1ER COLLOQUE DU PROGRAMME INTERNATIONAL DE GÉOSCIENCES (PICG638) AU SÉNÉGAL

Dakar, 5-10 Décembre 2016

Salle de conférence UCAD II

Thème: **GÉODYNAMIQUE ET MINÉRALISATIONS DES FORMATIONS PALÉOPROTÉROZOÏQUES POUR UN DÉVELOPPEMENT DURABLE**

RECUEIL DES RESUMES ET PROGRAMME
ABSTRACTS VOLUME AND PROGRAMME

Parrainé par l'UNESCO et **organisé par:**

- **L'Université Cheikh Anta Diop, Département de Géologie** (FST/ UCAD/ Sénégal)
- **Le Ministère des Mines et de l'Industrie du Sénégal**
- **L'Association Vision Géologie** (UCAD/ Sénégal)

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Responsables du PICG638:
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ANRA: Agence Nationale de la Recherche Appliquée
CEREEQ: Centre Expérimental de Recherche et d'Etude pour l'Equipement
FST: Faculté des Sciences et Techniques
IFAN: Institut Fondamental d'Afrique Noire
IRD: Institut de Recherche pour le Developpement
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UCAD: Université Cheikh Anta Diop de Dakar
FST: Faculté des Sciences et Techniques
IFAN: Institut Fondamental d'Afrique noire
IST: Institut des Sciences de la Terre
IRD: Institut de Recherche et Développement

PREFACE

Chers participants,

C'est avec une grande satisfaction soutenue par une joie partagée avec tous les organismes et établissement qui ont rendu possible la tenue du présent colloque international, que nous avons le grand honneur de vous adresser le mot de bienvenue au premier colloque PICG638 du Sénégal portant sur "la géodynamique et les minéralisations des formations paléoprotérozoïques pour un développement durable".

Cette manifestation scientifique est l'occasion d'échanger, de communiquer et de découvrir, grâce aux professionnels, acteurs et chercheurs du domaine minier, les enjeux et les perspectives de la recherche géologique dans la connaissance et l'exploration des ressources minérales à l'échelle nationale et régionale. Elle permettra également aux participants de mettre le point sur les derniers développements dans ce domaine par des conférences et des communications de grand intérêt.

Le choix de ce sujet est dicté par les divers défis liés à l'identification, l'exploration, la gestion et la valorisation des ressources minérales à l'échelle nationale et régionale et à ses retombées politique, économique et sociale. En effet, la connaissance profonde de ces ressources minérales a des conséquences positives sur le développement économique et social des nos pays émergents. L'identification du potentiel minéral, la connaissance du contexte géodynamique des différentes minéralisations permettra sans nul doute de réduire considérablement les coûts de la prospection et d'optimiser les rendements à l'exploitation.

Par ailleurs, les ressources minières sont inextricablement liées à l'environnement géologique. En conséquence, la connaissance des contextes géodynamiques de mise en place des ressources minières est d'un atout considérable pour l'exploration et l'estimation des réserves. Les stratégies pour avoir une cartographie et une estimation efficiente des ressources devront relever plusieurs défis: le financement de la recherche, l'équipement des laboratoires, la création d'un pôle national voir régional de la géologie chargé de l'estimation et de la valorisation de nos ressources minières.

La connaissance de l'histoire de notre sous-sol permettra de mieux maîtriser nos ressources.

En outre, l'impact de l'orpaillage traditionnel sur les ressources en eau et la santé des populations mérite une attention particulière. En effet, l'usage de produits chimiques constitue une lourde menace pour la santé des populations locales qui bénéficient d'un accès limité aux ressources en eau potable (SONES). C'est dire que chaque individu vivant dans ces provinces minières est directement ou indirectement exposé à ces menaces de santé liées à l'activité extractive.

Pendant ces dix jours, nous affronterons la complicité liée aux thématiques ci-cités et nous aborderons des sujets divers en vous proposant des présentations orales et affichées. Toutes ces présentations sont importantes, mais encore plus précieuse est l'opportunité qui vous est offerte de rencontrer des chercheurs, des ingénieurs et des acteurs dans le domaine de la prospection et de la valorisation des ressources minières venant du monde entier. Ils ne manqueront pas de vous donner leur point de vue sur tous ces thèmes. Nous ne traiterons pas tous les aspects liés à cette problématique minière pendant ce colloque, mais, en portant les

problèmes sur le devant de la scène, nous chercherons à donner l'occasion aux différents participants pour échanger les idées, les expériences et tisser des ponts de coopération et de collaboration.

Pour finir nous voudrions remercier:

L'UNESCO qui nous a accordé ce projet financé ;

- Les comités d'organisation et scientifique et l'Association Vision Géologie;
- Le Ministre des Mines et de l'Industrie pour sa disponibilité à présider l'ouverture de ce colloque et pour son soutien financier dans l'organisation;
- Le Recteur de l'Université Cheikh Anta Diop de Dakar dont le soutien financier, matériel et les conseils ont été très déterminants pour la tenue de ce colloque ;
- Le Doyen de la Faculté des Sciences et Techniques pour sa disponibilité et son soutien ;
- Le représentant de l'IRD au Sénégal qui a accordé des bourses aux doctorants des pays de la région ouest africaine;
- Le Comité national de l'UNESCO de Dakar ;
- Le Ministère de l'Enseignement et de la Recherche à travers la Direction de la Recherche ;
- Le Chef de Département de Géologie ;
- Les enseignants-chercheurs et les étudiants du Département de Géologie, de la FST et de l'UCAD en général ;
- Le personnel administratif et technique du département de Géologie ;
- Les orateurs des communications orales et des affichées ;
- Les présidents et rapporteurs de séances qui apporteront à ce colloque leur crédit scientifique ;
- Tous les participants au colloque.

Grâce à votre présence, nous ne douterons pas que le premier colloque du PICG638 sera un succès.

Nous vous souhaitons un bon colloque et un bon séjour au Sénégal.

Avec toute notre reconnaissance.

Le comité d'organisation

PROGRAMME

Notes aux conférenciers

Les conférenciers doivent respecter l'heure assignée (20-25 mn d'exposé et 10-15 mn de question-réponse) pour assurer le bon fonctionnement du programme

Les présentateurs(trices) doivent venir avec leur présentation sous format PowerPoint. Les équipements pour la projection seront fournis par le comité d'organisation ou le bureau d'enregistrement.

Les présentations seront faites de préférence en français. Toutefois les présentations en anglais sont aussi admises.

Notes aux Présidents de séances et aux présentateurs oraux

- Les présidents doivent être dans leurs salles respectives 10 minutes avant le début de leur session. Les présentateurs doivent rencontrer les Présidents de leur session 10 minutes avant le début de la session pour leur donner le fichier de présentation PowerPoint.
- 15 minutes (10-12 minutes de présentation et 3-5 minutes de question-réponse) sont réservées pour chaque présentation. Les présentateurs doivent respecter l'heure assignée pour assurer le bon fonctionnement du programme.
- Le programme risque de subir des changements de dernière minute. Veuillez se référer au panneau d'affichage du programme de la conférence pour plus d'information mise à jour.

Notes aux présentateurs d'affiche

- Les présentateurs(trices) d'affiche doivent venir avec leurs affiches imprimées. Les équipements pour monter les affiches seront fournis éventuellement par le bureau d'enregistrement.
- Toutes les affiches seront exposées dans le hall de la conférence. Les participants ont l'occasion de voir et de discuter les affiches avec les présentateurs pendant les pauses-café.

Séances

Deux séances parallèles sont programmées pour le Mardi 06 Décembre dans des salles différentes:

Salle de conférence A: Géodynamique et Minéralisations / Geodynamics and Mineralizations

Salle de conférence B: Eau, Environnement, Bassins sédimentaires, Education et Géoparcs / Water, Environment, Sedimentary Basins, Education and Geoparks

Lundi 05 Décembre 2016 / Monday December 5th, 2016

8h30-9h30: Accueil et inscription des participants / Welcome and registration

9h30-10h30: Cérémonie d'ouverture / Opening ceremony

10h30-11h00: Pause café / Coffee Break

Séances Plénières et Posters: 11h-18h

Lieu: salle conférence UCAD II

NB: Des tableaux d'affichage sont disponibles pour les posters qui pourront être affichés à partir du 5 Décembre dans le hall de la salle de conférence UCAD II.

Horaires	Thème et Conférencier	Modérateur
11h-11h35	Mining resources of Senegal / Dr. R. Samba, DPPM	Pr. S. Naba
11h35-12h10	Mines and sustainable development in West Africa / Dr. A. Sy, SGO	Pr. D.P. Diallo / Pr. M. Gueye
12h10 -12h45	Nature and characterization of oil and gas formations of Senegal (West African margin) / Dr. J. Medou, Petrosen	Pr. T. Aïfa
	Déjeuner / Lunch	
14h30-15h05	Nature and evolution of the Paleoproterozoic formations of the West African Craton / Dr. L. Baratoux, IRD	Dr. A. Kouamelan
15h05-15h40	Tectonics-mineralisation relationships in ancient cratons, a new structural framework / Pr. D. Gapais, Univ. Rennes 1	Pr. R. Malou
15h40-16h15	The Education of Earth sciences in West Africa / Pr. M. Fall, UCAD	Pr. P.G. Lô
	Pause café / Coffee Break	
16h15-16h45	West African Craton and Mauritanides: a geotrail from Atlantic margin to Sahara / Pr. O. Saddiqi, Univ. Casablanca	Pr. P.M. Ngom / B. Diouf
16h45-17h20	Geoparks and geotourism / Dr. S. Siby, ANRA	Pr. P.M. Ngom
17h20-17h55	Groundwater: hydrogeologic characterization and pollution / Pr. S. Faye, UCAD	Dr. F. Ngom / Dr. M. Diène

DPPM: Direction de la Prospection et de la Promotion Minière
SGO: Sabodala Gold Operations
ANRA: Agence Nationale de la Recherche Appliquée

Mardi 06 Décembre 2016 / Tuesday December 6th, 2016

Présentations orales et Posters

Les posters seront affichés sur les tableaux aménagés à cet effet dans le hall de la salle de conférence UCAD II.

Les communications orales seront programmées dans deux salles séparées.

Salle de conférence A: Géodynamique et Minéralisations

(1) Ressources minérales et développement durable

(2) Contraintes tectono-structurales, événements géologiques, inclusions fluides, métamorphisme, géochimie et géochronologie des terrains paléoprotérozoïques

Salle de conférence B: Eau, Environnement sédimentaire, Education et Géoparks

(1) Hydrogéologie et environnement pour une eau durable et potable

(2) Exploration géophysique et ressources minérales

(3) Education et politiques des sciences de la Terre

(4) Chronostratigraphie, sédimentologie et stratigraphie du Précambrien

(5) Géoparc, géotourisme et Géo-éthique pour la promotion du patrimoine de la Terre

(5) Autres thématiques géologiques

Tableau de programmation des communications orales dans les différentes salles.

Horaires	**Salle de Conférence A:** Géodynamique et Minéralisations / Geodynamics and Mineralizations **Présidents / Conveners**: Mamadou Gueye – Yacouba Coulibaly **Rapporteurs / Co-Conveners**: Alain Kouamelan – Séta Naba
9h	Abass Saley Abdoulatif, Moussa Konaté: Characterization of birimian rocks deformation in the Sirba greenstone belt (Liptako Niger, West Africa).
9h15	Alain N. Kouamelan, Serge K. Kra, Chérubin S. Djro, Jean-Louis Paquette, Jean-Jacques Peucat: The Logoualé Band: a large Eburnean (2.05 Ga) crust in the Kenema-Man domain (Man-Leo Rise, West African Craton) recycled from Archean formations.
9h30	Baraou I.S., M. Konaté, Y. Ahmed: Characterization of the pan-African mobile belt basement deformation in Southern Maradi (South Niger), relationship with gold mineralization.
9h45	Bekker, A: Resolving history of the early Paleoproterozoic time reveals patterns similar to those in the late Neoproterozoic.
10h	Coulibaly Y., M.C. Boiron, M. Cathelineau, K.E. Assié: Fluid inclusion characteristics of Aniuri and Jonction gold deposits (Aboisso, Southeastern Ivory Coast).
10h15	Djamal-Eddine Aissa, Mokhtar Bagui, Abdelhak Boutaleb: Controls on Gold Mineralization at In Ouzzal Mole, Western Hoggar, South Algeria.

10h30	Famara Diatta, Papa Moussa Ndiaye, Mahamadane Diène, Prince Ofori Amponsah, Jérôme Ganne: The Structural Evolution of the Dialé-Daléma Basin, Kédougou-Kéniéba Inlier, Eastern Sénégal.
10h45-11h15	**Pause café / Coffee Break**
11h15	Fossou Jean Luc Hervé Kouadio , Alain Nicaise Kouamelan , Sagbrou Chérubin Djro, Lenka Baratoux, Marc Ephrem Allialy, Yacouba Coulibaly: The orthogneisses of SASCA domain (Ivory Coast, West African Craton): some Birimian crustal segments with a strong archaic signature.
11h30	Gapais, D., Cagnard, F., Boulvais, P., Ledru, P, Poupeau, B.: Tectonics-mineralisation relationships in ancient cratons, a new structural framework.
11h45	Gbele Ouattara, Gnammytchet Barthélémy Koffi: Contribution of Remote Sensing Imagery to Geological Mapping, Mining Research and the Understanding of Geodynamics in the Paleoproterozoic of Côte d'Ivoire (West Africa).
12h	Hocine Benramdane, Abdelhak Boutaleb, Hanafi Benali, Omar Kolli: Metallogeny of Paleoproterozoic Yetti-Eglab Massif, South-Western Algeria.
12h15	Houssa Ouali, Muhammad Ouabid, Carlos J. Garrido, Jean-Marie Dautria: Petrographic and Geochemical characterization of the Goaïda Neoproterozoic granitoids (Morocco Central Massif- Western Meseta).
12h30	Jacques Kone, Lenka Baratoux, Papa Moussa Ndiaye, Olivier Vandherhaaeghe: Thermomechanical evolution of the Proterozoic Eburnean Crust and Implications on Gold-bearing Mineralizations in the Kédougou Kéniéba-Inlier.
12h45	Lenka Baratoux, Jessell, M.W., Block, S., Ganne, J., Perroury, S., Siebenaller, L., Béziat D., Davis, J., Fontaine, A., Moussa, P.M., Miller, J., Dioh, E., Metelka, V., WAXI team: Tectono-metamorphic Evolution of West Africa: Implications for Mineralization.
13h30-15h	**Déjeuner / Lunch**
15h	Mohamed Bhilisse, Abdelkhalek Alansari, Lhou Maacha, Aomar Ennaciri: The Co, Ni, Cr and S mineralizations during serpentinization process in the BouAzzer ore deposits (Anti-Atlas, Morocco).
15h15	Moussa Dabo, Tahar Aïfa, Arona Bâ , Anne Mvomo Klorane: Lithological Architecture and Petrography of the Mako Birimian Greenstones Belt, Kédougou-Kéniéba Inlier, Eastern Senegal.
15h30	Ndoye A.N.R., M.Gueye, P.M.Ngom, M.Diene: Structural study of gold-bearing shearzone system at the Kédougou-Kéniéba Inlier, SE Senegal: evidences of strainpartitioning during the Eburnean orogeny
15h45	Saddiqi Omar, Michard André, Zouhri Samir, Bea Fernando, Haissen Faouziya, Montero Pilar G., Mansour El Mehdi,Mouttaqi Abdallah, Rjimati Ech-Cherki: The West African Craton and the Mauritanides in Southern Morocco: A recommended geotrail straddling the Atlantic margin and the Sahara approaches.
16h	Rauda Addae, Patrick Sakyi, Daniel Asiedu, Samuel Dampare: Petrology of K-rich granitoids in the Bole-Nangodi belt of the Paleoproterozoic Birimian Supergroup of Ghana.
16h15	Séta Naba, Nestor Végas, Martin Lompo, Jean Luc Bouchez: The magnetic methods: a tool for understanding geodynamic evolution of Paleoproterozoic crust of west Africa.
16h30-17h	**Pause café / Coffee Break**
17h	Sharad Master, Richard Armstrong, Souleye Wade: SHRIMP U-Pb zircon geochronology of basement rocks from the ring uplift of the Velingara Impact Structure, Haute Casamance, Senegal - a comparison with the Mauritanides from Bakel.
17h15	Zahra Mourabit, AbdelhalimTabit, Ahmed Algouti, AbdellahAlgouti, Fatiha Hadach, Maryam khal: Mechanical mixing of garnet pyroxenite layers and surrounding lherzolite: massif of Beni Bousera (Internal Rif, Morocco).
17h30	Zié Ouattara , Yacouba Coulibaly , Marie-Christine Boiron: Veins generations related to the gold deposition in the Bonikro deposit, Fettèkro greenstone belt, Côte d'Ivoire.

Horaires	**Salle de Conférence B:** Eau, Environnement sédimentaires, Education et Géoparcs / Water, Environment, Sedimentary Basins, Education and Geoparks **Présidents / Conveners:** Papa Malick Ngom – Bachir Diouf **Rapporteurs / Co-Conveners**: Tahar Aïfa – David Baratoux
9h	Akame Joseph Martial, Assembe Pactrick Stéphane, Zo'oZame: "The Sangmelima Greenstone Belt Reliticts" (South Cameroon): Integrating Landsat-7 ETM+/SRTM and Airborne Magnetic Data for structural Interpretation.
9h15	Birane Niane, Robert Moritz, Papa Malick Ngom, Stéphane Guédron, John Poté: Environmental impacts of recent artisanal small-scale gold mining along the Gambia river, Kedougou region, eastern Senegal.
9h30	David Baratoux, Mark Jessell, Makhoudia Fall, Jean-François Moyen, Olivier Vanderhaeghe, Papa Moussa Ndiaye, Anne-Sylvie Mayer: Interpreting U-Th distributions in the continental crust from radiometric data.
9h45	Farès Kessasra, Nor El Houda Chetibi, Soumia Seraoui, Mohamed Mesbah, Soumeya Khaled-Khodja: Geology, Hydrogeochemical Modeling and Prediction of Water Pollution in the lower alluvial Aquifer of the Soummam Valley, in north-east of Algeria.
10h	Fatiha Haddach, Ahmed Algouti, Abdellah Algouti, Zahra Mourabit: Contribution to the localization of favorable layers for traditional exploitation of pottery: example of theHigh Atlas of Marrakech, Morocco.
10h15	Miloud Benhamou, Tahar Aïfa: Fluvial event and associated intra-Carixian facies in the Liassic carbonate platform of the Grand Pic, Ouarsenis Massif, Algeria: duration, causes and effects.
10h30	Savadogo Alain Nindaoua, Youssouf Koussoubé: Concept and technical feasibility of achieving production center built on mega-fractures of the basement rocks for drinking water supply in rural areas of Burkina Faso.
10h45-11h15	**Pause café / Coffee Break**
11h15	Salah Mahmoud, Richard Wonnacott, H. Farah: Current Situation of AFREF and First Results from GNSS Networks in Africa.
11h30	Zouhair Ourhzif, Ahmed Algouti, Abdellah Algouti: GIS-Based Landslide Susceptibility Mapping by AHP Method, a Case Study, High Atlas of Marrakech, Morocco.
11h45	Tables rondes / Panels
13h30-15h	**Déjeuner / Lunch**
15h-16h30	Presentation en 3-5 mn de 2-3 photos essentielles sous powerpoint pour les posters souhaités / Powerpoint presentation in 2-5 mn (2-3 main slides) for interesting desired posters
16h30-17h	**Pause café / Coffee Break**
17h	Tables rondes / Panels
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Characterization of Birimian rocks deformation in the Sirba greenstone belt (Liptako Niger, West Africa)

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The structural study of Sirba sector shows that the deformations of the Birimian (Palaeoproterozoic) greenstone belt and the granitoid intrusions are integrated in a regional shortening field, associated with the pluton emplacement, in relation with the activation of N45°E trending major shear zone.

The field work and the microtectonic analysis highlight two deformation events (D1 and D2). The first event includes three successive stages (D1a, D1b and D1c).

Ductile to semi-ductile D1 event, with NW-SE trending shortening, would be in connection to diachronous crustal block collage (D1a stage)(Feybesse et al., 1994, 1990). It is responsible for the schistosity and foliation development with NE-SW orientation.Late-kinematic granitoids emplacement, facilitated by dextral to normal reactivation of the major shear zones oriented N60°E, ended this stage.This D1a stage is followed by a semi-ductile (D1b stage) with N60°E to E-W hortening, and it is characterized by the reactivation of dextral large-shear zones and sinistral N125 to N145°E faults. In these shear zones, the schistosity/foliation and quartz veins have a sigmoid geometry feature mylonitization.During the rather brittle D1c stage, with NS shortening, the N45°E shear zones were reactivated in sinistral movement.

The last D2 deformation event, really brittle, is characterized by NW-SE to NE-SW stretching. The NE-SW trending stretching event could be related to NW-SE dolerite dykes emplacement.

In agreement with the idea of a continuum of deformation, this study seems to indicate a reduction of the material ductility from the D1a to the D1c stages, in close relationship with a decrease of magmatic events in this area (Ama-Salah et al., 1996, Pons et al., 1995).

Keywords: Liptako, Birimian, Paleoproterozoic, shear zones, greenstone belt, granitoid.

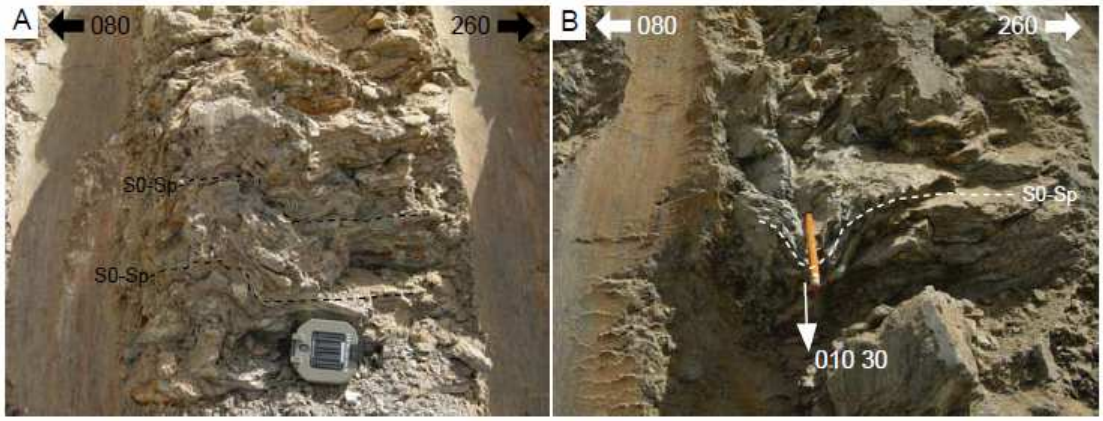

Figure 1. Chaotic folds. A) chaotic folds defined by the S0-Sp surface folding. B) same as A, with a sub-parallel axis to the stretching lineations.

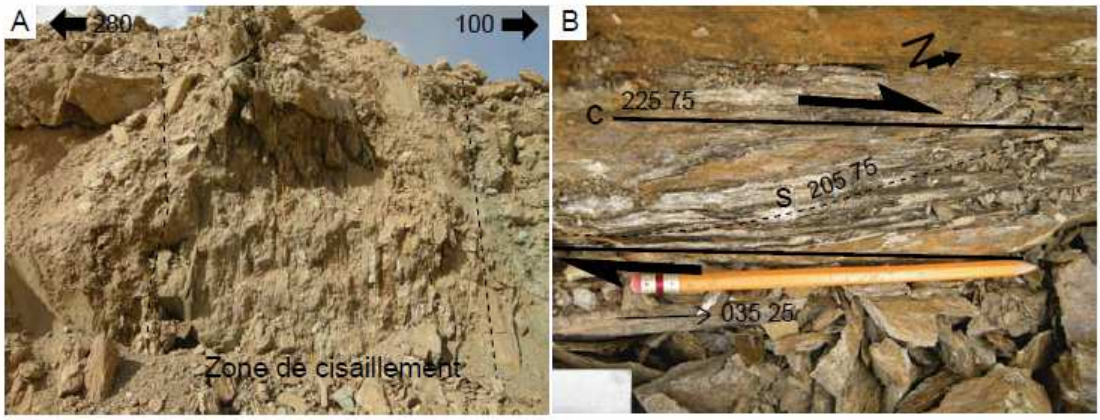

Figure 2. Shear zone. A) shear zone with vertical schistosity. B) CS fabric in dextral shear zone.

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Petrology of K-rich granitoids in the Bole-Nangodi belt of the Paleoproterozoic Birimian Supergroup of Ghana

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The Paleoproterozoic Birimian province of Ghana is made up basically of parallel and equally spaced NE-SW trending belts (with the exception of one which trends NS), one of which is the Bole-Nangodibelt which outcrops in the northern parts of Ghana. These belts petrologically consists of metasedimentary and metavolcanic rocks, both of which are intruded by granitoids of various ages. These granitoids can broadly be grouped into four: the Cape Coast, Winneba, Dixcove and Bongo (and Banso) granitoids. Of interest to this study is the Bongo granitoids (2097±3 Ma) in the Bole-Nangodi belt, whereby the petrogenetic history may be constrained. Field studies indicate that these rocks are very rich in felsic minerals than mafic minerals. The rocks are easily distinguished based on their characteristic pinkish nature due to its voluminous feldspatic content. Mineralogical composition recorded in hand sample include K-feldspar, plagioclase, hornblende, biotite, quartz and muscovite; all in varying proportions. Structures observed include veins, veinlets and joints. The Bongo granitoids can be classified into five major types based on microscopic studies: granite, pegmatite, aplite, granodiorite and adamallite. The granitic types are mineralogically composed of plagioclase (0-28%), pyroxene (2-6%), hornblende (0-4%), K-feldspar (10-80%), biotite (0-30%), muscovite (0-15%) and quartz (10-60%). Accessories include opaque oxides/sulphides, zircon, apatite, titanite, allanite, carbonate, fluorite, epidote and hornblende. The aplitic species are mineralogically composed of K-feldspar (2%) and quartz (98%). The granodioritictypes are mineralogically composed of plagioclase (20-45%), hornblende (0-0.5%), biotite (2-18%), K-feldspar (14-25%), muscovite (0.5-2%) and quartz (25-55%). Accessories include opaque oxides/sulphides, titanite, zircon, epidote, allanite, carbonate and apatite. The adamallitic types are mineralogically composed of plagioclase (27-38%), biotite (4-5%), K-feldspar (23-32%), muscovite (0.5-1%) and quartz (25-40%). Accessories include opaque oxides/sulphides, titanite, epidote, allanite, hornblende and apatite. Microstructures observed include veins (feldspatic and quartzo-feldspatic) faults, folds, bends, alignments in preferred orientations, foliation and elongation.Mineral chemistry data helps constrain crystallization conditions such as geothermometry, geobarometry, oxygen fugacity and water

content of melt. Ti-in-hornblende and Al-in-hornblende thermometer yields temperature conditions of ~640-750°C and ~411-429°C, respectively. Pressures obtained from Al-in hornblende geobarometers range from ~2.09-19.2 kbar. Hence, the K-rich granitoids of the Bole-Nangodi belt crystallized at a wide range of pressure-temperature conditions. They are oxidized with few reduced types. It can therefore be inferred that the K-rich granitoids of the Bole-Nangodi belt may have been emplaced under both compressional and extensional tectonic regimes.

Keywords: Birimian, Paleoproterozoic, Bongo, potassium-rich granitoids, petrology, mineral chemistry.

Controls on Gold Mineralization at In Ouzzal Mole, Western Hoggar, South Algeria

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The Hoggar is the core of the Tuareg Shield, a Pan-African belt which was formed between 750 and 550 Ma by continental collision between the converging West African Craton, Congo Craton and East Sahara metacraton. At In Ouzzal mounts (Western Hoggar), the sub-meridian East Ouzzal Shear Zone (EOSZ) separates two contrasted Precambrian domains: the Archaean block to the Westand the Middle Proterozoic block to the East. The Archaean blockis constituted mainly by charnockites, kinzigites, banded mafic granulites and carbonatite sills, granulitized during the *ca.* 2 Ga Eburnean event; and the Middle Proterozoic by sub-alkaline orthogneisses interbanded metasediments, intruded by diorites and granites and metasediments, involved during the Pan-African orogeny under lower amphibolites facies.

The EOSZ is a mega-shear zone extending NS over 900 km (thickness up to 3000 m) from Algeria to Mali, and involved during a Late Pan-African dextral strike-slip fault. Horizontal displacement along this major lithospheric fault is of a few hundred kilometers. At In Ouzzal Monts, along this mega-shear zone, on a section segment of 100 km, the ORGM (National Bureau of Mining and Geology of Algeria) has prospected two world class gold deposits (Tirek to the north and Amesmessa to the south), and more than hundred small gold deposits and occurrences between these two world grade. The gold mineralization consists of a series

of “en-echelon” veins, striking NS to N20° (Amessmessa), N50°(Tirek) and dipping 55° to 85°W. The veins of irregular morphology (lense-shaped veins) are usually 100 m to up to 1000 m in length with a thickness varying from 25 to 150 cm. They extend down to 450 m down dip, with however a decreasing gold content with depth. Gold is irregularly distributed, with contents from 0.5 ppm up to 500 ppm, and mean grades between 9 and 18 ppm. At Amesmessa, gold not only occurs in the quartz veins but also in metasomatised host rocks (mylonite-ultramylonite) that have undergone a high hydrothermal alteration represented by the association “quartz, albite, sericite, muscovite, calcite, dolomite, rutile, ilmenite, epidote, chlorite” where the gold content vary from 0.2 to 33 g/t up to 114.80 g/t.

The mineral association is very simple pyrite, galena, sphalerite, native gold and rarely chalcopyrite, bismuthinite, scheelite. Fluid inclusions performed in auriferous quartz vein highlight a predominance of carbonic fluids and are relatively low (150 to 330°C) homogenization temperatures compared to that is known in the orogenic gold vein type.

But what controls the gold mineralization along a segment of 200km within the EOSZ mega-shear zone? There are various controls at different scales:

1- Hoggar scale: the preliminary controls are i/ the EOSZ mega-shear zone, ii/ultramylonite-mylonite rocks, iii/the eastern boundary of the Archean block (Archean side).

2- District scale: deposits are located in t areas where the EOSZ is fragmented and displaced by secondary shear zone. The rotated tectonic block in relationship with shear movement contributes also to favor mineralization. At this scale big massifs of mafic and felsic magmatic rocks are decisive.

3- Gold field scale: gold mineralization occurs in the releasing bends (transtensional and dilational bend, jog) and releasing offset (overlap, step-over).

4- Outcrop scale: along quartz veins, rich zones are linked to the abrupt variations in strike and dip ; yet gently dip 50-60° are most favorable.

5- Hand specimen scale: rich gold mineralizationis associated with a quartz, which is intensely fractured and brecciated. In the metasomatised wall rocks, the rich zones are encountered in the parts which are characterized by the high proportion of quartz veinlets contents.

Keywords: Pan-African orogenesis, orogenic gold, shear zone, Archean-Proterozoic boundary

The impact of the hydrological events on the area of Marrakech: case of the degradation of the banks of the Rdat's, Zat's and Tensift'srivers and floods of the infrastructures on the Issilriver

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The evolution of the banks of the Rdat's, Zat's and Tensift's rivers depends essentially on the intensity of the risings and floods generated by downpours shot down on the level of the various wadis which started in the axial zone of the Marrakech High Atlas. The climatic conditions in the area make valleys of studied rivers, zones which are favorable to the floods and degradation of the soil.

The heavy rains, such as those fell between 4 and 5 May 2016 and those of November 2014, lead to impressive floods in different rivers that originate in the highest peaks of the High Atlas of Marrakech. Muddy water of high sediment loads have carted soils, trees, crops, houses and roads down the slopes to the plains of Haouz.

The banks of the wades have not escaped this destruction. This degradation can be observed and analyzed by satellite images and field studies.

The phenomena and forms of the most frequently observed in the downstream part of the studied rivers are erosion due to the current under the action of water, sliding mass after a rapid fall and landslides.

Thus, in parallel to the degradation of the banks of the rivers mentioned above, Issil's wadi cross-cutting the city of Marrakech in its eastern part, is very known by these floods, particularly, those that touched the infrastructure all around.

Keywords: impact, floods, degradation, rivers, riverbanks, Issil, Zat, Rdat, Tensift, Marrakech.

"The Sangmelima Greenstone Belt Reliticts" (South Cameroon): Integrating Landsat-7 ETM+/SRTM and Airborne Magnetic Data for structural Interpretation.

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Geoscience data integration involving field geology, geophysics and remote sensing seems to bear a promising future in the mapping of the entire South-Cameroon's region which is not easily accessible, because of its dense vegetation and the thickness of laterites. The application of this methodology in the Sangmelima (South Cameroon) area shows that therein, the Archaean basement has been affected by two main tectonic events. These are characterized by D_1 penetrative structures resulting from an EW compression which are generally cross-cut by D_2 shear zones. The aforesaid D_2 shear zones are imprints of the Eburnean orogeny in the Ntem complex. The regional geometry is controlled by a NS subhorizontal shortening in a transpressional setting. The regional geological architecture emplaced at the end of the D_2 phase has been slightly affected by late Eburnean or Panafrican brittle deformations as well.

Keywords: geophysics, remote sensing, shear zone, transpression, Archaean, Cameroun.

Tectonic framework of the Archeaen Ma'an-Nyabessan granite-greenstone belt (NW Congo Craton, Southern Cameroon)

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The Archaean sector of Ma'an-Nyabessan was affected by two major tectonic events: the SyngranuliticD_1phase is characterized by a composite foliation marked by several generations of isoclinal folds, small domes and N340-NS subvertical shear zones. The shear zones result from a dextral transpressive regime. Distributed thickening, marked by a subvertical shortening and a subparallel stretching at the shear zones, could partly result from a synchronous lateral creep of the transpression. The D_2 phase is characterized by zones of shearing (C_2) semi-brittle or brittle, oriented N30°-60°with a sinistral shear component, to which some conjugated dextral bands areas sociated.

Thedeformationsobservedarecomparablewiththosedescribedinoldorogensimplyingofhotterand not veryresistantlithospheres.ButtheageoftheD$_1$deformation is discussed (all is possible: Archaean, Eburnean and even Panafrican deformation?), because the sector of Ma'an-Nyabessan is not far from the contact zone between the Nyong Complex and the Ntem Complex.

Keywords: Transpression, vertical structure, shear zone, Archean, Congo Craton, south Cameroun.

The Senonian in the western High Atlas, Morocco: sedimentology, sequence stratigraphy, biostratigraphy and geodynamic evolution

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From the geological studies performed on the Senonian series in the western High Atlas, Morocco, new insights on stratigraphy and paleogeography are provided.

We individualized the Anou-nfeg, Ait Abbes formation, and OuedLahouar formations and the phosphated series (Calcareous formation of Tagragra and phosphate sand formation of Chichaoua), corresponding to the Coniacian, Santonian, Campanian and Maastrichtian age, respectively.

The Anou-Nfeg formation is attributed to Coniacian, from Ostracods associations, Bryozoa and Ammonites.The Ait Abbes formation is dated at Santonian by Bryozoa, Ostracods associations, Echonoderms, Foraminifera and Ammonites. The phosphate series is attributed to Maastrichtian by Ostracods associations, Echinoderms and Ammonites.

The preponderant role played by eustatism in the distribution of sedimentationoccurred during the Senonian. Nevertheless, many tectonics phases were recorded.

Paleogeography was usually in the form of shallow inner neritic with paleoreliefs inducing formation of little confined basins, affected by marine incursions, under hot and arid climate. During the Coniacian, a regression is due to the ante-Senonian embryonic tectonic phases.During the Santonian, the sea recovers progressively nearly all the study area. A second tectonic phase wasrecorded essentially at the northern side of western High Atlas and is represented by an angular unconformity. This phase induced the formation of small confined basins separated by emerged highs. After a peneplanation, the sedimentation took place on a shallow platform of Sebkha type subject to marine incursions, under hot and arid conditions. During the Campanian, an important return movement of the sea, due to noticeable tectonic movement, put all the eastern sector of western High Atlas as emerged land, and during the Maastrichtian an important Atlantic marine transgression followed ante-Maastrichtian embryonic tectonics, and included all the studied area.

Keywords: Sedimentology, Sequence Stratigraphy, Senonian, western High Atlas, Morocco.

Characterization of the pan-African mobile belt basement deformation in Southern Maradi (South Niger), relationship with gold mineralization

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The Southern Maradi basement belongs to the pan-African mobile belt located eastward from the West African Craton (Fig. 1). In this region, the basement outcrops discontinuously over an E-W striking and long about 80 km, covering an area of approximately 633 km^2. In the study area the basement, consisting mainly of schists, metavolcano-sediments, gneiss and more or less mylonitized granitoids, which age is ranging from 2000-560 Ma.

Structural analysis of the South Maradi basement highlights the existence of at least four phases of deformation noted D_1 to D_4. Correlations with northern Nigeria basement formations used to assign a Birimian to Kibarian age (2000 to 1064 Ma, Ogezi 1977; Danbatta, 1999) to the D_1 first phase of deformation. A Pan-African age was assigned to the second phase of deformation D_2 (610-560 Ma, Breemen, 1977; Ferré, 2001). D_3 and D_4 deformation phases would be likely post Pan-African.

The D_1 phase includes three stages (D_{1a}, D_{1b} and D_{1c}). The D_{1a}, ductile episode, NW-SE shortening, is responsible for the development of a cleavage / foliation orientation average of N50° trend. The D_{1b} stage also ductile, is characterized by dextral reactivation of large-shear zone of N50° trending. In these shear zones, the foliation has a dextral sigmoidal geometry consistent with a mylonitisation (Soumaila and Konaté, 2005). The D_{1c} episode, relatively semi-ductile, is marked by sinistral reactivation of large-shear zones.

The D_2 Panafrican phase of deformation has two stages D_{2a} and D_{2b}. The D_{2a} stage is marked by a pure flattening foliation N15° to N25° trending, recovered strongly connected to a mean shortening N110° trend (Konaté, 1996). The D_{2b} episode is characterized by simple shear mylonite foliation, NS to N15° trending.

The D_3 and D_4 deformation phases was characterized by S_3 cleavages fracture subvertical orientated N80° to N120°, dextral shifted by another cleavage S_4, slightly inclined with N40° trend.

Rock samples were taken from the alluvial deposits and the basement formations in both shear zones and in less deformed areas. Preliminary results of geochemical analysis of the samples showed varying gold values. The highest values were observed within or close to the shear zones.

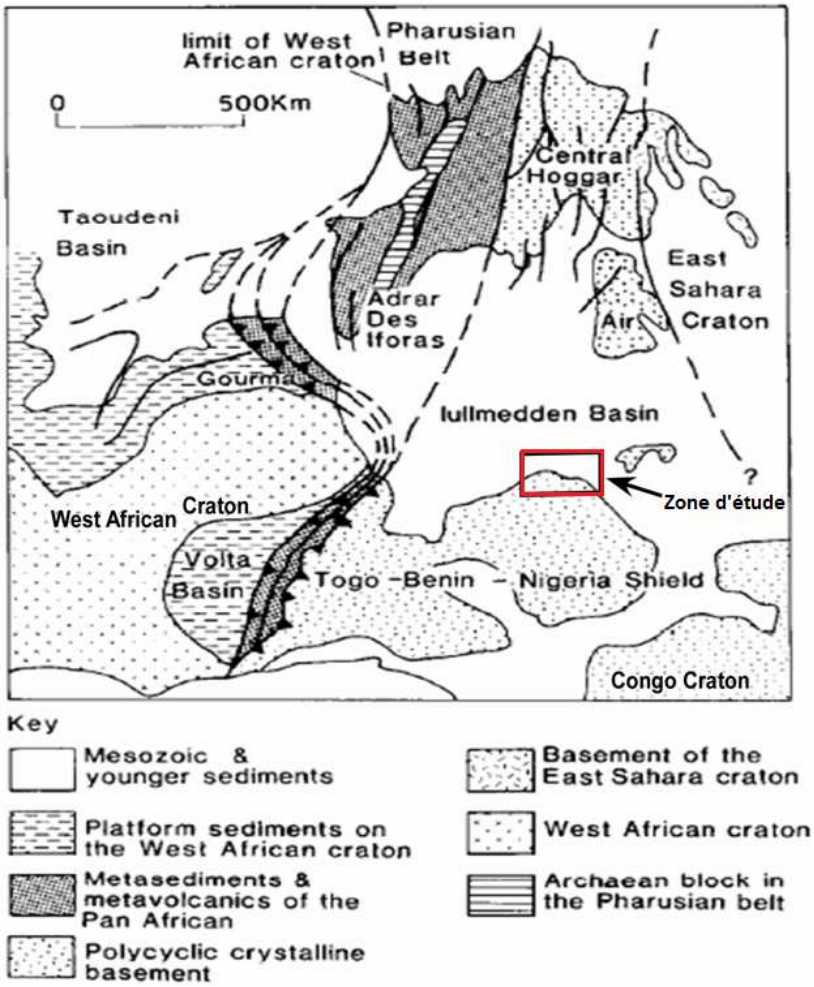

Figure 1: The eastern pan-African domain of West Africa showing the study area (Ajibade and Wright, 1988).

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Interpreting U-Th distributions in the continental crust from radiometric data

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In the mineral system concept, attainment and preservation of extreme levels of concentrations of metals require several critical elements, including a fertile source, a pathway for aqueous and magmatic fluids, and a trap. The processes involved in the transfer of energy and materials in mineral systems are inherently multi-scale.At the same time, the existence of (process-dependent) scaling laws for the trace element concentrations in the Earth's curst has been debated for several decades, with implications in economic geology, such as grade-tonnage relationships. U and Th are incompatible trace elements whose concentrations vary over several orders of magnitudes in the continental crust. Theycan be mapped at various scales (1 m to hundred's of km) using airborne radiometric surveysorhand-heldspectroradiometers. Such datasets offer a new opportunity to examine the spatial organization of Th and U and tore-assess theexistence of scaling laws and nested scales in geochemistry. We will present here a) a conceptual and numerical model for a quantitative analyse of airborne radiometric and b) its application to interpretation of radiometric data in the West Africa and Pilbara cratons. Our hypothesis implies that the relative importance of magmatic, fluid-rock and surface processes may be recognized by the analysis of the geostatistical parameters (distribution and variograms). Our model simulates a sequence of elementary geochemical processes (partial melting, fractional crystallization, dissolution-precipitation) and takes into account the scale of radiometric datatosimulate U-Th concentrations andgeostatistical parametersresulting fromvarious scenarios. The characteristics of the distributions (e.g., normal, log-normal, fractal or multi-fractal) and variograms for Th-U concentrations on mafic and felsic units of the West Africa and Pilbara cratons are tentatively interpreted within this new framework.

Tectono-metamorphic Evolution of West Africa: Implications for Mineralization

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The West African Craton (WAC) consists of an Archean nucleus tectonically juxtaposed to Paleoproterozoic granite-greenstone domains. The southern part of the craton (sWAC) was affected by up to six deformation events, which can be correlated across the craton. The first deformation episode of predominant constrictional character, called Eo-Eburnean or Tangaean, was identified in the eastern part the sWAC, operating between ~2160 and ~2130 Ma. The major phase of the Eburnean Orogeny took place between ~2130 and 2100 Ma, and it is characterized by a transition from constrictional to transcurrent regime. The latest deformation phase is as young as 2060 Ma, it is of transcurrent character, and was described in Senegal, Mali and Guinea.

Up to three metamorphic phases M1, M2 and M3, were distinguished in various studied areas. However, it is difficult to correlate them craton-wide due to the overall poorly constrained absolute ages of metamorphism. High temperature and high pressure conditions of M1 were found at the boundary between the Archean and Paleoproterozoic terrains in Ivory Coast. Another widespread occurrence of early HP and MT metamorphism M1 was found in north-western Ghana characterized by cold metamorphic gradient (15-20°C/km). High pressure-low temperature metamorphism (10-15°C/km) was found in eastern Burkina Faso. Medium to high pressures (5-10 kbar) and medium apparent thermal gradient (25-40°C/km) are common for the M1 and in particular for the M2 metamorphic phase craton-wide. The P-T paths reach early M1 pressures of 6-8 kbar and temperatures of 420-500°C

(apparent thermal gradient of 25°C/km) followed by isobaric M2 heating up to 700°C. In some areas across the craton (SW Burkina Faso, southern Mali) the peak greenschist facies metamorphic conditions during the M2 metamorphism are predominant. Late metamorphic stages M3 are characterized by low temperatures (100-400°C) and very low pressures (1-3 kbar).

Zinc, copper, and nickel deposits are associated with the very early phase of the Eburnean orogeny and are interpreted to be related to the volcanic and magmatic activity in the volcanic arcs. Gold deposits occur throughout the Eburnean orogeny. The early gold deposits such as Morila, Kiaka are related to magmatic intrusions or are found in pyrite-bearing sediments in the case of Wassa. Most of the gold deposits are associated with the regional scale late-orogenic transcurrent shear zones. Multiple mineralization events and gold remobilization was observed at many gold deposits (e.g. Obuasi, Inata, Wassa and others). To conclude, base metal deposits are essentially related to the pre- or early orogenic volcanic island arc magmatic activity, while gold deposits occur at various stages of the Eburnean orogeny, in various geodynamic settings, and under various metamorphic conditions.

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Resolving history of the early Paleoproterozoic time reveals patterns similar to those in the late Neoproterozoic

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Transition from low-oxygen to oxygenated Earth's surface environments in the early Paleoproterozoic (2.5-2.0 Ga) was accompanied by a number of equally dramatic changes. Geochronologic and stratigraphic data help constrain cause and effect relationships among these events. The supercontinent Kenorland assembled at low latitudes was impacted by a number of mantle-sourced magmatic events (=superplume) resulting in the emplacement of Large Igneous Provinces (LIPs) between ~2.50 and 2.42 Ga in association with the final stages in the supercontinent assembly and the onset of the protracted supercontinent rifting. Intense chemical weathering of juvenile volcanic rocks under low-latitude conditions and enhanced biological productivity related to a large terrestrial P flux to the oceans likely led to atmospheric methane (an important greenhouse gas in low-oxygen atmosphere) oxidation and CO_2 drawdown and, ultimately, to global glaciations. Rises and falls in atmospheric and ocean oxygenation were closely coupled to the four early Paleoproterozoic glaciations, with oxygenation events leading to and reducing conditions restricted to the Snowball Earth glaciations and their immediate aftermaths. The period marked by dramatic surface redox fluctuations and three glaciations ended up with the ~2.36-2.32 Ga arc-related magmatic activity along the margins of the supercontinent and irreversible surface oxygenation. Extensive mafic magmatic activity at ~2.22 Ga at low latitudes affected all continents and initiated the breakup of the supercontinent; in South Africa, it is associated with a glaciation, which is not yet recognized on other continents. Near-equatorial tenure of the supercontinent ended up in a series of rifting events between ~2.22 and 2.0 Ga; separated cratons were dispersed with some reassembled during the ~2.1-2.0 Ga orogenic events (e.g., Transamazonian, Ubendian, Birimian, Magondi, and Limpopo orogenies in South America, West Africa, and Southern Africa, respectively). Carbon isotope values in sedimentary carbonates, reflecting global relative rate of organic carbon burial, began to fluctuate before the first early Paleoproterozoic glaciation with the progressively increasing magnitude with the decreasing age. Large, positive carbon isotope excursions occurred between the second and third glaciations, at ~2.4 Ga, after the third glaciation at ~2.32 Ga, and, finally, between ~2.22 and 2.1 Ga (as the long-lasted, large-magnitude Lomagundi Excursion). In the

aftermath of the second glaciation, the only so far recognized Paleoproterozoic cap carbonate horizon was deposited in several basins. High rates of relative organic carbon burial and organic productivity during that time have been linked to high continental P flux delivered by acidic continental drainage systems with low pH conditions developed in response to the oxidation for the first time of continental sulphides. The sedimentary successions deposited between the aftermath of the third glaciation at ~2.32 Ga and the end of the Lomagundi Excursion at ~2.06 Ga often contain mature, clean quartz sandstones and Al-rich shales, indicating extremely high rates of chemical weathering under warm and humid climatic conditions. The Lomagundi Excursion ended up with a deoxygenation event inferred to be due to either decreased terrestrial nutrient flux or chemical weathering of organic matter- and sulfide-rich shales deposited during the Lomagundi Excursion. At least one short-lived, large-magnitude carbon isotope excursion is now recognized after the end of the Lomagundi Excursion.

Tantalizingly, similar events and temporal trends are also observed leading to the Neoproterozoic oxygenation event more than billion years later. The supercontinent, Rodinia, was assembled by ~900 Ma and was affected by emplacement of a series of subaerial LIPs at low latitudes. The accompanying enhanced flux of nutrients resulted in high relative burial rate of organic carbon, instability of the biogeochemical carbon cycle, and ocean and atmosphere oxygenation leading to the Snowball Earth glaciations. A series of three Neoproterozoic glaciations, with two marked with the overlying cap carbonates, eventually terminated with the Neoproterozoic oxygenation event linked with the emergence of Metazoa and extensive deposition of the Late Ediacaran to Early Cambrian clean and mature quartz sandstones and phosphorites. True polar wander has been inferred to swing Rodinia to low latitudes. Impressive similarity among these events and their temporal sequences at the beginning and the end of the Proterozoic argues for similar underlying controls and mechanisms. It thus seems likely that tectonic and magmatic activity, specifically supercontinent cycles and superplume events, rather than the evolution of life and surface environments determined long-term changes in climate and composition of the atmosphere and ocean at both ends of the Proterozoic.

Fluvial event and associated intra-Carixian facies in the Liassic carbonate platform of the Grand Pic, Ouarsenis Massif, Algeria: duration, causes and effects

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The succession of the Jurassic formations of the Ouarsenis massif provides a good example for the study of the carbonate platform sedimentation. It belongs to the external domain (Alpine domain) on the Tethyan margin of North Africa. On the southeast Tellian edge, the particular study of the Jurassic massif culminating Ouarsenis (Grand Pic) provides valuable tools for understanding the external zones of the Rif-Tellian Orogen and appraise the operational structures of the platform. The Carixian lithostratigrahic unit is composed of two well prioritized formations and limited by a major unconformity, called intracarixian fossilizing net paleosurface. These formations, tectonically overturned, begin with tidal carbonates namely "Kef Sidi Amar carbonate formation" by which the initial carbonate platform probably developed from the Sinemurian. They delivered brachiopods, including multi-folded Zeilleria (*Tauromenia*) from late Sinemurian (~Upper "Lotharingian") to early Carixian (lower part of Jamesoni zone). Above, the oolitic limestones are dated by rare ammonites (*Gemmellaroceras* sp.) indicating a Lower Carixian age. On the paleosurface the "Djorf Touka limestone formation" expanded. It consists of a succession of "dark limestones" rich in lituolids, limited by a "2nd intra-Carixian unconformity" so-called break, in which limestones with large bivalves can be found. They are bordered by a ravinement surface highlighted by the occurrence of gastropods associated with *Metaderoceras* sp. (Carixian). The upper part is characterized by a combination of *Lobothyris fusiformis* (Dubar) and *Gibbyrhynchiatounatensis* (Rouselle & Bisch) collected in the "chaetetid level" of Upper-Middle Carixian age. This level is framed by two unconformities, channelled at the base, bio-turbated and bio-eroded with accumulation of brachiopods at the top. This surface marks the ante-Toarcian unconformity.

The first step in the platform history shows that it was invaded by the transgression of a shallow sea affected by several interruptions during the Liassic (Lower Carixian). The most

important event is that intra-Carixian unconformity emplaced within internal platform deposits, being able to briefly communicate with the open sea.

The boundary between both the lithostratigraphic units is marked by a net sedimentation stop accompanied by digging "incisions" filled by a complete fluvial sequence (conglomerates, coarse and middle sandstones, sandy clays, stringer glaebules, rhyzoliths). This sequence is followed from either side by associated sedimentary facies (paleosol, marmoration, dolomitization, calcrete) during a general regression in the region as evidenced by desiccation phenomena, soil formation processes and karst fissures probably of tectonic origin. For these reasons, the unconformity D_1 called "1st intra-Carixian unconformity" corresponds to type 1 unconformity definition and/or forced regression. It is a sequence boundary ["Sequence-Boundary"=SB, Vail et al., 1987]. Note also that the surface is rugged by a mafic magmatism. The intensity of the break is amplified by tectonic processes that initiated the breakup of the initial carbonate platform.

This prescribed unconformity recorded a transgression-regression cycle which shows a stack of elementary sequences marking a trend of deepening, corroborating marine facies increasingly and denoting a general retrogradation phase on top of *Oxynotum-Obsutum* tidal facies zones. During this period, frank marine conditions and a high sea level induced bio-constructrive activity which automatically "failed" by the drastic drop of the sea level.

Biostratigraphic, sequential and paleostructural data allowed to better replace the evolution of the Liassic carbonate platform of the Grand Pic. It is part of the regional dynamics that caused, during Middle Liassic, differentiation of a structural mosaic with a decametric mesh. Supratidal environments remain on paleotopography while adjacent areas deepened as a result of a tectonic decoupling complicating the consequences of the "Demonense" event well known in North Africa.

The survival of this paleosurface which fits between the Jamesoni zone (Lower Carixian) and Demonense and Dilectum zones (Upper-Middle Carixian) marks a very short time, probably hundreds of thousands of years (0.5 Ma) (upper part of Jamesoni zone) before the continental witnesses are flooded by the transgression of the Middle Carixian (Djorf Touka limestone formation) and consequently causing abortion of the platform continentalization form at the end of the Lower Carixian (ante-Demonense event).

Keywords: plateform, forced regression, unconformity, biostratigraphy, Carixian, Ouarsenis.

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Metallogeny of Paleoproterozoic Yetti-Eglab Massif, South-Western Algeria

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The Yetti-Eglab massif, located in south-western Algeria and belonging to the north-eastern part of the Reguibat Ridge (northern branch of West African Craton) shows Paleoproterozoic formations (2.21 to 2.07 Ga) Birimian-Eburnean dominated by magmatic events (Peucat et al., 2005). It follows an arc collage (Kahoui et al., 2001) from 2.09 Ga (Lefort et al., 2004) and that evolved later in shear zones (e.g.Yetti-Eglab and Chenachane Shear-Zones).

Mineral exploration works carried out on the area enabled the discovery of numerous mineral deposits (Mo-Cu, Sn-W), precious metals (Au), (U-Th, REE) and diamond shows; but still little studied the metallogenic standpoint (Lagraa et al., 2016). Thus, initiating new studies on specific themes (magmatism, tectonics, geophysics, metallogeny) is crucial for understanding the geology to better define the mineral potential of this Paleoproterozoic region.

Keywords: Yetti-Eglab massif, Reguibat Dorsal, Paleoproterozoic, mineral deposits, metallogeny.

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The Co, Ni, Cr and S mineralizations during serpentinization process in the BouAzzer ore deposits (Anti-Atlas, Morocco)

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The serpentinization of the harzburgitic mantle section of the BouAzzer Neoproterozoic ophiolite is studied by field mapping, structural observations, optical micrography, SEM and X-ray diffractometry, and relationships with Co, Ni, Cr and sulphides minerals are discussed. Serpentinization occurred in two major steps with:

(i) intra-oceanic pseudomorphic serpentinization materialized by the isotropic serpophite often associated with antigorite fibres preserving the primary form of olivine crystals, and

(ii) tectonic serpentinization with lizardite and chrysotile crystallization during ophiolite obduction and deformation in relation with synkinematic granitoid intrusions (*ca.* 650-635 Ma).

Brucite is fairly frequent as inclusions in the serpentine aggregates. The serpentinization processes led to the remobilization of S, Fe, Ni and Co included in the primary magmatic assemblage. The sulfide assemblage varies with the degree of serpentinization, with from low to high degrees: pentlandite + pyrrhotite + pentlandite + heazlewoodite (godlevskite); pentlandite + polydymite (or violarite); pentlandite + millerite, and polydymite + millerite. The presence of orcelite, the only stable Ni arsenide during serpentinization, reflects conditions of high activity of Ni and low activity of Fe in the fluids involved in serpentinization. The relative frequency of maucherite underlines the importance of arsenic in mantle-sourced fluids. The values of the arsenic activity could locally be as high as that of sulfur to form an immiscible As-rich liquid, which is the origin of As-rich paragenesis of high temperature.

Keywords: Bou Azzer, Ophiolite, Serpentinization, Pseudomorphic, Morocco.

About dark Magmatic Enclaves of Ait-Oklan and Teg-Orakgranitic massifs, Hoggar, Algeria

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Like other petrological and geochemical criteria, the nature of enclaves is likely to provide information on the origin of magmas. It allows to distinguish the original crustal granites, the mantle and mixed granites.

The first contains abundant over micaceous enclaves but not dark microgranular enclaves. The second contains dark microgranular enclaves but not over micaceous enclaves. The last whichis also the most numerous, since it corresponds to the wide range of orogenic granodiorites and monzogranites, contains both dark microgranular enclaves and over micaceous enclaves.

As for the xenoliths and clear microgranular enclaves are found within the intrusions, regardless of their petrographic characteristics. They present enclave characteristics of setting up intrusives.

Very few magmatic enclaves have been observed in these massifs. It is in the central end granite that has been observed this phenomenon. These are microgranular enclaves, with widely varying sizes. The most common are centimetric size, they have an ovoid shape and a rounded contour and are formed by magmatic microgranular or grained rocks, net or diffuse contact with their host rock.

Keywords: magmas, granite, enclave, EMS, Hoggar.

Fluid inclusion characteristics of Aniuri and Jonction gold deposits (Aboisso, Southeastern Ivory Coast)

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The Aniuri and Jonction gold deposits are located in the Afema shear zone which contains the most significant gold mineralizations within the gold fields of Aboisso, southeastern Ivory Coast. These mineralizations are enclosed in quartz veins affecting metaarenites. Two primary ore types are recognized: (i)combinedgold mainly contained in the gold-bearing pyrite associated with arsenopyrite; (ii) free gold associated with arsenopyrite, chalcopyrite, and pyrite in quartz veins. Mineralized quartz is observed as: (i) well crystallized, smoke-grey quartz (quartz I) contemporary of gold-bearing pyrite, and (ii) white to grey quartz (quartz II) resulting from a subsequent silicification. Three types of primary fluid inclusions are observed in quartz I: aqueous, aqueous-carbonic (≥60 %), and carbonic fluid inclusions. The coexistence of these three types of fluid inclusions in the same clusters allows us to propose that fluid immiscibility has occurred in the primary quartz vein of the Aboisso gold field, the original fluid being an homogeneous H_2O-CO_2-NaCl fluids with minor amounts of N_2± CH_4 and low salinity (lower than 13.4 wt % eq. NaCl). Only aqueous fluid inclusions were observed in the second generation of mineralized quartz vein (quartz II); they have also been observed in quartz I as fluid inclusion planes. Fluid inclusion studies indicate that Aniuri and Jonction deposits resulted from two successive stages of mineralizations characterized by two distinct P-T conditions: (i) event 1 occurring at 300-420 °C and 125-260 MPa; and (ii) stage 2 at 200-340 °C and 100-200 MPa.

Keywords: Gold, Fluid inclusions, P-T conditions, Birimian, Aniuri, Jonction (Ivory Coast)

Lithological Architecture and Petrography of the Mako Birimian Greenstones Belt, Kédougou-Kéniéba Inlier, Eastern Senegal

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The Mako sector in the southwest of the Mako Supergroup consists of ultramafic, mafic, intermediate and felsic rocks associated with intercalations of sedimentary rocks. The whole unit is intruded by Eburnean various granitoids and affected by a greenschist to amphibolite facies metamorphism associated to a high grade hydrotermalism. The ultramafic rocks consist of lherzolites, wehrlites and pyroxenites outcroping on the hills of east and west of Mako village. They are associated with mafic rocks made up of meta-gabbros with variable textures passing gradually to massive meta-basaltes and pillow lavas at the top. Lenses of dark and ribboned quartzites are on top of or inserted within the mafic rocks. The intermediate and felsic rocks comprise lava flows and tuffs of andesites, rhydacites and rhyolites arranged in tectonic corridors between Mako and Bafoundou villages. Three generations of Eburnean granitoids are recognized: (i) early π_1 (2200-2160 Ma); (ii) syn-Eburnean π_2 (2140-2100 Ma) and post-Eburnean π_3 (2080-2040 Ma). Two lithological units can be distinguished according to the geometrical relations between these various facies. A lower assemblage made up from bottom to top of: (i) ultramafic rocks which inclusions can be observed in the mafic rocks; (ii) layered, isotropic and pegmatitic metagabbros which gradually pass to metabasaltes at the top; (iii) massive and in pillow lavas metabasalts; (iv) quartzites superimposed over the mafic rocks locally and thus forming the top of the lower unit.

This lower unit presents a volcanism of tholeiitic affinity near to the IAT and PMORB (Ngom, 1995). The lithological succession and its geochemical characters point out an ophiolitic Supra-Subduction Zone (SSZ) (Pearce et al., 2003).

The upper unit consists of andesitic to rhyolitic lavas and tuffs of calc-alkaline affinities of active margins (Ngom, 1995), arranged in the tectonic corridors. From bottom to top it concerns (i) andesitic, and (ii) rhyodacitic and rhyolitic lava flows and tuffs, respectively. Granitoids are made up of granites, granodiorites and diorites and emplaced in both previous units.

Keywords: Birimian, Mako, Senegal, lithology, ophiolites, pillow lavas.

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The mafic enclaves within the Eburnean granitoids of the Mako Paleoproterozoic Greenstone Belt, Eastern Senegal

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The Eburnean granitoids of the Mako sector consist of diorites, granodiorites and granites. They form several generations of massifs with variable dimensions, which are intrusive into the ophiolitic and mixed volcanic complexes.

The mafic enclaves of the granitoids are of two types: basaltic enclaves with reactional crown and dioritic enclaves with diffuse boundaries. The basaltic enclaves are made up of secondary amphiboles, of plagioclases associated with rare olivines, pyroxenes, feldspars and quartz.

In the granodiorite of Soukourtou (northern Mako), these mafic enclaves are metagabbros which show a brown reactional crown microgranular texture which separates them from minerals of the granodiorites. It locally appears injections of the granodiorite within fractures of the enclaves. The dioritic enclaves are mainly made up of secondary amphiboles associated with quartz and feldspars and rare relics of pyroxenes. The contact between minerals of the enclaves and those of the granodiorite is diffuse. By places, enclave minerals are isolated within minerals from the granodiorite and viceversa. It is the case of the granodiorite with dioritic enclaves of Niéméniké. These two types of enclaves would result from a mixture between mafic and felsic magmas. In the case of basaltic enclaves the mixture would be incomplete (mingling) or non-existent (Pitcher, 1993; Nédélec and Bouchez, 2011). Both the magmas would be diachronic. The mafic material already cooled is included in a cooling felsic magma. In the case of dioritic enclaves both the magmas would be

contemporaneous and the mixture is more important leading sometimes to hybrid diorite rocks standard (Nédélec and Bouchez, 2011). Mesocrat diorite quarzite located 1 km SE of the granodiorite with dioritic enclaves of Niéméniké would be the ultimate phase of this mixture. The rock shows a grained texture made up of centimetric plagioclase and amphibole rods, intermingled with some quartz and biotite. It presents fractures secondarily borrowed by quartzo-feldspathic arrivals. The mineralogical similarity and the geographical proximity of mesocrat diorite quarzite and the enclaves of the granodiorite let suppose a comagmatic link. The complete mixture occurs within the framework of a turbulent plume leading to the formation of a dioritic hybrid rock (Huppert et al., 1986; Nédélec and Bouchez, 2011). Thus, the mafic enclaves of the Mako granitoids would be dependent on an incomplete (mingling) or complete (mixing) mixture between a mafic and a felsic magma, respectively. The age of the Mako granitoids turns between 2.2 Ma and 2.0 Ma (Delor et al., 2010).

Keywords: Enclaves, Granitoids, Eburnean, Paleoproterozoic, Mako.

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The Structural Evolution of the Dialé-Daléma Basin, Kédougou-Kéniéba Inlier, Eastern Sénégal

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The Dialé-Daléma group is located in the eastern part of the Kédougou-Kéniéba Inlier (KKI). It is essentially composed of Paleoproterozoic formations. Several lithostructural studies in this area have allowed the proposition, often controversially, of several phases of deformation during the geodynamic evolution of the region. In this study, we suggest the existence of D_1 and D_2 deformation phases. D_1 is of a tangential nature. It is mainly characterized by flat folds and a main shortening stress generally NW-SE oriented. D_2 is of a transpressional character. It is divided into two stages. Thefirst one, (D_{2a}) is of a coaxial and compressive nature. It is characterized by a NS to NNE-SSW trending foliation S_{2a}. It evolves gradually to a transcurrent phase (D_{2b}), characterized by F_{2b} folds with generally subvertical axes, affecting the S_{0-1} and by a NNE-SSW to NE directed S_{2b} foliation. During the D_2 phase, the main shortening stress gradually pivots from the EW direction to NNW-SSE direction after a clockwise rotation in a context of continuum of deformation. Furthermore, we have identified two regional phases of deformation named D_3 and D_4. The D_3 is also divided into two stages: D_{3a} and D_{3b}. D_{3a} is of a transtensive and transcurrent nature. It is characterized first, by NE-SW sinistral shear corridors, which are locally associated with extensional jogs. During this stage, σ_1 is NS to NNE-SSW oriented. Secondly, the D_{3a} shortening stress (σ_1) evolved from the NS to NE-SW orientation causing dextral NS shear corridors of a transcurrent nature. D_{3b} is of a compressive nature with a weak sinistral shear component. It is at the origin of brittle structures and conjugated shear corridors crosscutting D_2 fabrics. These structures are generally NE-SW, EW and NW-SE oriented. The D_4 corresponds to an extensional phase, in NS direction, which generates normal faults of overall EW direction. D_4 could correspond to the final stage of the evolution of the Eburnean orogeny in the KKI

Keywords: Structural evolution; Paleoproterozoic; Daléma; Senegal.

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Litho-Structural interpretation of magnetic anomalie in South-West Mali: Kédougou-Kéniéba Inlier.

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The study area lie in the Malian part of the Kédougou-Kéniéba Inlier (KKI). The KKI is the westernmost exposure of Paleoproterozoic crust in the West African Craton. It consists of linear volcano-plutonic belts and sedimentary basins, which are separated by the Main Transcurrent Zone (Ledru et al., 1991) and the Senegal Mali Shear Zone (Bassot and Dommanget, 1986).

This work presents the results of the first year of the Ph.D. thesis. It presents an updated litho tectonic map of the Malian side of the Kédougou-Kéniéba Inlier based in the interpretation of field and airborne geophysical data. This map shows major NNE-SSW structures in the southern part intersecting a magnetic anomaly. This anomaly is a tourmalinite rock intersected and shifted by these NNE structures. It consists essentially of tourmaline (up to 80%), quartz, and rutile. Muscovite, goethite, zircon and apatite were also found in this rock. This tourmalinite anomaly is one manifestation of a regional boron anomaly that extends for more than 200 km along the strike of the Senegal-Mali fault system (Lawrence, 2010). A release of B-rich fluids from fractionated felsic melts (London et al., 1996) is one potential source for the anomaly, and the pervasive growth of epigenetic tourmaline (Lawrence 2013a). It is likely that the source and the establishment of this tourmalinite is the same as Loulo (Lawrence, 2013a and 2013b, Lambert-Smith et al., 2016). A tourmaline isotope study is warranted to further examine the origin of these tourmalines.

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Hydrogeology of the base and sustainable development

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Hydrogeology is a science that studies the flow of groundwater, its management and its optimal protection against pollutants. It uses in his logical approach to other disciplines such as physics mathematics, computer. In the African continent, groundwater resource is important to note the aquifers of the Northern Sahara (Algeria, Tunisia and Libya), sandstones Nubians

In sub-Saharan countries like Senegal, the scarcity of surface water because it involved little to supply the population with water (Serigne Faye 1995). The essential water destine to the water supply of the population is drawn from Lake Guiers and the largest aquifer system that is the Maastrichtian. Among the water resources of the Senegal we distinguish 4 major aquifer systems namely the shallow aquifer system called "terminal complex" which includes the sandy clay and sand dominant formations of the Quaternary (QT), the Continental Terminal (CT) and the Oligo-Miocene (OM), the intermediate aquifer system that groups mainly karst limestone formations in places, marl and limestone of the Eocene (EO) and Paleocene (PA), the deep aquifer system regarding single sand formation in sandy loam or sandstone Maestrichtian (MA), covers almost all of Senegal basin and is a huge reservoir and finally the aquifer base system which includes the semi-continuous discontinuous aquifers cracks and alteration granitic and metamorphic formations of eastern Senegal (Southeast),

with tablecloths, the quality and volume are still not satisfactory (source ministries of hydraulic, October 2015). The configuration of the aquifer system in the Senegalese base is arranged as a result; the base was fresh rock that is impermeable, followed by a rock fracture zone can be a very productive aquifer when these fractures are related and finally we have a highly altered rock area called regolith including their storage capacity in water Apart from these flow parameters (porosity, permeability storage coefficient) depends on its thickness.

The operation of the water base areas is very complex and requires mapping and precise data to identify the junction of these fractures for productive drilling and avoid empty only an isolated fracture during operation. The exploitation of these resources and exaggerating the climate change phenomena make these water resources are becoming increasingly scarce.

Indeed groundwater resources are now highly exploited in the country with the implementation of several boreholes throughout the 14 regions, and that accompany climate change, resulting in a change in rainfall, which is like one natural source of groundwater recharge of aquifers to share the exchanges of flow of water that is between a river and the groundwater. Sustainable development requires good water resources management and protection especially in base zone because it is very vulnerable aquifers to pollution but this may be dampened by the realization protect area around the water harvesting zones for consumption and also make long-term investments in this sector because it is also its sustainability.

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Index of Lithium and associated substances mineralization in the Kédougou Kéniéba Inlier, East Saraya area

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In pegmatites, Li appears as metasomatic process in the differences phases of evolution: at an early phase, it replaces K in microcline to form spodumene. In a second advanced phase (greisen), it would intervene with Rb, K, Ca to form lepidolite.

The East Saraya area constitutes a portion of the Kédougou Kéniéba inlier; which contains geological formations dated from Lower Proterozoic (Birimian), divided into two Supergroups (Bassot, 1987): Mako and Dialé Daléma. These Birimian formations consist mainly of volcanic, sedimentary and volcano-sedimentary rocks which are cross-cut by granitic intrusions (Saraya and Badon Kakadian).

The courses which are magmatic continuation of Saraya consist of a nested cogenetic massif forming the Saraya Batholith in nested plutons. These plutons are characterized by elliptical shapes highlighted by magma produces paths (ENE-WSW general axis).

In the East Saraya sector, the banking granitoids is mainly sedimentary and volcano-sedimentary (Daléma). These formations were folded and schistosed during the major deformation (D_2) which had structured this area. These granitoids are represented by synkinematic massifs (Saraya, Moussala, Gamaye, Boboti and Dar Salam) that are post-tectonic which is rare in this part of the inlier.

As in all the massifs, one notice the presence of plurimetric micro-veins of pegmatites containing black tourmaline:

In the area of Saroudia, the typical facies of biotite and muscovite with coarse texture is oriented and represented by some small shreds and distributed between Dinndiari and Nafadji. The thin facies with biotite is weakly oriented or not. Yet this facies is well represented between Toubakouta and Samékouta. It contains numerous pegmatite fields (black tourmaline in pegmatites). Between Nafadji and Toubakouta, the granitic Saraya massif has a border facies at biotite and amphibole slightly oriented or not. Melanocratic endopolygenic enclaves are common. Many pegmatites quartz, feldspar, tourmaline often cross-cut this facies and form true pegmatitic fields (Kobokoto).

The typical facies is a porphiroid with coarse muscovite. It is found in several isolated outcrops in the micaschists between Nafadji and Moulounga. Two greisen associated with this facies have been recognized.

In the Ylimalo area, the Saraya granite is homogeneous in the central part of the sector. The most typical facies is an oriented granite with muscovite. In the northern sector, a facies of border whith thin grain and rich in pegmatite with tourmaline is well developed on the Balakonko-Ylimalo axis. At the northern extremity of the Saraya granite, the melanocratic enclaves (biotite, amphibole, tourmaline) are frequent, elongated and oriented parallel between them, introducing witnesses of original schistosity and many pegmatites with muscovite and tourmaline.

The East Saraya sector contains in the same area many index of Li mineralization and associated substances:

In the Ylimalo area (13°64'N, 11°29'W), the works carried out in the sector (e.g. BRGM, 1962) show that the encountered ore is constituted by a lithium aluminosilicate or spodumene. It is found in the pegmatites of this region that are related to the granitic massif of Saraya. The contents of Li_2O are about 6%. The evaluated reserves of spodumene are over 5,000 tons.

Samples of strems sediment were taken from three sectors (Kolia, Bambadji and Nafadji), established on the basis of mineralization index mentioned in the documentation of previous geological work. The results are presented as informative geochemical map. Such map offers preliminary information on the presence of mineralization of Nb, Ta, Li, Sn and Il in this region. Following geochemical interpretation of the results of analyses carried out on rock samples and termite mounds (Binia Resources, 2014) and the study of the geological documentation, the sector of Saraya detects favorable areas for lithium mineralization and related substances.

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Multi-scale analysis of Potassium, Thorium and Uranium concentrations in Paleoproterozoic granites from eastern Senegal

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Airborne gamma rays surveys have been used in Australia, and more recently in West Africa, for geological mapping in a context of scarcity of outcrops. The quantitative use of airborne surveys (e.g., evaluation of total budget in rocks, scaling laws, or correlation with elements of economic interest) requires an understanding of the factors controlling the airborne signature, including the spatial distribution in fresh rocks, soils and regoliths at small scale. In order to tackle this question, we have examined the distribution of K, Th and U concentrations from airborne (~30000 km^2 in Eastern Senegal, 250 m line spacing) and ground-based radiometrics (several grids of 150 m x 150 m, 5 m resolution) acquired with a portable gamma ray spectrometer at 4 Paleoproterozoic granitoid massifs of East Senegal (Balangouma, Moussala, Saraya and Badon). We find that the spread of K, Th, U concentrations within a grid may be comparable or may even exceed the spread of concentrations from airborne data over the entire granite, suggesting fractal or multi-fractal behaviors. Log-normal distributions are common in ground measurements, whereas normal and log-normal distributions are observed in airborne data. We assign modification of distributions, at least in part, as being the consequence of the application of the central limit theorem to gamma ray data, given the difference in scale between the two data sets. Mean values observed from ground-based data do not usually match the mean value for the corresponding granite from airborne data. Other factors are there fore involved, such as the variable surface proportion of soil, regolith and fresh rocks in each pixel. Our study illustrates that K, Th, U concentrations vary at all scales (from regional to outcrop scale). The new evidence for asymmetric distributions at small scale implies that the concentrations in airborne radiometrics are usually shifted to higher values with respect to most frequent concentrations met on the ground.

The orthogneisses of SASCA domain (Ivory Coast, West African Craton): some Birimian crustal segments with a strong archaic signature

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The coexistence of archaic and modern lithological characteristics in the Paleoproterozoic domain (Birimian) of the Man shield (southern West African Craton) once more calls into question the secular change of the Archaean-Proterozoic boundary, which would correspond to the end of the archaic processes of crustal genesis. The study of orthogneisses of the south-west of Ivory Coast (SASCA domain for the rivers Sassandra and Cavally which cross the domain), precisely those localized from Bliéron to Grand-Béréby shows indeed the persistence of the archaic processes in the Birimian domains with the presence of TTGs. Sm-Nd isotope systematics of two paragneisses associated with the orthogneisses give model ages and εNd close to 2.5 Ga and zero, respectively, indicating the incorporation of Archaean inherited components in the protoliths of the Birimian formations of the studied sector. The studied area belongs to the transition zone located between the Archaean and Birimian domains sensu stricto, where Archaean relics dated at 3.2 Ga were found. The geodynamic model that we propose for the genesis of the formations of the studied area in particular and for the SASCA domain in general takes place in two stages. Firstly, we suggest a subduction of an oceanic crust. Secondly, this oceanic slab melts during the subduction to generate an abnormally thickened crust at the base of which TTG magmas occur. The upward vertical movement of the TTGs and a general NW-SE shortening generate the vertical structures which characterize the formations of the area.

Keywords: Orthogneiss, TTG, SASCA, Birimian, West African Craton, Ivory Coast

Tectonics-mineralisation relationships in ancient cratons, a new structural framework

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Field and experimental works on deformation modes of hot continental lithospheres in compressive regimes show major differences compared to modern orogenic belts (Gapais et al., 2014). These works led to a new tectonic model marked by compression-induced downward motions of pop-downs of upper-crustals. Downward motion of upper-crustals does not require any gravity-induced processes as has been proposed for sagduction of heavy greenstone belts in the Archaean. The first-order requirement is a weak lithosphere with a ductile lithospheric mantle (Fig.1). In such a context, pop-downs of upper crust pile up along vertical deformation zones potentially connected with the underlying ductile mantle. These zones are marked by high strains, steeply dipping foliations and steeply plunging stretching lineations. They are particularly favourable for circulations of fluids of various origins from surface to mantle, and for long-lived fluid trapping and fluid-rock interactions (Fig. 1).

We present field examples from various areas (Africa, Canada) arguing that pop-down tectonics maybe a key for various ore concentrations (Sb, Au, Ni, U) in various crustal levels (from greenschist facies to partial melting) within Archaean and Paleoproterozoic belts. Potential applications to western Africa and Guiana shield are further discussed.

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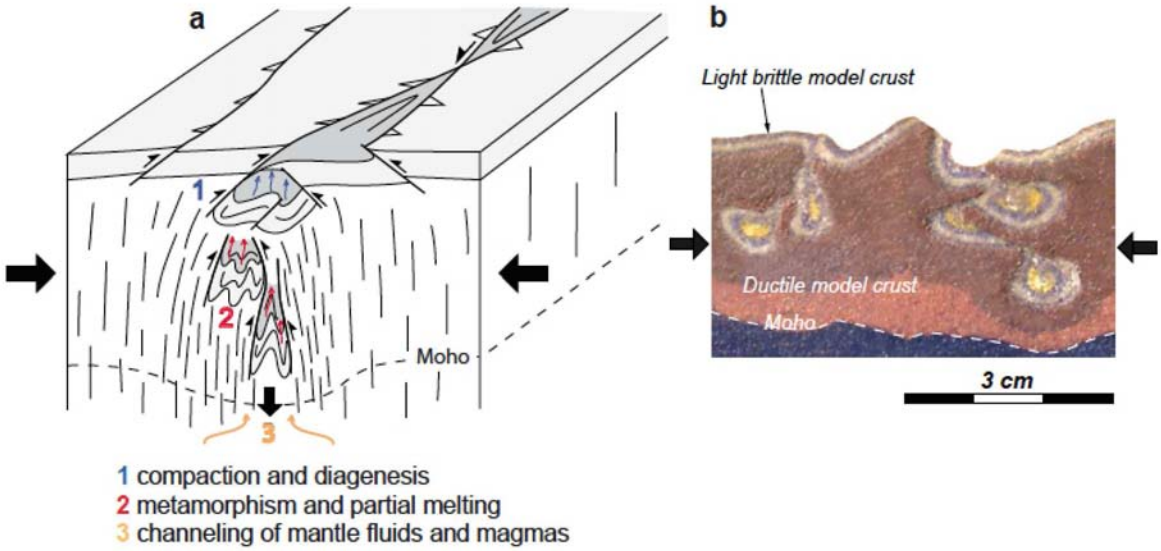

Fig. 1. (**a**) Model of compression of a hot lithosphere where piling-up of upper crustal pop-downs may favour interactions between crustal deformation, fluid transfers, fluid trapping, and potential ore deposits. (**b**) Analogue model of shortened weak continental lithosphere showing piling-up of upper crustal pop-downs within underlying weak crust (Gapais et al., 2014).

Contribution to the localization of favorable layers for traditional exploitation of pottery: example of the High Atlas of Marrakech, Morocco

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This contribution is to locate and characterize favorable layers for traditional pottery mining using geochemical analysis of clay samples in the High Atlas of Marrakech area. The macroscopic and microscopic descriptions of the different layers identified in the study area allow the interpretation of sedimentological and structural characteristics of each facies. At the outcrop, these facies are generally marked by abundant desiccation figures and the presence of traces of biological activity, reflecting a low layer of water depositional environment under a moderate to low hydrodynamic regime. The geochemical analysis on claysamples show relatively similar results to that of the Ourika Douar Tafza region. As such, we are convinced that the results presented in this work will be useful and will provide a good orientation for the future potential developmental projects.

Keywords: traditional pottery mining, clay geochemical analysis, High Atlas.

Example of paleo-Sebkha littoral Senonian deposits in the AitOurirBasins area, High Atlas of Marrakech, Morocco

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The comparative analysis of three sections oriented West-East at the level of the Jbel Sour Basin, helped to defining during the Santonian:

* A western sector of detrital coarse sediments, deposited in the context of a fluvial dynamics.

* An eastern sector of mainly carbonate-evaporite sedimentation, in a less deep and confined environment, subject to significant subsidence under a hot, arid climate favoring the formation of Sebkha facies.

These Santonian deposits are organized in a regressive megasequence, surmounted by a Maastrichtian transgressive formation, corresponding, in this area, to a tidal-flats environment. This evaporite series is marked by the return of the epicontinental sea, under a hot, arid climate, by an Atlantic transgression encompassing the entire study area.

Keywords: Senonian, Sebkha, sedimentation, ichnofacies, containment, subsidence Marrakech High Atlas.

Geology, Hydrogeochemical Modeling and Prediction of Water Pollution in the lower alluvial Aquifer of the Soummam Valley, in north-east of Algeria

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A qualitative approach has been applied in order to study hydrogeochemical functioning and evolution of water quality of the alluvial aquifer in Lower Soummam Valley in the North-East of Algeria. The Soummam valley is at the heart of environmental major preoccupation in Algeria, it represents an important dynamic artery which insures development of the Kabyle hinterland. This work is the first integrated approximation between surface water and groundwater quality in the valley. Seasonal concentration evolution and effects of the natural (Geological context) and anthropogenic factors (agriculture, industry and urban wastes) were evaluated. Then, a hydrogeochemical model was developed in order to simulate contaminant transport in the alluvial aquifer and enhance the understanding of the impacts of agriculture and industrial activities and urban wastes, on groundwater quality. It is used as a predictive model for the valley and will constitute a roadmap in order to restore water quality as required by the European water quality guidelines. Three objectives were developed in this paper, *i)* understand sources and transport of pollution flux between Soummam oued and aquifer, *ii)* simulate and predict groundwater concentrations until 2030 and *iii*) evaluate impacts of human activities and establish vulnerability and pollution risk map. This work encourages integration of quantitative management tools and environmental control and predictive tools in order to preserve water resources of the valley.

The Eburnean granitoids of the Mako Birimian Greenstone Belt, Kédougou-Kéniéba Inlier, Eastern Senegal

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The granitoids of the Mako sector consist of diorites, granodiorites and granites. They form several generations of massifs with variable dimensions, which are intrusive into the ophiolitic and mixed volcanic complexes. According to their age, their relationships to Birimian formations and Eburnean deformation, three groups of massifs can be distinguished: (i) early granitoids π_1 (2200 Ma to 2160 Ma), deformed and intrusive into the Greenstone Belts; (ii) conformable syn-tectonic granitoids π_2 (2150 Ma to 2100 Ma); (iii) and subarounded post-tectonic granitoid π_3 (2090 Ma to 2040 Ma). Both the last groups are intrusive into the Greenstone Belt and the sedimentary Birimian basins.

Early Granitoid $\pi 1$ are represented in the Mako sector by Soukourtou microgranite with biotite cross-cut by granodiorite with mafic enclaves. At the outcrop, the coloured rock is folded and foliated, presenting a microgranular texture mainly composed of quartz, feldspar, biotite, muscovite, epidote and opaque minerals. This microgranite underwent the effect of contact metamorphism related to the emplacement of the granodiorite with mafic enclaves which involved its deformation and its transformation into orthogneiss. This granite with orthogneiss biotite would represent a part of the granodiorite of Badon located at ~3 km northward and which was dated by Pb/Pb method on Zircon at 2213 ± 3 Ma (Gueye et al., 2007). This early plutonism is associated with the ophiolitic complex of the Mako sector.

Conformable syn-tectonic granitoid π_2 are the massifs elongated according to NE-SW to NS Eburnean directions and often containing enclaves of mafic rocks. They show a planar anisotropy marked by the stretching of minerals according to foliation. In the study sector, they are represented by the granodiorites of Soukourtou and the curve of Sékhoto Peul along the RN7 road as well as mesocrat diorite of Niéméniké. The mafic enclaves of the granodiorites are generally deformed (boudinaged, sheared, twisted) with irregular borders. In chronological viewpoint, these diorites and granodiorites would be the equivalent of the

granodiorite of Soukouta, located at ~5 km westward, dated by U/Pb on zircon at 2142 ± 7 Ma (Delor et al., 2010).

Post-tectonic granitoids π_3 form subarounded massifs with equant texture often without enclaves and unconformable on Eburnean structures. They are represented by the pink granite of Niéméniké, made up mainly of orthoclase, bluish quartz, plagioclase, amphibole and mica layers. These post-tectonic granites can be chronologically related to that of Tinkoto, located at ~7 km southward and dated by U/Pb on zircon at 2074 ± 9 Ma (Gueye et al., 2007).

Keywords: Granitoids, Eburnean, Birimian, Mako, Kédougou-Kéniéba

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The Barite, Chalcocite and Galena Mineralization of the Ougarta Chain (South-Western Algeria)

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The Ougarta chain is a folded region which underlines the old suture between West African Craton and the Hoggar shield. The Ougarta chain is formed by two distinct structural units: a volcano-sedimentary basement probably structured during the Pan-African orogeny and lately intersected by volcanic rocks. Basement and volcanic rocks are covered by a Paleozoic cover in a major unconformity position. The Paleozoic cover is formed by a big detrital series and folded during the Hercynian orogeny. This Paleozoic cover is in its turn overlain unconformably by Cretaceous formations or by Neogene deposits. It has a general NW-SE orientation. It is divided into two main distinctive domains: (i) the Daoura Domain in the Northern part and (ii) the Saoura Domain in the Southern part.

This chain is characterized by the existence of many Ba, Pb, Cu (Ag) which are divided into several vein fields. The veins are hosted within detrital formations of Precambrian and Cambrian age. Mineralization appears as filled open fractures. The veins show net wall rocks and several textures (massive, breccia banded and sheeted textures). Their shape is irregular and their length is from hectometer up to kilometer. The thickness ranges from 1 to 5 m and the vertical extension varies from 50 to 150 m. They show a zonal distribution from Northeast to Southwest. Copper minerals dominate in the northeastern part of the Saoura domain while barite dominates in the southwestern part of the Daoura domain.

In the Saoura domain, mineralizations are centered on the anticline structures of Draa El Kelba and Djebel Bet Touaris. In this area mineralzation is only composed by sulfide minerals of vein type: (i) chalcocite, pyrite and chalcopyrite. The veins show a N80°E direction; (ii) galena veins with subordinate pyrite. They strike N70°E and(iii) chalcocite veins with subordinate bornite, pyrite, chalcopyrite and galena. The chalcocite veins show a N130-140°E direction.

In the Daoura domain, mineralization is mostly composed of barite minerals with subordinate sulfide minerals. Barite mineralization appears in three main vein fields: (i) the vein field of Djebel Draissa where mineralization may be only barite orbarite with minor galena or barite with minor chalcocite, pyrite and chalcopyrite. This field vein of Draissa shows a zonal distribution from North to South: Ba, Pb in the Northern part and Ba, Cu in the Southern

part;(ii) the Toumiettes field veins that hosts two kind of veins: barite veins and sulfide veins of chalcocite, pyrite, chalcopyrite and manganese oxide; (iii) the Oglat Beraber field veins where the veins are only filled with barite minerals. In this last field vein, the veins cross-cut rhyolite rocks.

In these field veins, the mineralization appears as a succession of barite filled lenses. They generally strike N55°-85°E with the exception of some veins exhibiting a N130°-140°E orientation. The length of outcrop varies considerably from 100-200 mup to 3-6 km. The thickness of these veins varies from 20 cm to 5 m.

Their age is not well known with accuracy. They cross-cut Precambrian-Cambrian formations. Till now, observations on the field did not show Ordovician or more recent formations which are intersected by mineralized veins. As this chain was structured during the Hercynian orogeny, it seems that the barite veins postdate clearly the Hercynian orogeny.

Thermomechanical evolution of the Proterozoic Eburnean Crust and Implications on Gold-bearing Mineralizations in the Kédougou Kéniéba Inlier

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The metamorphic formations of the amphibolite facies (T=500-660°C) located in the Kédougou Kéniéba Inlier in the Diale-Daléma Supergroup are affected by Proterozoic thermomechanical crustal evolution between 2.5 and 2.0 Ma. We have studied this deformation and metamorphism in surrounding of the Saraya pluton, which represents the middle crust (4-9 kbar). While some authors attribute this metamorphism to the contact aureole of the Saraya pluton (Ndiaye et al., 1989); thermodynamic calculations identified an early stage HP/MT relics preserved in a form relict garnet cores. We have studied a series of metasediments in the vicinity of the Saraya pluton, located at variable distances from the pluton. The metamorphic assemblage is garnet-staurolite-plagioclase-biotite-white mica-quartz at 2-4 km from the pluton and garnet-staurolite-plagioclase-sillimanite-cordierite-biotite-white mica-quartz at the contact between the metasediments and the granite intrusion. The P-T conditions calculated using a P-T pseudosection (de Capitaniand Petrakakis, 2010) suggest a multiphase metamorphic evolution in eastern Senegal during the Proterozoic with a first regional phase M1 HP/MT (8-9 kbar, 520-560°C) and a second post thickening stage M2 related to the thermal maturation and partial melting of the upper crust (5-7 kbar, 600-630°C). The U-Pb geochronology data obtained on metamorphic monazite range between 2040 to 2060 Ma for the metamorphism M2.

By combining a study of field data, thermodynamic modeling of metamorphic equilibria, modeling of the thermal evolution of the crust and geochronology, we have investigated the geological and geodynamic conditions that took place during the polyphase Eburnean Orogenesis. This information is essential in a data collection perspective to boost mineral exploration in eastern Senegal.

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The Logoualé Band: a large Eburnean (2.05 Ga) crust in the Kenema-Man domain (Man-Leo Rise, West African Craton) recycled from Archean formations

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The Archean domain of the Man Rise was strongly remobilized during Eburnean coincidentally with the genesis of the Baoulé-Mossi domain (Birimian). This remobilization has allowed the recycling of Leonian and Liberian formations to generate a large Eburnean crust represented by the Logoualé Band.Zircons dated by LA-ICP-MS laser ablation of two samples of biotite-bearing pink gneisses of the Logoualé Band confirm the Archean origin of the Logoualé Band formations with ages at 2709 ± 15 and 2804 ± 11 Ma. The Logoualé Band's Eburnean age is justified by total resetting of both U-Th-Pband Sm-Nd chronometers in recrystallized zones of monazites, and in garnets with average ages at 2050 ± 16 Ma and2053 ± 15 Ma, respectively. Non-recrystallized zones of monazites gave an average age at 2712 ± 16 Ma. We propose that the Logoualé Band rocks are originally sediments lay down in some protocratonic rift-type basins. During Eburnean, these sediments were buried, underwent high-grade metamorphism and were exhumed in a tectonic context dominated by transcurrent motion. The configuration of banded iron formations (iron deposits), which are abundant in the Logoualé Band, would date back to the Eburnean.

Keywords: Logoualé Band, pink gneiss, Leonian, Liberian, Eburnean, remobilization, recycling, zircon U-Pb dating.

Porphyry Type Mo-Cu Mineralization at the Bled M'Dena (Eglab Massif, Algeria): A Unique Occurrence in the West African Craton

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The molybdenum-copper mineralization of the Bled M'Dena circular structure occurs in Paleoproterozoic Birimian formations. The mineralization is concentrated in a quartz-diorite, quartz-monzodiorite and granodiorite and is interpreted as porphyry Mo-Cu style. Geochemical data show moderate light rare earth element enrichment, high Sr/Y ratio and low Yb concentration, suggesting volcanic-arc affinity and I-type signature. Two main paragenesis are distinguished: (1) molybdenite - chalcopyrite - pyrite and (2) chalcopyrite - pyrite - galena as stockwork veins essentially marked by widespread propylitic alteration close to vein margins. Fluid inclusions related to the sulfides range from aqueous to aqueous-carbonic to solid bearing with moderate to high salinities. The Bled M'Dena complex represents one of very few Precambrian porphyry Mo-Cu described in the African continent.

Keywords: Bled M'Dena structure, Paleoproterozoic, Molybdenum-copper porphyry, propylitic alteration, Fluid inclusions

Current Situation of AFREF and First Results from GNSS Networks in Africa

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The African Geodetic Reference Frame (AFREF) is conceived as a unified geodetic reference frame for Africa. It will be the fundamental basis for the national three-dimensional reference networks fully consistent and homogeneous with the International Terrestrial Reference Frame (ITRF). When fully implemented, its backbone will consist of a network of continuous, permanent GPS stations such that a user anywhere in Africa would have free access to, and would be at most 1000km from, such stations. Full implementation will include a unified vertical datum and support for efforts to establish a precise African geoid, in concert with the African Geoid project activities. The realization of AFREF has vast potentials for geodynamics, geodesy, mapping, surveying, geoinformation, natural hazards mitigation, earth sciences, etc. Its implementation will provide a major springboard for the transfer and enhancement of skills in surveying and geodesy and especially GPS technology and applications.

AFREF is, therefore, an African initiative to unify the geodetic reference frames of Africa based on the ITRF through a network of GNSS base stations at a spacing such users will be at most within ~1000 km of a base station.

First Reference Frame Solution of about 80 geodetic GPS stations in Africa has been started in February 2013 at some processing centers in Europe and Africa. Results of independent solutions being developed by various African scientific teams: Hart RAO, South Africa; Ardhi University, Tanzania and SEGAL, University of Beria Interior, Portugal, show an accuracy of aligned ITRF 2008 using 42 IGS stations in E and N components with 3.0 mm and in U component 7.5 mm.

SHRIMP U-Pb zircon geochronology of basement rocks from the ring uplift of the Velingara Impact Structure, Haute Casamance, Senegal - a comparison with the Mauritanides from Bakel

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The 48 km diameter Velingara structure, centred on 14°07'40" W, 13°02'13" N, in Haute Casamance, Senegal, was initially discovered on Landsat imagery (Master & Woldai, 1998). It is situated on Mid-Eocene marine sediments of the coastal Senegal Basin, and is buried by up to 90 m of post-Eocene non-fossiliferous continental sediments and laterites. Geophysical and drilling information indicates that the central part of the structure, the Anambé basin, is underlain by a structural uplift of metamorphic basement rocks. These features are interpreted to be evidence for a large buried complex meteorite impact crater (Master et al., 1999). Further support for an impact origin of the structure comes from a 3D digital terrain model, obtained from satellite radar interferometry, which shows a well-defined ring structure, as well as a central partial ring, interpreted as part of a ring uplift (Wade et al., 2002, 2006).

We report on new SHRIMP zircon U-Pb ages of metavolcanic rocks from the central ring uplift of the Velingara Structure at Soutouré, where the only surface exposures were found in a trench. We obtained late Neoproterozoic (Ediacaran) ages for two metavolcanic samples. These ages are comparable with a new age from the Bakel River section of the Central Mauritanides, along the Senegal-Mauritania border region. Our new data confirms the presence of Mauritanide Belt basement in the central ring uplift of the Velingara Structure, and is the strongest evidence to date for an impact origin of the structure.

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The WAC-CADOMIA-LATEA Collision as recorded by the Saghro Group (Morocco) and Série Verte (Algeria)

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Along the northern and northeastern boundaries of the West African Craton (WAC), the younger metamorphic event of the Pan-African cycle is recorded in the Saghro Group (SG) of Morocco and the Série Verte (SV) of western Hoggar (Algeria), respectively. The Saghro Group is a folded, low-grade volcano-sedimentary series of the Neoproterozoic basement of the central (Siroua massif) and eastern (Saghro and Ougnat massifs) Anti-Atlas Mountains. We particularly studied the SG metagreywackes of the Ougnat inlier in the easternmost Anti-Atlas. There, the SG display NNE-trending, mostly upright folds, associated with axial-planar slaty cleavage and intruded by the 547±26 Ma-old Mellab granodiorite. Both the low-grade metagreywackes and the pluton are unconformably overlain by the main ignimbrite formation of the Upper Ediacaran Ouarzazate Group (OG) and overlying Cambrian formations. Detrital zircon dates from the literature suggest 610-620 Ma as maximum age of sedimentation of the SG further to the west (Saghro and Sirwa massifs). The SG correlates with the Ahnet SV of the Pharusian II Belt of western Hoggar whose greywacke deposits accumulated in the Pan-African suture zone before 603 Ma next to a volcanic arc, either an island arc or an active continental margin, after 620-610 Ma. The SG basin and its southeastern equivalent of the Ougarta-Ahnet-western Hoggar were converted into a metamorphic fold belt intruded by

numerous high-K granodiorites at *ca.* 580-570 Ma. In the Saghro and Ougnat massifs, the folds that characterize the Saghro Group show a dominant NE trend suggesting a NW-SE convergence of Avalonia/Cadomia with respect to the WAC, whereas the coeval Pharusian folds show a dominant NNW trend suggesting an ENE-WSW convergence of eastern Hoggar terranes with respect to LATEA during the latest event of the Pan-African cycle.

Keywords: Pan-African; Ediacaran; Cadomian; Anti-Atlas; Ougarta; Hoggar

Evolutionary Tectonics of Combined Gondwana - Proterozoic Basins of Peninsular India

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Certain Gondwana rift and grabens are located in the central part of Proterozoic basins in peninsular India. Pranhita-Godavari, Mahanadi, Damodar valley grabens and Narmada-Tapti Tectonic Zone are best examples of such basins. Various geological evidences suggest, that the tectonic evolution of these basins did commence with the beginning of Proterozoic Era. Pranitha- Godavari and Mahanadi grabens have dumbell shape and are wider at both northwestern and southeastern extremities. On northwestern side they intersect Narmada-Tapti Tectonic Zone, to form Satpura and Rewa basins respectively. On the southeastern side, these grabens intersect East Coast Fault Zone to form Krishna-Godavari and Mahanadi offshore basins. All these basins are dominated by freshwater facies; however, certain sections are indentified by marine facies and fossils.

Intricate tectonic evolution is the most important understanding which has emerged from the present study. Combined Gondwana-Proterozoic basins were initially filled by sedimentary succession, which was terminated by extensive Proterozoic volcanism. Extensional tectonics is believed by the present authors, to be largely responsible for development of these rift and grabens. In response to continued extensional forces, the central portions of these rift and grabens were faulted down to accommodate Gondwana sequence. This succession was also terminated by extensive Cretaceous volcanism. Both Proterozoic and Cretaceous volcanism were rift related, more pronounced in intersectional areas of rift and grabens. Magma was generated due to decompression melting of the lithosphere. Emplacement of major dyke swarms is also related with these structures. Igneous complexes of felsic, alkaline and kimberlitic suite of rocks are also found associated with these rift and grabens.

Fumarolic Activity and Formation of Bedded Barite and Naturally Occurring Fullerene in Proterozoic Cuddapah Basin of Peninsular India

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Enormous fumarolic activity associated with eruptive pulses of agglomerates mark most significant and interesting event the Paleo-Proterozoic history of Cuddapah Basin. Black carbonaceous slates interbedded within the volcano-sedimentary sequence resemble with shungite rock of Karelean province of Russia and has naturally occurring fullerene in it. Spectra obtained by laser desorption/ionization spectrometry has confirmed the presence of both C60 and C70 allotrope within this unit. This carbonaceous horizon is cleaved due to low grade metamorphism and has both carbon and barite in varied proportions. However, some bands are quite thick and thus form world's largest bedded barite deposit. Presence of thick pyrite horizons testifies reducing condition during deposition. The formidable presence of heavy element such as barium suggests that there source is from deeper levels of Earth. Furthermore, presence of fullerene, one of the extremely rare carbon allotrope suggests unique fumarolic activity in Proterozoic volcano-sedimentary environment.

The comprehensive of mantle heterogeneity, composition and dynamics based on the mineralogy, geochemistry and geochronology characteristics: case study orogenic peridotites of Beni Bousera (Internal Rif, Morocco)

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The composition and dynamics of the mantle is the subject of multidisciplinary studies and multi-scale. The integrated approach focus on comprehensive of geochemical fractionation in the mantle by the addition of geochemistry of the elements in traces and isotopes applied to the study of derived products of upper mantle, kimberlites, basalts, ultrabasic rocks lifts nodules or crop out massif.

The case study of ultramafic massif of Beni Bousera outcrops in the internal Rif is supposed to be a fragment of upper mantle established tectonically on the continent, allowing an understanding of the in situ structure, part of the Earth "upper mantle".

Keywords: mantle, ultramafic, Beni Bousera, internal Rif.

The magnetic methods: a tool for understanding geodynamic evolution of Paleoproterozoic crust of west Africa

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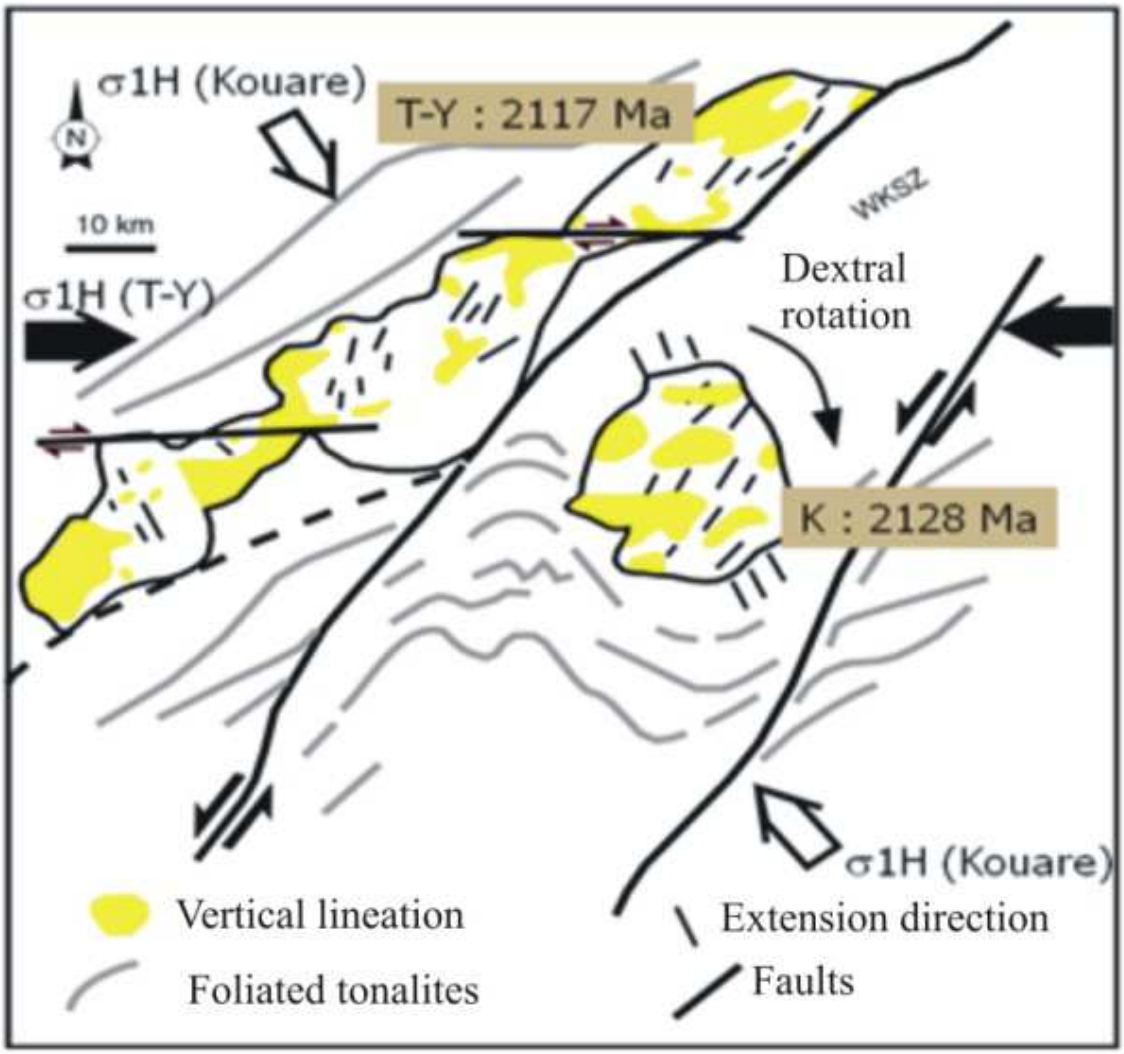
In the Palaeoproterozoic basement of West Africa, when outcrops conditions are good, it is often easy to access to deformation structures in the greenstone belts. In contrast, in the granitoids which represent more than 70% of the geological formations of this basement (Hottinand and Ouédraogo, 1975; Castaing et al., 2003), structures are not evident at field scale. This is the reason why the technique of anisotropy of magnetic susceptibility (AMS) is used for this kind of rocks (Guillet et al., 1983; Borradaile and Henry, 1997; Bouchez, 1997). A study undertaken on three granite plutons (Kouaré, Tenkodogo-Yambaand Nanéni) using the AMS technique associated with airborne data (spectral and geophysics) and microstructures examinations allowed to reconstitute the rheological state of the crust and orientations of regional stress at the moment of emplacement of these plutons. The main conclusions are consistent with the radiometric ages on some of these plutons (Castaing et al., 2003). At 2128 Ma, the pluton of Kouaré was emplaced in a soften TTG crust which becomes brittle at the moment of emplacement of the Tenkodogo-Yamba (T-Y) alignment (2117 Ma). More latter, the pluton of Naneni was emplaced. This last pluton is probably a result of crystallization of a more fractioned magma from T-Y type.

Keywords: magnetic methods, structures, emplacement of plutons, rheological state, regional stress



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Geological and structural context of the Bakoudou gold deposit (Gabon)

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Gabon is a country in Central Africa whose geological history is part of the spatial and temporal framework of the geology of the African continent. The age of the geological formations outcropping in this country vary from Archean to Cenozoic, and include important natural resources such as the gold deposit of Bakoudou and the Manganese deposit of Comilog, located in the southeast of the country in the Archean Chaillu massif.

The Bakoudou gold deposit, owned by MANAGEM group since 2005-2006, is hosted by Archean (2.7 to 2.1 Ga) granites and gneisses of the Chaillu Massif, which is an extension of the Congo Craton. The massif is composed by a granite-gneiss basement including tonalitic orthogneiss with few amphibolite layers and by biotite ± amphibole granitoid intrusions. The whole formations are affected by subhorizontal to steeply dipping foliation, high grade metamorphism and ductile to brittle shear zones. The gold mineralization occurs as free grains hosted in quartz structures localized within shear zones affecting biotite granitoids. Hydrothermal alteration in the proximity of the mineralized structures is marked by a strong silicification and chloritization of the host rocks. A fairly well developed lateritic supergene alteration affects the whole geological formations of the region.

Mapping the metamorphic foliation around the Bakoudou deposit (Fig. 1) shows a dome-shaped structure with a central zone where foliation is subhorizontal and external areas where the cleavage becomes steeply dipping. The mineralized quartz structures are localized in normal ductile and brittle shear zones, striking 135-140°N. The mineralized structures, steeply dipping in the outer parts of the dome, become subhorizontal in its inner part. Southeast of the deposit, the northwestern block of the dome is thrusted on the southeastern block by a reverse fault striking 35-40°N. These preliminary results suggest that the genesis of the gold mineralization was contemporaneous with the exhumation of the granite-gneiss dome.

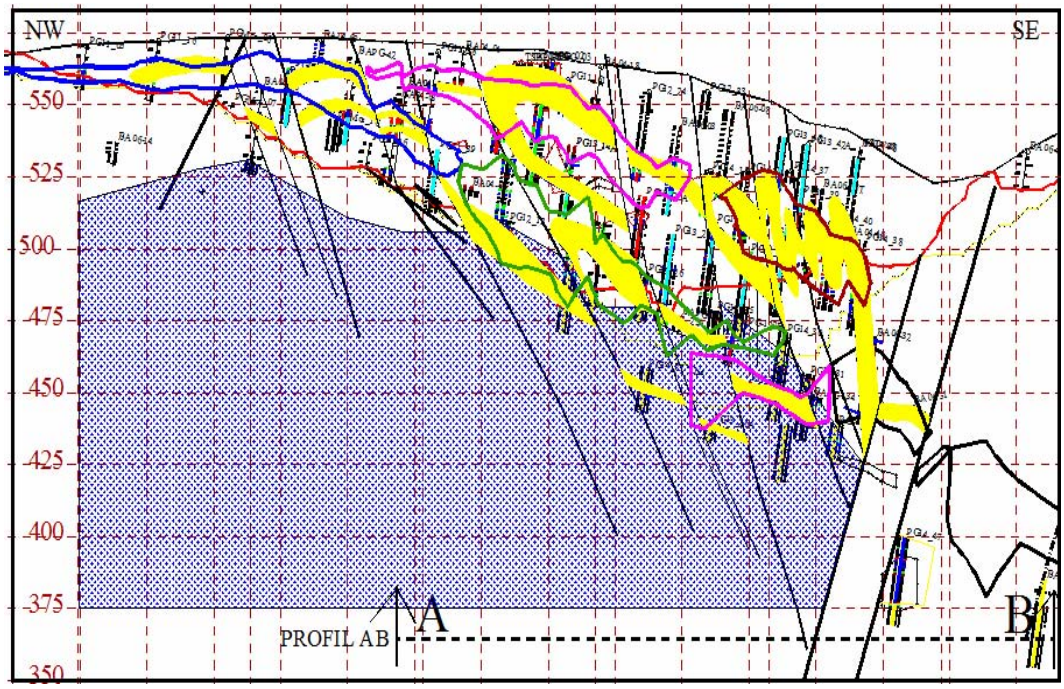

Fig. 1. NW-SE cross section of the Bakoudou deposit
(purple: granite gneiss dome; yellow: mineralized quartz structures).

Structural study of gold-bearing shear zone system at the Kédougou-Kéniéba Inlier, SE Senegal: Evidences of strain partitioning during the Eburnean orogeny

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The western part of the Kédougou Kéniéba Inlier (KKI) is composed of Paleoproterozoic NE-trending elongate belts of metavolcanic and granitic rocks that alternate with metasedimentary belts. Four lithostructural domains from east to west are defined across this region. The KKI preserves a polyphase deformation history that is intimately associated with orogeny-parallel dextral shear along the major shear zone, which we interpret as the partitioned wrench component of bulk transpressional deformation during the main Eburnean orogeny.

A new structural evolution consisting of both extensional and contractional events has been defined for the Mako Belt in the West African Craton. These events shaped the development of the fault architecture which controlled the location of the regional anticlines, the magmatic centres, gold mineralization, and the deposition of the Eburnean greenstone successions.

In this contribution, we present new structural and kinematic data from theMako Belt of SE Senegal, providing a detailed model for the kinematic evolution of the adjacent Dialé Basin fill deposits, which are strongly influenced by a component of dextral wrench tectonics.

Detailed structural studies of the Mako Belt and the Dialé-Daléma Basin reveal that intense, polyphase deformation was strongly influenced by dextral faulting shear parallel to the NE-SW regional structural grain, and along major pre-existing faults, which we interpret as the partitioned wrench component of bulk transpressional deformation. Partitioning of dextral transpression described in the KKI is consistent with dextral wrench faulting along the MTZ Fault. Importantly, the distribution of this strain is highly heterogeneous, due to kinematic partitioning of the regional deformation into structurally distinct, NE-SW to NS-trending dextral wrench-dominated domains and extension-dominated domains. Field observations and new geophysical data confirm that the deformation in both domains is broadly synchronous with emplacement of the late granitic suite (Saraya, Mamakono, Boboti, etc.) and mafic dykes. Hence, the structures in the wrench-dominated domains and the extension-dominated domains are contemporaneous.The bulk wrench-dominated transtensional strain in the KKI, accommodated by the major structures, is well documented by evidence for

contemporaneous dextral shear and fault-normal extension and by the geometry and patterns of the associated mesoscale deformation.

The formation of folds has been interpreted as being due to the horizontal shortening component of wrench-dominated transtensional strain. Fold orientations are consistent with other mesoscale shortening structures recorded in the wrench-dominated domain.

The structural data presented here may have certain implications for exploration of shear-hosted gold deposits in the KKI. We demonstrated that the gold deposits are best interpreted in terms of dextral transpression involving oblique convergence between rigid walls.

Keywords: Kédougou Kéniéba Inlier, Birimian, transpression, transtension, oblique convergence.

Reduced Gold Skarn Deposits: Formation, General Characteristics, Paragenesis and Implications for Potential Reduced Skarn mineralization in the Loulo District

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The word Skarn is an old Swedish mining term originally used to describe a type of silicate waste rock, associated with iron-ore bearing sulfide deposits apparently replacing Paleoproterozoic age limestones in persberg mining district (Meinert, 2005). In modern usage the term "Skarn" has been expanded to refer to any altered rock type containing calc-silicate mineralogy such Garnet, pyroxenes, amphiboles, plagioclase, epidote, albite etc. Skarns are found on every continent, in all rock type and in rocks of all ages. They have been mined for a variety of metals, including Fe, W, Cu, Zn, Mo, Sn, Pb and Au. Skarns can form during regional or contact metamorphism from a range of metasomatic processes including fluids of magmatic and metamorphic origins, amongst others. Most of the skarns are exoskarns and developed around causative plutons at deep or shallow level.

For reduced gold skarn the pluton needs to be reduced and the protolith could be limestone or any other rock type. Skarns can also be structurally controlled and develop along faults or major shear zones.

Reduced gold skarn are in the same tectonic environment as orogenic gold (volc.arc related int.).The main alterations are: clinopyroxene, garnet, amphibole and low temperature minerals compare to Silica, albite, chlorite and sericite for orogenic gold.

In term of ore mineralogy reduced gold skarn contain pyrrhotite greater than pyrite, asenopyrite and lollingite compare to pyrite greater than pyrrhotite plus asenopyrite plus or minus chalcopyrite for orogenic gold. Reduced gold skarn contain Fe^{+2}, Bismuth and tellurium in additional to some metal associated to orogenic gold.

One of the main characteristics of reduced gold skarn and skarn in general is the zonation in time and space. Skarn paragenesis is defined by 4 mains following phases:

Phase1: Petrogenesis of the emplaced intrusive. Binary and ternary diagrams highlight various types of skarn deposits intrusive related (Gold, Iron, W, Cu, etc.). For the diagram showing silica content Au plot is in the intermediate domaine (Diorite, granodiorite) between Mafic and Felsic intrusive.

The oxido-reduction ratio diagram highlights two mains domains separated by a red limit. Below the red line are the reduced intrusive and the domain above is for oxidized intrusive. Reduced gold skarn are associated with reduced and non-magnetic pluton (non magnetic because richer in ilmenite than magnetite). Intrusive reduced gold skarn tend to be metaluminous (relatively in deficit of aluminum but this deficit is enough to be greater than (Calcium + sodium + potassium) and have more affity with calc-alkaline series than tholeiitic ones.

Phase 2: Hornfelsing. A hornfels refer to contact metamorphic rocks that have been baked and indurated by the heat of igneous masses. In hand specimen the first phase of hydrothermal alteration at Tongon manifests as a brown to dark purple biotite alteration, which is clearly overprinted by later calcsilicate skarn. It appears as fine grained randomly oriented.

Phase 3: Prograde phases. Skarn prograde phases are characterized by high temperature minerals as Clinopyroxene (Cpx), Garnet, amphiboles, Calcite etc. For reduced gold skarn Cpx and amphiboles tend to be more iron rich than oxidized and Garnet more aluminous than iron rich. The cores pictures from Tongon South deposit show prograde skarn mineral (calc-silicate coarse garnets; Garnet-calcite vein with Cpx and Cpx in the matrix with reactions rims). Garnet and pyroxenes are specificities of skarns. Another specificity of skarn is the zonation in time and space. Tongon South deposit shows that skarn zonation reflects changes in mineralogy (aluminium to iron rich from proximal to distal), grain size (coarse, medium to fine grain from respectively proximal, intermediate to distal zone) and degree of retrograde alteration. A typical Tongon South section highlights pervasive calc-silicate (blue color) and retrograde (light and dark pink) alterations controlled by the NE strike and NW dipping mineralized structures. The thickness of the calc-silicate alteration haloes is greater than the silica-sulphide-Au zones which lie proximal to the shears.

Phase 4: Retrograde phases. Skarn retrograde phases are characterized by a progressive replacement of the garnet/Cpx by low temperature minerals such silica, epidote, prehnite, plagioclase, albite. The retrograde phase is accompanied by a decrease in temperature and decrease in gold solubility. Skarn shows complexes geophysical signature and are denser than the protolith (could be responsible of gravimetric anomaly or seismic discontinuity). Reduced pluton are relatively low magnetic because rich in ilmenite (not magnetite). But pyrrhotite of the exoskarn can show high magnetic signal around the low magnetic response of the pluton. Induced Polarization (IP) and Electromagnetic signals (EM) need to be carefully interpreted because sulphides are conductors but high conductivity could be also related to distal graphite

(case of Tongon). Due to their complexity, geophysical signature of reduced gold skarns does not constitute first choice method for regional exploration program.

The regional environment is a favorable context of possible skarn mineralization for in the Loulo district: There are gold skarns elsewhere in the Birimian (Ity, Tongon); Favourable skarn host rocks in the region (limestones); Supposedly Au skarn Alamoutala satellite at Sadiola; Faleme iron (Fe) skarns; Diorites at Loulo, Gounkoto; Gravimetric anomaly running from Loulo-Gounkoto to Bambadji.

29 keys words were identified in this reduced gold skarn abstract and 14 of them were found in the Loulo district mineralized system vocabulary. But a deep investigation needs to be done in a detailed scale for example: if there are diorites in the Loulo system are they reduced? non magnetic? metaluminous?

From the work done is kindly recommended to:

- start looking for gold skarn mineralization in the Loulo District as we have been looking since longtime for orogenic gold.
- do more thin sections or to exploit thin sections available data for the district in order to find calsilicate minerals such garnet, Clinopyroxene.
- identify intrusives, to do Electron microscopy studies (EMS) and rank them according to the chemical composition.

Geological modeling of Paleoproterozoic Formations of Yalea and Gara underground gold deposits (Mali)

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Yalea and Garaore deposits are located in the south of the West African Craton (WAC) and in the center of Mali(Taoudeni Basin), respectively. The main lithological units intersected in these areas belong to Paleoproterozoic formations.

Hand drawing and digital geological models show that Yalea deposit is mainly composed of Sheared Quarzite (SQR) in contact with a package of quartzite locally alteredalbite with several bands of SQR and limestone. NS ductile shear runs along the different lithologies and cross-cut a brittle silica-carbonate-albite structure. The ductile shear is mainly characterized by a strong chlorite-sericite overprinting albite alteration with stretched

brecciated clasts and is associated with hematite-massif sulphides and local strong tourmaline. The plan view shows that the purple patch area (high grade zone) corresponds to the zone where brittle and ductile structures are combinate.The geological modeling highlights that Gara is composed of folded units running along two bands of limestone: the hanging wall and the foot wall limestones located within a large package of SQR in contact with the pink quartzite, the quartz tourmaline (QT) or the greywacke. Gara QT is in reality a very fine grained quartzite tourmalinized and hydrothermally brecciated. This fine grained quartzite possibly belongs to an initial fine grained greywacke indurated and silicified enough to become quartzite in an early phase of tourmalinization. The quartz tourmaline occurred on one or several bands alternating with the tourmalinized (mineralized) and not tourmalinized(internal and external waste)greywackes highlighting two host rocks for the mineralization. The tourmaline is playing an important role in the system but seems not to be the only control of mineralization. The poorly quartz-carbonate veined QT does not carry grade and the tourmalinized greywacke always carry grade even low. This suggests an early phase of tourmalinization predating the hydrothermalization and mineralization putting Gara in a context of lithostructural deposit but studies should progress to determine the real history and controls of Gara orebody.Modeling is the basic pillar which underpins production in a mine.A good geological model helps to better define the orebody, well manage the production and reduce dilution and reconciliation issues in a context of deposits associated with folding, faulting an shearing. Two main causes of dilution were highlighted from grade control activities and technical solutions proposed involving deep structural analysis of compiled underground and exploration data for Yalea and Gara orebody.From the work done several points of recommendations are listed as contribution of exploration geology to Loulo underground gold mine production for Yalea and Gara deposits.

Keywords: Yalea, Gara, underground, WAC, Paleoproterozoic, Quarzite, limestone, ductile, shear, silica-carbonate-albite, chlorite, sericite, brecciated, hematite, sulphides, geological modeling, hanging and foot wall, tourmalinization, mineralization, hydrothermal, orebody, folding, dilution, reconciliation, faulting, shearing, production, mine, technical solutions.

Focus sustainable development in Senegal extractive industries: Toward a Green Economy

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Sustainable development is continuously improving the life quality of citizens by taking into account the indivisibility of environmental, social and economic perspective in an equity within and between generations.

Indeed, since 1995 Senegal has expressed its deep commitment to the goals of sustainable development through the establishment of the multidisciplinary National Commission for Sustainable Development (NCSD) and formulation in 2007 of the first draft of the National Strategy for Sustainable Development (NSSD).

After the Rio conference in 2012, Senegal is firmly committed to promoting sustainable development at national and local level, based on the lever selected by the international community, the Green Economy. The report of the consultations for this purpose entitled "Senegal we want" developed the key local issues and challenges of sustainable development with a new direction which revolves around the second strategic area including the promotion of a competitive economy creating decent jobs.

In its structure, the green economy includes two types of activities: the traditional economic activities with processes cleaner and consume less energy and ecoactivities whose purpose is the protection of the environment or natural resources management. Green economy activities are part of a green growth target: it is therefore to promote a sustainable development for the environment over the long term and that could generate green jobs.

Green economy is a relatively new concept in the African country. She comes early and inspire originality by the particular approach embodied his cross and commitment to the fundamentals of sustainable development. Today, despite its identification by the United Nations, as a lever to accelerate sustainable development, its integration into national and sectoral strategies remain timid or little coherent.

In the case of Senegal, the national sustainable development strategy integrates good articulation with the economic and social policy repository country, Senegal Emergent Plan (SEP). But the implementation of this commitment to promote the green economy in all sectors remains a challenge.

The Strategic Planning Document to the green economy in Senegal shows enormous distortions particularly in the level of inclusion of the extractive sector. Indeed, the research phase to the closure of mines and quarries through exploitation, mining remains one of the most offensive in terms of environmental aggression. Today, if the green economy can help to increase growth to 7% in 2037 horizon, the effort to do so should not under use the mining sector which is among the six priority areas chosen for reaching this performance. It should also take into account the new challenges of the discovery of oil and gas in Senegal.

The first edition of the days of the green economy in Senegal was held in November 2015. The main objective was to provide national actors a platform for exchange on policy and strategic framework to boost the promotion of the transition to a green economy in Senegal.

Also, Green Jobs National Promotion Strategy does not take into account the known initiatives in the extractive sector, secure niche opportunities of green jobs. While green jobs are transverse, actions with a view to promote them should integrate appropriately, sectors that denote the most damaging production methods to the environment. The challenge of the transition to the green economy and its implementation at sectoral level must be raised optimally integrated and based on issues and greening prospects of each sector to promote green modes of governance and greening extractives industries.

Sustainable growing is a process that is why its implementation pass through strategies, planning. Fortunately, a perspective Guidance Governance of mineral resources to the green economy is offer to Senegal. Its realization necessarily requires a synergy of action and reflection, endogenous and inclusive approach, inspired by international standards and especially that values simultaneously human and natural resources.

To orient effectively the governance of mineral resources to the green economy, all stakeholders have their scores to play but governments have a major role: this is first formulating a strategy orientation of mineral resources governance toward the green economy. Then, operationalization and the definition of an implementation framework of the green governance and greening of extractive operations.

Keywords: Sustainable, development, environmental, social, economic, equity, generations, multidisciplinary, National Commission for Sustainable Development, National Strategy for Sustainable Development, Rio2012, Green Economy, "Senegal we want", competitive, decent jobs, eco-activities, natural resources, green growth, United Nations, National Sustainable Development Strategy, Senegal Emergent Plan, extractive, mines, quarries, exchange, policy, strategic framework, Green Jobs National Promotion Strategy, implementation, synergy, inclusive approach, international standards, value, human, resources, governance, strategy orientation of mineral resources governance, operationalization.

Geodynamics and mineralizations of Birimian terrains (West African Craton) for a sustainable development

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The geological investigations carried out on West African Craton (WAC) show that the Paleoproterozoic formations (Birimian) consist of greenstones belts metamorphosed and structured during the Eburnean orogeny dated between 2.3 and 2.0 Ga (Bassot et al., 1983; Liégeois et al., 1991). These formations composed of volcanic and sedimentary material, intruded by granitoids with a wide compositional spectrum can be subdivided into two units: (i) a varied volcanic unit, sometimes represented by a bimodal volcanism with rare sediments in Mauritania, Senegal and Burkina Faso (Deschamps et al., 1986); (ii) a sedimentary flyshoid unit associated with volcanites and pyroclastites.

The geodynamic studies showed that these formations were induced by a major crustal accretion with production of juvenile material uncontaminated by an Archaean continental crust (Abouchami et al., 1990). Despite the geochemical and geochronological studies, the geodynamic evolution of these units is still poorly understood:

- A first accretion model militates for an adequacy with an environment of oceanic plate (Abouchami et al., 1990; Boher et al., 1992).
- A second accretion model in affinity with an environment of island-arc was proposed in Niger (Ama Salah et al., 1992) and in Senegal (Dia et al., 1997; Diallo, 2001).

These divergences result from a geochemical heterogeneity of the rocks, insufficiency of the geochronological dating, different structural interpretations and inaccuracy of the paleo-geographical reconstitution.

However, two great stages are distinguished during the formation of Paleoproterozoic crust:

- The first (2.2 Ga with 2.15 Ga) from Lower Birimian, corresponds to the formation of greenstones belts and TTG granitoids.
- The second (2.15 Ga with 1.9 Ga) from Upper Birimian, is characterized by the development of volcanogenic basins and the production of leucogranites.

The authors agree to recognize the following points:

1. Absence of inherited Archaean base: all the material is juvenile and post-2.4 Ga,

2. Absence of thrust sheet: the emplacement of plutons or setbacks are responsible for diachronic and various foliations,

3. Absence of metamorphic exhumation rocks of high grade: possible crustal thickening is very weak,

4. Weakness of the metamorphism: the regional metamorphism of “green schist facies to amphibolite” is spatially related to the intrusions,

5. Absence of migmatites (except in the extreme south-west).

This debated geodynamic evolution is in addition associated to the thermo-tectonic and hydrothermal events which generated the concentration of various mineral substances in particular, Mn, Fe, Au, Zn-Ag, Cu ± Mo ± Au. The spatial distribution of these mineral concentrations remains non-uniform and even very unequal.

The metallogenic history of the Birimian shows a three-phase evolution coinciding with the orogenic evolution, and extends over almost 150 Ma (Milési et al., 1992). The economic mineralization of belt thus consists of:

"Pre-orogenic" (pre-D_1) deposits related to early extension zones. This was diverse with stratiform Au tourmalinite (type 1 Au: Loulo in Mali; Dorlin in Guyana), stratiform Fe (Cu) (Falémé in Sénégal) and Mn (Nsuta in Ghana; Tambao in Burkina Faso), and a single massive Zn-Ag sulfide deposit (Perkoa in Burkina Faso) associated with regional volcano-sedimentary (variably tholeiitic) stratigraphic marker beds;

"Syn-orogenic" (post-D_1 to syn-D_2/D_3) deposits with disseminated Au-sulfides (type 2 Au: Yaouré in Côte d’Ivoire) in extensional zones of the B_2 followed by auriferous paleoplacers (type 3 Au) in B_2 extensional zones (Tarkwaian Banker conglomerate) or syn-D_2 transtensional zones (debris flow of Orapu in Guyana).

"Late-orogenic" (post-peak D_2/D_3) deposits with mesothermal Au mineralization evolving from a "disseminated gold-bearing arsenopyrite and Au-quartz lode" type (type 4 Au: Ashanti in Ghana) to a "quartz-vein" type with free gold and Cu-Pb-Zn-Ag-Bi paragenesis. Most of the gold in West Africa comes from this phase. These mining resources, if they are well exploited, well managed and goodly used, will constitute a pillar of major economic development. Unfortunately, with the situation of the mining sector in the various countries where the metallogenic Birimian land occurs, a very interrogative consternation remains: How to manage this resources in order to lead a satisfying statute of economic development and conform to the concept of sustainable development?

To take advantage of these resources efficiently, Africa must sustainably manage the use of these resources and protect the quality of the environment by the restoration, the adjustment and the maintenance of essential habitat’s species. It must enhance the competitiveness of their companies and discipline its extractive activities. Also integrate in the industrialization

strategies for development of the social responsibility for the companies including environmental and social concerns, transparency and good governance.

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Environmental impacts of recent artisanal small-scale gold mining along the Gambia river, Kédougou region, eastern Senegal

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In eastern Senegal, in the region of Kedougou, a gold camp of Senegal where primary gold lode deposits occur in basement rocks and rivers contain abundant alluvial gold (Fig.1), increasing artisanal small-scale gold mining (ASGM) activities using mercury (Hg) for gold amalgamation have been recorded since 1995 as a result of the rising gold price and the low costs of ASGM techniques. The main objective of this study is to provide new data (environmental impact of the use of mercury in order to assess the potential risk of Hg exposure for the local population, the mechanism of mercury methylation and mercury biomagnification in the food web) for a region, where ASGM activities involving Hg-amalgamation are recent and poorly documented. For this purpose, we have assessed the current status of Hg pollution in the Gambia River ecosystem by analyzing sediment, soil, water, fish and shellfish as well as the exposure of the local population to Hg via fish consumption. Total Hg (THg) concentrations were determined by atomic absorption spectrophotometry with catalytic decomposition and gold amalgamation with an automatic mercury analyser. Methylmercury (MeHg) was also determined in water by fluorescence spectrometer. Results revealed high concentrations of total Hg (reaching up to 9.9 $mg.kg^{-1}$) in sediment cores sampled in the vicinity of ASGM activities (Niane et al. 2014). These mercury concentrations are higher than the Sediment Quality Guidelines (SQGs) and the Probable effect concentration (PEC) for surface waters proposed by MacDonald et al. (2000). Analysis of soil samples and water revealed that soils in sites unaffected by gold mining range between 7 and 60 $\mu g.kg^{-1}$, whereas the soils of gold mining sites have higher concentrations ranging between 300 and 3900 $\mu g.kg^{-1}$. Sequential extraction showed high concentrations of elemental Hg (Hg^0), but a very low soluble + exchangeable Hg fraction between (1 to and 6 $\mu g.kg^{-1}$), suggesting low Hg mobility in soil and low bioavailability. The concentrations of total mercury (5.8 to 973.8 $n.gl^{-1}$), dissolved (5.6 to 33.8 $n.gl^{-1}$) and methylmercury (0.1 to 4.6 $ng.l^{-1}$) measured in water confirm mercury contamination and

active methylation in the aquatic ecosystem. Our study documents that concentrations of total and dissolved Hg and methylmercury (MeHg) are very high. It also shows that Hg discharged and transported from ASGM sites is susceptible to methylation for MeHg formation, which is toxic for biota. Based on their diet habit, the lowest and the highest concentration in fish were found in the herbivorous and piscivorous groups respectively, primary consumer including (Sarotheron melantheron) and highest in secondary consumers (omnivorous and piscivorous). THg in mollusc species caught in sampling site affected by ASGM is higher than the concentration of molluscs from site devoid of ASGM activities. Stable isotope ($\delta^{13}C$) analysis indicated that fishes and molluscs species had contrasting feeding niches, which may also affect the Hg accumulation.

Keywords: Mercury contamination, Methylmercury Artisanal small-scall gold mining, Kedougou, Gambia River

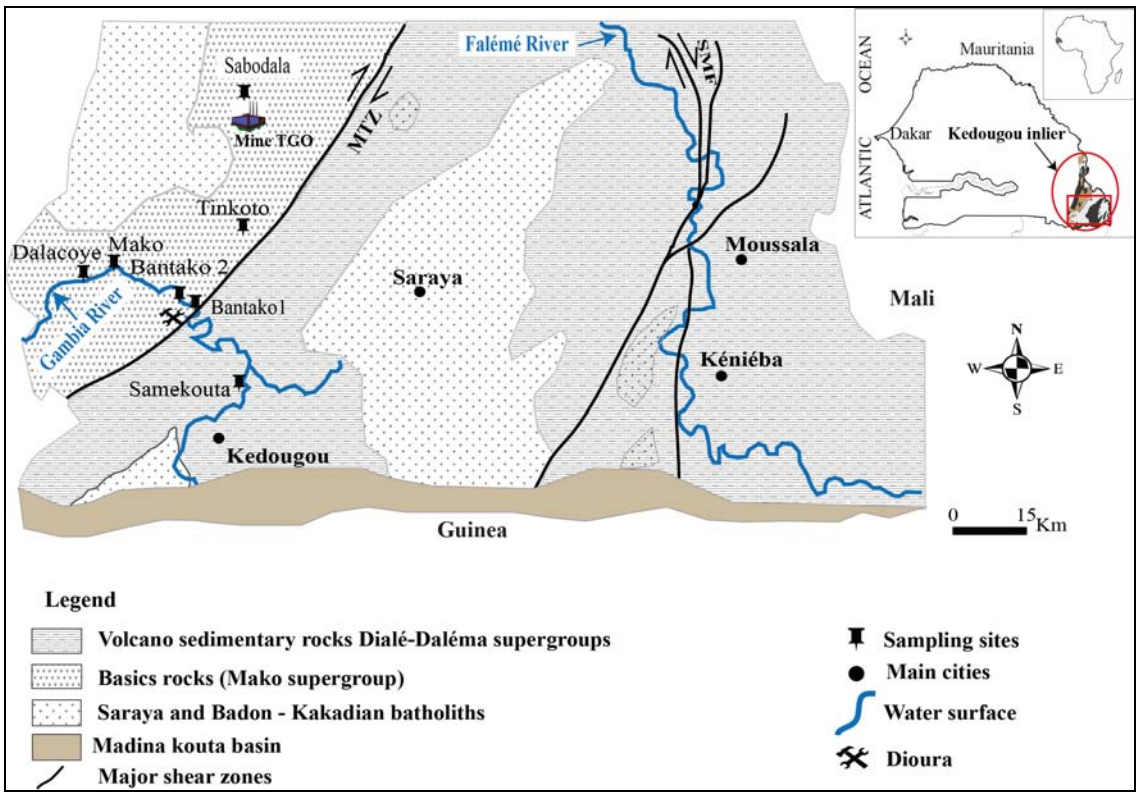

Figure 1: Simplified geology of the Kedougou region, modified after (Niane et al., 2014) and sampling site locations. MTZ: Main Transcurrent Zone. SMF: Senegal Malian Fault.

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Use of gamma ray spectrometry in the study of impact structures on the West African craton

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The impact record of West Africa (Reimold and Koeberl, 2014) is under-explored in comparison to that of North America and Europe, whereas the presence of old terranes (Archean - Paleoproterozoic) suggests a strong potential for further significant discoveries. Large impact structuresmay host mineral deposits of economic interest (Reimold et al., 2005). Some 25% of the> 5 km) impact structures are associated with ore deposits (12% are exploited). For instance, the Vredefort and Sudbury impact structures are associated with enormous resources in gold and uranium, and Ni-Cu-PGEs, respectively. The tremendous amount of energy released during an impact may generate melt sheets and hydrothermal circulations, which are able to concentrate metal of economic interest present in the target rock. Excavation of originally deep-seated rocks may also bring economic material close to surface, facilitating exploitation of possible ore resources.

The discovery of new impact structures in West Africa is challenged by several obstacles, including the limited knowledge and training about the identification criteria of impact structures, and the scarcity of outcrops with common presence of soil, vegetation and/or lateritic cover. In this context, radiometric data are commonly used, either for geological mapping or mineral exploration (Dickson and Scott, 1997). Radiometric data provide maps of the concentrations of the elements K-U-Thin surface material and are available at different resolutions (typically 10 m - 1 km) depending on the type of survey. However, so far the radiometric signatures associated with impact structures are only poorly documented. Only two cases have been studied: Bosumtwi in Ghana (Boamah and Koeberl, 2002) and Serra da Cangalha in Brazil (Vasconcelos et al., 2012). In both cases, circular anomalies of the concentrations of K, Th, and/or U have been reported, However, the cause of these anomalies

is not clear and the scientific value of radiometric data for impact crater research has not yet been demonstrated. Considering the geochemical behavior of K, Th and U with respect to vaporization, partial melting, and fluid-rock interaction, the formation of anomalies associated with impact melt sheets, ejecta, impactites or rocks affected by impact-related hydrothermal systems appears possible. We report here on the first systematic study of radiometric signatures of impact structures in Australia and West Africa. Preliminary results indicate that radiometric signatures are commonly observed at Australian impact structures. These results suggest that new strategies for targeting possible impact structures in West Africa based on available regional radiometric surveys may be developed, in combination with other imagery and geophysical data sets.

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Petrographic and Geochemical characterization of the Goaïda Neoproterozoic granitoids (Morocco Central Massif- Western Meseta)

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In the Western Moroccan Meseta, the Goaïda inlier outcrops in the centre of the Ordovician quartzo-pelitic Zaïan block. It constitutes, together with Rabat-Tiflet zone, and Bou-Acila and Jbel Hadid horsts, the old formations in Moroccan Central Massif. These formations include felsic and intermediate lavas and felsic plutons. The correlation with the Anti-Atlas Neoproterozoic facies suggests the similitude in their stratigraphical position. The Goaïda inlier covers an area about 20 km^2 and consists of a granitoid complex surrounded by a metasedimentary series. The age of the investigated felsic plutons, as yet, is a discussion subject, some authors interpret it as Neoproterozoic while others suggest a Variscan age. According to the field observations, the Goaïda granitoids are unconformably overlain by Lower Cambrian Calc-schist series. All are deformed and metamorphosed (under greenschist-facies conditions) by the Variscan events and intruded by rhyolitic, doleritic and gabbroic bodies.

The petrological, mineral chemistry and geochemical data indicate that Goaïda granitoids formed three distinct groups including dark, pink and white granitoids. The dark granitoids is varied mainly form syenodiorites to granodiorites, whereas the pink and white granitoids show a granitic features *sensu stricto.* All belong to high-K calc-alkaline, alkali-calcic towards alkaline series. Compared the Neoproterozoic high-K calc-alkaline granitoids and rhyolites of the Anti-Atlas to the studied rocks together with other Neoproterozoic rocks from the Moroccan Meseta (e.g. Tiflet granites), there are large similarities and analogous in their stratigraphic position and geochemical data. All show characteristics of both subduction-related and post-collisional geotectonic setting.

Contribution of Remote Sensing Imagery to Geological Mapping, Mining Research and the Understanding of Geodynamics in the Paleoproterozoic of Côte d'Ivoire (West Africa)

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This communication underlines the use of remote sensing imagery for geological and structural mapping, and mining research, as well as understanding the geodynamics of the Paleoproterozoic, particularly in Côte d'Ivoire.

Despite the abundance of data collected in the field by researchers and Mining Companies, the layout of these informations is not always realized.

Given the scarcity of outcrops and the strong lateritic coverage, many studies have been made, from radar images, Landsat, Spot, etc. The results were used to develop local geological mapping, structural maps at regional scale. These different maps helped to guide mining research by offering favorable zones for different types of mineralization. Field controls of these maps also help to explain the geological history at local or regional scale.

Therefore, Remote sensing imagery appears to be one of the effective tools for achieving accurate geological maps, essential tool for research of mineral resources, as well as understanding the main phases of deformation of the Paleoproterozoic in the West African Craton, particulary in Côte d'Ivoire. However, a particular methodology should be known by geologists to better take advantage of this powerful tool.

Keywords: Remote sensing imagery, geological mapping, mining research, geodynamics, Paleoproterozoic, Côte d'Ivoire, West Africain Craton.

Veins generations related to the gold deposition in the Bonikro deposit, Fettèkro greenstone belt, Côte d'Ivoire.

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The Fettèkro greenstone belt is one of the most productive gold belts in Côte d'Ivoire. In its southern part, the intensive exploration through this Birimian belt has revealed the gold deposits of Agbahou, Bonikro and Hiré aligned in a linear distance of 40 km, thus, forming the Oumé-Hiré gold district.

The Bonikro gold deposit presents three lithologic units: the mafic volcanic unit of basaltic to andesitic composition in the East, the westerly volcano-sedimentary unit made of shale, siltstone and pyroclastic lavas (basaltic to dacitic) and the felsic plutonic and dykes made of granodiorite, aplo-pegmatite and acidic lava in the centre of the deposit. The deposit is dominated by a major structure: the Bonikro Shear Zone (BSZ). The strong hydrothermal activity occurred in Bonikro can be observed by the sericitisation, the silicification, the chloritisation, the albitisation in the granodiorite and also the presence of three veins generations: sheeted, planar and transversal. The sheeted veins are earlier: thick (1cm) and sub-parallel sets of quartz and feldspar veins. They are composed of milky quartz (70 to 80 %), albite (5-10 %), scheelite (up to 15 %) and pyrite (up to 5%). They are characterized in the granodiorite by the fluorescent scheelite. Most of the visible gold deposit is located in the sheeted veins. The mineralisation presents the paragenetic association of: 91% Au + 7% Ag + 0.9% Mo + 0.5% Bi with traces of Cu and Te. Gold is associated with minerals of scheelite, tetradymite as the principal sulfide and altaite. The planar veins support the powellite minerals. They show the introduction of molybdenum in Bonikro. The transversal veins are late and composed of: milky quartz (40%), calcite (30%), albite (10%), biotite (15%), and sulfides (molybdenite up to 5%). The metallic paragenetic association is: 93% Au + 5% Ag + 0.9% + 0.5% Bi with traces of Te and S. Gold is associated with molybdenite as the principal sulfide, tetradymite and pyrite. Each of these veins has its minerals and resumes different stages of gold deposition. It starts with the sheeted veins then the planar and ends with the setting of the transversal veins. The presence of the minerals like scheelite, molybdenite, tetradymite and the other minerals of Bi and Te are not familiar in the Côte d'Ivoire gold

deposits. This is why the Bonikro gold deposit is a particular deposit in Côte d'Ivoire as well as in the West African Paleoproterozoic formations.

Keywords: Birimian, gold, Bonikro deposit, Sheeted veins, Fettèkro greenstone belt, Côte d'Ivoire.

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The Nassara gold prospect, Gaoua District, southwestern Burkina Faso

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The gold deposit of Nassara in southwestern Burkina Faso (west African shield) is located in the Birimian greenstone belt of Boromo, which is dominated by regional structures trending NS, acquired during the Eburnean orogeny. In the deposit area, two main shear structure orientations are observed, the principal one is oriented NW-SE and is cut by NE-SW shearing structures of lower amplitude. AMS data show that the Nassara zone is affected by transpessional shear, with a material flow to the SE. The host rocks of the gold mineralization are metamorphosed basalts and andesites, pyroclastic and graphitic schists. Along this corridor, the rocks are affected by hydrothermal circulation marked by an alteration assemblage consisting of quartz, carbonate, albite, chlorite and pyrite.

Mineralization is of orogenic-type, characterized by low-pressure structural features such as pressure shadows, and vein structures partially or completely transposed into the foliation during the second phase of deformation ($D2_{NA}$), where subscript $D2_{NA}$ refers to local structures. The $D3_{NA}$ structures do not contain gold mineralization. Gold is intimately associated with pyrite and very rarely found as gold free in the hydrothermal alteration assemblage. Mineralized gold pyrites occur either as disseminated or arranged along the foliation planes (in the wall rocks of the veins). Visible gold is present as inclusion in the clear parts of pyrites. The trace elements that are associated with gold are mostly silver, copper, bismuth, antimony, arsenic and iron. Pyrites commonly contain mineral inclusions of galena, monazite, sphalerite, chalcopyrite, cobaltite, gersdorffite and rutile.

Keywords: West African Craton, Birimian/Eburnean, Paleoproterozoic, Burkina Faso, Nassara, Shear Zone, gold deposit.

GIS-Based Landslide Susceptibility Mapping by AHP Method, a Case Study, High Atlas of Marrakech, Morocco

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The present study focus on the Marrakech High ATlas. We investigated the Imini district, situated south of the Marrakech High ATlas. The region is located at the intersection between the Variscan fold and thrust belt of the Anti-ATlas, the uplifted Panafriacn basement of the Marrakech High Atlas, the Neogene Siroua (or Sirwa) volcano and the Ouarzazate Basin (Saddiqi et al., 2011) (Fig. 1). The area is well known for its economic manganese ore deposit, but has not been throroughly investigated from a structural point of view ((Moret, 1931; Pouit, 1964; Errarhaoui, 1998; Missenard et al., 2007), may be due to its low grade deformation. One observe a monoclinal Cretaceous-Tertiary plateau (Imini plateau) slightly inclined towards the south and limited to the north by the South Atlas Front. The main outcropping feature is the N90° Imini anticline which has an Ordovician shale core and which is surrounded by an apparently poorly deformed plateau of Meso-Cenozoic sedimentary rocks.

The GIS multicriteria decision analysis (GIS-MCDA) technique is increasingly used for landslide hazard mapping and zonation. It enables the integration of different data layers with different levels of uncertainty. In this study, three different GIS-MCDA methods were applied to landslide susceptibility mapping for the Imini-Ounilla watershed south of the Moroccan High Atlas. Eight landslide causal factors were used, whereby parameters were extracted from an associated spatial database. These factors were evaluated, and then, the respective factor weight and class weight were assigned to each of the associated factors.

Keywords: Imini-Ounilla , Watershed , GIS, MCDA, Landslide,Hazard

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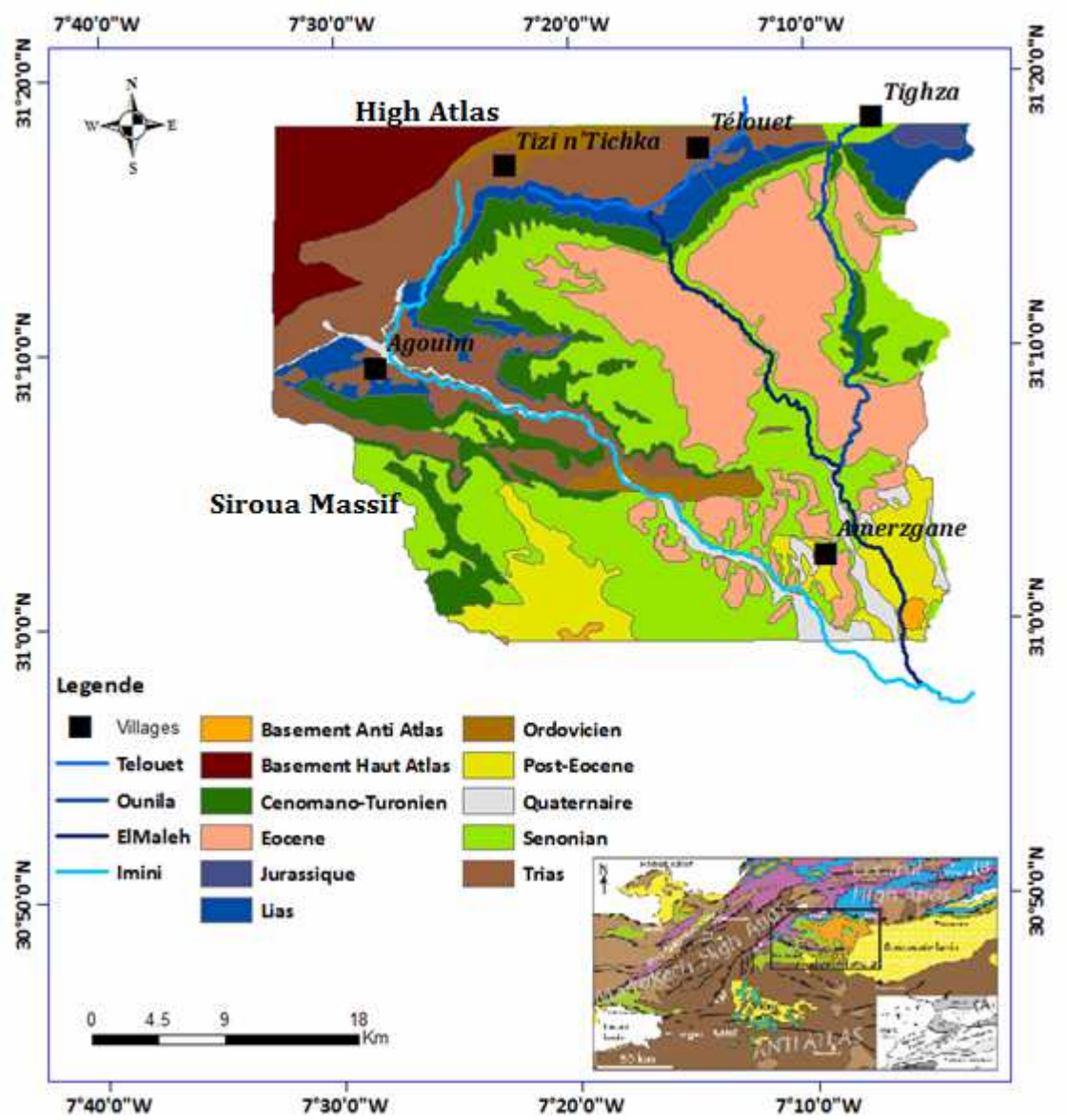

Fig. 1: Geological Map of the Imini area, amended in reference to the geological map of Morocco, to the scale 1:200000, Ouarzazate.

The West African Craton and the Mauritanides in Southern Morocco: A recommended geotrail straddling the Atlantic margin and the Sahara approaches

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The West African Craton (WAC) extends in the Saharan regions of southernmost Morocco. The WAC crystalline basement crops out in the Reguibat Shield or Arch, whereas it is hidden beneath Mesoproterozoic to Cenozoic undeformed sediments in the Tindouf, Reggane and Taoudenni Basins to the north, east and south of the arch, respectively. To the west, i.e. in the Dakhla transect of Southern Morocco, a stack of Variscan thrust units labelled the Moroccan Mauritanides (Oulad Delim massif) is sandwiched between the Reguibat terrains and the Mesozoic-Cenozoic series of the Atlantic margin. These regions are rich in outstanding landscapes and outcrops not familiar to most people. Here, we propose a 200 km long, southeast-trending geotrail starting from the Dakhla sea-resort and ending at Awsard at the gate of the Sahara Desert, with a total of ten geosites of particular interest for geotourists and geologists. The geotrail gives the opportunity to observe the oldest rocks (Archaean) of Morocco, belonging to the West African Craton (WAC) nucleus, with splendid outcrops of migmatites and nepheline syenite. Upper Ordovician periglacial sandstones overlie directly the WAC rocks, followed upward by thin Silurian shales and Devonian limestones. The trail also presents a profile across the Mauritanides nappes (reworked Archaean orthogneisses,Neoproterozoic (?) quartzites and metagabbros, Cambrian syn-rift intrusions) thrust over the WAC during the Appalachian-Variscan collision. This tectonic setting is exceptional in Morocco but extends widely in the south (Mauritania, Senegal). The trail includes finally four geosites in the Cretaceous-Cenozoic deposits of the Coastal Basin, belonging to the Atlantic margin onshore. The Early Cretaceous red beds record the major, Upper Jurassic uplift event of NW Africa. These subaerial sandstones show frequent Neolithic engravings. They constitute the main water table of the area and continue westward in the form of a thick sandy prism offshore (a potential oil/gas reservoir). The Eocene

deposits south of Dakhla offer abundant vertebrate remnants (whale bones, shark teeth). The Dakhla-Awsard cross-section contrasts with the classical section 700 km in the north between the Tarfaya Basin and the Variscan Anti-Atlas Mountains where the Palaeozoic series are much thicker and show a quite different structure. The adjustment and promotion of the Dakhla-Awsard geotrail will increase the attractiveness of the wild Nature in the Saharan regions of Morocco.

Regolitic, geochemical and structural mapping associated with mineralization investigation west of dembala hill prospect within dembala berola zone, diale-dalema supergroup, kedougou-kenieba inlier, senegal

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Birimian formations of the Dembala Hill prospect, in the Dembala Berola zone (Dialé-Daléma Supergroup, western Senegal), are subjected to a field geochemistry, termite mound and rock investigations, supplemented by regolitic, geochemical and structural mapping in order to study gold-bearing mineralization.

Field data compiled with results of analysis and interpretation of geophysical images evidenced four Eburnean structural directions: NS, NNE-SSW, ENE-WSW and NW-SE. The results of field geochemistry and/or termite mound show interesting zones having contents higher than 20 ppb and may reach more than 200 ppb. The dispersion of these anomaly points is not random on all the extent of the prospect. Indeed, in certain parts, these points tend to follow a preferential direction. The analysis of the geochemical contours shows that the anomalies are overall NNE-SSW oriented. The structural map reveals that the geochemical anomalies are correlated with structures following NS, NNE-SSW and ENE-WSW directions. Anomalies along with NNE-SSW direction are located within intersections of NNE-SSW and ENE-WSW oriented structures. The intersection areas are marked by a reactivation of NNE-SSW structures induced through ENE-WSW and NW-SE structures, thus creating open fractures in which hydrothermal fluids emplaced. These hydrothermal fluids accumulated and precipitated mineralization into such opened fractures in the shape of quartz veins and veinlets.

The possible model (Fig. 1) may be explained using the following suggestion: the NNE-SSW structures synchronous with the major shear zone or “main transcurrent zone” movements (Ledru et al., 1989), are reactivated by the ENE-WSW shears. Late NW-SE shears reactivated both the previous structures at the same time. Such reactivations would be at the

origin of the opening of fractures thus allowing the deposit of gold-bearing hydrothermal fluids.

Keywords: Kédougou, mineralizations, gold, Birimian, tectonics, geochemistry.

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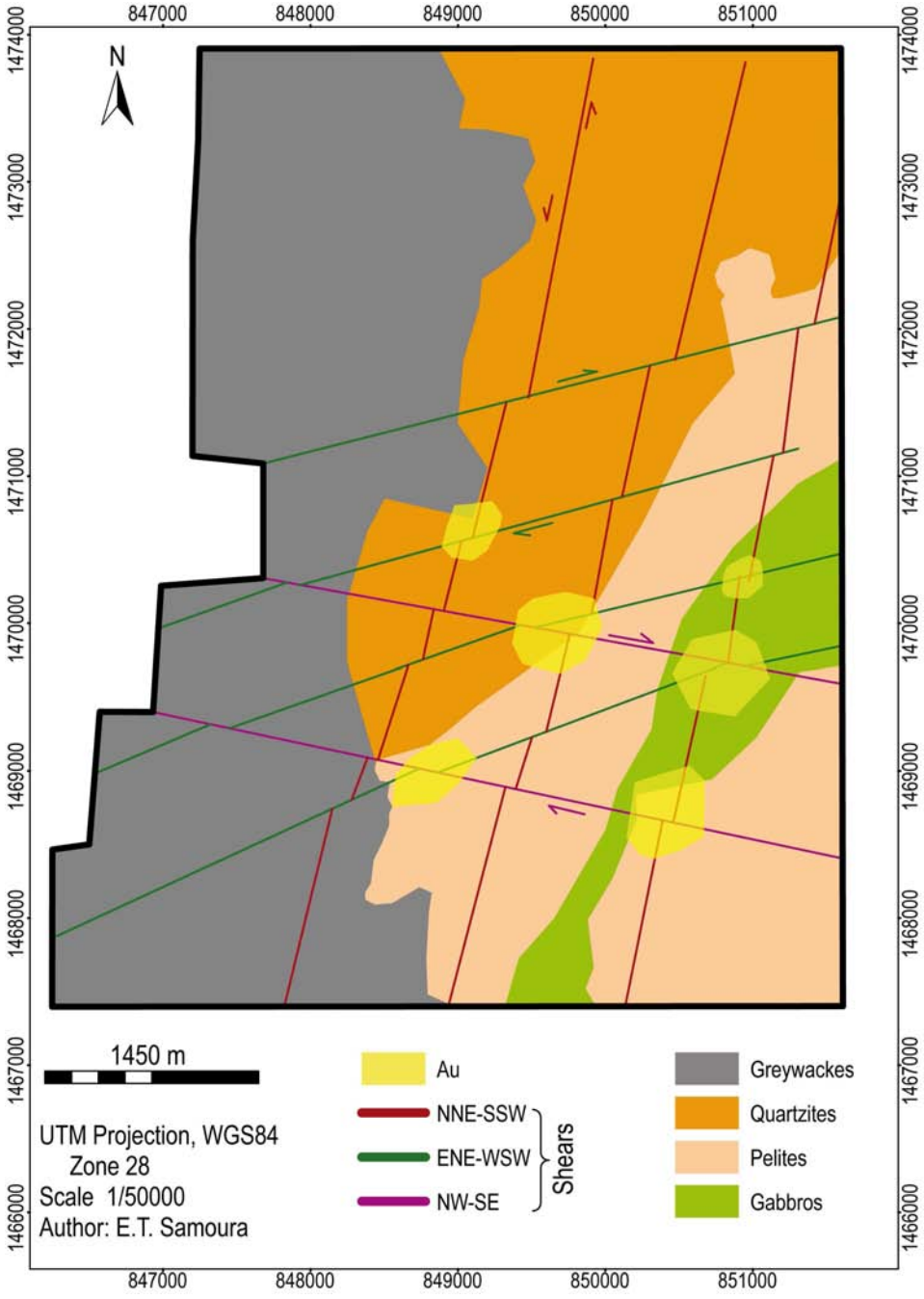

Figure 1: Simplified diagram of the structural model of the Dembala Hill mineralization.

Concept and technical feasibility of achieving production center built on mega-fractures of the basement rocks for drinking water supply in rural areas of Burkina Faso

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In Burkina Faso, since four decades of application hydraulic programs, water supply access rate in urban areas is today 84%. Besides this, 90% of villages have their modern wells and drilled boreholes with hand pumps whose number increased from a few hundred to nearly 70 000 in 2013 (Fig. 1); the national average rate to access to drinking water is only 64%. The average density of these infrastructures is one borehole or modern well every 4 square kilometers representing about 9 modern wells and / or boreholes per village. The rate of water supply brought to the country's population in 2014 (18 000 000) indicates that about 260 people who share one borehole. These average rates mask the great disparity between climate zones, urbanization and the geological context. In the sedimentary zone, the situation is less alarming than the crystalline basement area covering almost 82% of the territory. Thus, people's access to safe drinking water and watering of important livestock is complicated.

Surface water resources are important and are mobilized by a thousand of dams, but they have the disability of the high potential evaporation (more than 2000 mm/year).

For the SDG vision, this article makes the diagnosis of the current approach for producing drinking water for hydraulic programs (low-flow rate, low maintenance of hand pump, hydraulic infrastructure management problem, insufficient water quality, etc.) and offers a different view of prospection water production center for mobilization groundwater. If 70 000 boreholes or wells have failed everywhere for water supply, indeed, the spatial distribution of high flow rate borehole (over 5 m^3/h) compared to the productive faults shows that there is a good correlation between fault network and the distribution of high rate borehole.

This study presents a new approach based on the achievement of water production centers made not from the traditional approach based on the lineaments or mega-lineaments, but on fractures nodes or mega-fractures. These mega-fractures are built on the fault identified from geological surveys (Fig. 2); these faults can be confirmed or extended by the fault identified from geophysical implementation during hydraulic programs. The high density of the

borehole in Burkina Faso permits such mapping. A new structural map at scale 1/1000 000 is proposed to serve as a guide for implementation of water production centerfor the multi-village water supply systems. Thus, the water will be provided by fountains and private connections terminals in rural communities. The hand pumps which are the rule today become the exception restricted to isolated farming hamlets.

Keywords: hydraulic drill, mega-fracture, water production center, multi-village network, SDG.

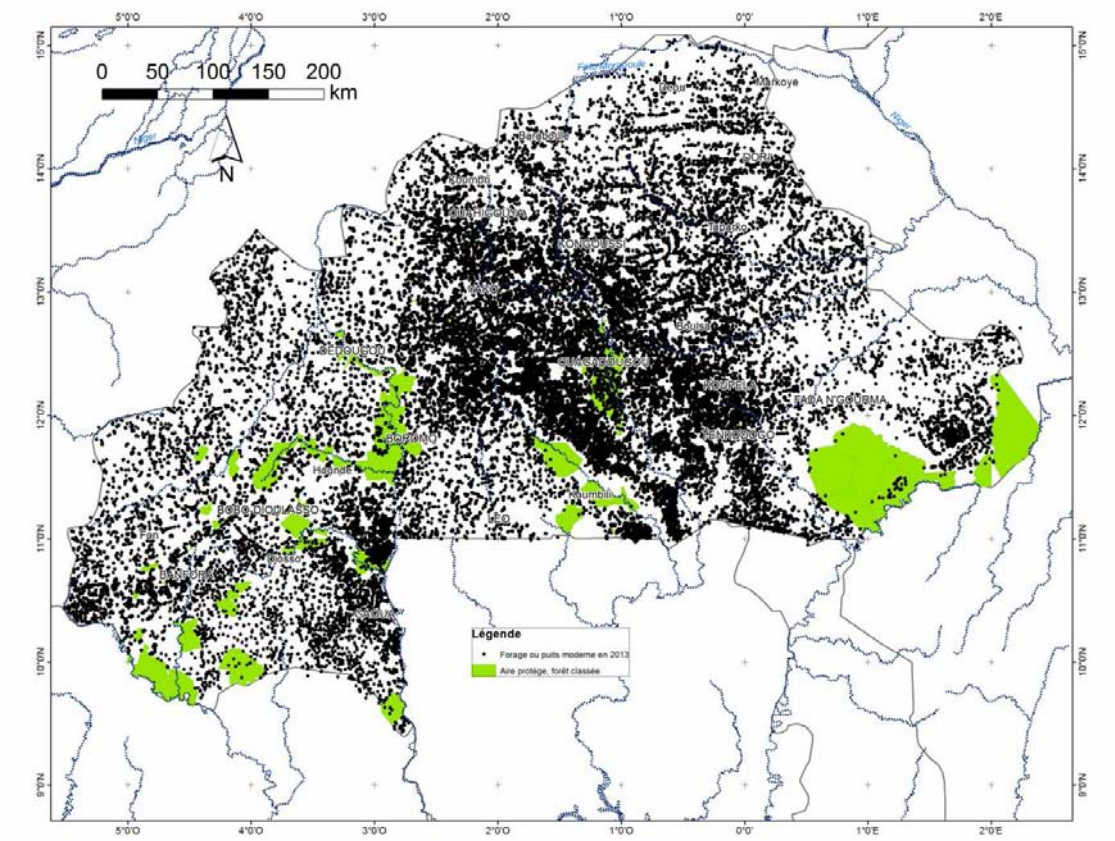

Fig. 1: Boreholes and modern wells distribution in Burkina Faso.

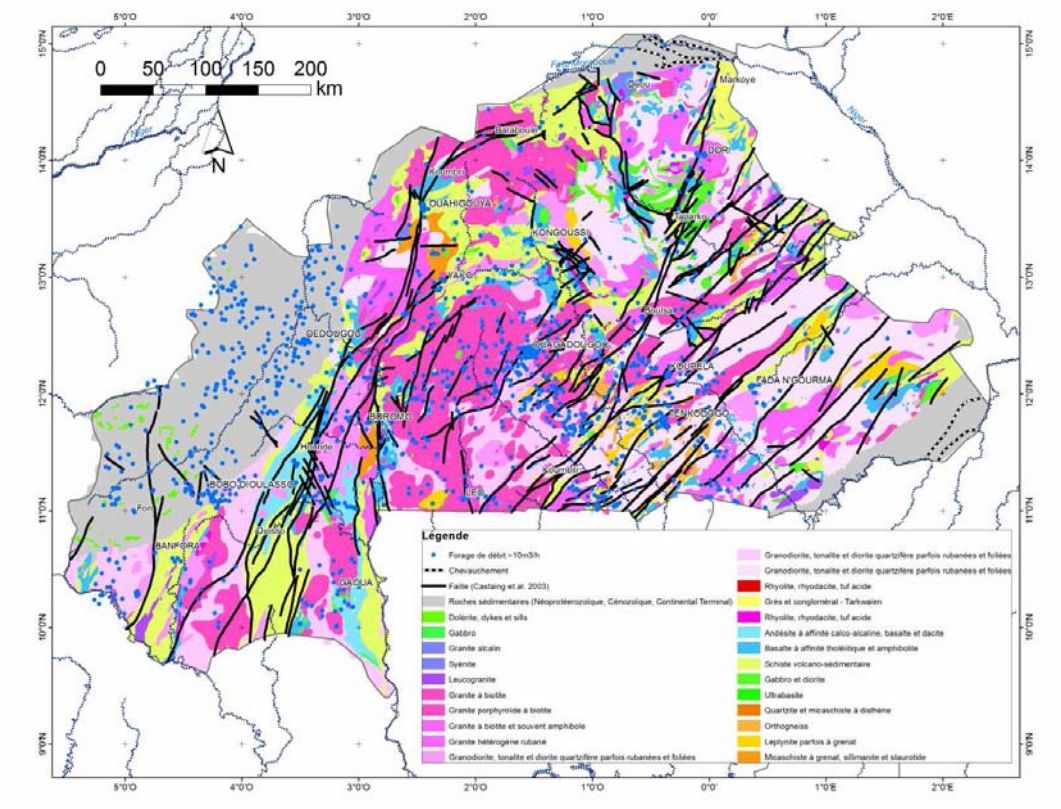

Fig. 2: geological and structural map of Burkina Faso (from Castainget al., 2003) and the distribution of borehole which flow rate is > 10 m^3/h.

Implications of granitic plutons for gold mineralization: the case of the Belahourou granite, Northern Burkina Faso (West Africa)

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The Belahourou granitic pluton, located in northern Burkina Faso, has been the object of a detailed cartographic study in order to determine its emplacement mechanism, with the main objective of the study being its implications for the spatial distribution of gold mineralization. The methodology is based on modern techniques of complete cartography of plutons and their host rocks: remote sensing satellite imagery, airborne geophysics, gravimetry, the Anisotropy of Magnetic Susceptibility (AMS) method and microstructural analysis. Each technique involved field observations and data analysis.

The study allows the following results:

(i) The Belahourou granitic pluton has an elongate crescent shape with 16 km length and 7 km width for an area of 101 km^2. It is a calc-alkaline granite with a zircon age of 2132 ± 4 Ma. It is hosted in turbiditic sediments in the west, and in volcanosediments in the southern and eastern sides. The pluton is followed by the Belahourou-Souma shear zone in the western border (Fig.1).

(ii) The pluton displays particular zoning in magnetic susceptibilities (Km), deformation rates (P%) and shape parameters (T) values.

(iii) Magnetic foliations and lineations are parallel to the pluton shape.

(iv) Penetrative structures of the granite ensue from submagmatic and orthogneissic conditions. Mylonitic microstructures were observed in the western border.

(v) Gold occurrences and the Souma ore body are located all along the western border following the Belahourou-Souma shear zone and in the eastern side of the pluton. A gold occurrence was also observed in the pluton itself following a NE fault.

A 3D model resulting from the whole interpretation allows us to conclude that the Belahourou granite had a syntectonic to late tectonic emplacement (during D2 deformation phase). Its emplacement is thought to focus at a regional scale the mineralized fluids with gold crystallization in low pressure zones corresponding to lithological contacts between the granite and sediment and volcano-sediments.

Keywords: Belahourou, magnetic susceptibility, microstructures, anisotropy.

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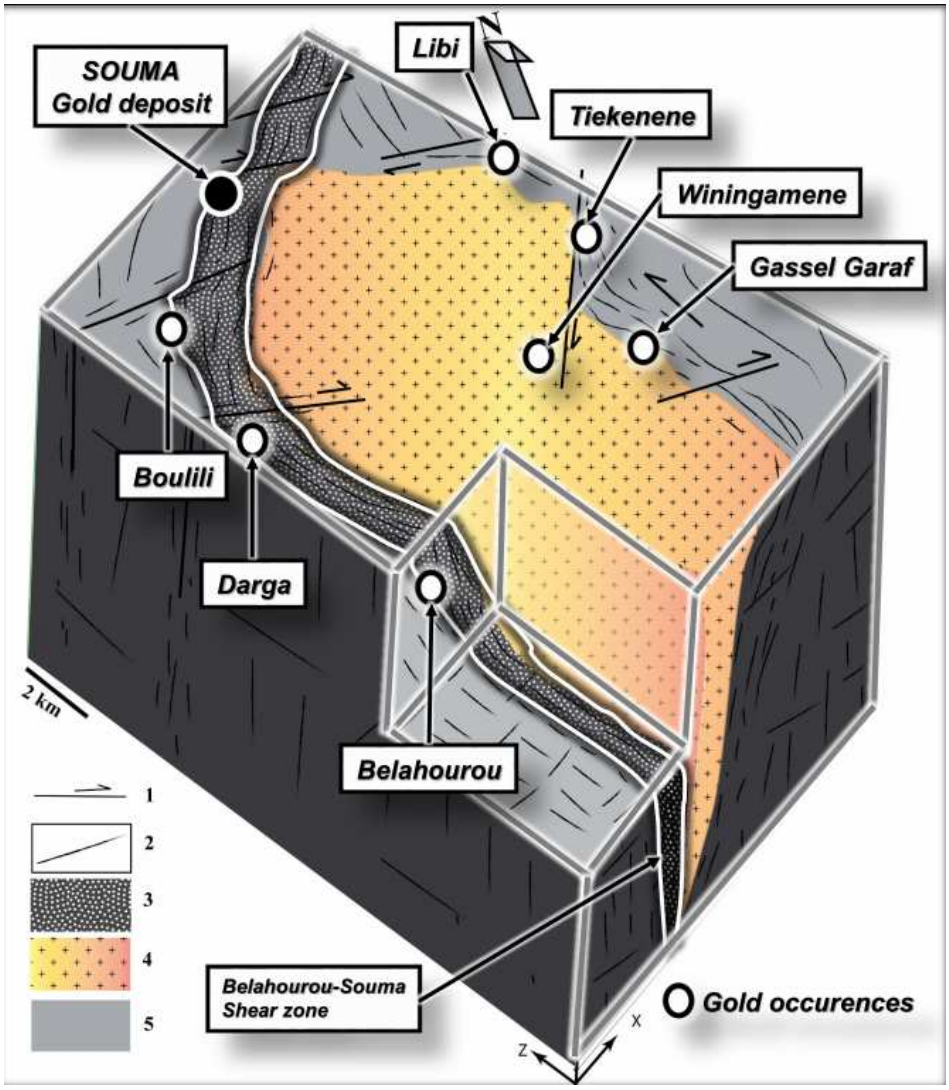

Figure 1: 3D model of Belahourou granitic pluton and its host rocks showing the spatial distribution of gold mineralization 1- late faults; 2: penetrative structures; 3: shear zone ; 4: Belahourou granite ; 5: host rocks.

Evidences of new potential gold deposit type in Burkina Paleoproterozoic granitoids: the granitic of Koupèla massif

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The gold mineralized Koupèla granite is located in the central-east of Burkina Faso (West Africa) and constitutes an example of a new potential type of gold deposit (IRGD) in the Paleoproterozoic granitoids. The mineralization is scattered in the sheared and altered portions or linked to quartz veins and veinlets of a granodiorite. The massif of a NE-SW extension is hosted by tonalite except in its northern and southern parts, where it is in contact with Birimian volcano-sedimentary formations. It is cross-cut by veins of leucocratic granite, microgranite, pegmatite, quartz and aplite. It is a porphyritic granodiorite with potassic feldspar phenocrysts (~0.5 cm length) and numerous mafic enclaves. We present here the petrographic, geochemical and structural characters that made this granite a metallotect.

The mineralogy is composed most often of perthitic and poikilitic feldspars, myrmekite, quartz, biotite, amphiboles and incidentally of zircon, apatite, sphene and allanite.

It is a "mixed" S + I type, metaluminous and reduced to magnetite and ilmenite.

To the effigy of the volcano-sediments, the massif records the major structuring led by the Markoye-Tiébélé fault, as testified by its numerous and various microstructures.

The mineralization is associated to precocious assemblies of potassic type (potassic feldspar-biotite), propylitic (quartz-chlorite-epidote-sericite) and a belated silicification with the development of quartz veins and veinlets. It is poor in sulphides (pyrite and arsenopyrite <1%) with thin gold grains (<1 to 50 μm) representing thus a potential target of gold mineralization explorations.

Keywords: Gold, sulphide, alteration, shearing, granodiorite, Koupèla, Burkina Faso.

Context and period of emplacement of Deou granite (north of Burkina Faso)

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Granitoids represent about 70% of the geological formations of Leo dorsal in West Africa. They are divided into two generations, the first generation is fairly homogeneous with TTG type affinity (tonalite, granodiorite and trondhjemite). The second generation consists of calc-alkaline potassium granitoids, peraluminous granites and alkaline granitoids. The structure and geodynamic context of emplacement of the latter have been studied only in Niger. These structures are nevertheless important to interpret the emplacement of mechanisms and deduce the tectonic regime that prevailed at the end of Eburnean orogeny (active or inactive). The study of Deou granite pluton is in this purpose that is to say, understanding the mechanisms that prevailed at the end of Eburnean orogeny.

Petrographic and geochemical study (Streckeisen, 1976) reveals that the Deou granite is alkaline belonging to the A-Type (Whalen et al., 1987).

Magnetic susceptibility values show that the Deou granite is essentially ferromagnetic due to the presence of magnetite. The magnetic fabrics measured give always strongly dipping foliation and lineations plunging sharply in places. These areas lineation plunging heavily, be read as feeding areas magma pluton. These fabrics are those of emplacement of plutons as the observed microstructures are essentially magmatic. The fabrics obtained in alkaline Deou granite from measurements of the anisotropy of magnetic susceptibility and the different geotectonic diagrams (Dawei et al., 1996) used, allow to propose a context emplacement by diapirism view that this fabrics is concentric. These data clearly confirm the post-orogenic Deou granite which also undergoes no major overhaul after its emplacement.

Keywords: Leo dorsal, Geodynamics, granite, Eburnean, quartzitic monzonite, A-type, magnetic fabrics, microstructures.

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Space-time relationships between the emplacement of the plutons of Dori and Gorom-Gorom, transcurrent shearing and gold mineralization

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In the Paleoproterozoic basement of West Africa, the emplacement of biotite granite plutons is often related to the activities of the major transcurrent shear zones (TSZ) which characterize Eburnean orogeny (Naba et al., 2004; Vegas et al., 2007). These major TSZ are also recognized for their implications in the gold mineralization history (Milési et al., 1992; Feybesse et al., 2006). The Tiébélé-Dori-Markoye fault (NS trending) is one of these major TSZ which is known in Burkina Faso. Along this shear zone we can distinguish the economic size deposits of Essakane, Taparko, Bomboré and Kiaka. The biotite granite plutons of Dori and Gorom-Gorom are located at east and west of this structure, respectively. These plutons cross-cut volcanic and sedimentary rocks metamorphized in greenschist facies and also foliated granitoids with TTG affinities.

The present study based on a precise field mapping, airborne data, measurement of anisotropy of magnetic susceptibility (AMS) and the examination of microstructures was undertaken in order to underline the space-time relationships between the emplacement of these plutons, transcurrent shearing and gold mineralization in this locality.

The combination of all these techniques allowed to actualize the geological map of the study area and specify the rheological conditions of the emplacement of these plutons.

Laboratory analyses are currently performed in order to establish a possible relationship between the emplacement of these plutons and gold mineralization.

Keywords: Paleoproterozoic, shear zones, pluton emplacement, gold mineralization, AMS, microstructures.

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