic matter mainly arising from inert organic matter.

Photogrammétrie et photo-interprétation sur images aériennes de haute définition et observations de terrain pour la caractérisation du recul du front de mer sur la côte de Kribi-Cameroun

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Abstract

La zone étudiée est située sur la côte de Kribi-Cameroun, d'orientation N-S sur l'océan Atlantique, entre 2°45' et 3°00' latitude Nord. La majorité des vagues ont une hauteur inférieure à 1 mètre avec des périodes comprises entre 4 et 8 secondes ; mais le déferlement de la houle peut dépasser 5 mètres de hauteur avec des périodes de 9 à 10 secondes lors des plus fortes tempêtes. Les mécaniques d'ensablement et d'érosion littorale, qui ont parfaitement fonctionné en équilibre jusqu'aux années 80 sont en déséquilibre en plusieurs endroits, avec pour corollaire le recul du front de mer. A travers la photogrammétrie et la photo-interprétation sur des images aériennes de haute définition prises en 1990 et 2010, et une campagne de tracking sur le terrain en 2016, on observe des domaines d'abrasion au niveau des zones de marnage et dans les zones dunaires, mal orientées contre les assauts de l'océan ; avec une moyenne des gains annuels de l'océan allant de 5,2 à 27,5 cm/an.

Tracking metals pollution using wetland sediments in Lagos Metropolis, Nigeria

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Abstract

Wetlands are transitory sites and serves as depository for land derived materials. This make them active accumulators and potential sources of heavy metals, which can be available for uptake by plants, and, in some cases, reach groundwater, but also suitable sites for tracking pollution from the drained areas. Thus, this study aimed to assess the concentrations, distribution of heavy metals in the study locations and their potential health implications.

Sediment cores were obtained from city center wetlands (Ogudu, Maryland and Ikeja) and from the peri-urban (Ikorodu) areas using 30 cm long by 10 cm diameter core barrels made from High Density Polyvinyl Chloride (HDPC) pipes. The core samples were water drained, air-dried, subdivided at 5 cm intervals and sieved to <75 μm size fraction. The physico-chemical parameters (pH, TDS and EC) of the water samples were determined using appropriate digital meters. The mineralogical constituents of the sediments were determined using XRD, while the chemical analysis was performed by ICP-MS after an acid digestion. The availability of selected metals was addressed through selective chemical extractions (SCE), and Pb-isotope analyses were performed to determine the origin of the metals in the wetlands sediments. The pollution status for the selected metals was evaluated through Enrichment Factor, Geo-accumulation index, Contamination Degree and Pollution Load Index calculations. The potential health risk assessment was also evaluated mathematically using USEPA model.

The values of the physico-chemical parameters of waters ranged as: pH (5.4-6.3); electrical conductivity (40-90 $\mu\text{S}/\text{cm}$) and TDS (26.7-60.3 mg/L). Identified minerals in the sediments include quartz, kaolinite and some pyrite. The geochemical analysis revealed high concentrations of metals of environmental concern such as: Cu (15-104 mg/kg), Pb (29-169 mg/kg), Cd (0.4-22 mg/kg) and Zn (98-590 mg/kg), above the expected natural background and the recommended guideline values. The peri-urban wetlands showed the lowest concentrations compared to the city center wetlands, which was an indication of the urbanization-controlling factor in the contamination of the wetland sediments. The SCE results revealed that the selected metals were more enriched in the organic and the carbonate phases. The range of concentration (mg/kg) of the Pb-isotopes determined were ^{204}Pb (0.28-6.31), ^{206}Pb (5.06-104.57), ^{207}Pb (4.43-92.12), and ^{208}Pb (11.13-224.82). This revealed enrichment in the radiogenic Pb-isotopes, an indication of the influence of anthropogenic sources of the Pb and other heavy metals in the wetland sediments. In addition, the Geo-environmental assessment indicated that Cu, Pb, and Zn have attained significant environmental implications, while the toxicity levels revealed that Pb and Cd pose greater risk to both children and adults as indicated by the higher values of the Daily Intake (DI) and Total Chronic Hazard Index (THI). This is the more worrisome since the wetlands sediments are usually cultivated during dry seasons for vegetables and cereals making possible the bio-absorption of these metals by these plants and their subsequent introduction into the food chain.

Anthropogenic activities indicated as sources of these metal include fossil fuel combustion, improper disposal of household and industrial wastes.

Geochemical characterisation of lead in urban soils and sediments of Nigeria: a case from Southwestern Nigeria

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Abstract

The presence of Heavy Metals (HM) in soils, sediments and dusts are good indicators of contaminations of urban environment. Lead (Pb) is of grave concern amongst other HM because of its toxic impact on the environment and human health. Previous studies on HM have focused on the determination of concentrations and spatial distribution in various Nigerian cities. However, the geochemical fate and nature of Pb in Nigeria's environmental media is relatively unknown. This study was therefore designed to quantify and characterize Pb in soils and sediments from Southwestern Nigeria.

A total of ninety composite soils, 56 sediments, and 10 representative rock samples were collected randomly from two mega-cities in southwestern Nigeria (Ibadan and Lagos). Soil and sediment samples were air-dried, screened, pulverised and sieved through 63µm nylon mesh. The sieved fractions and pulverised rock samples were digested using standard methods and analyzed for elemental components using ICP-MS. The chemical fractionations of Pb in the samples were determined by sequential analysis. Lead isotopes compositions of the samples were determined using quadrupole-based ICP-MS. Mineralogical analyses of rocks and other samples were determined using X-Ray Diffraction.

The concentration (ppm) of Pb in soils and sediments for Lagos were: 21.0-1963.0 and 23.0-830.0; while in Ibadan soils and sediments were: 13.0-470.0 and 17.0-3288.0; respectively. Chemical fractionation (%) of Pb were: organic-sulphide (42.78-82.45); reducible (8.23-27.20); carbonate (9.00-43.60) and exchangeable (0.01-0.23) phases, respectively. Lead isotopes (ppm) showed that ²⁰⁴Pb ranged 1.72-47.41; ²⁰⁶Pb, 30.69-779.68; ²⁰⁷Pb, 27.00-664.46 and ²⁰⁸Pb, 65.67-1642.27 in Ibadan samples while that of Lagos were: ²⁰⁴Pb, 1.43 - 31.00; ²⁰⁶Pb, 25.26 - 509.74; ²⁰⁷Pb, 21.96-446.22 and ²⁰⁸Pb, 52.61-1089.93. Ibadan and Lagos rocks Pb isotopes (ppm) were: ²⁰⁴Pb, (0.02-0.07 and 0.03-0.06); ²⁰⁶Pb, (0.56-2.33 and 0.56-1.21); ²⁰⁷Pb, (0.38-1.56 and 0.47-1.01) and ²⁰⁸Pb, (1.19-4.13 and 1.22-2.57), respectively. Quartz, microcline, k-feldspar, plagioclase and kaolinite were the preponderant minerals in powdered rocks, soils and sediments. An enrichment of radiogenic Pb (²⁰⁶Pb, ²⁰⁷Pb and ²⁰⁸Pb) were observed in soils and sediments relative to their local background values, an indication of anthropogenic origin of Pb. The plots (²⁰⁸Pb/²⁰⁷Pb)/(²⁰⁶Pb/²⁰⁷Pb) revealed that over 80% of Pb in the environmental media was derived from anthropogenic sources. The LIRs of soils and sediments were characterised by lower ²⁰⁸Pb/²⁰⁶Pb ratios while the bedrocks had higher ²⁰⁸Pb/²⁰⁶Pb.

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**Integrated
approaches
in Geology
(Medical Geology,
Geophysics and
Geochemistry)**

Organic petrology of Lower Grudja Formation of the Well X-1 and Well X-2 (Mozambique Basin)

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Abstract

Mozambique Basin is one of the main basins for exploration and production of hydrocarbons in Mozambique, however it is relatively under explored. The Basin covers an area of 300,000 km² of onshore and offshore Mozambique. The geological record comprises Upper Jurassic to Cenozoic sedimentary rocks that rest on the basalts of the Karoo. The Lower Grudja Formation, equivalent to Late Cretaceous, is characterized by shallow marine deposits where sands, silts, clays and limestone prevail. In order to characterize the dispersed organic matter (OM) of the Lower Grudja Formation and assess thermal maturation, 23 samples from the Well X-1 and Well X-2, drilled in the offshore part of Mozambique Basin, were submitted to organic petrography analysis (reflected white, and incident blue lights). Organic petrography was performed on whole rock polished blocks prepared according to standard procedures (ASTM D2797-11a). Vitrinite and solid bitumen (when present) reflectance was measured following ASTM D7708-14 standard procedures.

The petrographic analysis revealed small amounts of OM. Vitrinite was present in all samples but usually small in size. The vitrinite random reflectance ranges from 0.71 to 0.81% in Well X-1 and 0.68 to 0.75% in Well X-2, pointing out to a mature stage of the OM.

The samples also presented some inertinite and several families of solid bitumen, that were distinguished according to their optical features (surface aspect and reflectance). Under reflected white light, bitumen show a grey color, and tends to occur within voids in the mineral matrix. The particles surface is irregular or smooth, presenting in some cases a mosaic structure. In Well X-1, three types of solid bitumen were identified. Families B1 and B2 are present in all samples and the reflectance varied between 1.60-1.82% and 2.19-2.27%, respectively. The third family, B3, shows values of 2.60-2.72%. In Well X-2, solid bitumen is rare having been detected only two families in one sample, with 1.88% and 2.21% (B1 and B2, respectively). According Jacob's classification, and based only in the reflectance data, these solid bitumens are classified as impsomite. The presence of solid bitumen is common in several basins dispersed throughout the world, being related both to source rocks and reservoir rocks. Solid bitumens are by-products that fill spaces or fractures in rocks (carbonate or siliciclastic) and that result from advanced stages of thermal maturation. The presence of impsomite may indicate a possible presence of natural gas or condensate.

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Geochemical and geochronological study of refractory inclusions in the CV Chondrite NWA 4502

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Abstract

Chondrites and their components are a main tool by which we can better understand the processes and the sequence of processes that occurred during the formation and evolution of the early solar system. Here we describe the mineralogy, chemistry and ages of five refractory inclusions (CAIs), from North West Africa (NWA) 4502 a CV chondrite.

NWA 4502 is the second largest CV chondrite so far after Allende [1], and contains large (up to ~1cm in diameter) CAIs, suitable for precise geochemical and geochronological analysis. CAIs, the oldest known objects that formed from the early solar nebula [2,3] preserve direct clues to the nebula phase of our solar system. This study was motivated by perceived inconsistencies in CAI ages as reported by various laboratories. These inconsistencies have been attributed to the influence of secondary processing (parent body or terrestrial) on isotope systems (e.g., U-Pb, Al-Mg, Rb-Sr) even though this is not well understood [4,5,6]. Other studies have associated this with the choice of sample processing methods used (e.g., acid leaching) [6,7,8].

CAIs from NWA 4502 show many similarities with CAIs from Allende and other CV chondrites. However, at a mineralogical level, NWA 4502 and its components appear rather pristine. Petrographic observation and chemical data suggests most of the studied inclusions are more pristine compared to Allende inclusions which have seen extensive parent body alteration. All studied NWA 4502 inclusion types have low levels of secondary hydrothermal alteration, thermal and shock metamorphism that affected CAIs in other CV chondrites. Even though NWA 4502 shows pristine parent-body characteristics, complexities discovered in some of the isotope systems (Al-Mg and Rb-Sr) may indicate significant imprint of terrestrial weathering. These unique characteristics of NWA 4502 CAIs make it a good candidate to better understand the formation processes and determine a more precise age for the early solar system.

Acid leached residues of NWA 4502 CAI fractions yield a Pb-Pb age (4567.40 ± 0.27 Ma) and initial $^{87}\text{Sr}/^{86}\text{Sr}$ (0.698886 ± 0.000026) and $^{26}\text{Al}/^{27}\text{Al}$ (4.04 ± 2.09 to $5.43 \pm 0.37 \times 10^{-5}$) ratios consistent with values reported for Allende and Efremovka CAIs in spite of the differences in secondary processes between these CV chondrites. This leads to the conclusion that secondary processing did not bias the U-Pb isotopic ages of these CV CAIs.

This study enabled us to expand the population of well characterized CV CAIs and provided an insight to better understanding the influence of secondary processes on isotopic systems and the chronology of CAIs.

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Effectiveness of reduced rates of n on productivity and economic returns of Sorghum in Striga infested semi-arid areas of Tanzania

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Abstract

Performances of three sorghum (*Sorghum bicolor* L. Moench) genotypes (Wahi, Hakika and Pato) and inorganic soil amendments (i.e. 10, 20, 30, 40, 50 and 60 kg N/ha) were studied under naturally *Striga asiatica* [L.] Kuntze infestation for one cropping season (2015/16) in two locations: Ngamu (6° 37' 10" S; 34° 57' 05" E, and altitude of 1650 m.a.s.l) and Hombolo (5° 54' 29" S; 35° 57' 36" E, and altitude of 1020 m.a.s.l). It was use a split plot design laid out in a randomized complete block design with four replications. A susceptible sorghum (Pato cultivar) was used as a bioassay to evaluate the effectiveness of reduced rates of N under *Striga* infestation.

At Hombolo, 40 kg N/ha had significantly ($P < 0.05$) lower emerged *S. asiatica* shoots count/m² than all other rates of N, except at 11 week after planting (WAP). Yields with 30 kg N/ha (0.64 t/ha) was significantly ($P < 0.05$) lower than yields from all other rates of N (1.08 - 1.52 t/ha). At Ngamu, fertilization played no significant ($P < 0.05$) role in *S. asiatica* emergence and attachment. Yields with 10 kg N/ha (4.89 t/ha) was significantly ($P < 0.05$) lower shoots than yields from all other rates of N (5.2 - 6.0 t/ha).

Across locations, variety Hakika had significantly ($P < 0.05$) fewer emerged *S. asiatica* shoots count/m² compared with varieties Wahi and Pato. At Hombolo, Yields on Hakika variety (0.96 t/ha) was significantly ($P < 0.05$) lower than the yield in all other varieties (1.21 - 1.28 t/ha). At Ngamu, variety Pato gave more yields (7.21 t/ha) than the other varieties (2.81 - 5.95 t/ha).

At Hombolo, when rates of N were applied, economic analysis showed no maximum net profit was gained since it resulted in economic loss. Benefit-cost ratio for sorghum production showed that for every shilling invested, there was a loss of -550/= Tshs and -810/= Tshs for 60 kg N/ha and 30 kg N/ha, respectively. The best treatments for *S. asiatica* control were 30 and 40 kg N/ha with 24 140 and 13 670 Marginal Rate Return (MRR), respectively.

At Ngamu, where farmer's field trial was located, economic analysis showed that the highest net income (Tsh 1 912 160/= per hectare) was obtained from 50 kg N/ha and the lowest income (877 160/= Tsh) was obtained with 10 kg N/ha. Benefit-cost ratio for sorghum production, the results showed that for every shilling invested, there was a return of 470 and 220 for 50 kg N/ha and 10 kg N/ha, respectively. The best treatments for *S. asiatica* control were 40 and 10 kg N/ha with 2 330 and 3 800 MRR, respectively.

This study showed that the most effective rates of N; 40 and 60 kg N/ha (Hombolo) and 50 kg N/ha (Ngamu) should be promoted in semi-arid areas of Tanzania where *S. asiatica* poses a serious threat. Results also showed that varieties Hakika and Wahi proved their resistance/ tolerance to *S. asiatica* compared to variety Pato.

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