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Plenary and keynotes speakers

André MICHARD
Professor Emeritus, University of Paris-Sud, Orsay, France.
Conference title: ***The Precambrian basement of Morocco (Sahara, Anti-Atlas and Meseta): a review***

Lhou MAACHA
Directeur Exécutif Exploration, MANAGEM Group, Morocco
Conference title : ***Le développement minéral***

Addi AZZA
Conseiller du Ministre de l'Environnement, des Mines et du Développement Durable, Maroc
Conference title : ***Les perspectives de l'exploration minière au Maroc***

Mohamad HAFID
Professor, Ibn Tofail University, Kenitra, Morocco
Conference title: ***Geological evolution, salt tectonics and petroleum potential of the Atlantic passive margins of Morocco and Mauritania***

Moussa DABO
Professor, Cheikh Anta Diop University, Dakar, Senegal
Conference title: ***Thrust to braiding transpression and transtension tectonics during the Paleoproterozoic evolution of the Birimian Greenstone Belt of Mako, Kédougou-Kéniéba Inlier, Eastern Senegal***

Nasrrddine YOUBI
Professor, Faculty of Sciences Semlalia, Cadi Ayyad University, Marrakech, Morocco
Conference title: ***Precambrian Large Igneous Provinces of Morocco: The record preserved in regional dyke swarms***

Ousmane Wane
Université des Sciences, des Techniques et des Technologies, Bamako, Mali
Conference title: ***Petrographic and geochemical signatures of Paleoproterozoic formations of the Massigui square degree sheet (southern Mali)***

PLENARY LECTURES

The Precambrian basement of Morocco (Sahara, Anti-Atlas and Meseta): a review

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Morocco is the most uplifted part of North Africa, and as a consequence its Precambrian crust is widely exposed. During the last couple of decades a lot of detail geological mapping including U-Pb age measurements have been performed that greatly improved our knowledge of its evolution. In the present review of the state of the art we consider the autochthonous domains of Morocco from south to north (Fig. 1), leaving aside the northernmost Rif domain whose Precambrian rocks belong to an Alpine European allochthon. *The Sahara Domain* exposes to the east (Awserd) the Archean part of the Reguibat Rise of the West African Craton (WAC), with a 3.03-2.96 Ga greenstone belt surrounded by TTG formed between 3.1-3.0 Ga and intruded at 2.46 Ga by high-K feldspathoid syenites. To the west, the Variscan Mauritanide thrust nappes of the Oulad Dlim massif include varied Precambrian units, some of them derived from the Archean autochthon intruded by 1,85 Ga carbonatites whereas the others are made up of Pan-African metagabbros and charnockites dated between 635-605 Ma. Further to the NE, the *Anti-Atlas Domain*, which is the foreland of both the Mauritanides and Meseta Variscan belts, exposes two types of Precambrian terrains beneath a common, weakly deformed Late Ediacaran-Paleozoic unconformable cover. The southern inliers of the central and western Anti-Atlas expose Paleoproterozoic rocks comparable to those of the eastern Reguibat Rise (Algeria). They shows calc-alkaline granites dated at 2180 Ma, likely emplaced in a subduction framework, and synorogenic, 2050-2030 Ma peraluminous granites. Metasedimentary (Birimian) screens including felsic lavas have been locally dated at 2072 Ma. These Eburnian massifs are overlain by folded remnants of their detached, previously unconformable siliciclastic and carbonate cover, labeled the Taghdout Group, recently dated between 1800-1600 Ma. Cross-cutting, 1760-1630 Ma-old dolerites are observed both in the Eburnian basement and its detached cover, suggesting a major Mesoproterozoic extensional regime along the northwestern WAC margin. In contrast, the northern and eastern Anti-Atlas inliers expose rock units typical of the Neoproterozoic Pan-African Belt, thrust over the WAC margin. The suture zone is underlined by the Bou Azzer and Siroua dismembered supra-subduction ophiolites, with accretion ages scattered between 761-697 Ma. They are associated with orthogneissic remnants of two island arcs dated at 770-760 Ma and 755-750 Ma, respectively. Two collision phases are dated by syntectonic intrusions at ca. 700 and 650 Ma. Thick orogenic greywackes (Saghro Group) accumulated between ca. 620-600 Ma next to a new volcanic arc. They were folded by the last, >580 Ma Cadomian phase of the Pan-African cycle. The cycle is sealed by the Late Ediacaran Ouarzazate Group volcaniclastic formations, whose andesite breccias, felsic ignimbrites, domes and granite intrusions are dated between 580-541 Ma. The Pan-African Anti-Atlas Belt connects with the Trans-Saharan Belt to the southeast with some differences in chronology, fold orientation and metamorphic grade. In the second case, the colliding continental block is the eastern Hoggar metacraton (LATEA), whereas in the first case it is the Cadomian Block that today forms the basement of the *Meseta Domain*. The latter domain corresponds to the Variscan basement

of the Atlas System. Precambrian outcrops are scarce beneath the folded and metamorphic Paleozoic units. However, 625-590 Ma rhyolites and granites are exposed in some uplifted zones, and inherited zircons at 2 Ga and 700 Ma testify for the widespread occurrence of a typical Gondwana deep crust. An outcropping sliver from the Western Meseta Shear Zone also yielded a 2.05 Ga age. Hence the Meseta Domain drifted away from Gondwana during the Early Neoproterozoic before coming back at home during the Cryogenian-Ediacaran. The only Meseta unit of more exotic origin is possibly indicated by a sample of charnockite collected at 2600 m depth on the Mazagan escarpment and dated by K-Ar at 900-1000 Ma. This sample could correspond to a piece of Grenville basement left by Laurussia on the Gondwana Atlantic margin during the Pangea breakup.

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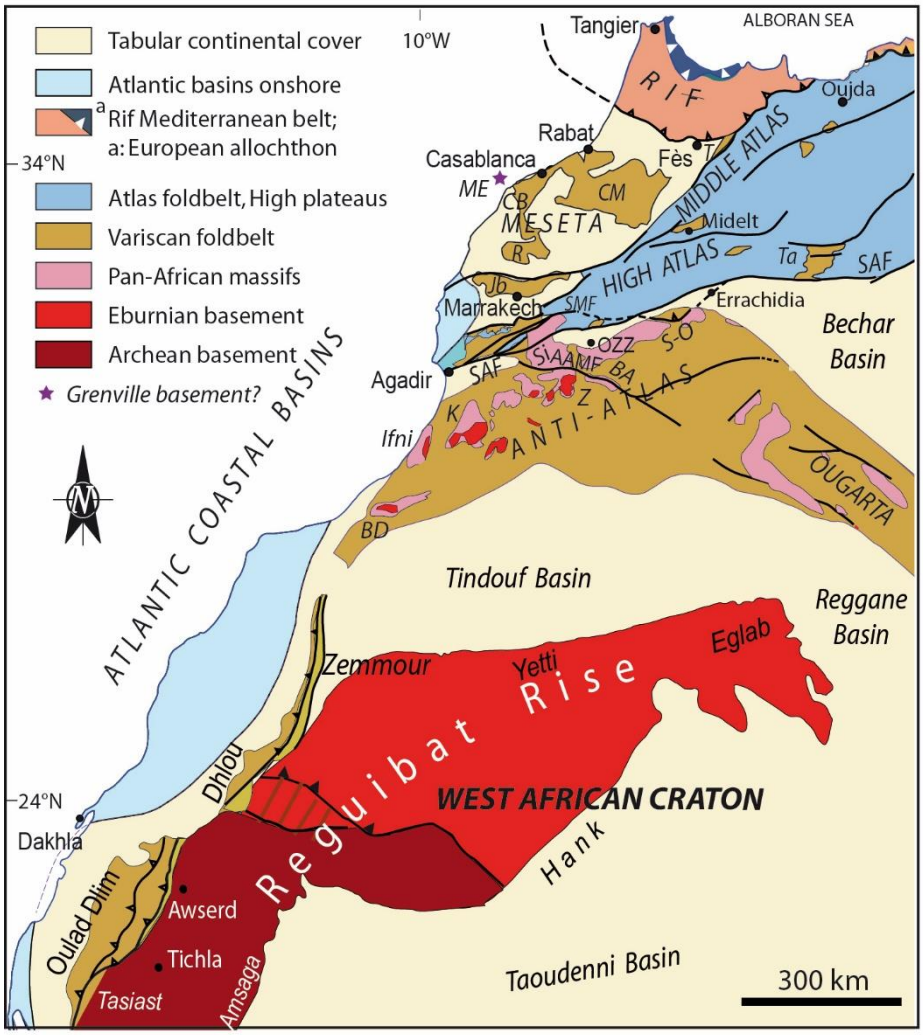

Fig. 1: The Moroccan geological domains, after Michard et al., 2017, modified. AAMF: Anti-Atlas Main Fault; BA: Bou Azzer; BD: Bas-Draa; CB: Coastal Block; CM: Central Massif; Jb: Jebilet; K: Kerdous; ME: Mazagan escarpment; OZZ Ouarzazate; R: Rehamna; SAF: South Atlas Fault; Si: Siroua; SMF: South Meseta Fault; S-O: Saghro-Ougnat; T: Tazekka; Ta: Tamlelt; Z: Zenaga.

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Most of the references used in this review are listed in Géologues, 194 (Morocco Special Issue, sept. 2017), published by the Société Géologique de France, available at http://www.geosoc.fr/numero-actuel-geologues.html

Le développement minéral

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La séquence du développement minéral

D'une manière générale, un programme de R$D suit un processus séquentiel regroupant et dans l'ordre événementiel les programmes exploratoires, programmes focalisés, analyse de faisabilité et mise en œuvre. Plus particulièrement, le développement minéral commence par l'exploration dont les ressources peuvent être assimilées à un produit semi-fini. La phase de mise en valeur va permettre une évaluation plus quantitative allant servir de base à une étude de faisabilité. Ainsi, une réserve exploitable (mine able ore reserve) est cette partie du dépôt minéral (mineral deposit) qui peut être économiquement et de façon légale extraite ou produite au moment de la détermination des réserves. Dans nos pratiques, une réserve est la partie des ressources indiquées et/ou mesurées dont la faisabilité au sens large est positive. Le stade du développement minier intervient pour assurer le tremplin avec l'exploitation minière proprement dite ; Y sont alors engagés les travaux d'infrastructure et préparatoires dont fait partie la préparation géologique en vue de répondre aux objectifs cités ci-haut. La valeur commerciale d'un produit est tributaire de ses teneurs en éléments bonifiant ou pénalisants, et/ou de ses caractéristiques morphoscopiques ou tout autre paramètre physique ou chimique dépendamment du produit fini commercialisable. La teneur en Cobalt dans le concentré de Bou Azzer, ou encore, la teneur en Arsenic dans le concentré de Hajjar sont de bons exemples à ce cas de figure. Par ailleurs, la planification des projets de développement constitue l'essence du plan de développement quinquennal. En effet la préparation géologique va permettre de confronter et capitaliser les visions à différents stade du développement minéral et une visibilité à court et moyen terme de l'exploitation. L'exploitation minière est une activité capitalistique. Elle est soumise à une loi de marché dont la régulation et la synchronisation est imparfaite. Dans une mine donnée, la préparation géologique tant par sa conception et ses outils que par son degré de rigueur et son efficience doit contribuer à développer une capacité de résistance aux périodes maigres des cycles miniers. La morphologie d'un gisement n'est parfaitement connue qu'après son épuisement. Par la nature des travaux de la préparation géologique, celle-ci doit permettre de constituer une base de données pouvant servir à des modélisations gitologiques appropriées. C'est l'exemple de l'échantillonnage, assise des schémas des zonalités géochimiques.

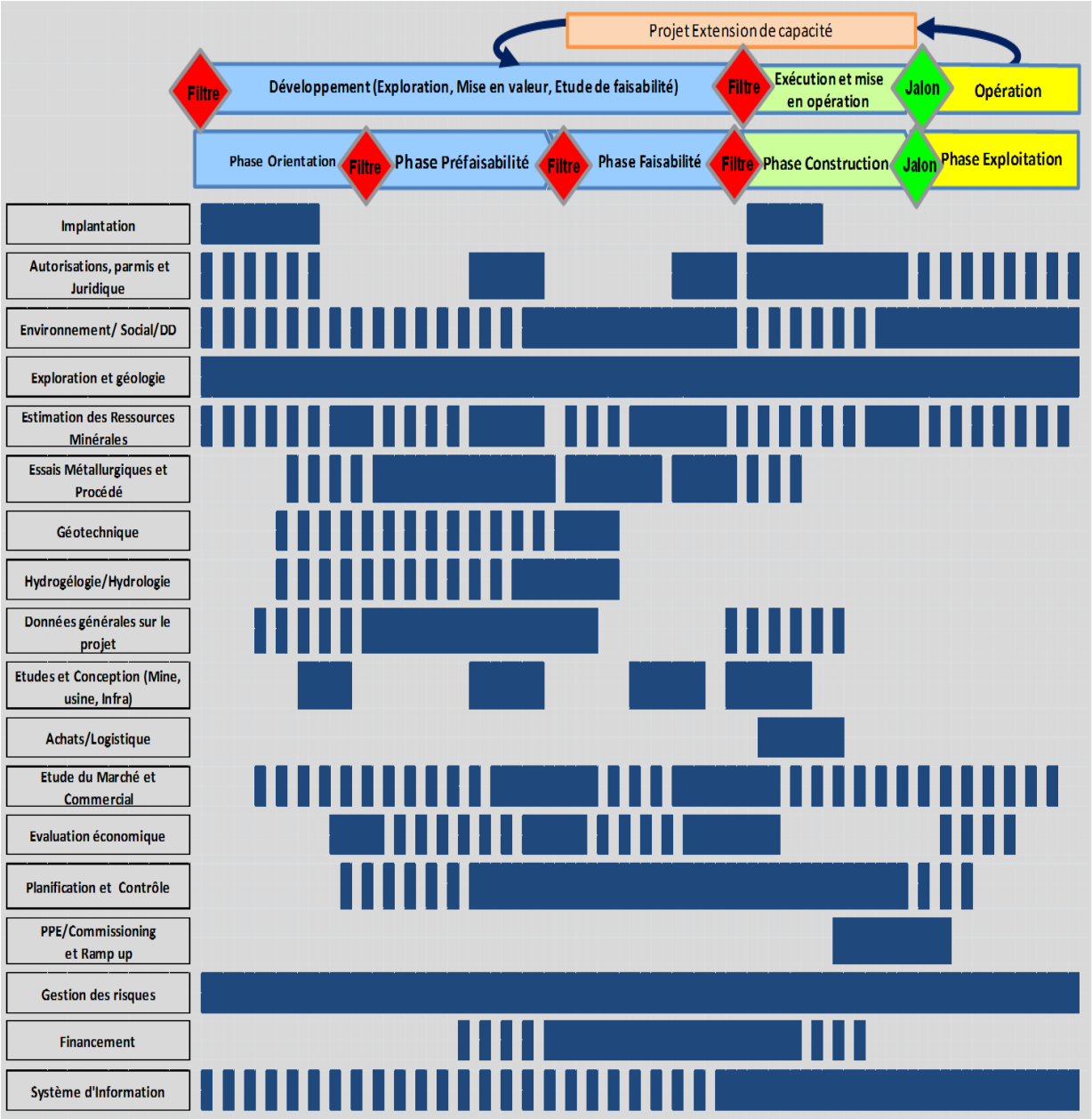

Figure 1 : Processus de développement d'un projet minier (Managem, 2014).

Les normes et standards internationaux

Ces objectifs vitaux pour l'industrie minière et pour les sociétés d'exploration et d'exploitation minières requièrent un système d'inventaire approprié, qui répond aux exigences d'assurance qualité et d'amélioration continue et une conformité infaillible aux normes et réglementation en vigueur (NI43101, JORC…)

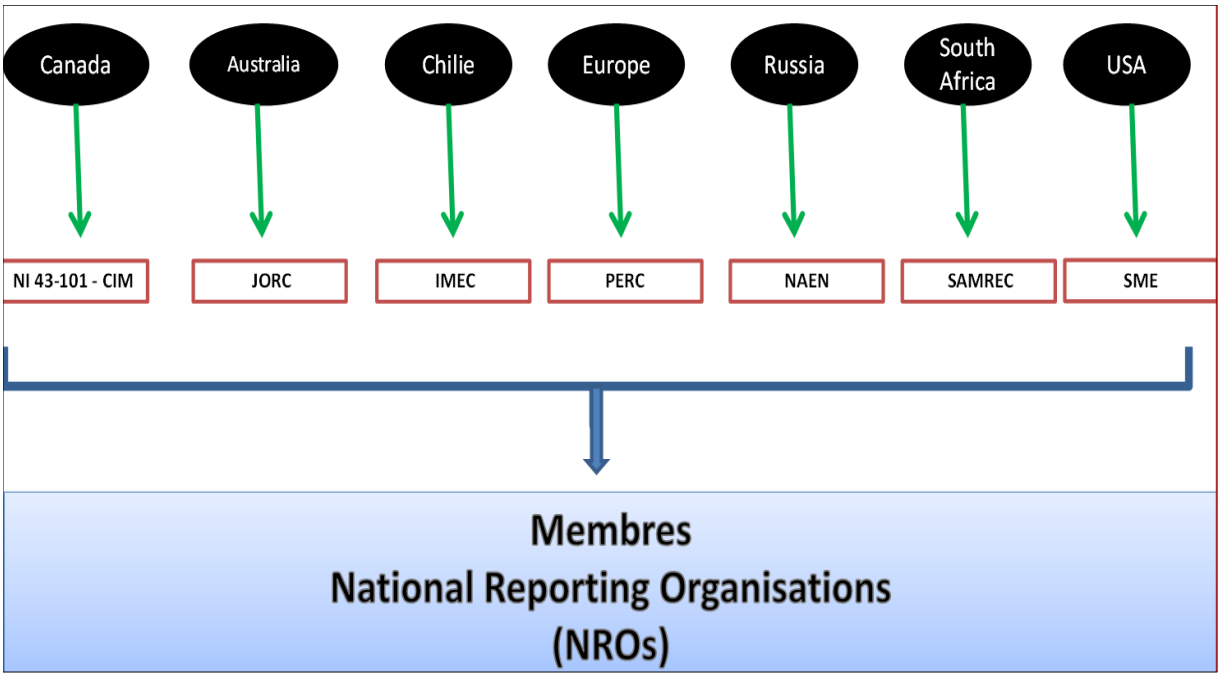

Figure 2 : Membres de CRIRSCO : Regroupement des représentants d'organisations responsables à l'émission de codes et rapports minérales.

Durant la dernière décade, un consensus s'est constitué graduellement dans l'industrie minière autour de la structure d'inventaire développée par l'Australian Institute of Mining and Metallurgy. La réglementation canadienne définie par l'ICM est un système basé sur la distinction entre l'inventaire géologique, dont la connaissance quantitative est principalement géologique, les ressources minérales qui requiert un niveau suffisant pour appréhender la rentabilité de leurs exploitabilités et la réserve de minerai (ou minérale), dont l'exploitabilité est permise et est justifiée.. Une stratégie optimale de développement s'appuie sur des études séquentielles pour orienter les décisions et assoir une discipline d'allocation des ressources. Un succès technique de l'exploration est matérialisé par la découverte des ressources géologiques avec un minimum de volume, de teneur et de contenu métal pour justifier des simulations économiques généralement appelées « PEA, études d'orientation, Scoping study). Si la simulation technico-économique est positive, l'étape suivante est la PFS (prefeasibility Study), laquelle est suivie le cas échéant par la BFS (Bankable Feasibility study).

Economie minérale

Pour une réserve de minerai, «une teneur cible de rentabilité» est établie, suite à une planification détaillée, à partir des paramètres d'ingénierie et d'économiques (tous les coûts applicables incluant les frais généraux / versus les revenus escomptés) des divers gisements et zones d'une part, de l'ensemble de l'opération d'autre part; c'est le prix de revient de la production. À ces coûts, on ajoute le rendement recherché sur l'investissement et le coût d'option (le profit minimum acceptable compte du risque (Lane 1988).

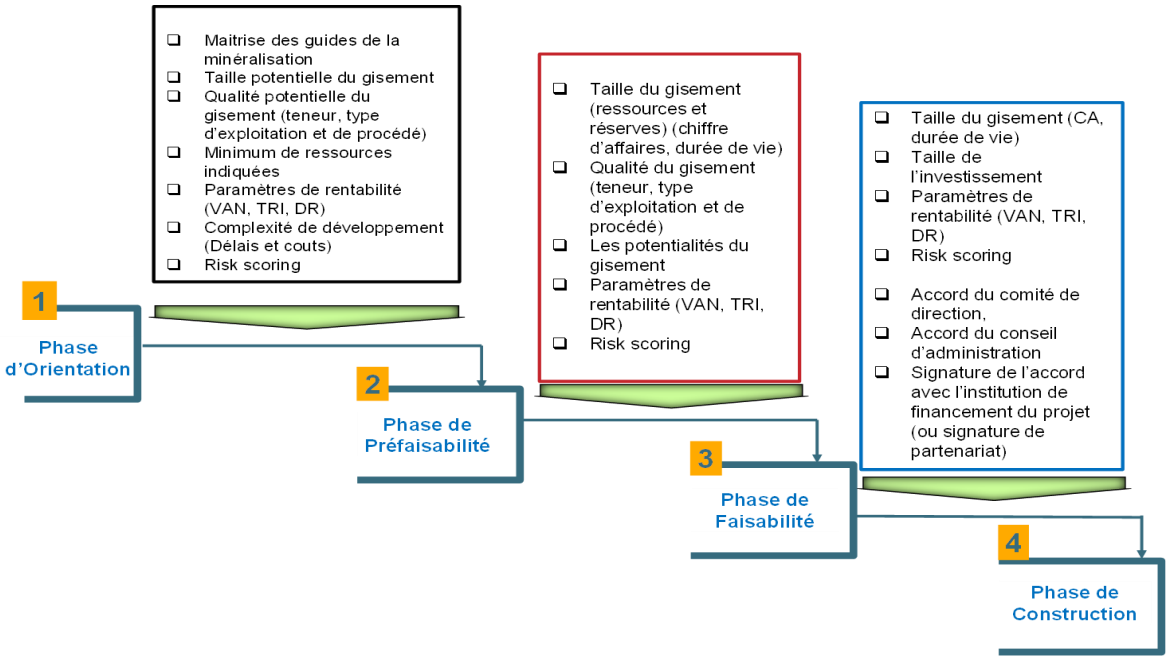

Figure 3 : Processus de maturation d'un projet de développement minéral et critères et règles de passage d'une phase à l'autre

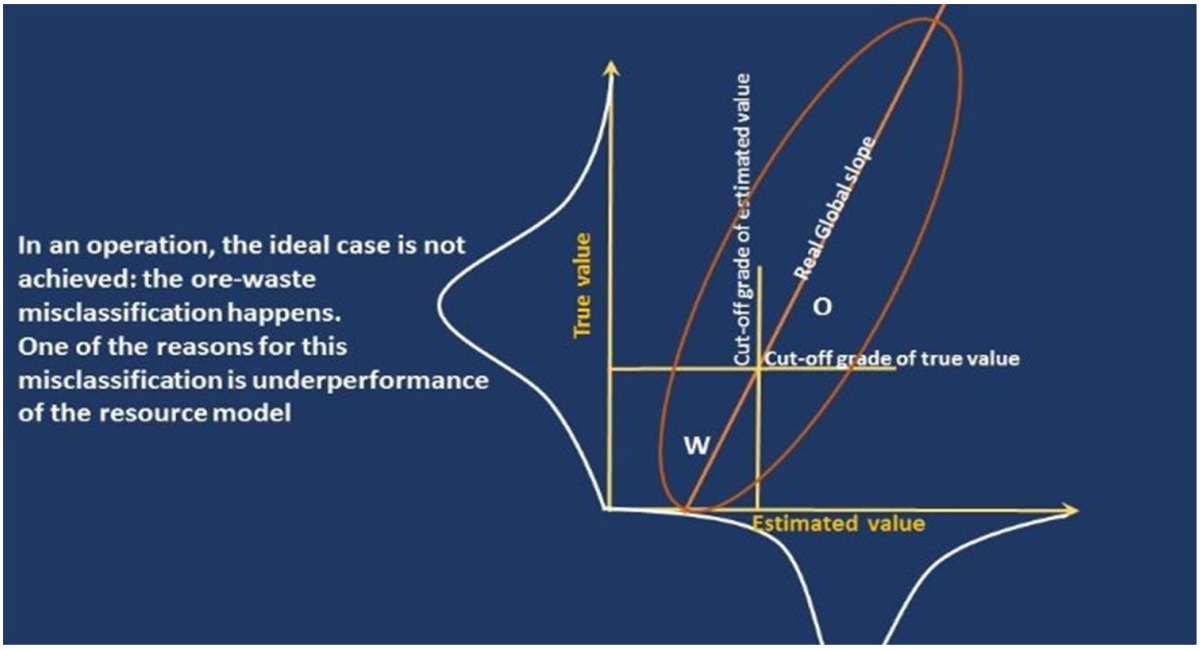

Figure 4 : Illustration théorique d'une valeur estimée à la base d'une teneur de coupure de l'estimateur par rapport à la teneur de coupure réelle et la valeur réelle subséquente.

La complexité de l'étude de la faisabilité pour un nouveau projet minier vient de l'importance de l'investissement, associée aux incertitudes associées à l'exploitation d'un nouveau gisement, à la teneur, la masse, la récupération du métal ou minéral d'intérêt, etc. En terme de physicien, c'est un "saut quantique." L'étude de faisabilité pour un nouveau projet constitue un complément et une vérification diligente de toutes les études antérieurs portant sur la géologie, l'ingénierie (minière, minéralurgique, environnementale), les aspects économiques (marchés et prix, développement des marchés, finance et fiscalité, études socio-politiques, ressources humaines) et sur toutes

autres études inhérentes au projet. Pour les études économiques requises, plusieurs méthodes sont utilisées, toutefois, la méthode DCF (discounted cash flow) demeure la plus populaire par la simplicité de sa logique et par son concept « cash is king." Cependant, il faut réaliser que cette méthode dépend de très près des taux d'escompte, donc l'évaluation à plus long terme entre deux projets de durée différence sera biaisée de ce fait vers le projet de plus courte durée, d'autant plus que les taux d'intérêt seront plus hauts, au dépens du projet de plus longue durée. Il faudra donc pondérer les évaluations DCF par d'autres méthodes et, également, élaborer divers scénarios. Au-delà des études technico-économiques (incluant les aspects financiers et fiscaux), l'étude de faisabilité devra tenir tient compte des contraintes socio-économiques et politiques.

Risk Management

Les questions à poser lors de l'étude de la faisabilité, rejoignent les principales interactions dans un projet minier telles qu'illustrées par la figure ci-dessous. De fait, de telles questions ont leur place dans le processus itératif de la mise en valeur, lors des études de préfaisabilité en particulier. Et sur un plan technique, des plans sont établis pour affiner les paramètres géologiques, miniers, minéralurgiques et environnementaux et réduire les risques afférents.

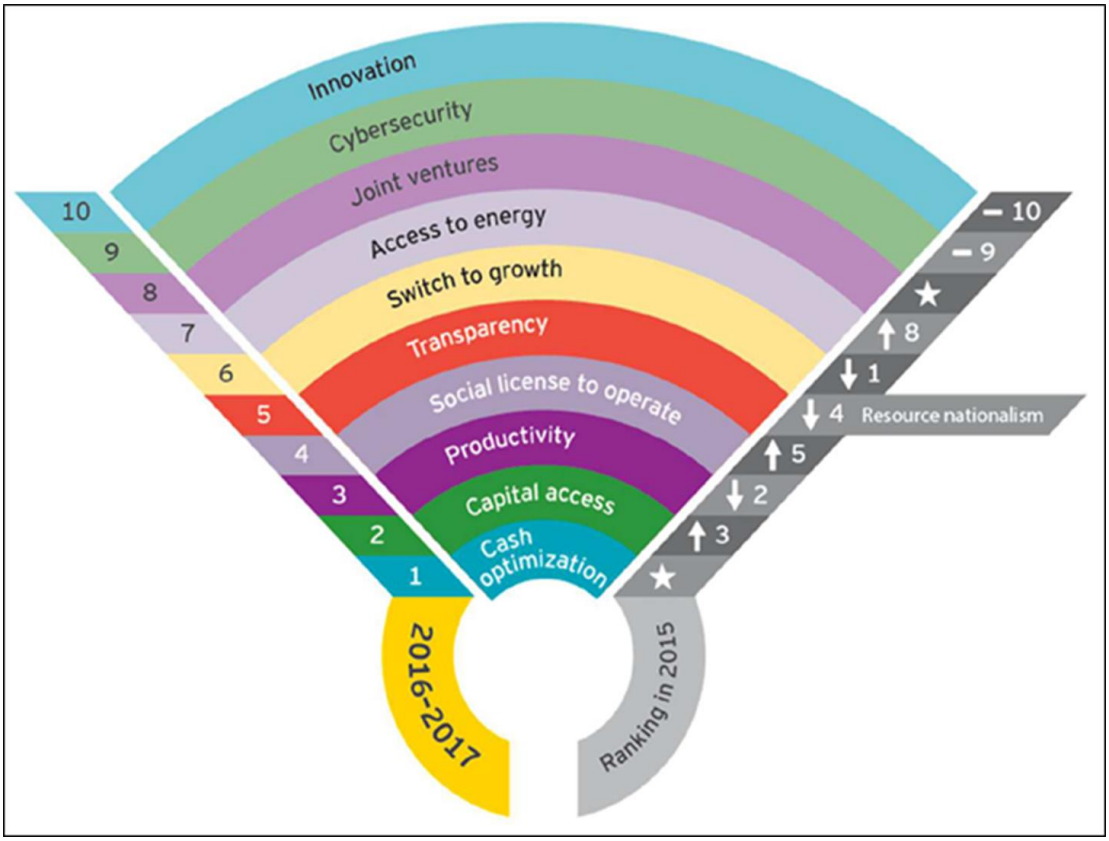

Figure 5 : Exemple de pyramide de risque dans l'industrie minière (E&Y, 2017).

Les perspectives de l'exploration minière au Maroc

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Il est de notoriété que le Maroc est un pays de tradition minière. Ce secteur a connu un développement notoire depuis le début du siècle dernier avec l'ouverture d'un certain nombre de mines et particulièrement des mines de phosphates mais aussi des mines de substances métalliques et des mines de roches et minéraux industriels.

Si ce secteur a connu un tel développement, c'est avant tout grâce à la richesse de sa géologie. Toutefois, malgré cette géologie riche et variée, il n'en reste pas moins flagrant que, en dehors des phosphates, le secteur minier national reste peu développé. Certes, à l'échelle de l'Afrique, le Maroc occupe des places assez honorables pour plusieurs substances dont le plomb, le zinc, la barytine, la fluorine, mais, ne peut-on pas faire mieux ?

C'est dans ce sens que, et pour développer ces ressources, le Ministère de l'Energie, des Mines et du Développement Durable a mis en place une stratégie minière qui vise le doublement des emplois, la multiplication par dix des investissements dans le domaine de la recherche minière et la multiplication par trois du chiffre d'affaires du secteur. Elle est déclinée en plusieurs axes dont, particulièrement, l'amélioration de l'infrastructure géologique, l'actualisation de la réglementation minière, la promotion des atouts miniers du Maroc et la restructuration de l'activité minière artisanale.

Geological evolution, salt tectonics and petroleum potential of the Atlantic passive margins of Morocco and Mauritania

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The Atlantic margins of Morocco and Mauritania are among the oldest passive margins on Earth. They host the two major salt basins of the NW African margin, the Moroccan and the Mauritanian salt basins for which the east-American conjugate counterparts are the Nova Scotia salt margin and the Carolina Trough, respectively. The Moroccan and Mauritanian margins show a similarity in their stratigraphy, with Triassic red bed rift infill, followed by Early Jurassic salt, Jurassic to Early Cretaceous carbonate platforms, and a marine clastic infill in the Cretaceous and Tertiary. They also show a remarkable broad homogeneity in their geodynamic evolution that can be subdivided into two main phases: a rifting phase that started in Late Triassic to Early Jurassic times, followed by a drifting phase which initiated around 180-170 Ma.

The Essaouira-Agadir segment of the Moroccan Atlantic margin is characterized by the incursion of the salt basin into the onshore and by the interception of the passive margin by the High Atlas Alpine Fold belt. Therefore, from Upper Cretaceous onwards, this segment underwent a NNE-SSW compression resulting from the Atlasic orogeny and leading to: (i) the inversion of Triassic faults, (ii) the formation of salt anticlines in the onshore basins and (iii) to the formation of a flexural basin in the offshore. This flexural basin is characterized by a thick northward wedging Cretaceous series and NE-SW striking décollement folds. These folds which correspond to the Cap Tafelney fold belt constitute a system of lateral ramps which terminate the Atlas system at its intersection with the Atlantic margin and marks the transition from a thick-skin deformation style in onshore to a thin-skin deformation style in the offshore. Triassic-Liassic salt played an important role in the genesis of these structures. It was injected upward into the anticlines along strike from a basal décollement and eventually encounters the slop and initiates basinward raft sliding systems. Large allochthonous salt bodies thus developed and terminate westward by a toe thrust zone.

Salt was deposited on Moroccan and Mauritanian segments of the NW African margin in Upper Triassic to Liassic Times. In Morocco, the CAMP basalts can be found in the salt, in many cases interpreted as sills. The Moroccan salt basin has an along-strike length of about 1000 km and an average of 100 km wide dip-oriented segments, locally extending even onshore. In contrast, the Mauritanian basin is only about 300 km long and has only an average of 50 km width in a dip direction. The effects of the post-sedimentary mobility of salt on sedimentation and on structural styles are analyzed in both basins and linked to the main stages of their geodynamic evolution. Salt was deposited during the syn-rift, or more specifically, the syn-stretching stage of continental rifting between the African and North American plates, therefore it has a patchy, discontinuous original distribution in fault-controlled extensional troughs. A great variety of salt structures were identified including gentle salt-cored folds and pillows, compressional diapirs, salt withdrawal synclines and completely allochthonous pluri-kilometric salt sheets and canopies which are bounded to the west by toe thrust salt structures that overly the oceanic crust in the deep offshore

basin. Salt played an important role in the genesis of most of the structures presently encountered in this area. In the Cap Tafelney High Atlas, salt-provided regional décollement levels for Cenozoic thrust-folds during the inversion of the Moroccan margin due to the Atlas mountain building. Therefore the overall pattern of salt tectonics is more complex in Morocco than in Mauritania.A great variety of favourable settings for possible hydrocarbon traps are offered by this particular tectono-sedimentary framework.

In this presentation we propose to review the main stratigraphic and structural features that characterize the Moroccan and Mauritanian Atlantic margins with a description of their salt tectonics and a review of the role the Triassic salt played in the structural evolution of the onshore/offshore Essaouira Basin and the Western Atlas. The description is essentially based on regional seismic transects and borehole data. This is the best way to directly compare the basin-scale geometry of different segments of the Margin.

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Thrust to braiding transpression and transtension tectonics during the Paleoproterozoic evolution of the Birimian Greenstone Belt of Mako, Kédougou-Kéniéba Inlier, Eastern Senegal

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The structural cartography of the Birimian formations of the Mako area shows a polyphase deformation marked by variable structures such as imbricated shear zones, thrusts and reverse-shears, poly-foldings, “boudinages”, normal faults. The multiscale analysis of the various mapped structures combined with the satellite images allowed to distinguish three major phases of Eburnean deformations D_1, D_2 and D_3. The D_1 phase is compressive to thrust deformation due to SSE-NNW principal shortening direction which involves large overturned folds verging to the NW associated with minor thrust fault which are preserved in some lithologies (metabasalts, quartzites). The D_2 phase is a sinistral transpressive deformation which comprises an early (D_{2a}) stage followed by a late (D_{2b}) stage. The early D_{2a} stage is characterized by major NE-SW reverse-shears verging to the NW associated with NW-SE minor dextral shear zones. It is followed by D_{2b} stage characterized by ENE-WSW shortening direction which creates major NNW-SSE sinistral reverse-shear zones. Interference between NE-SW and NNW-SSE major reverse-shear zone of D_{2a} and D_{2b} respectively creates an anatomizing pattern of the deformation. Shearing along D_2 shear zone is associated with development of minor extensional zone which filled by varied magmatic products (mafic, intermediate and felsic). D_3 phase is a transtension deformation associated with a dextral movement which creates conjugate normal faults with locally negative flower structures. D_3 principal maximum stress is ENE-WSW oriented. The orientation of the main shortening direction of Eburnean phases D_1, D_3 and D_3 is NNW-SSE, NW-SE and ENE-WSW, respectively. Such a pattern could be induced by an anticlockwise rotation of principal maximum stress in the Mako sector. The Eburnean granitoids emplaced before and during these three Eburnean orogenic phases.

Keywords: *Eburnean, Birimian, thrust, transpression, transtension, Kédougou-Kéniéba inlier*

Precambrian Large Igneous Provinces of Morocco: The record preserved in regional dyke swarms

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Morocco hosts a Dyke Swarm Bonanza! Remarkable mafic dyke and sill swarms (plumbing systems of Large Igneous Provinces, LIPs) have been recognized in the Sahara and in most inliers in the Anti-Atlas of southern Morocco. In the Sahara, numerous mafic dyke swarms with various trends are found in the southwestern and oldest portion of the Reguibat Shield, of the West African craton (WAC). An Archean age of 2688 ± 3 Ma (U-Pb baddeleyite) was obtained for a member of the plagioclase phenocryst-bearing, NW-trending Aousserd-Tichla swarm (Söderlund et al., 2013, Youbi et al., in progress). In the Anti-Atlas, the Paleoproterozoic basement is composed of metasedimentary schists, granites, paragneisses, migmatites, with U–Pb zircon ages ranging from 2200 to 2030 and cut by dolerite dyke swarms, mostly with unknown age. The ages of the dolerite dyke swarms were previously poorly constrained by an old Rb-Sr isochron date of 787 ± 10 Ma (Cahen et al., 1984), and Walsh et al. (2002) obtained a U-Pb age of 2040 Ma for a dyke in the Tagragra of Tata Inlier. More recently, our group (Youbi et al., 2013 and references therein) obtained 6 clusters of ages in Zenaga, Agadir Melloul Iguerda-Taïfast, Tagragra of Akka, Kerdous and Bas Drâa inliers: 2040 Ma, 1380-1416 Ma, 1750 Ma, 1650 Ma, 885 Ma and 612 Ma. In addition to these dated Precambrian mafic dyke and sill swarms, a number of mafic units can be linked to the Central Iapetus Magmatic Province (CIMP) event. The 615-540 Ma (CIMP) was emplaced in multiple pulses during Ediacaran-Cambrian times, and has been linked to the disruption of the Rodinia supercontinent leading to the opening of the Central Iapetus Ocean. It is well represented in Laurentia and Baltica but also present on other formerly attached blocks such as the Congo craton, the WAC and Amazonia. In Morocco, the CIMP occurrences are particularly impressive in the High and Anti-Atlas of Morocco, as the 600-541 volcano-sedimentary sequences of the Ouarzazate Supergroup (i.e. "XIII" or PIII of Choubert et al., 1963) that covered ca. 2 x 10^6 km^2 with an estimated magma volume of ca. 1 x 10^6 km^3 and volcanic thicknesses greater than 3000 m. The CIMP event also occurs as dyke swarms and sill complexes that are the plumbing systems of the Ouarzazate Large Igneous Province. All these results combined with the U-Pb geochronology in the literature are used to provide a new interpretation of the regional lithostratigraphy and also reveal several periods of tectonic and magmatic activity in the central and western Anti-Atlas, particularly during the Paleoproterozoic and the Mesoproterozoic. Essentially, a new magmatic (LIP) barcode can be defined for the northern part of the WAC.

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Petrographic and geochemical signatures of Paleoproterozoic formations of the Massigui square degree sheet (southern Mali): Geodynamic Implications

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The Massigui square degree sheet (MSDS) belongs to the northern margin of the Man Shield, one of the two shields of the West African Craton (WAC), the other being the Reguibat Shield. It is located on the northern edge of the Bagoé Basin which is the largest Paleoproterozoic basin in southern Mali. This basin extends to the south, into Côte d'Ivoire, where it is named "Boundiali Belt". It disappears to the north below the Neoproterozoic-Carboniferous Taoudeni basin.

The MSDS is made of metavolcano-sedimentary rocks that are intruded by various generations of plutonic bodies. Both metavolcano-sedimentary and plutonic rocks are of Paleoproterozoic age. It is transected, from the southwest to the northeast, by a shear zone located at the interface of the plutonites and the metavolcano-sedimentary rocks. This shear zone, called the Banifing Shear Zone (BSZ), extends from Côte d'Ivoire to the Taoudeni basin. It could correspond to the northern extension of the major shear zone of Sassandra, which separates Archean and Paleoproterozoic domains in Côte d'Ivoire.

The metasedimentary rocks of the MSDS are made of metagreywackes, metapelites, schists and locally micaschists. They essentially contain quartz, plagioclase and micas (biotite ± muscovite). The metagreywackes contain locally, microcline, pinnite, amphibole and garnet. They differ mainly from the metapelites by the size of the clasts and the proportion of the matrix. The metavolcanic rocks intercalated with the metasedimentary rocks are usually metadacites and metarhyolites. The metavolcano-sedimentary series is folded and metamorphosed in the greenschist facies, generally biotite zone. Metamorphism can reach the amphibolite facies in the BSZ or near the plutonic rocks.

The plutonic rocks show three magmatic units: (1) Massigui granitoids; (2) Tiéfala-Syobougou dioritoids; and (3) Sodioula foliated granitoids.

Massigui granitoids belong to the Massigui batholith, which occupies the western part of the MSDS. The Tiefala-Syobougou dioritoids are located within or to the west of the BSZ. The Sodioula foliated granitoids are exclusively located within the BSZ. Both dioritoids and foliated granitoids strikes NE-NNE. Their orientation is parallel to that of the BSZ. Massigui granitoids are the oldest plutonic rocks in the area (~ 2112-2095 Ma), the Sodioula foliated granitoids are the youngest plutonic rocks (~ 2074 Ma) and the Tiefala-Syobougou dioritoids are of intermediate age (~ 2106-2103 Ma).

All the plutonic rocks define a calc-alkaline trend with K-enrichment without a participation of alkaline magma. The forms of the rare-earth spectra as well as those of the spidergrams

show similar patterns which suggest that the plutonic rocks would derive from an enriched source similar to that of the upper-mantle of the subduction zones. The Massigui granitoids and the Tiefala-Syobougou dioritoids fall in the field of Volcanic Arc Granites (VAG) opposite to the Sodioula foliated granitoids, which predominantly occur in the field of Syn-Collisional (Syn-COLG) Granites.

The metavolcano-sedimentary rocks of the MSDS share the same magmatic trends as the plutonic rocks, mainly rocks of granodiorite composition. They still have the magmatic characteristics of their protolith. The rare-earth patterns and spidergrams indicate that the metavolcano-sedimentary rocks have formed in a subduction environment.

Keywords: *Massigui; Square-degree sheet; Bagoé; Metavolcano-sedimentary rocks; Paleoproterozoic; Granitoids; Dioritoids; Banifing Shear Zone; Geochemistry; Geodynamic.*

ORAL PRESENTATIONS

Post-Panafricain tectonic effect of the Bouskour-Tagmout mineralization (Eastern Anti-Atlas, Morocco) using remote sensing and structural interpretation

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Remote Sensing data have become more important for the study of geology, structural geology and extraction of lineament which give us an overview of the tectonic events.

The aim of this work is to identify the post-panafrican tectonic effect of the polymetallic mineralization in the Bouskour-Tagmout district (central part of Saghro inlier, eastern Anti-Atlas, Morocco), through a well detailed geological mapping. To achieve this goal, different processing techniques were applied on the Landsat 8_OLI and Sentinel-2 Satellite images of the study area (acquired successively on January and March, 2017). Several techniques such as radiometric calibration, atmospheric correction, principal composent analysis, and directional filters were applied to improve the localization of geological structures and mapping of the geological lineaments with a refined and precised manner. The results obtained are validated by the regional geological map, and confirmed by structural observation and measurements through a fieldwork on the Bouskour-Tagmout deposit.

The statistical analysis of the structural result indicates that the study area is affected by several structural trends: NNW-SSE and the NE-SW to ENE-WSW (dominant orientation),

The principal mineralized veins (Pb-Zn-Cu) are hosted by the NW-SW faults system and shows mainly dextral shears,

The NE-SW to ENE-WSW fault system represents the dominant one, which intersects the mineralized structures and rhyolitic dykes of the Bouskour deposit showing dextral and sinistral shears,

The analysis of fracturation-mineralization reports indicate that the main mineralized veins (Pb-Zn-Cu) of Bouskour are probably controlled by the remobilization of pre-existing stock metal (El Azmi et al., 2014) during the post-panafrican events (Hercynian & Atlasic).

Keywords: *Saghro inlier, Bouskour-Tagmout district, post-panafrican, Remote Sensing, Lineaments*

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New paleomagnetic data on dykes to assess the accretions of West African Craton to Columbia and Rodinia

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A new Apparent Polar Wander Path has been calculated for the West African Craton (WAC) using paleomagnetic data obtained on the Yetti-Eglab intrusions and stromatolite-bearing formations. As no contact test was available, the magnetic stability of carriers was demonstrated thanks to rock magnetic measurements. One, two or three magnetization components on 159 oriented specimens (14 sites) have been isolated using principal component analysis or great circles technique, mainly on doleritic dykes. High and low unblocking temperature components were isolated in six dykes but also in four sites of the well dated Hank stromatolite-bearing formation (875-890 Ma). For the two kinds of rocks, the main components show stable remanent magnetization mainly carried by magnetite (or titanomagnetite) as described using thermomagnetic or Isothermal Remanent magnetization curves, where no significant mineralogical transformation occurred at high temperatures.
Five groups of paleopoles have been calculated: they witness the existence of a large circum-terrestrial loop with a drift from the high latitudes of the lower hemisphere to the high southern latitudes of the upper hemisphere followed by a re-entry in the high latitudes of the lower hemisphere. This is in agreement with the previous loop computed by Sabaté and Lomax (1975) between 2.1 Ga and 1.7 Ga. The Yetti and Eglab blocks amalgamated around 1.9 Ga and participated to the formation of Columbia Supercontinent. The paleopole computed for the stromatolite-bearing formation corresponds with the location of Rodinia Supercontinent at its early stages of amalgamation.
The geodynamic evolution of the WAC respect with that of Columbia and Rodinia Supercontinents suggests that the Eglab and Yetti were clearly separated by a large oceanic crust before 1.9 Ga. A volcanic arc developed during the subduction of this ocean followed by crustal thickening which generated an intrusive suite (Aftout granites) when it was at the northern low latitudes. Fennoscandia and Rio de la Plata Cratons were close to the WAC after 1.7 Ga. Fennoscandia probably followed the same loop as the WAC between 1.7 and 0.9 Ga. In Africa, the collapse of the Birimian orogen was probably contemporaneous with the fragmentation of Columbia. At 0.9 Ga, Fennoscandia was probably not attached together with the WAC since the latter was not affected by the Grenvilian orogen, so did not necessarily have the same loop.

Keywords: *West African Craton, dykes, Columbia, Rodinia, Paleomagnetism, Rock magnetism, Apparent Polar Wander Path.*

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Controls on Gold, Rare Metals, Rare Earth Elements deposits in the Hoggar, Tuareg Shield (Southern Algeria)

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The Hoggar is composed of well preserved and largely reworked Archean (3200 to 2500 Ma) and Paleoproterozoic terranes (2000 Ma) as well as juvenile Pan-African terranes (750-550 Ma) (Liégeois et al., 2003). During the last 50 years of exploration and prospecting, the ORGM (National Bureau of Mining and Geology of Algeria) has discovered many thousands of various minerals occurrences where the overwhelming majority are without economic importance.

We will depict only mineral deposits which are valuable, beginning by the more eldest to the recent.

1- BIF: the banded iron formations with gold traces are embedded in granulitic Archean formations of In Ouzzal and Gour Emellalen regions (western Hoggar) (Ouzegane, 1987)

2- The Paleoskarns outcrop at Alouki and Tekhamalt regions (In Ouzzal, western Hoggar) and are hosted in the archean granulitic greenstone belt. They are mainly constituted by Be-Musgravite, pyrochlore, scheelite and monazite (Boumaza, 2008)

3- The REE bearing carbonatites and metacarbonatites (2000 Ma) are only found at the margins of the granulitic Archean craton (block) of In Ouzzal (western Hoggar). They are associated with alkaline rocks and are located only in the In Ouzzal Archean block, more frequently at its margins. They consist of dykes and lenses and are constituted mainly by calcite, dolomite , clinopyroxene, amphibole, biotite K-feldspar, titanite, allanite, fluorite, magnetite garnet. bastnaesite, apatite, monazite and britholite. They are poor in HREE and relatively rich in LREE (Ouzegane, 1987; Ouzegane et al., 2003; Cherbal and Aissa, 2012; Cherbal et al., 2016)

4- The Hoggar gold deposits are linked to the translithospheric faults trending 2°30', 4°13', 7°30' and 8°30' (excepted the 4°13' and 4°50' faults where the gold occurrences are successively poor and very poor) (Aissa et al., 2002; Marignac et al.2016; Aissa and Marignac 2017). The richest gold deposits are of orogenic type, and located in metacraton margins which undergone granulitization

5 - The Rare Metals (Sn, W, Nb, Ta, Be, Li) with economic importance are also located at the metacraton margins or deeply faulted metacraton. They are linked to the more evolved late Panafrican granites ore pegmatites.

Thus, all the valuable ore deposits are situated on the margins of craton or metacraton (Archean to Paleoproterozoic), whereas those located in the juvenile terranes (Neoproterozoic to Cambrian) are very poor.

New structural and petrographic data of magmatic dykes and sills of the Tadaout-Tizi n'Rsas anticline, Eastern Anti-Atlas, Morocco

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In the eastern extremity of the Anti-Atlas, the ESE-WNW anticline of Tadaout-Tizi n'Rsas consists of Ordovician to Devonian formations intersected by some magmatic intrusions. These Palaeozoic rocks carry several Pb-Zn-Cu-(Ba) mineralized structures in the northern part of the Tadaout-Tizi n'Rsas anticline; these structures constitute the so-called Tadaout-Tizi n'Rsas mineralized field. The magmatic bodies of the Tadaout-Tizi n'Rsas anticline are subdivided into two distinct types: (i) The first, in the form of dykes crossing the Palaeozoic (Ordovician to Devonian) formations trending N20° to N60°. (ii) The second type corresponds to magmatic sills injected into the Silurian and Devonian layers. They have a WNW-ESE direction. Both magmatic intrusions types (dykes and sills) are doleritic intersecting the eastern part of the anticline.

The Variscan tectonic events have affected the Tafilalet region in general and more particularly the anticline of Tadaout-Tizi n'Rsas. The effect of Variscan shortening on doleritic bodies is materialized by some offsetting due to the ENE to E-W strike-slips, and by the sills showing folding structures. As a result, the age of these magmatic events may be prior to Variscan compression events. Recent work concerning the magmatic bodies of Tafilalet (Pouclet et al., 2017) attributed alkaline nature with Famennian-Tournaisian age to the Tadaout-Tizi n'Rsas ones (dykes and sills).

Macroscopically, the dolerites of Tadaout-Tizi n'Rsas show a greenish colour and a porphyry texture with well visible phenocrysts of elongated feldspars. These bodies also show orthose, biotite and schist enclaves of the surrounding rocks. The microscopic study shows a primary paragenesis dominated by plagioclase and alkaline feldspars, amphiboles and biotite, and a secondary paragenesis constituted by quartz, calcite, chlorite and iron hydroxides.

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Characterization and valuation of clays in the northeastern region of Morocco

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From a perspective of sustainable local development, this study focuses on the characterization of clay materials in the northeastern zone of Morocco. It is characterized by a high content in very diverse useful substances including clay deposits which have a wide range of composition and properties, origin of their multiple applications such as building, industrial and craft ceramics, pottery, pharmaceutical, cosmetic, chemical industries, oil purification, etc. This study has the advantage of contributing to the promotion of local building materials while improving the quality of artisanal ceramics produced. In this region, the terracotta clay-based are used mainly for the manufacture of traditional and modern building materials (bricks, tiles) and for making many pottery items.
Most Moroccan bentonite deposits are located in northeastern Morocco, in the Nador region. This natural resource is linked to the volcanic activities of Gorougou and its satellites. The present work focuses on the study of Trebia bentonite deposit located 18 km west of the city of Nador, on the western flank of the Tidiennit volcanic massif. Tight sampling was carried out. The raw samples were subjected to several analytical tests such as geotechnical identification tests, namely water content, organic matter, calcimetry and sand equivalent. The granular repair was carried out using the laser particle size. The extracted clay fraction was prepared as a powder and oriented aggregate and then analyzed with DRX. The clay processing was differentiated by comparison of the three routine test diffractograms (Normal, ethylene glycol, heating to 500°C). The analysis of the disoriented powder spectrum allowed the mineralogical characterization of the raw samples.

Keywords: *Characterization, clay, DRX, Laser granulometry, northeast Morocco.*

Refining the stratigraphy of the Tizi n'Taghatine Group via U-Pb Geochronology of the Ifzwane Suite and detrital zircons of sedimentary rocks (Zenaga and Bou Azzer-El Graara inliers, Anti-Atlas, Morocco)

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The Precambrian stratigraphy of the Anti-Atlas comprises several groups, some of them with poor age constraints. The Tizi n'Taghatine Group (Taghdout or Lkest Group,) of the Anti-Atlas (Morocco, northern portion of the West African craton, WAC) consists essentially of basalts, quartzites, and stromatolitic/oolitic carbonates and represents a passive margin sequence, deposited during the break-up and rifting of the northern margin of the WAC. The rifting culminated with the creation of an oceanic basin between the northern edge of the WAC and an unknown terrane at ca. 760 Ma (U-Pb zircon age). The age of the Tizi n'Taghatine Group has been poorly constrained. It was previously thought to be c. 1000-800 Ma based on (1) the presence of stromatolites that point to a Neoproterozoic age, i.e. younger than 1000 Ma, and the (2) age of the contact-metamorphosed walls of the associated mafic dykes (Rb/Sr, 789 ± 10 Ma, Clauer, 1976). However, with the U-Pb dating of numerous dyke swarms in the Anti-Atlas Inliers at 2040 Ma, 1750, 1650, 1416-1380, and c. 870, Youbi et al. (2013) suggested that the Tizi n'Taghatine Group could be Mesoproterozoic in age, with a preference for an age of about 1750 Ma. In order to test this idea, a mafic sill within the Tizi n'Taghatine Group in the Zenaga inlier has been dated by the U-Pb SHRIMP (Sensitive High Resolution Ion Microprobe) method, yielding an age of 1639 ± 34 Ma. This age confirms that the lowermost part Tizi n'Taghatine Group is nearly 1.0 Ga older than previously thought. Similar result were obtained on the Ighrem dyke that cross-cut the Tizi n'Taghatine Group in the Ighrem Inlier dated at 1706 ± 7 Ma (U-Pb on baddeleyite; Ikenne et al., 2017).The maximum depositional age and the provenance of the Tizi n'Taghatine Group is constrained by new detrital zircon ages from the lower, middle and upper part of this sedimentary succession in Zenaga and Bou Azzer El Graara inliers and which indicate the source provenance from the WAC (i.e. Reguibat shield, Anti-Atlas and Meseta Block) and possible others Cratons such as Amazonia.

***Keywords**: Morocco, Anti-Atlas, Proterozoic, Tizi n'Taghatine Group, Taghdout sill, detrital zircon, U-Pb geochronology*

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A general tectonic framework in the Sangmelima Greenstone Belt in southern Cameroon (NW Congo Craton): Mining exploration implications

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The Sangmelima Greenstone Belt in southern Cameroon (NW Congo Craton) displays a D_2 regional fabrics that consist of an S_2 sub-vertical foliation, L_2 stretching lineation and F_2 folds resulting from a dextral transpressive regime. D_3 late granulitic deformation synchronous with a migmatisation episode is characterized by F_3 post-folds with oblique axes, sometimes associated with localized C_3 shear zones showing inverse movements alongside an anatexy phenomenon. The plutons were emplaced during the regional deformation. The regional structure, combined with the existence of contemporary intrusive and extrusive rocks in the surface today, buttress a vertical tectonic model with burial of supra-crustal rocks in soft underlying material during the ENE-WSW to EW horizontal crustal shortening.The important magmatic intake within the craton allows a warming and a general softening of the lithosphere.Finally, CN has been affected by the Eburnean orogeny (D_4), characterized by the development of the N40-60E transverse step with a generally sinusoidal component, to which some dextral conjugate bands are associated.

Keywords: *Horizontal shortening, weak lithospheres, pop-down, Archaean, Ntem Complex, Cameroon.*

Using the box-counting method to analyze the disturbances of phosphate series of Sidi Chennane (Central Morocco)

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The phosphate series of Sidi Chennane is frequently disturbed by sterile bodies called “disturbances” or “derangements” dispersed without order of a very high hardness, an irregular geometrical form. These sterile bodies are masked by the Quaternary cover and they are not directly mapping from the surface. Consequently, The presence of the disturbance in the phosphate mines causes two major problems: (1) from an economical side, it is not easy to determine exactly the part of these bodies in the overall volume of the deposit and therefore we cannot correctly calculate the phosphate reserves; (2) from a technical viewpoint, when we come up against a "disturbance body", it is necessary to

constrict the firing pattern and increase the number of holes in order to draw up the disturbances boundaries, and to boost the explosives power during the blasting operation.
Based on a database of 15,000 apparent resistivity data, the present contribution shows how going back fractal geometry may help to characterize the disturbances. The work is carried out on geoelectrical maps of a study area of 50 hectares in the northern part of Sidi Chennane deposit. Fractal geometry is thus seen to be a defining or a representative parameter used for examining the disturbances rate by using the box-counting method. A simple algorithm is presented that allows measuring the fractal dimension of the disturbance areas through the sample image to be calculated. It is an easier tool in calculation process and more effective to deal with the irregularity than the traditional geometric methods which is often time consuming.
This analysis may improve the way of phosphate exploration planning through the comprehensive understanding of the spatial character of disturbances. It describes how much space is filled by disturbances and therefore can help in the phosphate reserves estimation. The study is simple enough to be applied to phosphate deposits in Ouled Abdoun, as such opening a window of opportunity for the development of other automatic and quantitative toolsto estimate the disturbances rate.

New zircon U-Pb ages of the Imiter granitoids (Saghro massif, eastern Anti-Atlas, Morocco): Geodynamic implications

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At the Northwestern edge of the West African Craton (WAC), the Imiter inlier in the eastern part of the Anti-Atlas exhibits a large range of Neoproterozoic granitoids. The Igoudrane massif, Bou Teglimt granodiorite and Bou Fliou granite crosscut the flysch-like unit related to the Saghro Group. In this study, we present new zircon U-Pb ages on these three massifs, obtained by SHRIMP at IBERSIMS laboratory in Granada University. The geochronological results give 582 ± 6 Ma for the Bou Fliou granite and 567 ± 6 Ma for the Bou Teglimt granodiorite; the ages obtained on the Igoudrane quartz-diorite (540-585 Ma) are considered to correspond to both the age of emplacement (540 Ma) and inherited zircon grains from the surrounding rocks (e.g. Bou Fliou granite).
These new data reveal that the Igoudrane Complex is younger than previously reported (Schiavo et al., 2007). Accordingly, all the granitoids of the Imiter area are Ediacaran in age and belong to the Ouarzazate Group. The Igoudrane massif, which was assumed until now as Cryogenian in age and coeval to the major Pan-African event in the Anti-Atlas, is actually Ediacaran. In addition, the present ages offer a maximum age (585 Ma) for the Saghro Group, in the Imiter inlier. In fact, the age and geodynamical context of the Saghro Group

basement is still debated, from Cryogenian to Ediacaran times (Liégeois et al., 2006; Abati et al., 2010).
Our geochronological data reveal also the presence of inherited zircons of Neoarchean to Paleoproterozoic ages (2500 - 1900 Ma). These results confirm the existence of an Eburnean cratonic basement beneath the eastern Anti-Atlas, and therefore confirm that the northern border of the WAC must be placed further north, as suggested previously (Ennih and Liégeois, 2001; Gasquet et al., 2008).
The geochemical and isotopic data of the Imiter granitoids (Baidada et al., 2017) are reinterpreted on the basis of these new radiometric ages in the post-collisional Pan-African context of the Anti-Atlas range during the late Neoproterozoic times.

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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 Ma to 560 Ma.
Structural analysis of the South Maradi basement highlights the existence of at least four phases of deformation noted D_1, D_2, D_3 and 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 deformation phase. 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 D1a, 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 mylonitization (Soumaila and Konate, 2005). The D_{1c} episode,

relatively semi-ductile, is marked by sinistral reactivation of large-shear zones.The D_2 pan-African deformation phase 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, N-S to N15° trending.The D_3 and D_4 deformation phases are characterized by S_3 cleavages fracture subvertical orientated N80° to N120°, dextrally 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 show that all the samples have varying gold values (Table 1). The highest values were observed in the shear zones samples or close to them.

Keywords: *Schist, granitoids, Birimian, Pan-African, Tectonics, Niger*

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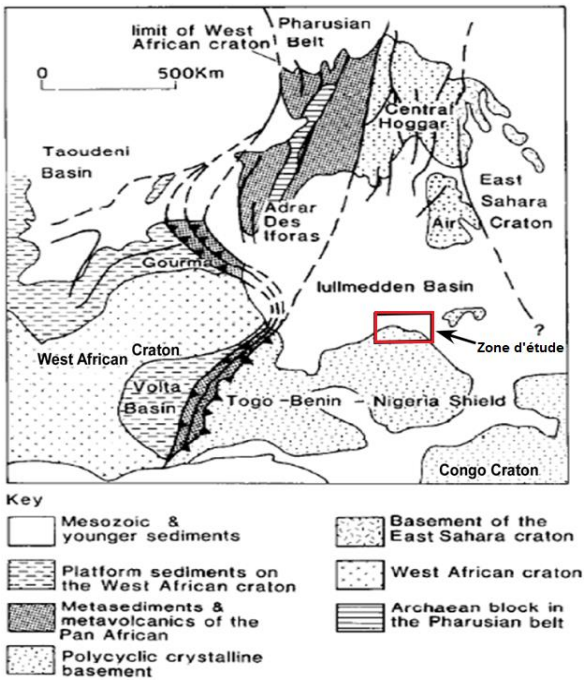

Figure 1.The eastern pan-African domain of West Africa showing the study area (Ajibade and Wright, 1988).

A Complex Paleoproterozoic Evolution of the In Ouzzal Terrane (Hoggar, Algeria) revealed by zircon and monazite Geochronology and P-T path of Al-Fe granulites

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The In Ouzzal Terrane (IOT) is an elongated block N-S trending, more than 400 km in length. Its northern part is 80 km in width and thins until complete disappearance to the south to- wards Malian borders where it is relayed by the Iforas granulitic unit. The majority of the orthogneiss and paragneiss lithologies of the IOT, dated at 3.3-2.5 Ga, present geochemical characteristics of the Archean crust. However, their mineral assemblages and structural characteristics were mostly overprinted during the Eburnean (2 Ga) granulitic stage by an UHT metamorphism exceeding 1000°C (Peucat et al., 1996 ; Ouzegane et al., 2003).

The present study is interested in Al-Fe granulites which outcrop in a little known region of In Ouzzal situated in its southeastern part. These granulites are mainly composed by quartz, corundum, spinel, garnet, sillimanite, cordierite, biotite, perthitic feldspar, ilmenite.

Phase relationship and classical thermobarometry coupled with pseudosections calculated in the NCKFMASHTO system suggest a clockwise P-T path characterized by prograde evolution at high pressures (800-1050°C at 9-11 kbar), followed by an isothermal decompression (7-6 kbar) then an isobaric cooling to 700°C. This P-T path is identical to that determined in other regions of the IOT.

New Laser-ablation U-Th-Pb analyses of zircon and monazite have been realized from four samples of these Al-Fe granulites. The primary results suggest three major events: 1- the existence of at least one metamorphism older than 2.5 Ga, completely obliterated by the Paleoproterozoic metamorphism; 2- a long live Paleoproterozoic high temperature metamorphism between 2 and 1.9 Ga ; 3- a moderate thermal event between 1.8 and 1.75 Ga.

As highlighted by Vielzeuf et al. (1990) and Clark et al. (2011), partial melting buffers the maximum temperatures that the crust can reach. These authors suggest that in order for the crust to experience UHT metamorphism, it has to first become refractory during preceding orogenic events; alternatively Brown and Korhonen (2009) suggest that the heat source driving metamorphism has to be maintained for a long time (>50 Ma). While the metamorphic peak is considered to have occurred at c. 2 Ga, it is possible that the 2.5 Ga event, revealed by this study, has contributed to the preparation of the lower crust in the IOT for UHT metamorphism. These results suggest also the persistence of high temperature geotherms during a long period of time.

The thermal event at 1.8-1.75 Ga is coeval with anorogenic magmatism exposed on both sides of the In Ouzzal granulite block (1837 ± 17/19 and 1755 ± 10 Ma, Caby and Andréopoulos-Renaud, 1985). It is propably related to a world-scale rifting event (1850-1750 Ma), at the scale of western Gondwana (Danderfer et al., 2009 and references therein).

Precambrian evolution of the Tirek Terrane (Hoggar, Algeria): Evidence for the existence of an Archeo-Paleoproterozoic continent in the western part of the Tuareg shield

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New geological mapping of the Tirek Terrane (western Hoggar, Algeria), and petrological, geochemical and geochronological study show the existence of an orthogneissic basement having a composition of TTG, dated at 1965 ± 18 Ma (inherited zircons give Paleoproterozoic and Archean ages, 2006 to 2771 Ma). This basement is topped by a metasedimentary unit composed of sillimanite-bearing quartzites and metapelites. The zircons of these metapelites indicate a range of ages from Archaean to Proterozoic (the youngest age is 2050 Ma). Sills of alkaline orthogneisses that cut across previous lithologies, have been dated at 1810 ± 38 Ma (inherited zircons give an age of 2610 Ma). They indicate a deposit age for metasedimentary series between 2050 and 1810 Ma. Migmatitic granitic-granodioritic batholith, which occupies 50% surface of the study area, has chemical composition with a subduction affinity. It is dated at 663 Ma (inherited zircons dated at 1800 and 1969 Ma).

The high-temperature - low pressure Pan-African metamorphism that affects the studied area indicates a clockwise P-T path with a peak at 750-800°C and 6 kbar followed by decompression, then decreasing temperature (600 °C to 4 kbar). The dating of this metamorphism (U-Pb monazite) gives an age at 578 ± 5 Ma contemporary of the emplacement of the syn-kinematic granites in the same terrane.

The comparison with the western terranes of the Tuareg shield suggests that Tirek, In Ouzzal (IOGU), Iforas granulite unit (IGU) and Kidal terranes constitute a same Archaeo-Paleoproterozoic Continent. Currently, in the central part of this micro-continent, outcrops the Archean lower crust which has been remobilized in the Paleoproterozoic, and on both sides of it, outcrops the Palaeoproterozoic crust remobilized which has been in the Neoproterozoic.

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Discovery of Ichtyofauna at the Cenomanian-Turonian boundary in Ouarsenis (Algeria)

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The discovery of rich Ichthyofauna in the lands of the Upper Cretaceous marine of Ouarsenis is a first in Algeria. In addition to some forms that remain to be determined, these fossil fishes include species belonging to the *Pycnodontidae, Ichthyodectidae, Plethodidae (=Tselfatiidae, Bananogmiidae*) and *Dercetidae* families. This discovery is obviously interesting and will allow to complete the palaeobiogeographic knowledge of the Mediterranean region during this geological period. Until now, the Cretaceous Ichthyofauna of the Eurafrican Mesogea were essentially known in Morocco, Portugal, Italy, Egypt, Lebanon and Palestine. The event of the Cenomanian-Turonian interval in Ouarsenis is interpreted as a maximum transgression surface representing condensation sequence. This event is characterized by a "siliceous level" rich in globular planktonic foraminifera (*Whiteinella, Globigerinelloids, Rotalipora, Hedbergella, Heterohelix*). Associated with these forms are also radiolaria and calcispheres, generally very abundant, and, for the first time, the presence of halecostomes and teleosts fishes (*cf.* figure *infra*) (e.g. Brahim, 2014). This entity (siliceous bar) is part of the "Ouled Sidi Djillali Formation" which constitutes the Nappe B in the eastern Ouarsenis of C-T age (e.g. Mattauer, 1958). This lithostratigraphic unit is presented in an alternation calcareous/marl section by a limestone bar loaded with siliceous beds constituting an excellent projection in the topography. This reference level is composed by a trilogy of facies : (i) clear chocolate argilite with fish ; (ii) black shales with organic matter (OM) containing siliceous grains, phosphate and pyrite ; (iii) siliceous limestone with radiolaria associated with globular planktonic forms (*Heterohelicidae, Whiteinelles* and *Hedbergelles*), and with keels of the *Rotalipora* type. The very abundant *Heterohelix* form marks the event or boom (e.g. Caron *et al*., 2006) and named Heterohelix shift (e.g. Leckie, 1985), which succeeds filament level (small test bivalve) that would have reached adult size in deep pelagic environment under non-anoxic conditions. Their valves fall by decantation on the bottom and are arranged in a bed evoking the "filament event". The presence of foraminifera type *Helvetoglobotruncana helvetica* would have confirmed the end of the black shales level.
Such rich deposits at the same time, OM and siliceous organisms indicate the Cenomanian-Turonian Boundary Event (OAE2) reported in the C-T series in several localities forming a continuous belt along the northern African platform during the Cretaceous period, encompassing Tunisia, Algerian Atlas and Moroccan Pre-Rif.

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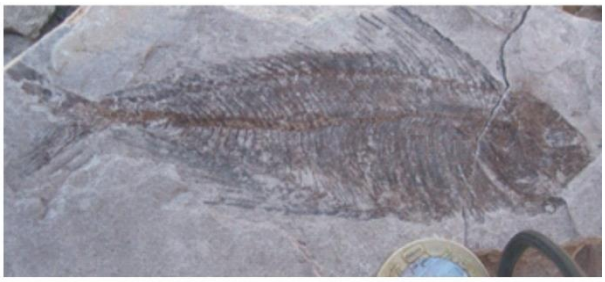

Risk attenuation and Seismic activity at Nyiragongo and Nyamulagira volcanoes in the western branch of the East African Rift for DR Congo

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About 50 to 60 volcanoes erupt every year worldwide. Large eruptions endanger lives, human settlements and livelihoods of the almost 500 millions people estimated to live near active volcanoes in 2000. That number will increase in the future as today more than 60 large cities are located near potentially active volcanoes, threatened by volcanic eruption. Volcanoes with high activity are located predominantly in developing countries, particularly in Latin America, the Caribbean, parts of Asia and in the southwest Pacific. In these countries, despite the improvements in many national civil defense agencies, capacities to manage volcanic emergencies, eruptions are becoming increasingly risky because of rising population density and intense interweaving of infrastructure in the areas surrounding volcanoes. An activity of glow visibility has been noted at Nyamulagira volcano from June 22nd 2014. After few days, the NASA noted this situation by satellite detection and published on its website the appearance of a new lava lake in the Nyamulagira crater. We may note that Nyamulagira volcano (in its known history) logged again in his crater a lava lake from 1921 to 1938 (Mavonga et al., 2010). Here are analyzed the seismic parameters before and after this new event at mount Nyamulagira, and we found that this event was preceded by volcanic tremors (about 12 hours). For these reasons, a revised assessment of seismic and volcanic hazard is urgently needed. In this subject, we describe effort to gather data and derived models of geological processes that can be used to monitoring volcanoes and assess the earthquake hazard, plan the settlement of displaced people and to build back better.

Geotechnical characterization of Mugara site material, its contribution to the building of Goma town

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Mugara is located at 1°38'S, 29°E in the northern of Goma town (north Kivu, DR Congo). Belonging to Nyiragongo volcano area, Mugara is a volcanic cone lithologically constituted by volcanic slag with varied colors (yellow, red, black) from top to bottom, that are dip-oriented to the south and following disposal. This lithology is essentially concentrated of silica seen mineralogically, that confirms its projection nature. Besides, a relative portion is constituted of a thick layer, like a resemblance of metamorphic zone according to the recent basaltic lava flow at the top of Mugara hill.

This paper consists mainly to the geotechnical survey of Mugara, showing geotechnical properties of the building materials. Field works were completed by laboratory analysis.

The Porchet method have given a low permeability degree (0.004 cm/s to 2.3 cm/s); however, with the identification test (water content, grain size and Atterberg limit) and compaction test (Proctor, CBR). Mugara corresponds to sandy domain, middle to thin sized (a CBR between 7-12%).

The consistence index of Mugara material is between 13-18%. According to HRB, the group index varies from good to excellent.

Geotechnical survey concluded that Mugara materials are usable for any constructions but need each time to be firstly stabilized before any great use.

During 15 years ago, Mugara site is contributing to the building of Goma town, especially in house construction, cement industry and road implantation (after stabilization). In 2015, about 35% of Mugara materials reserve had been used. In spite of it, the need still increased.

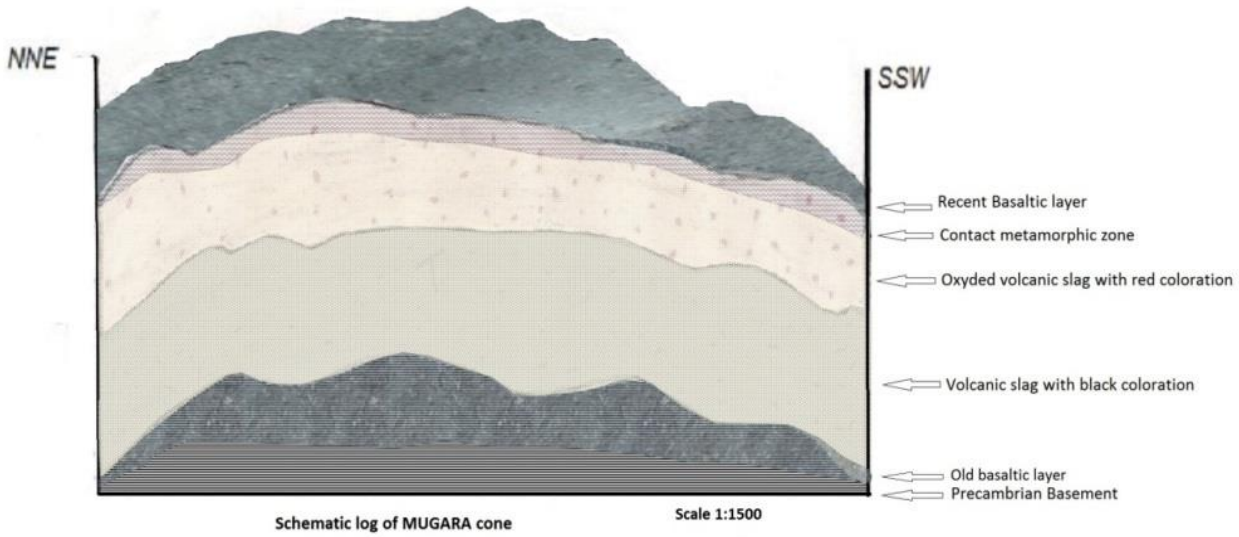

Fig.1. Schematic log of Mugara cone (Bora Uzima et al., 2015)

Inventory and Assessment of Geomorphosites for Geotourism Development: a Case Study of Aït Bou Oulli Valley (central High-Atlas, Morocco)

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Aït Bou Oulli valley is located in the heart of the Moroccan central High-Atlas, of which the height is 4068 m in Ighil M'goun and 3800 m in Rat Mountain. Mountain areas are characterized by higher geodiversity respect to other areas. The valley possesses a geoheritage, which is very rich, very diversified, an exceptional landscape of high mountains, and attractive to number of tourists every year. However, this number of visitors is still restricted due to lack of tools for promotion, valorization and mediation of this heritage. It is with that aim to promote this rich heritage that the present work was performed. The work focuses on the inventory, selection, and quantitative evaluation of the remarkable geomorphosites in order to classify them. The results reveal the presence of 81 potential sites, of which 24 are conducive to geotourism use. These conducive sites include 9 fluvial landforms among which 5 are enviable panoramic viewpoints and 4 are karstic forms, 4 structural landforms, 3 glacial landforms, 2 gravitative landforms, one anthropic landform and one lake landforms. Rich information provided by this study and knowledge of these new geomorphosites are important for promotion of tourism activities at the Aït Bou Oulli region and can assist planners and authorities to formulate suitable plan for sustained development of the region.
Keywords: *Aït Bou Oulli valley, assessment, central High-Atlas, Geomorphosites, Geotourism, Inventory.*

The Eocene (Bartonian-Priabonian) Vertebrate Record from Tarfaya–Laâyoune–Dakhla Basin, Morocco

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Several palaeontological field campaigns in the Tarfaya–Laâyoune–Ad-Dakhla Basin, in the northwestern edge of the West African Craton, have resulted in the discovery of rich

vertebrate assemblages formed by isolated bones and articulated material. These faunae are mainly dominated by marine taxa, including selachians, bony fishes, turtles, crocodiles, marine snakes, seabirds, whales and sirenians. In particular, archeocete whales are especially well represented by hundreds of vertebrae referred to at least eight species of Protocetidae and Basilosauridae. Terrestrial forms are rarer and are represented by testudinid turtles and proboscideans. All this material comes from two areas in the Moroccan Sahara desert: the Aridal Formation at Gueran, ca. 150 km southeast of the city of Boujdour, and Ad Dakhla.

At Gueran, all fossils come from a single meter-thick sandstone unit. The presence of both protocetid and basilosaurid whales indicate a probable Bartonian age for the locality, because basilosaurids are unknown during the Lutetian, and a single protocetid is known from early Priabonian. By the co-occurrence of these two families, also noticed in Wadi al-Hitan in Fayum (Egypt) and in Indo-Pakistani localities, Gueran is one of the most important sites in the world documenting early crucial stages of Cetacean evolution, especially for understanding the evolutionary transition from foot-powered to tail-powered swimming. The fauna from Gueran also includes abundant selachian teeth, a few remains of bony fishes, rare fragments of turtle shells, fragments of jaws, vertebrae and osteoderms of crocodiles, marine snake vertebrae, seabird remains and fragments of proboscidian teeth.

At Ad-Dakhla, fossils are known from stratigraphic sections along 30 km of Atlantic Ocean coastline, south and southwest of Ad Dakhla, in southern Morocco. The outcrops are located in three areas, which are from North to South, El Argoub, Porto Rico, and Garitas. At Garitas, vertebrate remains come from three levels called A1, B1 and B2. The lower interval A1 of Unit 1 of Adnet et al. (2010), that includes some 22 m of rhythmically-bedded, chert-rich marine siltstones and marls, has provided selachian teeth, palaeophiid snake vertebrae, sternebra of a small protocetid and several cheek teeth of the large protocetid *Pappocetuslugardi*. Protocetids are usually Bartonian in age and their occurrence in coastal strata deserves to be highlighted since they are better known from the inland locality of Gueran.

Unit 1 strata are overlayed by 1–1.5 m of vertebrate-bearing conglomeratic sandstone (B1), another 4–8 m of rhythmically-bedded siltstone and marl, and a second 3–6 m unit of vertebrate-bearing muddy sandstone (B2) which constitutes Unit 2. Bonebed B1 has yielded abundant and diversified selachians (Adnet et al. 2010) and archaeocete whales (Zouhri et al. 2014), as well as remains of sirenians, proboscideans, actinopterygians, turtles, palaeophiid snakes, crocodiles and pelagornithid seabirds (Zouhri et al. in press). The cetaceans from bed B1 represent at least five species, from smallest to largest: cf. *Saghacetus* sp., cf. *Stromerius* sp., *Dorudon atrox*, cf. *Dorudon* sp., and *Basilosaurus isis*. The only identifiable cetacean found in the upper sandstone (bed B2) is *Basilosaurus* sp. Dugongid sirenians identified as cf. *Eosiren* sp. are the most common mammals in bed B2. A late Eocene Priabonian age was assigned to the Unit 2 and to both B1 and B2 bonebeds, based on the selachian fauna (Adnet et al. 2010). This age is confirmed by the cetaceans from Bonebed 1, similar to those identified in the Priabonian Formation of Qasr el Sagha in Egypt (Zouhri et al. 2014).

At Porto Rico, intervals B1 or B2 include a well-preserved dentary of a new protosirenid sirenian similar in molar size to *Protosiren smithae*, but with a distinctive symphyseal conformation. A rich earliest Oligocene fauna of continental mammals (anomaluroid and hystricognathous rodent, etc.) is known from interval '2'at Porto Rico and El Argoub (Marivaux et al. 2017, in press).

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Contribution of field portable XRF to the characterization of Columbo-Tantalite placer deposits of Issia, Ivory Coast

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The area of Issia is characterized by the presence of columbo-tantalite (CT) placer deposits redistributed. The placers are observed around granitic formations affected by pegmatite dykes that are more or less weathered. The study is aimed at testing the potential of portable XRF for the determination of the source and Nb-Ta-rich placers and, more generally, for the elaboration of a model of formation for this type of mineral deposits. The first objective was to determine if the pegmatites and granites were fertile. For this purpose, we have use a field portable X-ray fluorescence (FPXRF) for chemical mapping of granites and pegmatites. We found that none of the rocks analyzed were fertile, whereas accessory minerals such as tourmaline and garnet are relatively enriched in Fe with respect to Mn, reflecting a low degree of fractioning of the pegmatites. A second objective was the preliminary characterization of Nb-Ta minerals in the placer deposits, which were placed in the columbo-tantalite diagram. These measurements were validated with EPMA analyses and moderate differences were attributed to Fe-Ti inclusions in CT which affect the XRF measurements. Differences in composition are noted between different localities, whereas compositions are homogeneous for different grains on the same localities. Another objective was to test the capability of FPRXF to determine bulk rock compositons of the granites from multiple analyses. For this purpose, small blocks of granite (sugar shape) were cut and grids of 3*3mm cells were traced. FPXRF measurements were taken for each cell. Chemical maps were derived and reprojected on a picture of rock section using specific software developed in Python language. FPXRF analyses were then compared with bulk-rock ICP-MS analyses on the same samples and show very good agreements for Ti, P, Ca, Fe, K, whereas results are less encouraging for Al, Rb and or Ba. At last, FPXRF analyses were achieved on micas; these mineral are excellent tracers of Nb-Ta mineralization. Concentrations up to 700 ppm of Ta

were reported but not confirmed by in-situ LA-ICP-MS measurements, and a better calibration of Ta appears to be required for future studies.

Keywords: *columbo-tantalite, pegmatite, x-ray fluorescence, muscovite, phengite, biotite-Fe, zinnwaldite, lithium, cesium.*

Evidence of syntectonic microleucogranites in polymetallic district of Tighza (Central Morocco): Geodynamic implication

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The lentiform microleucogranites highlighted in the polymetallic district of Tighza, situated on the path of major accidents, call into question the scenarios of the evolution of the magmatic activity in this area. The petrographic and structural petrology of these rocks are evidence of an establishment in transpressional regime controlled by a sinistral ductile shearing with sub-equatorial orientation. This result implies that such sinistral kinematic announced by mineralization of Pb-Zn-Ag (late Permian to early Triassic) could have occurred at an earlier period, from lower Permian. Plastic deformation recorded by minerals including quartz, feldspars and muscovite indicates the permanence of the deformation after emplacement of the magmatic body. Geochemical filiation of granitoids of Tighza is calc-alkaline monzonitic type. But the microgranites show an alumino-potassic character typical of a supracrustal source. The geotectonic context of emplacement of this magmatism is convergent in type with a declination to a syn-collisional type materialized by microgranites.

Keywords: *microleucogranite, magmatism, late Hercynian, Tighza polymetallic district, Morocco*

Study of the Haut-Sassandra granitoids (Midwest of Ivory Coast): towards a geodynamical evolution model

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The oldest parts of the African continent, the so-called West African Craton (WAC), are the focus of worldwide research not only because they represent primary constraints for our understanding of the early evolution of the Earth, but also because of their significant potential. This work contributes to the understanding of the geological and geodynamical evolution of the WAC, by an integrated analysis of airborne geophysical and petrology data constrained by field structural, lithological, geophysical, and geomorphological observations acquired around the region named Haut-Sassandra in the west of Ivory Coast. Magnetic Airborne data, aided in the mapping because the region is densely covered, allowed to define the geometry of the different massifs. Three rock types can be distinguished: migmatite, granodiorite and megacrystic or porphyritic two micas leucogranite. The petrological results of this study suggest that the granitoid domains are formed by peraluminous and metaluminous rocks. The general geochemistry of the granitoids evolves from Na-rich calc-alkaline to K-rich alkaline . The penetrative structures (mineral lineation, and left shear) were overprinted by extensive SSW to NNE (N20° to N40°) shear zones which is well visible in the magnetic data. These granites have caused contact metamorphism, and are also at the origin of important pegmatitic, pneumatolytic and hydrothermal processes, that are at the origin of rich metallogenic nature of this region. The northern part of this region is migmatized.

The granitic panels are cross-cut by a NE-SW to ENE-WSW oriented fracture system, which favors numerous vein-like fractures, including aplites, pegmatites, tourmalinites, greisens and quartz.

The basement of this region represent the Birimian part of the WAC and appears then structured by several geological events. The nature of the protoliths might be tracked using geochemical data. The potential source of the former Birimian sediments will be discussed.

In addition, U-Pb dating and low-temperature thermochronology data on apatite minerals will be carried out to constrain the formation age of the different massifs and to trace the thermal history of rocks and evaluate the rate of denudation of the massifs. This will allow to quantify the rate of uplift or vertical tectonics (isostasy or simple denudation) and the rate of erosion that has contributed to create the present-day flat topography. This part will make it possible to model the paleorelief and to help understand the current geomorphology of the WAC.

Keywords: *West African Craton, Ivory Coast, geophysic airborne, granite, low-temperature thermochronology.*

New geological structures in the Brobo region (Central Ivory Coast). Helping to understand the Paleoproterozoic tectonics of the West African Craton

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A lithostratigraphy study for gold mineralization in the Birimian Formations of the Brobo region (central Ivory Coast) was the works of Equigold mining, LGL Resources and Newcrest Mining. Despite the results obtained from the investigations, very few structural data were obtained or provided. Pre-existing maps mention faults (such as the N-S Brobo-N'Zi shear zone), but these do not allow regional interpretations of tectonic evolution. Our work aims to bring new structural data for this region.

The lithological and structural observations of the Brobo region indicate a succession of metasedimentary rocks (sandstone with mica cordierite and graphite) intercalated by volcanic rocks (rhyolite, dacite, andesite, basalt and volcaniclastic), reflecting volcanic activities. The whole is intruded by granitic rocks sometimes porphyroids, granodiorites, gabbros and gneissic granites.

The interpretations of the Landsat ETM$^+$ and RadarSat-1 remote sensing, as well as the field data, permit to identify several directions of lineaments. These directions are: N-S, NE-SW, NW-SE and E-W. Among these fractures, new ones are identified. These are: the fault of east Tiébissou (Fa) with NE-SW direction. This fault intersects the N-S Brobo-N'Zi shear zone; E-W faults were also identified (Fd, Ff, Fg and Fh).

The region has been subject to several phases of deformation marked by folds in older sediments, the result of a regional compression phase. Sedimentary flaps are thus found in the granitoids of the western part. The Brobo-N'Zi shear zone, with N-S direction, resulted in the mylonitization and foliation of the granitoids. The results show C/S shear zone structures (N010° to N030°) with sinistral movements, as well as stretches, mineral lineations and quartz veins, mainly in granitoids. The resulting general metamorphism is in the greenschist facies.

***Keywords**: Lithostructural mapping, Landsat ETM$^+$, RadarSat-1, Remote Sensing, Birimian formations, Brobo area, Central Ivory Coast, West Africa*

Geo-environmentalmodelingof a Birimian gold deposit (West African Paleoproterozoic Belt):Case study of Sissingué gold project Perseus Mining in Ivory Coast

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Since the advent of new mining codes and the general awareness on social responsibility, the players in the mineral extractive industry are seeking new prediction tools, identification and assessment of associated impacts to their activities.The rulers, financial and NGOs are becoming more serious with governance and environmental and social responsibility.Thus, this research project aims to contribute to the prediction, prevention, and mastery of the environmental risks of waste rock piles during exploitation of metalliferous deposits in general, and in particular those related to the Sissingue gold project in the West African Paleoproterozoic belt called locally the Birimian.Specifically, it will develop a reliable tool for predicting the Acid Mine Drainage (AMD) and its environmental consequences from the knowledge of the geological parameters.

In fact, the Sissingue deposit is located in the north of Côte d'Ivoire in the Paleoproterozoic (Birimian) Syama-Boundialy Belt where several gold deposits are known and the most important is that of Syama, Mali.The primary gold mineralization known in this geological context in West Africa is very often associated with sulphides whose exposure to free air in the presence of water and oxygen can generate AMD and releasing fairly toxic heavy metals into the receiving environment.
Through our research work we propose to build a geological model of the deposit from which we can deduce an environmental modelreflecting the ability of geological materials to generate the AMD or not.

The result work will allow to understand the geological and mineralogical control of the deposit, and then the geological model and environmental mode built will allow better prediction and management of major environmental problems related to geological mineralized material exposed to air, and adopt appropriate corrective and preventive measures.This tool can be used for environmental studies for new mines and the rehabilitation of old abandoned mines on one hand, and onother hand for various applications including geochemistry, environmental regulation andothers.This research project will also be a practical example of how scientific research beyond the academic promotion can lead to technological innovation and contribute to the sustainable development of our nations.

***Keywords**: Gold mine,geo-environmental model, Birimian, Sissingue, Ivory Coast, West Africa*

Assessing the contamination level of soils with heavy metals and rare earth elements around a Pb/Zn abandoned mining site in the northeastern region of Morocco

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The lead-mining districts of the Upper Moulouya (Aouli-Mibladen, Zeïda) in eastern Morocco, were the largest Pb-Zn mining districts in Morocco during the last century. The operation at the mine Zeïda (1972-1985) generated locally about 12 million tonnes of treatment tailings. Measurement of metals total concentration in soils is a valid approach to study the degree and extent of contamination in the soil system (Li and Thornton, 2001),however, the use of different pollution indices and multivariate statistical techniques is required for assessing the potential harm of the measured concentrations on the environment (Varol, 2011, Kalender, 2013). The contamination assessment was performed based on the levels of Pb, Zn, Ba, Co, Cr, Nb, Ni, Sr, V,Zr,Sc,Y,La,Ce,Nd, Sm, Eu, Gd, Er, Yb, Th, Ga, Rb, Hf. The evaluation of the potential accumulation of chemical elements in soil layers was determined using the geo-accumulation index (I_{geo}), contamination factors (Cf), pollution load index (PLI) and the Potential ecological risk index (E^i_r), the statistical analyses were carried out using XLSTAT - 2014.5.03, and IBM SPSS statistics 22. Geochemical and contamination distribution maps were obtained using the software ArcGIS 10.3.

New U/Pb ages of the calc-alkaline felsic volcanism of El Jadida (Moroccan Coastal Block)

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Field observations and U/Pb zircon ages of volcanic outcrops in the coastal border of El Jadida city, (western Moroccan Meseta) provide firm evidence of Neoproterozoic volcanism in the basement of the Moroccan Variscan domain. Petrographic study carried out on this volcanic substratum allows concluding that these rocks are rhyolitic, rhyodacitic and rhyolitic ignimbrites, overlain by a thick Upper Neoproterozic/lower Cambrian chaotic and dolomitic series. The geochemical study permits concluding that the felsic volcanic facies of El Jadida have a calc-alkaline magmatic affinity. Concordant U-Pb zircon data yield Ediacaran mean ages for rhyolitic ignimbrites facies (between 577.2±3.1 Ma and 580.8±1.4 Ma) and rhyolitic, rhyodacitic facies (between 605±11Ma and 577.7±3.8 Ma). The geochemistry of these felsic volcanic rocks allows to suggest that these rocks were formed in a subduction to within plate geodynamic context.

Keywords: *Subduction, Felsic volcanic rocks, El Jadida, Western Meseta, Morocco*

First evidence of marine Oligocene in the Tarfaya-Lâayoune-Dakhla Basin (Morocco)

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The Gueran Member of the Samlat Formation in southeast of Ad-Dakhla at the south periphery of the Tarfaya-Lâayoune-Ad-Dakhla Basin (TLDB) and the northwestern border of the North-West African Craton is a complex of rhythmic alternation of gray chert and marly silt where many fossil vertebrates bearing are intercalated. This member has been the subject of various dating proposals from the Bartonian to the earliest Oligocene (Adnet et al, 2010; Zouhri et al 2014; Marivaux et al, 2017; Gingerich and Zouhri, 2017).
This sequence also yielded planktonic foraminifera, which allowed proposing datings at different levels of the sequence (Elboudali et al., 2017, Elboudali et al, in press). At the locality of Alaouate, the complex limited at its base by the upper part of the fossiliferous level B2 attributed to the Priabonian by Adnet et al (2010) and Zouhri et al (2014) and at its summit by the Rhizolithes level (the summit part of the studied series). This level is about two meters thick and located at the base of the lithostratigraphic unit 3 of Adnet al (2010). It consists essentially of marly sand alternating with gypsum banks evolving laterally to fine laminar levels. This level reveals interesting in that it yielded an assemblage of planktonic foraminifera composed of *Pseudohastigerinamicra*, *P. naguewichiensis*, *Tenuitella gemma*, *Cassigerinellachipolensis*, *Catapsydraxunicavus*, *Globigerinaofficinalispraebulloides* and *G. praebulloides leroyi*. The presence of *Cassigerinella chipolensis* would correspond to the beginning of P18 zone in South Australia according to Li et al. (2003). Whereas *Tenuitellagemma* is referred to the end of E16 which corresponds to P17 (Pearson et al., 2006). Pearson & Wade (2015) cited *Globigerina praebulloides leroyi* in the Lower Oligocene of the Lindi area section of Tanzania. The assemblage 3 of the Planktonic Foraminifera of the Gueran Member has similarities with the lower Oligocene assemblages of Norona (Cuba) for which Molina et al. (2016) suggest that the small test forms such as *Pseudohastigerina naguewichiensis*, *Tenuitellagemma*, *Turborotaliaampliapertura*, *Catapsydraxdissimilis*, *Globigerina tapuriensis* and *Cassigerinella chipolensis* are cosmopolitan.
The presence of similar planktonic foraminifera assemblage of the O1 zone corresponding to the Rupelian (Lower Oligocene) is the first undisputed characterization of the marine Oligocene in the Tarfaya-Laâyoun-Dakhla basin.

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Geology and metallogenesis of the sediment-hosted Cu-Ag deposit of Tizert (Igherm inlier, Anti-Atlas Copper Belt, Morocco)

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The Tizert copper deposit is the largest copper deposit in the western Anti-Atlas. It is located at the northern border of the Igherm inlier. The Tizert Cu-Ag deposit is the largest of a series of sediment-hosted copper deposits of the Anti-Atlas copper province in Morocco.

Mineralized rocks in the deposit contain disseminated sulphides within a Late Ediacaran, dominantly siliciclastic sedimentary formation named the Basal Series. Isopach map of the Basal Series shows that during the Late Ediacaran the area was composed of large subsiding zones separated by paleohighs. The ore grade zones are well developed along basin margins adjacent to the basement paleohighs. These mineralized zones display a lateral sulphide zoning with central bornite-chalcocite zones grading outward to intermediate chalcopyrite and external pyrite zones. There is also a vertical sulphide zoning with evolution from bornite and chalcocite dominant mineralized rocks at the bottom to chalcopyrite and pyrite dominant mineralized rocks at the top of the lithostratigraphic succession. A late diagenetic age for this mineralization is indicated by the geometry of the mineralized zones that trangress bedding at a low angle, the sequential replacement of sulphides by other sulphide minerals, and the possible involvement of mobile hydrocarbons as reductants.
A second style of mineralization is represented by sulphide filled fractures and veins present in the Basal Series, as well as in the basement and the overlying dolomites. The location of better-mineralized zones of this style of mineralization near fractures and faults indicates it was epigenetic; it may have occurred during Late Hercynian shortening.
The similarity of the paragenetic sequences between the disseminated and the vein-hosted mineralization suggest that they may be related to the same mineralizing event, the disseminated style of mineralization being rapidly followed by the onset of the vein-style mineralization.

Relationships between North Téra Birimian gondites and manganese mineralization (Liptako, West Niger)

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North Téra manganese mineralization is located in the Diagorou-Darbani Greenstone Belts, closely to the Téra-Ayorou pluton (Fig. 1). Rocks bearing Mn mineralization are mainly gondites, a type of grenatites containing spessartine garnet. The methodological approach implemented consisted of field study (Fig. 2) followed by a polarizing microscope analysis (Fig. 3).
North Téra gondites result of Birimian manganese-rich sediments metamorphism in amphibolite facies (Soumaila, 2000; Soumaila and Garba, 2006).
The macroscopic analysis of the concretions, combined with the microscopic observations, shows that manganese mineralization is the result of gondites alteration. The processes of supergene alteration of the latter (oxidation, hydrolysis and leaching of chemical elements), under conditions of PH = 7 to 9 and Eh = + 0.4 to + 0.6 V, lead to a residual deposit of Mn (up to 39.4% of Mn metal; Machens, 1961). This preliminary work shows that north Téra Mn deposits consist of manganese oxide concretions of pyrolusite type (Figs. 2C,D).

***Keywords**: Gondite, manganese, north Téra, supergene alteration, amphibolite facies.*

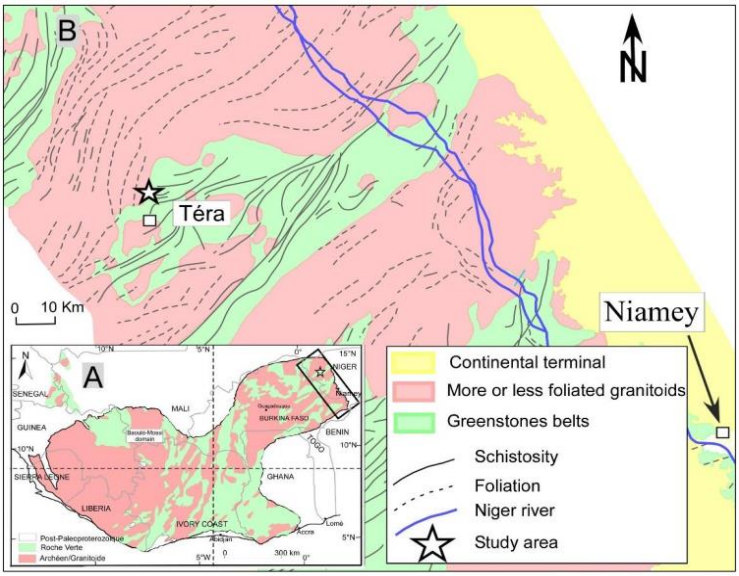

Figure 1: (**A**) - Liptako region of Niger in West African Craton context. (**B**) - Simplified geological map with the study area localization (Machens, 1967, modified).

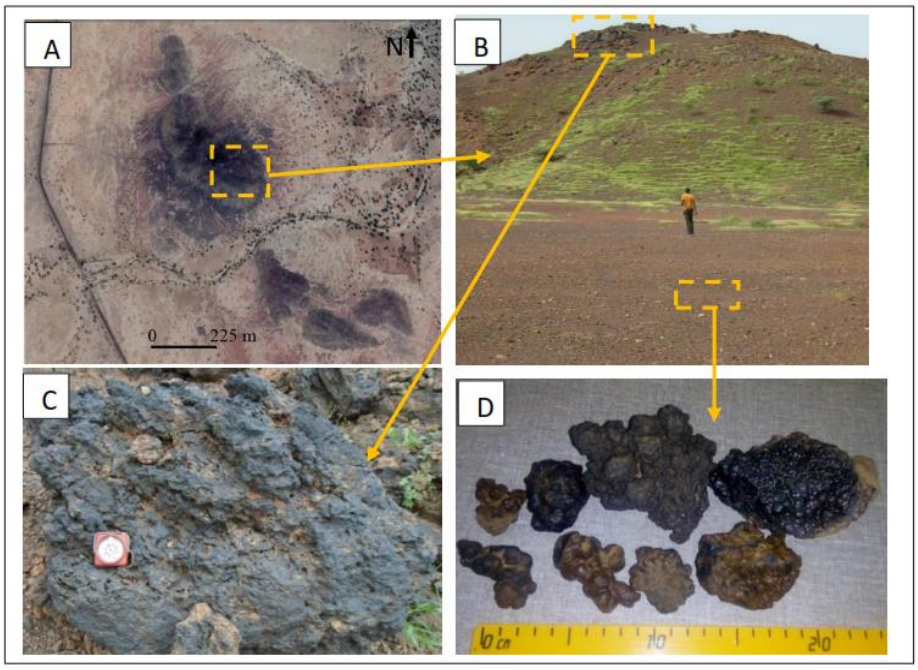

Figure 2: Northern Téra manganese deposits: **A**) Google Earth image of the study area; **B**) Main hill of Mn; **C**) and **D**) Manganese concretions.

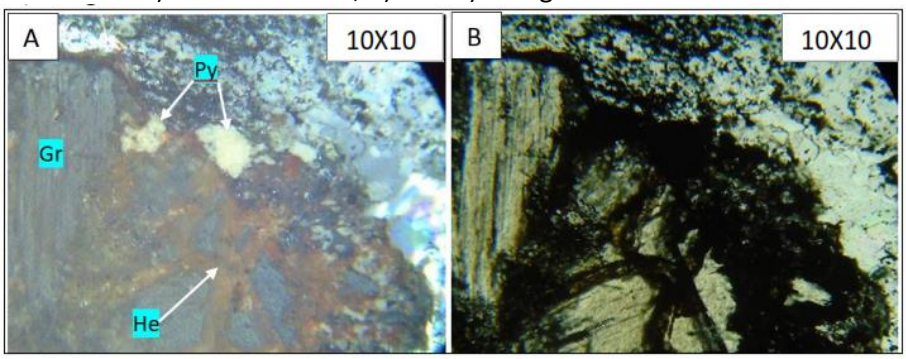

Figure 3: Metallogenic analyses of garnets (Gr) in altered gondites. **A)** Image in reflected light and **B)** in transmitted light microscopy. Manganese oxide with pyrolusite (Py) and iron hematite oxide (He).

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Essay of reconstitution of the surfacial geology of Ouargla Basin - southAlgeria

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This work is the result of combination of field work, remote sensing data, the visual description and analytical data of samples of surface formations executed on the study area.
In this area the sedimentary layer of a thickness of 5000 m is represented by the Palaeozoic, Mesozoic and Cenozoic deposits. The Paleozoic deposits from the sandy Cambrian to the lower Devonian clay-sandstone where sandy levels are inserted through an radioactive clayey Silurian and an clayey-sandstone Ordovician. The Mesozoicis represented by the continental Triassic delimited at the base by the Hercynian unconformity and at the roof by the saline S4 level. The Cretaceous characterized by the emplacement of detrital deposits at the base and carbonates at the top. The Cenozoic is incomplete, unconformable and represented by continental deposits of Mio-Pliocene.
Digital processing has allowed a non-supervised classification then a supervised classification of the satellite image and brings out at the end of treatment a thematic representation of superficial geological formations according to their spectral signatures. The final map is checked and validated on the basis of field data (sites visits and cored survey data) and analytical data (physico-chemical analysis), to achieve at the end to a map of the surface geology of the study area.
Therefore the comparison of remote sensing data and field data has accomplished to the identification of the following surface geological formations: • eolian sands medium to coarse; • silty sands fine to medium (alluvial sand); • limestone of plateau and reg; • alluvial terraces; • reddish sandstone; • white gypsum sands; • gypsum crusting; • saline wet soils; • non-soil surface (water surface and vegetation).

***Keywords**: Ouargla remote sensing, soil, geology, geochemistry, surface formations.*

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The Precambrian of the Reguibat Shield (West African Craton, Southermost Morocco): Petrology, Geochemistry and Geochronology

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Since the studies of Spanish geologists on southernmost Morocco (1940-1970) yielding to the discovery of Bou Craa phosphates in 1945, to the first geological map 1/200000 of Sahara and two monographs by Alia-Medina (1952, 1954, 1958) and a revision paper of his student Arribas (1968), this region remained unstudied because of military conflicts until recently. The national program of cartography started by the Moroccan Ministry of Geology by early 2000 and the exploration works conducted by ONHYM geologists encouraged several geologist teams from European and Moroccan universities to invest this region and to conduct a series of modern studies on its formation. Up to now, interesting results on this part of the West African Craton (Reguibat Shield) and adjacent Ouled Dlim Massif, commonly assumed as Mauritanides extention in Morocco, are being published and the knowledge of the geological history of this part of the West African craton is being considerably improved.
The Precambrian rocks of the Moroccan sector of Reguibat are mainly TTGs dated at 3.0 Ga (Montero et al. 2014); these were intruded at 2.46 Ga by an ultrapotassic peculiar magmatism (Awserd syenites group, Bea et al, 2013, 2014; Haissen et al., 2017), and at 1.85 Ga by a carbonatitic magmatism (Montero et al. 2016) and finally at early Cambrian 525 Ma by peralkaline hypersolvus granites (Bea et al., 2016). The distribution of the Precambrian cratonic rocks, generally assumed to be limited only to the east of Ouled Dlim massif, is now extend to the west under this massif and some recent formations of the Atlantic passive margin as attested by new geochronological studies (Bea et al., submitted; Montero et al, submitted). More information on this Precambrian cratonic rocks and subsequent intrusion events is expected from the future study of the easternmost outcrops near the Algerian border.

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Mineralization distribution in the Late Ediacaran-Cambrian transition northeast of Saghro Massif (Eastern Anti Atlas, Morocco): Tectono-stratigraphic controls

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The distributions of the mineralization in the Ediacaran-Cambrian transition in the moroccan Anti-Atlas is still debated. The aim of this study is to characterize the main structural and stratigraphical causes of unequal repartition of the mineralization in the Ediacaran-Cambrian transition of the northeastern Saghro massif, part of the northern border of the West African Craton. It is widely controlled by the reworking of Late Ediacaran basement faults (Soulaimani et al., 2014), based on the geological mapping; remote sensing techniques, structural observation, geological database from previous works and statistical analysis of fault-mineralization report. The main results of this study show that: (i) the Ediacaran-Cambrian transition presents different morphology types of mineralization in the Precambrian basement and its Paleozoic cover; (ii) the fracture network that affects the Ediacaran-Cambrian transition shows NE to E-trending faults with compressional deformation and polyphased kinematics, where most of the NE-trending fractures are mineralized in barite; (iii) in the Paleozoic cover, the mineralizations are hosted by ante "*Paradoxidès* Schists" formation (Middle Cambrian); (iv) the statistical analysis of the fracturation-mineralization report indicates that mineralization is distributed along the Variscan fault.
According to recent works based on fission track (Gouiza et al., 2016; Malusa et al., 2007), forming conditions and age of the mineralization (Borisenko et al., 2013) and our structural observation and interpretation, the distribution of the mineralization in the Precambrian basement and its Paleozoic cover are controlled (1) stratigraphically by alternating hard and soft formations in the Paleozoic cover, (2) tectonically by reactivation of the network of major basement fault materialized in the transition between the Ouarzazate group (late Ediacaran) and the Paleozoic cover (Middle Cambrian) probably associated with the upflow of post Ediacaran fluid-driven.

Keywords: *Ediacaran, Cambrian, Mineralization, Saghro*

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Petrology, geochemistry, and emplacement model of Tiébélé granite pluton, Burkina Faso (West-Africa): what capacity to build up metal?

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Work undertaken on Paleoproterozoic granite based on combined field and chemistry data allows defining two facies without any genetic relation, and among which the most important is the Tiébélé granite pluton (TGP). Initially described as granite, new data based on CIPW normative Ab-An-Or diagram and K-Ca-Na are in agreement with a "granodiorite" composition. The latter is part of the most abundant rocks of continental crust. The TGP with ΣREE 89-165 ppm is relatively enriched in LREE (La to Eu), 10-100 times the chondrite compared to HREE (Gd to Lu), 3-20 times the chondrite with a weak Eu anomaly (Eu/Eu*~1), more or less parallel to the pattern of the average of the upper crustwhich show moderate negative anomaly in Eu (Eu/Eu*~ 0.81). The TGP is I-type granite, from partial melting of basalt and andesite in oxidizing magma. The igneous nature is also supported with high values in Ba and Sr. Geotectonically, the pluton shows a diapiric emplacement, in volcanic arc setting as most rocks in Burkina Faso. This category of granite related oxidized magma is important sources for metallic mineral resources as their redox state primarily controls the types of metals concentrated in given ore deposit. Finally, the granite is more appropriate to build up metal such as Mo, Cu, Zn, Pb. So, this new information is essential as it helps to better understanding the potential of the area in such a mineralization.

Keywords*: Burkina Faso, Paleoproterozoic, granodiorite, partial melting, oxidized magma, metal.*

Geology, Geotectonic and Georesources in relation to sustainable development in Sudan

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This paper is an attempt to reveal the present status of geological criteria in Sudan so as to encourage mining industry. Sudan has been known for its diversity and prolonged history of geological processes and events. This and the vast area of the country make it one of the relatively richest African countries in geo-resources. Irrespective of this, most of the country is considered still virgin, as far as prospecting, exploration and extraction of geo-resources are concerned. Gold mining has been active in the "Nubian desert" since Pharaonic times. The general outline of the geology of the Sudan, displayed geochronologically, consists of: metamorphic and igneous rocks of Precambrian era referred to as basement complex. These are unconformably covered by Phanerozoic sedimentary and volcanic sequences. All of these units had been subjected to more than one phase of deformation. The geo-resources of Sudan consist of:

- Solid metallic and non metallic minerals and industrial and building materials; most of these are confined to the uplifted blocks of Precambrian basement complex.
- Hydrogeological aquifers and hydrocarbon energy are confined to subsidizing Phanerozoic basins and depressions of sedimentary sequences separating the uplifted blocks of Precambrian basement complex.

This paper also displays gold mining activity, with special stress on indigenous (artisanal) mining, prevailing now in the country and account for positive and negative impacts on socio-economic and environment. In Sudan, as well as other African countries, national and international conflicts (hot spots) are usually located, where geo-resources, of great economic potentialities are expected. The suggested recommendation, in this review, is to set a road map to adopt a national policy governing laws and regulations for sustainable and rational mining industry.

Analysis of the fracture network in the Séguéla-Mankono region (central-west Côte d'Ivoire, West Africa). Contribution to the understanding of the emplacement of the lamproid dykes and diamondiferous phologopite kimberlites

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The analysis of the spatial images ETM+ of Landsat 7, Radarsat and MNT-SRTM of the Séguéla region in the central-west of Ivory Coast, made it possible to extract the main lineaments (rectilinear and curvilinear), the most remarkable are:

1. The Séguéla (ZFS), Goma (ZMG), Nandala (ZFN) and Marahoué (ZFM) fracture zones of N-S direction;

2. Mankono fracture networks (RFM), Toubabouko (RFT), of E-W direction;
3. The fracture zones of Mankono West (ZFMo), Dualla (ZFD), Kohoué (ZFK) and Kohouyra (ZFKo), with a NE-SW direction;
4. Fractures of Yhouo (FY) and Kongu (FK) of NW-SE direction;
5. Fracture zones of Kongasso (ZFKo) and Kani (ZFKa), with a ENE-WSW direction.

Numerous circular structures are also detected and attributed to granitic intrusions. The analysis of all the fractures makes it possible to propose a structural model of emplacement of the lamproid dykes and of the diamondiferous phlogopite kimberlites. So, the late operation of the E-W direction dextral fracture zones has reactivated the former fracture zones oriented N170° in tension gashes and those of direction NW-SE and NE-SW Riedel synthetic (R) and antithetic (R'), respectively, which have thus favored the emplacement of the diamantiferous dykes in these respective directions.
The examination of the spatial relationships between the drainage network and the diamond occurrences has made it possible to locate the primary sites of the diamond.

Keywords: *Landsat 7 ETM+, RadarSat and DEM-SRTM, fracture networks, diamond, Séguéla, Côte d'Ivoire, West Africa*

Extraction of fractures zones at the borders of Guinea, Mali and Côte d'Ivoire (West Africa) using LANDSAT7 ETM+ optical imagery, ERS Radar and SRTM: Support for gold mining research

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The present study focuses on a region at the borders of Guinea, Mali and Côte d'Ivoire (West Africa). Its main objectives are the mapping of fracture networks using the LANDSAT-7 ETM+, ERS Radar and DEM (SRTM) remote sensing imagery. The geological approach using multi-spectral spatial imagery, thanks to their synoptic and synthetic visions, has allowed improving the outline of the structural elements (discontinuities of images).
The results obtained reveal six (6) families of fractures. These are the fracture zones of Sassandra, Kalana, Siguiri and Mandiana of N-S direction; the Tintioulen and Minigan fractures of E-W direction; the fractures of Tiefinzo, Tindila and Kankan of direction NNW-SSE; the fractures of Komodou and Kourou-Kélé of NW-SE direction; fractures zones of Niandankoro and Bodougou with NE-SW direction and finally fractures of Kiniero and Moribaya of NNE-SSW direction.
The overall results contribute to a better understanding of the fracture networks of this key region of the West African Craton and can assist in the predominantly regional gold mining research.

Keywords: *Remote sensing imagery, ERS Radar, - LANDSAT-7 ETM+, DEM (SRTM) Fracturing, mining research, Mali, Guinea, Côte d'Ivoire, West Africa.*

Mapping of geological accidents using Landsat ETM+, RadarSat and DTM (SRTM) remote sensing imagery and analysis of the fractures network of the Precambrian basement of the northwest sector of Côte d'Ivoire, West Africa

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The aim of this work is to map the fractures network in the northwest sector of Côte d'Ivoire. To achieve the desired objective, Landsat-7 ETM+, RadarSat and DTM (SRTM) remote sensing images are processed to extract the fractures network. This network is then broadly characterized by structural data collected in the field. All the results obtained show five main families of fractures. It is about:
1- fractures of Sassandra, Séguéla, Mankono-Tortiya and Ferké of sub-meridian direction;
2- the Tafiré, Katiola, Kani and Bako fractures zones of direction NW-SE;
3- fractures of Korhogo, Dikodougou, Dianra and Tieningboué, with E-W direction;
4- Séguéla and GFB (Greenville-Ferkessédougou-Bobo Dioulasso) fractures of NNE-SSW direction;
5- and finally fractures of Borotou, Worofla and Marabadiassa, with NE-SW direction.
This work may help to understand the context of the establishment of the Séguéla and Tortiya diamond dykes.

Metamorphism and U-P monazites dating of the SASCA domain (South-West of Ivory Coast)

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The Sassandra-Cavally (SASCA) domain (SW Ivory Coast) is located in the transition zone between the Paleoproterozoic and Archean domains (Fig. 1). It is characterized by the coexistence of high-grade and low-grade metamorphic units and the existence of Archean relics in the Birimian formations. Heterogeneous gneiss formations comprising migmatites, orthogneisses, garnet-cordierite-sillimanite-garnet metasediment and staurolite-bearing micaschists are affected by three main deformation phases (D_1-D_3). Thermobarometric calculations using Theriak-Domino (de Capitani, 1994) suggest a retrograde evolution from the granulite facies to the amphibolite facies, from Grand Bereby to Sassandra. The metamorphism in the paragneisses of Grand Bereby and in the orthogneisses of San-pedro with quartz-plagioclase-biotite-garnet-sillimanite-ilmenite and quartz-garnet-biotite-ilmenite partial fusion, respectively, evolves at the transition of granulite and amphibolite facies with

a maximum pressure of 10 kbar and a temperature of 820°C. It seems to characterize a decompression period in the granulite facies followed by cooling to the amphibolite facies with an apparent geothermal gradient of 40°C/km. However, the evolution of staurolite-bearing micaschistes occurred mainly in amphibolite facies with PT conditions corresponding to 3.5-6.6 kbar and 550-620°C. During this evolution, two metamorphic stages are distinguished: a prograde stage and a retrograde stage. The prograde path evolves according to a gradient of 30°C/km up to a peak of metamorphism estimated at 6.6 kbar-620°C in the amphibolite facies for the sample of Kounoukou. This path would correspond to a burial comparable to a thickening of the crust up to about 14 km in depth under an apparent geothermal gradient of 39°C/km. At this P-T path, the rock passes through a cooling phase with low decompression evolving according to a geothermal gradient of 40°C/km. This decompression would be associated with a cooling phase recorded in staurolite-bearing micaschist. U-Pb in situ dating of monazites gives ages of 2044 ± 11 Ma, 2003 ± 11 Ma, 1973 ± 11 Main the orthogneiss to quartz-garnet-biotite-ilmeniteand 2000 ± 10 Ma for staurolite-bearing micaschists. These ages correspond to metamorphic ages in the SASCA domain and their meaning will be further investigated.

Keywords: *Metamorphism, U-Pb on monazite, Ivory Coast, Paleoproterozoic.*

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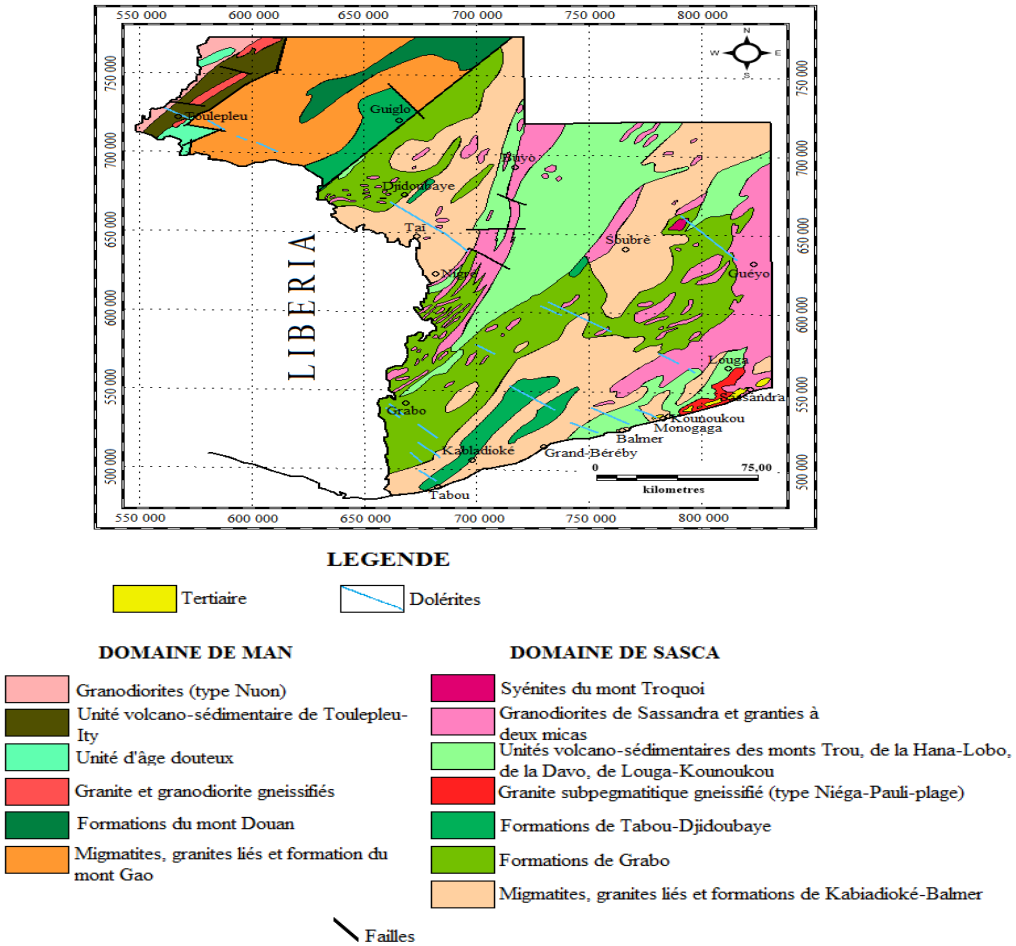

Figure 1: Geological map of the Southwest of Ivory Coast (modified after Papon, 1973)

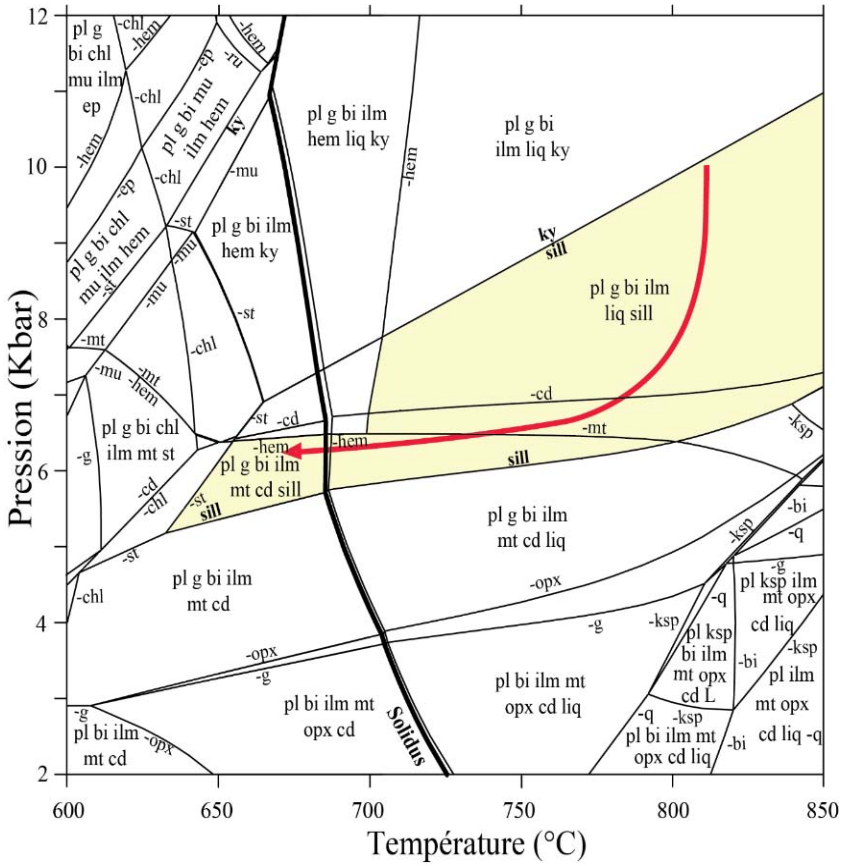

Figure 2: P-T Pseudo-section NCKFMASHTO showing the phases in equilibrium for the paragneiss of Grand Bereby. P-T path based on mineral assemblages of the studied sample is indicated in red.

Thermal Evolution of the Proterozoic crust during the Eburnean Orogeny, Kedougou Kenieba Inlier, Eastern Senegal

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The metamorphic formations of the amphibolite facies (T=500-660°C) located in the Kedougou Kenieba Inlier in the Diale-Dalema 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 pseudo-section (de Capitani and Petrakakis, 2010) suggest a multiphase metamorphic evolution in eastern Senegal during the Proterozoic with a first regional phase M_1 HP/MT (8-9 kbar, 520-560°C) and a second post-thickening stage M_2 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 M_2.
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.

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Archean inheritance in the juvenile Paleoproterozoic (Birimian) domain of Man Rise: Geochemical and Geodynamical implications

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The juvenile character of Birimian rocks of the Baoulé-Mossi domain is well established and the Birimian occupies a specific place in the evolution of the continental lithosphere between 2.5 and 1.9 Ga with a paroxysm at 2.1 Ga. Thus, this juvenile character has led many authors to evoke a tectonic context as oceanic plateaus, very far from Archean continent for the genesis of the Baoulé-Mossi domain, without any contamination. For others, the genesis of the Baoulé-Mossi domain is made with a high interaction of the Archean continent, particularly in a riftingcontext. Recent works based on thermo-mechanical models stipulate that the exhumation of metasediment lying on TTG basement is triggered by folding/shortening and gravitational instabilities in volcanic island arcs environment. Our geochemical and geochronological data obtained in the Transition Zone (TZ) of the Baoulé-Mossi domain indicate the existence of Archean components inheritance in the basement gneisses, the granitoids and the volcanites. The εNd are often negative or fairly positive (εNd = ±1) and the TDM model ages are sometimes older than 2500 Ma. Mixing model calculations carried out on the samples would indicate an average contribution of Archean crust from 5 to 20% in the Birimian magmatism, leading to a decrease of εNd (2.1Ga) from +5.5 to +2.5 on average. This contribution could reach or pass 30% for the Dabakalian rocks and in this case, the εNd (2.1Ga) can be smaller than -2. In-situ zircon dating (SIMS and ICPMS-LA) and evaporated zircon age (TIMS) highlight effectivelyArchean inheritance (2.6 to 2.9 Ga) in Dabakalian tonalitic gneiss (2.25 Ga), partially remobilized during Birimian sensu stricto event (2.08 Ga). The present results in the

TZ and those obtained in the Eglab (Reguibat Rise) lead us to support a rifting model of an Archean protocontinent for the genesis of the Baoulé-Mossi domain. This rifting was probably occurring during Archean at ca 3.0-2.7 Ga with oceanization. The recycling of the Archean crust during the rifting will contaminate later the juvenile Dabakalian and Birimian magmas at respective rates of 30 and 15%. More thought must be given on the Archean crustal contribution in the genesis of the Birimian mineralization. Up to now, no more study seems to reveal Archean relics in Birimian mineralization. Investigations should be initiated in the Birimian ore deposits located In the Kenema-Man domain to highlight such interaction.

Keywords: *Transition Zone, Baoulé-Mossi domain, Dabakalian, Birimian, Eburnean, U-Pb dating, zircon inheritance.*

The danger of the use of minerals in cosmetics and traditional medicine

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The purpose of this note is to point out a problem that can have serious health implications. Colored minerals are used as feedstock for the development of khôl in different colors. The most common is the black khôl, used by most women in our society, all age groups combined, as the product of beautification, and as therapy for small eye problems, as well as traditional medicine.

This product is featured on displays of street markets throughout the national territory, as finished product or raw, which will end-up in the kitchens of our household, produced in association with other materials.

The products which are sold, powder packaged in small vials or rock debris, are sulfides of heavy metals with a high toxicity (lead, copper, iron), which may have irreversible impact on health in the long term. These metal sulfides which come from a metallogeny of northern Algeria, present other characteristics: they parade a chemical trace of hazardous elements among cadmium, arsenic, cobalt, nickel, and copper.

Several analyses performed on a number of samples, recovered from retail outlets ”shops” in many cities such as Tlemcen, El Abed, Maghnia, Setif, Algiers, Blida, Tizi-Ouzou, helped to establish the exact origin of these substances, and fields where they were extracted. Exposure to these metals in the long term causes their accumulation, and leads to a high percentage of toxicity in the body. In fact, a very small quantity is enough to present a potential danger to the body. In addition, many investigations presented a long-term disease a serious and irreversible health trouble, which is alarming.

Keywords: *Galena, stibine, malachite, azurite, sulfurs. toxicity, pollution, speciation of elements, saturnism, autisme, genetic mutation.*

Ba- and Ti-rich mica in Aguelmane Sidi Ali volcano, Middle Atlas Volcanic Province (MAVP-Morocco): Chemistry, Substitutions and Paragenesis

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Magmatic barium- and titanium-rich phlogopite and biotite occur in strongly under-saturated alkaline rocks from the Aguelmane Sidi Ali (ASA) strombolian cone in the folded Middle Atlas. These micas occur usually as groundmass minerals but also as microphenocrysts, and contain up to 14.3 wt.% BaO and 13.0 wt.% TiO_2.With increasing BaO, there is a systematic decrease in SiO_2, K_2O, and MgO and increase in Al_2O_3, TiO_2, and FeO contents.Textural and petrological relations indicate that the micas are a late magmatic phase. According to the experimental studies of Wones and Eugster (1965), the ASA Ba-and Ti-bearing micas equilibrated at low temperature, low total pressure and high oxygen fugacity. Most of the micas analyzed show an almost stoichiometric interlayer occupancy and have apparent deficiencies in their tetrahedral and octahedral sites. Atomic substitution schemes indicate that Ba substitutes for K in interlayer sites, and tetrahedral occupancy for Ti appears unlikely. The study indicates that a combined substitution of $^{(12)}Ba + 2^{(6)}Ti + 3^{(4)}Al = {}^{(12)}K + 3^{(6)}(Mg,Fe^{2+}) + 3^{(4)}Si$ is appropriate for our micas. Temperature and fractionation processes don't seem to have played an important role in Ba- and Ti-enrichment in the micas. These latter crystallized as a late phase in the volcanic rocks at relatively low total pressure and temperature and high oxygen fugacity; they probably formed from Ba- and Ti-enriched fluids accumulated during the late stages of crystallization of the magmatic system.

***Keywords**: Barium, Titanium, Micas, Substitutions, Enrichment processes, Aguelmane Sidi Ali.*

Using mathematical morphology from Geoeye satellite image for automated extraction of dykes lineaments. Application to field Tasiast geology, Reguibat ridge, Moroccan Sahara

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In recent years, the use of high spatial resolution satellite images in geological environments study, especially in the detection of lineaments, hasn't stop evolving. Along with the progress of digital techniques in image processing, several approaches have been developed to detect intuitively and extract lineaments. For this purpose, extraction techniques such as the visual photo-interpretation and the conventional classification algorithms are used. Certainly these extraction methods lead to a result close to the reality of the field, but they have inherent operational limitations. In this document, an approach based on the use of

mathematical morphology set algorithms has been developed in order to automatically extract dyke lineaments. Mathematical morphology has been applied to a GeoEye satellite image acquired on 17/07/2005, South West side of the Reguibat ridge (Moroccan Sahara). This image underwent a set of processing, mainly based on textural filters of a co-occurrence matrix (5x5), and followed by a directional filter (5x5) ideal for lineaments detection. Then morphological operators were applied with a structuring element of a (3x3) neighborhood matrix. To validate the accuracy of the results, the statistical Kappa coefficient has been calculated using the geological map 1/50.000, and is equal to 70.7 %. It is therefore concluded that the use of mathematical morphology coupled with textural filters and lines detection algorithms for dyke lineaments extraction, provides greater accuracy and more details than traditional extraction methods that are used. The methodology suggested will thus enable to review and update the existing lineaments maps, as may be requested for the production of new map releases.

Keywords: *Automatic extraction; Mathematical morphology; Lineaments; Lines detection; GeoEye; Moroccan Sahar.*

Investigation of the inner structures of N'ait N'Aït El Haj and Hebri's maars (Middle-Atlas volcanic zone, Morocco): high resolution gravity data

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The processing of gravimetric data acquired in 2015 on the two maars N'Ait El Haj and Hebri allowed us to calculate the Bouguer anomaly. Regional trends were extracted to obtain the residual signals related to two volcanic edifices. The maxima of the horizontal gradient of the residual anomaly and its upward continuation show faults, contacts and their dips, subsequently confirmed through the Euler deconvolution. These results revealed the deep structures that have favored the drainage of the magma flow towards the surface. The modeling of the subsurface based on the interpretation of the residual signal made it possible to clarify the mechanisms of emplacement of this maars through complex interactions between the magmatic rise and the tectonic activation of a strongly karstified limestone basement.

Keywords: *Gravity, volcanic maars, Middle Atlas, subsurface modeling.*

Migration of the explosion focus within the Lachmine N'Aït El Haj maar (Middle Atlas - Morocco)

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The Lachmine N'Aït El Haj (NHL) is a well-preserved plio-quaternary monogenetic maar-diatreme volcano. It's seated in the Middle-Atlas volcanic province. The maar is a result of explosive eruptions through phreatomagmatic fragmentation that occurs when rising alkali basalt magma interacts with karstic groundwater, cutting the country rocks to make a deep dry crater (110 m).

The maar is surrounded by a low rim of bedded pyroclastic ejecta (60 m). The tephrostratigraphic study of these deposits has been developed to improve the understanding of the pyroclastic facies and depositional processes. It offers insights on the identification of the evolution of the maar from a phreatomagmatic to a strombolian style.

On the basis of the deposits characteristics (the size and the shape of the elements, the bedding, the arrangement, the structure of the clasts…), the study of eight radial sections, allow understanding the succession of the eruptive sequences and the dynamic of each one of them. This provides a preliminary hypothesis on eruptive styles and an overview of the general eruptive history during the NHL formation.

At the bottom of the volcaniclastic sequence, three meters of deposits are composed of lacustrine red tuff; it reveals that an old lake was seated before the volcanic explosion. The red tuffs are overlain by pyroclastic deposits surrounding the maars. Based on the stratigraphic criteria and mechanism of deposition, three main units are distinguished during the volcanic process of LNH, the first and second are related to the phreatomagmatic activity of the maar. The last one from a magmatic (strombolian) activity.

This first unit has seven distinct beds, the distribution and the thickness of which vary according to the intensity of the activity and the localization of the eruptive center; on the NW flank where this unit is very well developed (20 m), it narrows towards the W flank (5 m), as well as on the N flank (10 m). The continuity of the beds, their low dip and the low angle of inclination corresponds to a deposition of high pyroclastic density current (PDC), followed by less turbulent currents (peperitic deposits), presenting some forms of traction. The proportion of the juvenile and accidental lithics is depending on the changes in the water/magma ratio.

The second unit is deposited in unconformity with the first one, forming a lateral discontinuity with a thickness reduction in the N and W flanks compared to the NW. This disposition describes an invagination of the crater which distorts its circular shape in the NW. It is characterized by its reddish color evoking a proximal deposit, with the presence of cauliflower bombs indicating humid conditions of deposition. It is also distinguished by a specific formation known as "lapilli rich lithic" where the accidental lithics are very abundant. The increase in accidental lithic clasts have a deeper seated origin, it indicates that either the explosion focus down migrated during the eruptive history or that the vent

progressively widened, which explains the invagination of the crater in the NW. In the upper part, lapilli tuffs are essentially formed by agglomerated scoria; it is due to the decrease in the proportion of water with a transition of the eruptive dynamic from a phreatomagmatic to strombolian style. These deposits are disturbed by projections of bombs (up to 1 m of height), which meld the lapilli tuffs. The top of this unit is characterized by a thin film of mud cracks and very intense fracturation.
This ultimate unit contains massive breccia tuffs. It consists of fine round scoria, as well as coarse lava blocks and enormous volcanic bombs, forming a lava breccia rich in peridotite nodules of 2 cm and devoid of accidental lithics. The components are welded by the effect of the heat. This facies is a result of falls during a magmatic eruption. Scoria is produced when magma increases and discharged rapidly. The projected blocks and bombs derived from the degassing of magma. It is a typical facies of spatter-cone deposits. These deposits mainly cover the northern and north-eastern flanks, where the size of the elements is more important than those in the small outcrop in the west. This confirms that the eruptive centre of NHL is located more towards the north of the crater. The southern half of the crater is covered by a basalt flow rich in xenoliths from the plateau, which flows into the crater.

Lithostrutural framework for orogenic gold deposits in the Kédougou inlier (case of Massawa and Sofia on the MTZ)

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The lithostructural interpretation highlights that Kedougou-Kenieba Inlier (KKI) is characterized by volcanic domain and sedimentary basin with NE trending. The contact between the Mako bimodal volcanic belt and the Diale basin is defined by the NE trending Main Transcurrent Shear Zone (MTZ) of regional extension. At the latitude of Massawa and Sofia gold deposits, the MTZ is a corridor of 15 km wide where these two deposits set respectively at the eastern and the western borders.
The lithologies in the MTZ corridor are mainly constituted of explosive intermediary to felsic volcanism composed of pyroxene-plagioclase andesitic lavas with abundant volcanoclastites interbedded with detrital metasediments showing graphitic horizons. They are intruded by various generations of magmatic rocks ranging from ultramafic, mafic, intermediate to granitic compositions.
Intrusions of ultramafic and felsic rocks are more abundant in the western part of the MTZ (Sofia) in comparison to the eastern side (Massawa) where these rocks are weakly represented. These two (2) main domains are separated by a NE trending tuff horizon intruded by granitic plutons outcropping as circular shape bodies.
The structures intersected in this MTZ corridor are mainly defined as thrusts and transcurrent shear zones striking NNE. Rare isoclinal folds were refolded by later phases of deformation.

The Massawa deposit consists of gold, pyrite and arsenopyrite with quartz-stibnite-gold vein at the later stage, while in the Sofia mineralization, gold and pyrite are frequently observed in silica, K-feldspar and carbonate alteration horizons and hosted in strongly sheared felsic intrusive and quartz feldspar porphyry bodies.

***Keywords**: MTZ, orogenic deposit, gold, lithostructural, shear zone, Kedougou*

Fracture network mapping and petrophysical properties of the basement rocks: a case study of the Sidi Ifni inlier (Western Anti-Atlas, Morocco)

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A fractured reservoir consists of two entities that communicate more or less with each other: a matrix that corresponds to the rock mass and a fractured network. Their characterization is a paramount importance in the understanding of drainage conditions of hydrothermal reservoirs. In this work, a methodological approach has been applied to map the fracturing at the different scales and we also made some petrophysics measurements in fractured and altered zones. The results obtained from fracture network mapping will be the subject of statistical study to understand the spatial organization of fracturing at different scales through the analysis of satellite images, DEM, geological maps, and field data. This study is carried out in the Sidi Ifni inlier, which shows a horst structure in the context of a passive margin. Located at the western Anti Atlas (Morocco), the Sidi Ifni inlier covers about 1620 km2 and consists of Paleoproterozoic granites, unconformably covered with the lower Neoproterozoic quartzite and the late Ediacaran volcano-sedimentary series of the Ouarzazate Group. The latter is associated with granitic intrusions. Based on the results of statistical analysis, the lineaments show a main directional class (NE-SW) which is the longest, when compared to the other trends (NNE-SSE and NW-SE). The lengths of fractures follow a power law. The spacing statistical analysis of fractures longer than 1 km is different from those with less than 1 km; The kilometric fractures are organized in a uniform manner (Cv <1), while infrakilometric fractures are clustered (Cv > 1). The petrophysical parameters are mainly related to the alteration degrees of granitic rocks and fracturation. For this purpose, 18 samples were studied. As a result, the velocity values, thermal conductivity and thermal diffusivity decrease from fresh granite samples to highly altered and/or fractured granite samples, while the porosity increases from the fresh granite samples (0.9%) to highly altered and/or fractured granite samples (18%). This variation can be explained either by the grain size, changes in mineralogical composition, or by the presence of fractures.

***Keywords:** Fractures, reservoir, petrophysics, Sidi Ifni inlier.*

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Contribution of Landsat satellite images to the litho-structural mapping of the Oumjrane region (eastern Anti-Atlas, Morocco)

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The objective of our study is to develop an operational methodological approach using a geoscientific knowledge base and spectral data from the Landsat sensor in order to produce the mapping of the different faciesand the detection of the fracturing network of the Oumejrane region.
The mining district of Oumejrane, is located in the southern part of the Eastern Anti-Atlas, 50 km SE of Alnif town. It is characterized by Cu, Pb, Zn and Ba mineralizations, which are mainly encased in sedimentary terrains of the upper formation of the 2nd Bani group (Upper Ordovician).
The methodological approach adopted is based on the use of Landsat spatial images. The latter, which on a strategic scale is based on the analysis of the radiometric, morphostructural and textural characteristics of the existing geological formation.
The geological interpretation was made from Landsat images. Thus homogeneous geological units have been characterized. The contribution to the criteria of identification and even the fundamental criteria of the photo-interpretation (spectral signature, structure-texture and morphological aspect) is fundamental.
The analysis of satellite images of the region of Oumejrane allowed us to recognize some fractures of regional importance. These faults, of average orientation N00, N75, N85 and N90, all contributed, together or separately, to the structuring of the eastern Anti-Atlas. In summary we have 2 major directions: N-S and E-W.
The digital processing of satellite images shows that the lineaments which have a direction between 45° and 90° are more numerous. They are located in their entirety in the northwestern part of the study area.

Gold in the massive sulphide deposit of Jebilet massif (Hercynian, Morocco). The example of Sidi Mbark (Draa Sfar North)

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Most of the sulphide massive deposits of the Hercynian fold belt of Morocco are located in the central part of the Jebilet massif, an area characterized by an intense Carboniferous magmatic and hydrothermal activity. The deposits are hosted in the Sarhlef shales, a volcano-sedimentary series of upper Viséan age, folded and metamorphosed in the green schist facies, and intruded by granodiorite plutons and numerous acidic and basic intrusions. Some massive sulphide deposits are being exploited (e.g. Draa Sfar deposit) and others are under development (e.g. Koudiat Aicha deposit). These deposits are mainly explored for base metals. Recently, in the northern part of Draa Sfar deposit (Koudiat Sidi Mbark), the mining industry targets, in addition to base metals, gold, which has grades up to 0.5 g / t. The Sidi Mbark deposit is located on the northern shore of oued Tensift, 17Km to the NW of the city of Marrakech. More precisely, it is located at a hundred meters in the northern prolongation of Kt. Tazakourt (southern part of Draa Sfar). Although Sidi Mbark and Tazakourt are part of the same deposit, geology and exploitation differ from one part to another.

The southern part of Draa Sfar (Tazakourt deposit) is mainly exploited for zinc. The mineralization consists of 90% pyrrhotite in which other mineral phases are disseminated: sphalerite, galena, chalcopyrite, ilmenite and cobaltite. The mineralization is in the form of a subvertical mega lens exceeding 1km in length in the sub-meridian direction. Its depth exceeds 1500 m and its thickness varies from 1 to 50m. The orebody is hosted in a series of rhyodacites, tuffs and grey argillite on the footwall, and black carbonaceous argillite on the hanging wall.

The northern part of Draa Sfar (Sidi M'bark deposit) appears on the surface as a small elongated submeridian gossan emerged within an alluvial formation of oued Tensift. In depth there are ten lenses of sigmoidal shape, sub-concordant with the schistosity. These lenses can reach 150m in length and 10m in thickness, and are currently known to a depth of 250m. The host rocks consist of sandstone argillite and black carbonaceous argillite similar to those of Kt. Tazakourt, while rhyodacites and tuffs are absent.

Among the mineralized lenses of Sidi M'bark, only one is zinciferous and has a mineralogy and texture similar to that of the Kt. Tazakourt lens. The other lenses are copper-bearing and have variable textures, such as disseminated chalcopyrite within massive pyrrhotite, or alternating ribbons of chalcopyrite, pyrrhotite and/or pyrite. The ore minerals consist of pyrrhotite, chalcopyrite, pyrite, arsenopyrite, ilmenite, cobaltite, bismuth, sphalerite, galena (rare), and cassiterite.

The zinc-bearing and copper-bearing lenses have undergone different degrees of deformation. The zinc-bearing lens is highly deformed comparatively to the copper-bearing lenses. It is affectd by shearing and microfolding while inclusions of shale fragments are deformed and wrinkled. On the contrary ductile deformation is less pronounced in the copper-bearing lenses. Texturally, pyrrhotite is fine-grained in the zinciferous lens and coarse-grained in the copper lenses.

Gold of Kt. Sidi Mbark is invisible. It was observed using the scanning electron microscopy in massive ore where it is present as inclusions in chalcopyrite, cobaltite and pyrrhotite, and in banded ore where it occurs as inclusions in arsenopyrite. The inclusions have a size between 1 and 10 microns and are composed of native gold grains or associated with Bi and/or Ag.

Systematic prospecting of circular structures by satellite imagery for the search for potential new impact craters in Mauritania

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Impact cratering is a major geological process responsibe for the evolution and modification of planetary crusts. The geology of Africa spans more than 3 billions of years (from Archean to present), and the geological evolution of crustal blocks that form today the African continent was affected by impact processes. However, due to insufficient systematic exploration of Africa for impact structures, this African impact record is likely to very incomplete. Furthermore, known impact structures in Africa remained poorly mapped and investigated in comparison with impact structures in Europe or America.

Mauritania has 2 confirmed impact craters Tenoumer and Aouelloul (Monod andt Pomerol, 1966; Koeberl and Reimold, 1998), as well as 4 unconfirmed circular structures (Reimold and Koeberl, 2014) (Fig. 1).

Mauritania has old and relatively flat surfaces and may host old/large impact structures that remain to be discovered, for instance in geophysical data sets. Due to desertic condition, erosion is limited and conditions for the preservation or small and more recent impact craters (< a few tens of Ma old) are good. With these two facts in mind, we have started prospecting for circular structures using Google Earth imagery and other satellite data with available access (e.g. Sentinal data). The search for circular structure may also lead to the discovery of various geological processes affecting Mauritania, beyond the search of impact structures, including volcanic or tectonic structures, or even structures of economic internet such as kimberlites pipes (Reimold et al., 2014). The circular structures are listed in Fig. 1 and illustrated in Fig. 2.

This preliminary investigation allowed us to detect 26 new circular structures that we described and anaylse from the Sentinel-2a and Sentinel 2b images. The nature of these structures will be discussed during the presentation, with the objective to determine the most promising structure for further field investigation.

This research is part of the Africa Initiative for Planetary and Space Science (africapss.org)

Key words:*impact crater.*

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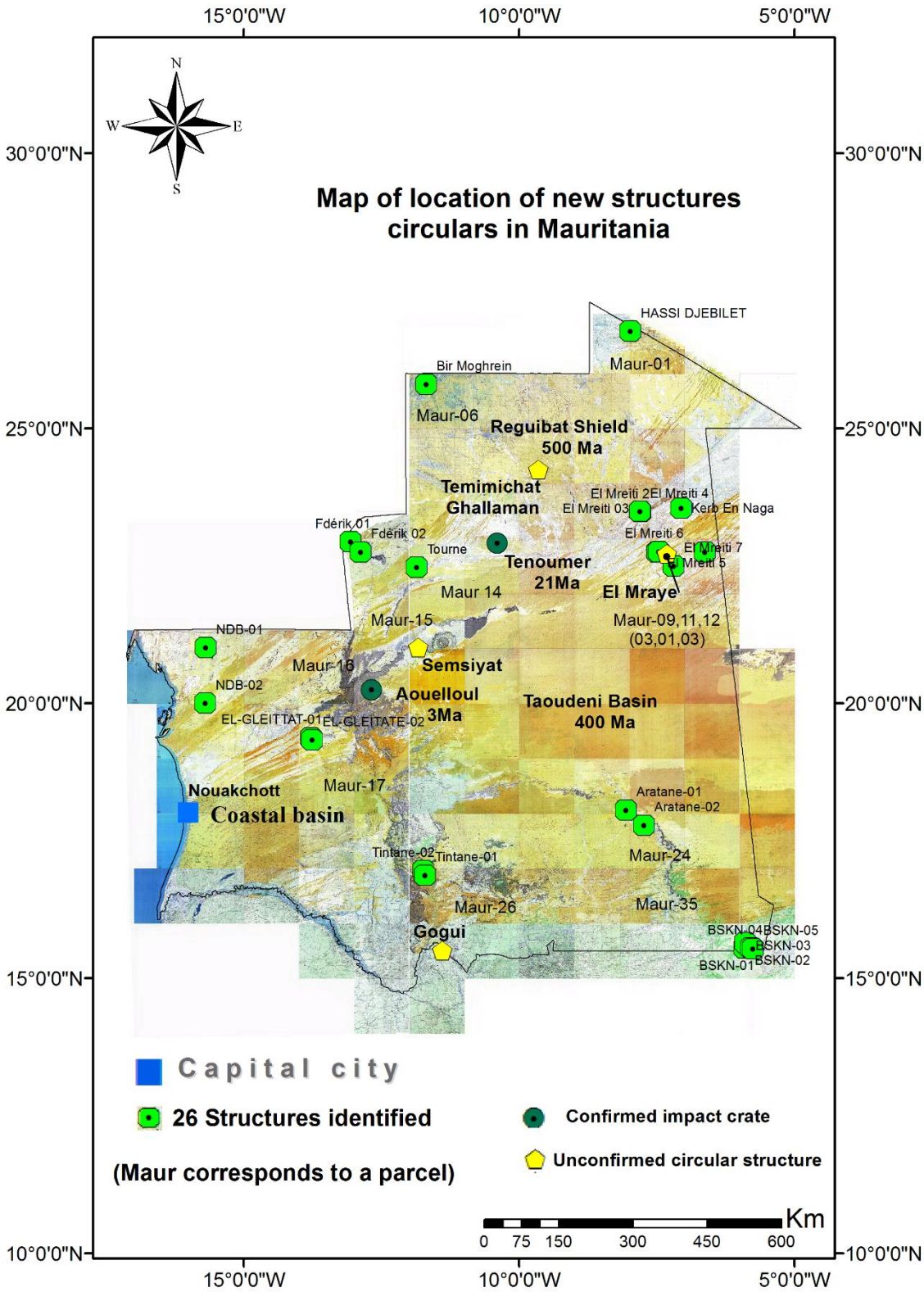

Fig.1: The location map of the circular structures detected by the Google Earth systematic prospecting.

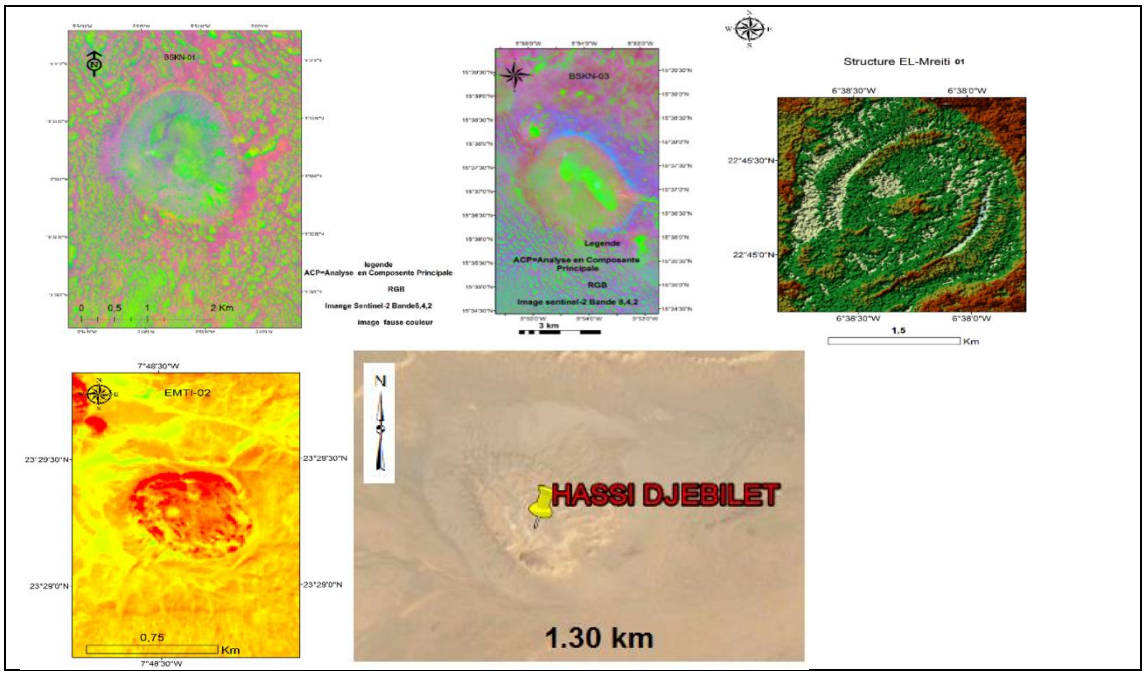

Fig. 2: Examples of circular structures detected by prospecting (e.g. Sentinal data).

The granitic complex of Kan (center of Côte d'Ivoire): petrography and mechanisms of deformation

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The Kan granite complex belongs to the Proterozoic basement of Côte d'Ivoire. It is located in the center of the country, precisely in the Toumodi region, at the eastern limit of the volcano-sedimentary sulcus of Toumodi-Fętekro and at the western edge of the Comoé basin. The aim of this work is to show the mechanisms of deformation through a structural analysis. This analysis extends from the macroscopic to the outcrop to the microscopic scale in thin plates (polarizing microscope).

At the petrographic level, we have identified granodiorite, oriented granodiorite, gneiss, mylonitic gneiss, migmatitic gneiss, amphiboliproxenite, basic metavolcanites, gabbro, greece-pelitic metasediments, mafic xenolith and aplite, pegmatite and quartz wire. The metamorphic formations evolve in the amphibolite facies.

At the structural level, two deformation mechanisms were observed in the study area. It is flattening and shearing (ductile and brittle). The generally oriented foliation N10° and similar folds are the markers of the flattening. On the other hand, the shear is materialized by intrafoliar folds, strands, step slits, mineral stretch lines, sigmoid figures, S/C' and S/C structures and fractures. Five mains directions of the shear bands are shown in the study area: these are N10°, N110°, N170° directions (sinistral) and N90°, N50° directions (dextral). The mains directions of fractures are NNE and ENE.

***Keywords**: Côte d'Ivoire, Proterozoic, Granitic complex of Kan, mechanisms of deformation.*

Petrology and geochemistry of K-rich Paleoproterozoic Birimian granitoids of the West African Craton, northern Ghana: Petrogenesis and tectonic implications

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Granitoids of different generation intrude the Paleoproterozoic Birimian sedimentary basins and greenstone belts of the West African Craton. Intruding Bole-Nangodi belt, which is one of the Birimian greenstone belts, are potassic-rich granitoids. These K-rich granitoids are believed to be relatively younger compared to other granitoid intrusions of the Paleoproterozoic Birimian Supergroup. The K-rich granitoids may be classified broadly as granite, pegmatite/aplite associations, granodiorites and adamellites. They are composed of K-feldspar, quartz, ±plagioclase, ±hornblende, ±pyroxene, ±biotite and ±muscovite. Accessory minerals include opaque oxides/sulphides, titanite, zircon, epiodote, allanite, carbonate, fluorite and apatite. Potassium contents can be as high as 5 wt% with general high concentrations of Rb, Ba, Sr, Cr and Ni. The K-rich granitoids are calc-alkaline highly fractionated I-type granitoids. They are enriched in LILEs and depleted in HFSEs relative to early Proterozoic upper continental crust. Chondrite normalized rare earth element plot indicate fractionated LREE patterns (average La_N/Sm_N=5.05) and HREE patterns (Gd_N/Yb_N = 4.56) with dominantly slight negative Eu anomalies (average Eu/Eu^*=0.75). The K-rich granitoids record $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ ratios in a range of 0.7090-1.8622 and 0.5109-0.5129, respectively, with initial $^{87}Sr/^{86}Sr$ and initial $^{143}Nd/^{144}Nd$ ratios in the range of 0.5987-1.8115 and 0.5099-0.5101, respectively. $\varepsilon Ndt_{(2.1\ Ga)}$ values range from -1.0 to +8.3 with $Nd_{(TDM2)}$ model age of 2.2-1.7 Ga (for the older and younger rocks respectively). Petrological and geochemical characteristics of these rocks suggest that the K-rich granitoids are arc related, and emplaced under post-orogenic and syn-collisional tectonic settings, at temperatures of approximately 680-750°C and pressures of 3.4 kbar for the granites and 17.1 kbar for the adamelites. Thus, initial thickening of crust by arc-collision (continental), followed by slab subduction under high pressure and temperature conditions resulting in underplating of mafic magmas in shallow crustal levels is likely to have generated these K-rich granitoids.

Keywords: *Paleoproterozoic, Birimian, potassium rich granitoids, petrology, geochemistry, petrogenesis.*

Sediment Dating of a sedimentary core from Moulay Bousselham region using ^{210}Pb and ^{137}Cs

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The sediments are valuable historical archives and their study (in particular the sedimentary column) makes it possible to trace the history of terrigenous and/or anthropic inputs in lacustrine, marine and estuarine environments.

In this work, we were interested in the study of a sedimentary core collected in 2009 in the region of Moulay Bousselham by considering two radionuclides, which are:

- The ^{210}Pb which is a natural radionuclide allowing the reconstruction of the geochronology via the estimation of the ages and the accumulation rates of the deposited sediments during the last 150 years;
- The ^{137}Cs, an artificial radionuclide which has the advantage of providing two absolute dates (1963-1964 and 1986).

The determination of these radionuclides was carried out by Gamma Spectrometry using a Hyper-Pure Germanium. Then, based on a number of hypotheses concerning the sedimentation rate, the ^{210}Pb flux and the surface activity, we have applied three mathematical models of dating by the ^{210}Pb, namely:

- The CF-CSR model (Constant Flux-Constant Sedimentation Rate);
- The CIC model (Constant Initial Concentration);
- The CRS model (constant Rate of Supply).

The results obtained show that the sedimentation rate is of the same order of magnitude for the three models CF-CSR, CIC and CRS (respectively 0.38, 0.31 and 0.26 g/cm²). Also, the dates obtained by the three models are essentially the same from the sampling date to the 1960s. However, CRS experienced a divergence from the other models for the lowest dates (deeper layers); this can be explained by the persistence of significant levels of ^{210}Pb at the base of the core making it difficult to accurately assess the ^{210}Pb sediment inventories required for the CRS method.

Keywords: *^{210}Pb, ^{137}Cs, Gamma Spectrometry, dating sediment, CF-CRS model, CRS model, CIC model, accumulation rates, chronology*

Fracture evolution in the Paleozoic massif of Tichka (western High Atlas, Morocco): Remote sensing and structural analysis

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The Paleozoic massif of the Tichka massif, in the western High Atlas (Morocco), is limited to the south by the Tizi-N-Test major fault zone. This massif constitutes a structural transition between the Meseta and the Anti-Atlas domains. It was affected by Variscan, late-Variscan and Alpine deformations. This massif, known by numerous syntectonic plutons of granitoids, is considered as a key for the understanding of the structuring of the Variscan belt.
Fracturing is present in the various stages of structuring of this sector. The analysis of this fracturing at different scales makes it possible to contribute to the reconstruction of the main phases of this structuring.
In this work, various techniques of lineaments extraction were applied to the satellite images (Landsat ETM+ and Aster) and Digital Terrain Module (Aster GDEM). Using remote sensing in fractures mapping combined with tectonic and micro-tectonic analysis in the Paleozoic Tichka massif provides a significant contribution to understanding the evolution of fracturing during the structuring of this massif.
The results obtained can be compared to the data available in other regions of the massif and Morocco. They permit to highlight the presence of a probable late-Variscan constraint that affects the whole granodioritic massif, and that the domains of the High Atlas and the Meseta have undergone a common tectonic evolution since the end of the Variscan folding period.
Keywords: *Tizi-N-Test, Tichka, Variscan deformation, structuration, lineaments, remote sensing*

Geostatistical and GIS analysis of the spatial variability of alluvial gold content in Ngoura-Colomines area, Eastern Cameroon: Implications for the exploration of primary gold deposit

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Nonlinear geostatistics is commonly used in ore grade estimation and seldom used in Geographical Information System (GIS) technology. In this study, we suggest an approach based on geostatistic nonlinear ordinary kriging (OK) and Geographical Information System (GIS) techniques to investigate the spatial distribution of alluvial gold content, mineralized and gangue layers thicknesses from 73 pits at the Ngoura-Colomines area with the aim to delineate the most prospective area for primary gold mineralization. Gold grade varies between 0.1 and 4.6 g/m^3 and has been broadly grouped into three statistical classes. These classes have been spatially subdivided into nine zones using ordinary kriging model based on physical and topographical characteristics. Both mineralized and barren layer thicknesses show randomly spatial distribution, and there is no correlation between these parameters

and the gold content.The combined OK model and GIS analyses have led to the delineation of Colomines, Madubal and Boutou villages as the most prospective areas for the exploration of primary gold deposit in the study area.

Keywords: *Geostatistic; Ordinary kriging; GIS; Alluvial gold; Mineral exploration; Ngoura-Colomines*

Study of the possibilities of acid mine drainage from the mining sites of the Yaouré gold province (Center of Côte d'Ivoire): implications in the pollution of surface and underground waters

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Most gold mining in West Africa occurs in the Birimian (Paleoproterozoic) geological context, known to contain primary mineralization often associated with sulphides. The storage of heaps from these exploitation in the open air can constitute a source of pollution known as Acid Mine Drainage (AMD).

This present research project, which focuses on heaps of mining sites in the Yaoure region, has the following objectives to: 1- locate (or identify) the mining sites; 2- specify the metal vectors of acidification reactions; 3- determine the potential for acid generation and the neutralizing power of soils and heaps; 4- assess the acidification risks and levels of metal pollution in the aquatic environment of the area, particularly the Bandama River, the main provider of fishery products in the region. It should eventually lead to the use of scientific evidence to influence policy on mining management issues.

Geological surveys have identified dozens of more or less active gold mining sites, especially downstream of the Kossou Dam, which have been the subject of petrographic, metallogenic and geochemical studies for the determination of sulphides and other heavy metals. Nineteen (19) samples of rocks and soils were collected. The preliminary macroscopic and microscopic studies were supplemented by multi-element analysis using a portable XRF spectrometer to determine the contents of heavy metals (Fe, Hg, Pb, Cr, etc.), sulfur and arsenic. The results obtained showed the presence in non-negligible contents of certain elements such as iron (38886.2 ~ 229000 ppm), arsenic (4.47 ~ 28.93 ppm), sulfur (334.6 ~ 3853.3 ppm), and, of course, gold. Only seven (07) of the samples contain a significant amount of sulfur and were selected for the rest of the study. These samples by correlations of certain metals with sulfur indicate that the iron sulphides could be pyrite, arsenopyrite and chalcopyrite, mainly in the andesites, dolerites, granodiorites and basalts.

To be certain and to know more about their possible implications in a possible acid mine drainage, the samples are currently subjected to analyses, especially for the determination of their acidogenic potentials.

The expected results will, if they are conclusive, evaluate the level of risks of acidification and metallic pollution of aquatic environments, in particular by periodic analysis of surface and groundwater (pH, conductivity, turbidity, mineralization, heavy metals, etc.) and, above

all, the determination of enrichment factors and heavy metal geo-accumulation indices of Taabo Lake, downstream from the mining sites concerned by the study.

***Keywords**: Heaps, acidogenic potentials, neutralizing power, acid generation potential, enrichment factors, geo-accumulation indices, Yaouré, Côte d'Ivoire, West Africa.*

Discovery of Banded iron formations mineralization in the Takeroumt area, Bou Azzer-El Graara inlier, central Anti-Atlas Morocco

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The district of Bleïda corresponds to a structure oriented NW-SE which extends about 11 km in length. It is located in the SE of the Bou Azzer-El Graara inlier, in the central Anti-Atlas, Morocco, and in the north border of West African Craton.
It is one of the most remarkable examples of copper mineralization in Morocco. Sometimes, it is cross-cut by veins of white sterile quartz, hematite quartz, or hematite corridors. These veins are exploited for orogenic gold, that Wafik et al. (2000) attribute to a Cauê Mine.
The natural concentrations of hematite represent a geological phenomenon of a regional character, closely localized in the northern border of Bou Azzer-El Graara inlier. In our study area, we encountered lithological formations, either magmatic or metamorphic quartz-ferruginous formations which accompanied amphibolite schist. These deposits are located within early Neoproterozoic sequence of Takeroumt area. They correspond lithologically to rocks formed by alternations of beds, millimetric to centimetric thickness in general, of pure silica and of a mixture of silica and hematite in southwestern part of El Graara.
To establish any structural, petrographic and geochemical relationship among lithological hosted facies in Takeroumt deposits, and tectonic setting, we sampled the Takeroumt deposits sequence. We also mapped the area and studied the relation between ore body and tectonic structures. The samples were subject to petrographic, metallographic, microstructural, and geochemical study (in DLGR, Laboratory, Semlalia Sciences Faculty, Marrakech).
This formation has a perfect ribbon texture which is very obvious. It is parallel to the S_0 stratification and is affected by the pan-African S_1 schistosity. The ribboning is very well marked and gives the rock its typical macroscopic appearance, typical appearance of Banded Iron Formation (BIF).
In this type of deposits, the mineralization occurs in compact rock, following bands with well-marked bedding and conformable with that of the surrounding gneiss and amphibolite.

Geology and githology of gold mineralization of the Far West Bleida deposit, Bou Azzer buddy, Central Anti-Atlas, Morocco, Typology

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The Bleida far west gold deposit, located at seven kilometers in the northwest of the Bleida mine in the inlier of Bou-Azzer-El Graraa, between the north and south Rouimiate faults. The study sector is composed of two lithologically different units separated by the south Rouimiate fault:
- A south unit, named the breccia zone (B), dominated by sedimentary rocks intruded by a complex of plutonic rocks which are themselves crossed by mafic and felsic dykes.
- A north unit, named the central zone (C), to which belongs our study zone, is dominated by volcano-sedimentary rocks in which two intrusions, the granodiorite and the quartz diorite emplaced. This unit takes the gold mineralization of far-west.
All the area is affected by two types of foliations, the S_1 foliation linked to the B_1 phase and the S_2 foliation linked to the B_2 phase.
The gradient of the metamorphism grows from the south towards the north, marked by the development of metamorphic facies northward.
The gold mineralization is unloaded in the shear corridors, characterized by a strong percolation of hydrothermal fluids to which are associated many hydrothermal alteration types namely silicification, epidotization, chloritization, hematitization, carbonation, and sericitization. Four gold mineralizator stages are distinguished in a chronological order : (i) early stage ante-S_1, (ii) synchronous-S_1 stage, (iii) synchronous-S_2 stage, and (iv) late-S_1 stage.
The compilation of the different geochemical maps on the structural lineaments clearly shows that the geochemichal anomalies appear in the fracture zones and on the limits as well, overlying the alteration halo.
According to all field observations, petrographical, structural studies, and the geochemical data corroborate with orogenic gold deposit type of syn-Panafrican magmatic arc.

Keywords: *Gold, Bleïda-far west, deposit, Panafrican, Anti-Atlas, Morocco, orogenic*

The 348-340 Ma Jebilet-Rehamna-FourhalLargeIgneousProvince of the Meseta domain (Variscan Belt, Morocco): U-Pb geochronology, geochemistry, and links with coeval magmatism on other crustal blocks

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The Variscides or Hercynides of the Meseta domain include all the Paleozoic massifs north of the South Atlas Fault, except the Ouzellarh Block of the Marrakech High Atlas which belongs to the Anti-Atlas Paleozoic domain. During Early Carboniferous, the mesetian basins of Jebilets, Rehamna and Fourhal (Central Hercynian Massif of Morocco) of western Meseta show great tectono-sedimentary evolution similarities. Their deposits record large instabilities and disorganization with huge thickness and lithological variations, related to a synsedimentary tectonic context. At the same time, tilted block tectonics affect the basement of these basins, controlled by bordering transfer faults. Abundant traces of magmatic activity during the Carboniferous period are recognized in Morocco, particularly in the Jbilets, Rehamna and Fourhal igneous areas. These rocks constitute a magmatic province consisting of basaltic lavas, mafic sills and dykes, and gabbroic intrusions together with subordinate layered ultramafic intrusions and silicic volcanic/intrusive rocks exposed in the MesetaDomain, part of the Moroccan Variscan belt. We report 6 new U-Pb zircon ages obtained by sensitive high-resolution ion microprobe (SHRIMP) and laser ablation–inductively coupled plasma-mass spectrometry (LA-ICP-MS). Available zircon U-Pb ages obtained (both from the literature and new data herein) from various rocks in this province, which has an areal extent of ~400,000 km^2 (~850 km × 470 km), indicate that magmatism occurring between 349 and 340 Ma ago, coeval with the Eastern Meseta volcanism in northeastern Morocco. Such a striking similarity in emplacement age, in combination with the tectonic reconstruction of northwestern Gondwana ca. 350 Ma ago, allows us to propose that the extensive Jebilets-Rehamna-Fourhal igneous rocks in western Meseta, the Tazzekka-Debdou-Mekkam igneous rocks in eastern Meseta in Morocco, the likely 353-346 Ma St. Jean du Doigt bimodal layered intrusion (Brittany, France) and other equivalents such as the 345-340 Ma Southern Vosges magmatism may represent the erosional and/or deformational remnants of a large igneous province, which we call the Jebilets-Rehamna-Fourhal LIP. Their intraplate tholeiitic and alkaline chemical character are consistent with rifting during this period. We argue that this newly identified LIP was likely caused by a mantle plume, which started in the Early Carboniferous and may have played a role in the breakup of northwestern Gondwana and the development of the local alpine glaciation. The plume was likely centred on the thick lithosphere of the West African Craton. The highly thinned western Meseta realm with widespread rift-type basins (pull apart basins) is interpreted here as a large thin-spot-type domain.The northeast-directed large-scale sublithospheric plume channeling from the plume site (WAC) to the western Meseta large thin-spot, lead to the development of widespread tholeiitic/alkaline magmatism in the western Meseta and calc-alkaline magmatism in the overthickened eastern Meseta.

U-Pb zircon dating of the Ediacaran Central Iapetus Magmatic Province (CIMP) in the Meseta Domain (Morocco)

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The 615-540 Ma Central Iapetus Magmatic Province (CIMP) was emplaced in multiple pulses during Ediacaran-Cambrian times, and has been linked to the disruption of the Rodinia supercontinent leading to the opening of the Central Iapetus Ocean. It is well represented in Laurentia and Baltica but also present on other formerly attached blocks such as the Congo Craton, the West African Craton and possibly Amazonia. CIMP occurrences are particularly prominent in the High and Anti-Atlas of Morocco, as the 600-541 volcano-sedimentary sequences of the Ouarzazate Supergroup (i.e. "XIII" or "PIII" of Choubert, 1963) that covered ca. 2 x 10^6 km^2 with an estimated magma volume of ca. 1 x 10^6 km^3 and volcanic thicknesses greater than 3000 m. It had been previously presumed that the Ediacaran CIMP magmatism occurs also in the Meseta Block (see Gigout 1951; Morin, 1962; Michard, 1967, 1976, Cornée et al., 1984; Corsini et al., 1988; Hoepffner et al., 2005, Michard et al., 2010 and references therein), and the presence of CIMP magmatism is confirmed herein. We present an updated review and new U-Pb dating on magmatic rocks from the Meseta Domain, which is part of the Moroccan Variscan belt. Rhyolites, granites and associated volcanics and sedimentary series of Ediacaran age crop out locally in the Zaian Mountains (southeastern of Moroccan Central Massif), Central Rehamna, and the Coastal Block (El Jadida) of the Meseta Domain. The Neoproterozoic-Cambrian stratigraphy in the Zaian Mountains (region of Goaïda) consists of limestones with conglomeratic and felsic volcaniclastic units, pelites and mafic volcanic rocks assigned to the Cambrian which unconformably overlie rhyolites, andesites, rhyodacites and felsic tuffs associated with the Goaïda and Berreda granites of probable Neoproterozoic age (Morin, 1962). The Goaïda granite yielded U-Pb zircon ages of Ediacaran age, ranging between ~ 610 Ma and ~ 540 Ma, with a discordia upper intercept age of 598±32 Ma that could be interpreted as the age of intrusion. The two youngest fractions yielded a Concordia age of 590±3 Ma (Pereira et al., 2014). Recently, Ouabid et al. (2017) reported U-Pb zircon ages for all the facies of Goaïda granitoids. Concordant U-Pb zircon data yield a lowermost Ediacaran mean age for white granites (625±9 Ma) and Ediacaran mean ages for dark granitoids (600±10 Ma) and pink granites (552±10 Ma). The Neoproterozoic-Cambrian stratigraphy of the Rehamna region is roughly similar to the

Goaïda region, and also includes a volcanic-sedimentary series with limestones, arkoses, rhyolites and conglomerates. The conglomerates contain pebbles of granite and rhyolite, whose source is in the Neoproterozoic basement. The majority of zircon ages in one granite pebble are Cryogenian-Ediacaran in the range ~ 640-600 Ma, with the youngest yielding a Concordia age of 609±2 Ma (Pereira et al., 2014, 2015) interpreted to be the emplacement age of the granite from which the pebble was derived. The rhyolitic basementshows porphyroclastic pink feldspars, corroded quartz and relics of volcanic textures. The rhyolites are metamorphosed into orthogneisses, and the Sidi Bahilil gneiss yielded an Ediacaran age: 593±8 Ma, U-Pb zircon (Baudin et al., 2003). This basement unit is the same as observed in the Moroccan Central Massifand the Coastal Block (El Jadida) outcrops. At El Jadida City, the coastal outcrops are composed of rhyolitic formation I, overlain by mainly dolomitic and at the bottom, conglomeratic formation II. These formations could be Neoproterozoic or Cambrian in age and are unconformably overlain by Cenomanian sedimentary rocks (Cornée et al., 1984). El Jadida rhyolites yielded a U-Pb zircon age of 597.6±4.6 Ma (this work). This Neoproterozoic age allows correlation of the El Jadida sequence with those of Rehamna and Moroccan Central Massif. All these CIMP ages suggest that the Meseta Domain is essentially built on Pan-African continental crust. So, caution is needed when interpreting the provenance of Ediacaran zircons in the northern margin of Gondwana (Morocco) which are usually interpreted coming from the Anti-Atlas, but perhaps a source in the Meseta Domain should be considered. The Edicaran volcanic rocks of the Meseta Block may have formed during extension leading to the formation of Iapetus Ocean and therefore are comparable to similar-age, rift-related volcanic rocks found in the High and Anti-Atlas.

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POSTER PRESENTATIONS

Contribution to the knowledge of paleoclimates through the geochemical signature of sediments: example of Morocco

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The drift of the African continent since the Precambrian has been largely demonstrated by palaeomagnetic arguments. The objective of this work is to establish the link between the movement of the African plate and the major climatic variations during the Paleozoic times essentially, using the geochemistry of the sediments.
We have obtained through the geochemical study of 59 samples collected in Morocco (mainly in the Anti-Atlas), results that have been described by other authors in other regions in the world, especially in the United States of America and China. The variation in K2O concentrations in all sediments collected from the Precambrian-Cambrian boundary (around 550Ma) to the Paleocene shows clearly a decrease in the potassium content in sediments towards younger ages. This same trend has been described previously in other Paleozoic basins in the United States of America.
The American authors explain this decrease of potassium rate in the sediments more and more recent by the formation of micas (K2O fixation) in the deepest sediments and so the most ancient. Or, in other words, the more the rock is ancient, the more it has tendency to become mineralized.
We believe that this regressive evolution of Potassium in sediments is linked to climatic variations, themselves linked to movements of continents at different latitudes. Thus, the sediments collected in Morocco have become poorer in K2O by leaching under hot and humid climate (tropical climates) of the rock. In fact, the global displacement of the African plate during the Paleozoic times is from the South Pole to the equator. We witness at the beginning at glacial periods (especially at the Upper Ordovician) that doesn't favor the leaching of the chemical elements of a rock causing a high concentration, especially of Potassium (K2O). The use of Cs/Ti and Rb/Ti on the total of our samples allows, as made in china, to suggest a period under a dry climate at the beginning of the Permian and two warm and humid periods: Lower Cambrian and Early Jurassic.
This contribution of the knowledge of the paleoclimates in this area of Africa join others similar studies made in Chine, Canada and USA and reinforce the role and utility of sediments geochemistry, conciselly traces elements and Oxides, in the reconstitution of paleoclimates.

Keywords: *Paleoclimate, Africa plate, Morocco, Geochemistry, Oxides, Potassium.*

The Shale Gas in Morocco: preliminary studie of Tafilalet basin (Oriental Anti-Atlas)

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In the Tafilalet Basin, Paleozoic sedimentation begins with Cambrian carbonate followed by detritic facies during the Ordovician and Silurian periods. A radical climate change marked by the melting of an important iceberg towards the end of the Ordovician caused a rise in the sea level. This is followed by very localized organic shales deposits of Silurian age (shale Gas) known as Tunnel Valleys (Hirnantian), thus constituting an important potential rock source in the basin.

The study of these rocks in the Tafilalet Basin is supported by seismic lines of this region and also by the existence of geological formations rich in organic matter, giving the particular interest to the Upper Ordovician-Silurian transition and the Lower Devonian. Samples were collected from surface outcrops and traditional water wells. They were subsequently processed by a series of analyses, including Rock Eval (% COT) analyses, X-Ray Diffraction (XRD), Scanning Electron Microscope (SEM). Also, the petrographic analyses of the thin sections and the thermogravimetric analyses ATD and ATG were used for the valorization and the characterization of these black shales.

This preliminary study of petroleum potential in the Tafilalet basin must be developed by other complementary analyses and field works.

Keywords: *Shale gas, Paleozoic, Sedimentary basin, Tafilalet, Anti-Atlas, Morocco.*

African marine radioactivity: case of marine sediments in the oceans and seas

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This work is a part of the Coordinated Research Project (CRP) on behavior and effects of natural and anthropogenic radionuclides in the marine environment and their use as tracers for oceanography studies.

For this purpose, we have been interested in a compilation of data covering the period from 2000 to present of radionuclide concentrations in marine sediments of the African continent by considering the Atlantic Ocean, the Mediterranean Sea, the Red Sea and the Indian Ocean.

For this comparative study we included three anthropogenic radionuclides as the most representative of natural radioactivity (^{226}Ra, ^{232}Th and ^{40}K).

To characterize the potential radiation dose to humans resulting from exposure to sediment radioactivity, five radiological hazard indices were estimated: D (total absorbed dose rate in

air), Ra_{eq} (radium equivalent activity), Hex (external hazard index), AGDE (annual gonadal dose equivalent), and AEDE (annual effective dose equivalent).
The principal objectives of this work are to establish the spatio-temporal evolution of radionuclide distribution in marine sediments and to identify the cause radiological effects in the African oceans and seas.

Keywords: *Radionuclide concentrations, marine sediments, African countries, radiation hazard*
Acknowledgements: *This project would not have been possible without the generous support of the International Atomic Energy Agency IAEA.*

Contribution of geophysics to the study of the Goumeré gold mineralization (northeast of the Ivory Coast): induced magnetometry and polarization

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In West Africa, Birimian formations, generally masked by laterites, are well known for their precious metal content. In the Gouméré region of northeast Côte d'Ivoire, geophysical studies (magnetism and induced polarization) showed the presence of three lithological complexes: granodiorites, basic formations and a complex of sedimentary and volcano-sedimentary formations. Tectonics are dominated by N-S, NE-SW and ENE-WSW oriented faults. Induced polarization (PI) studies revealed that sulphide mineralization is "disseminated" in mafic volcanic formations and granodiorites, and is mostly associated with quartz veins and veins. This is in favor of a model of "hydrothermal" type mineralization with structural control.

Keywords*: Magnetic anomaly, IP anomaly, Birimian, Gouméré.*

Geological and physiochemical characterization of clay materials in the Cristal Cerame quarry (region of Berrechid, Morocco)

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The Cristal Cerame quarry is located in Jemaa de Ryah region at 22 km northeast of Berrechid city (Morocco). Geological study, characterization and valorization of some clay raw materials extracted from Cristal Cerame clay deposit have been a focus of our mission. Clay materials are used mostly in floor tile production. Thus, field investigations show that most of these rocks are mainly argilitic in their composition, gray or purple in color, attributed to shale and sandstone of a folded Paleozoic basement. Infra-Cenomanian and Cenomanian-Turonian sediments unconformably overlie these argillites. Quaternary deposits locally cover all older rocks. Several studies are carried out to characterize this clay formation:

- Particle size analysis shows that the two clay-types (gray and purple) are slightly similar.
- *X-ray diffraction* (*XRD), X-ray fluorescence* (*XRF*) and *Infrared spectroscopy* (*IR*) *methods revealed that illite, kaolinite and muscovite were the major types of the rock-forming clay minerals.*
- Chemical analyses carried out on the two clay-types show a relatively high content of Fe_2O_3, and an amount of alkaline and alkaline-Earth elements reaching approximately 3% for the two clay-types. However, silica and alumina contents are admissible in the ceramics industry.
- Significant technological parameters such as firing shrinkage, mass loss and transverse strength, were defined in order to predict the behavior of the two clay-types during firing processes. In addition, the thermal decomposition on fine fraction of these clays was studied by thermogravimetric analysis (TGA) and differential thermal analysis (DTA). From the TGA curves, both clay samples exhibit a decomposition loss of 50% of weight. In fact, the curves show broad losses of mass in the temperature range of 30-150°C and 450-650°C, normally associated with loss of surface water and dehydroxylation of the clay material, respectively. Moreover, the DTA curves show two sharp endothermic peaks at 60°C and 540°C corresponding to the loss of surface water, and lattice water of the clay material, respectively, besides the decomposition of the calcium magnesium carbonates. In addition, another exothermic peak occurs slightly above the highest temperature (1000°C) and corresponds to crystallization processes.

General view of Cristal Cerame quarry

Mineralogical and seismic properties of serpentinite of Ait Ahmane fault zone of Bou Azzer ophiolite, Central Anti-Atlas of Morocco

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In Bou Azzer, two major serpentinization stages of Pan-African orogen are observed: pseudomorphic early stage materialized by the isotropic serpophite preserving the primary form of olivine crystals, often with antigorite needles. Brucite is fairly frequent, as micrometric inclusions in other serpentine minerals as antigorite and serpophite and tectonic late stage materialized by framework or parallel veins and fractures filled by chrysotile. These minerals are often cross-cutting the antigorite, serpophite and brucite crystals. The microscopic and Raman analyses confirm that the investigated serpentinite rocks suffered of a variable degree of serpentinization and the dominant variety of serpentine mineral is antigorite. The crystal preferred orientation (CPO) results show that the [001] axes of antigorite deformation are aligned subnormal to the foliation while the [010] axes are mostly aligned subparallel to the lineation, which are significantly different of that produced in the recent high-pressure experiment. The seismic anisotropy results of shear waves are large, the sample with the lowest serpentine content (30%) shows the lowest P- and S-wave anisotropy (Vp=7.2% and AVs=6.55%), and the sample with the high content of serpentine (85%) shows the highest P- and S-wave anisotropy (Vp=8.6% and AVs=11.06%). These results reflect that the seismic anisotropy increases with antigorite volume fraction. In addition, effects of the serpentinization degree and composition on seismic anisotropy are shown in the equal and lower areas of hemisphere projections.
Keywords: *Serpentinization,Antigorite,Seismic anisotropy, Seismic velocities, CPO, Ait Ahmane, Morocco*

Evidences of rare metals (Nb-Ta) mineralization in pegmatites from Mangodara district (South-West, Burkina Faso)

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Mangodara district (southwest of Burkina) is one of known occurrences of eventual rare metals mineralization in pegmatites in the West African Craton (WAC). It is situated in the

tonalite-trondhjemite-granodiorite (TTG) domain of Sidéradougou-Dabakala, between the Banfora Greenstone Belt and the Houndé Greenstone Belt.
Geological mapping works revealed the following lithologies: a biotite foliated granodiorite; a biotite and magnetite foliated, banded and intrusive leucogranite; a biotite granite with porphyroid and banded facies; a gabbro-amphibolite which forms with small metasediments series, isolated and infrakilometrics septa and corridors consistent with the regional foliation. Locally, country rocks are affected by partial melting, resulting in the occurrence of garnets gneiss isolated bodies.
Pegmatites occur as metric wide bulging dykes in the leucogranite (K-feldspar, albite, plagioclase, more or less biotite and rare apatite) or as larger dykes until 15 m wide in the granodiorite (muscovite-garnet type). This second type is mainly composed of K-felspar, albite, plagioclase, quartz, muscovite, biotite, tourmaline, apatite and spessartite-almandine garnets. Zircon, monazite, xenotime, columbite and Zr, U-Th-REE species (thorite, pyrochlore, rhabdophane) are the accessory minerals. These pegmatites show a regional zonation of tourmaline, apatite, and muscovite relatively to biotite.
The origin of the melt that has crystallized in pegmatites is yet undefined. Even if we notice a physical proximity of pegmatites with anatectic facies (apatite-bearing leucosomes in granodiorite, and garnet-gneiss occurrences), the absence of a vast metasedimentary domain, and the geological context dominated by granitoid formations are not easily compatible with a direct anatectic origin. The lack of knowledge on geochemical profile of the leucogranite does not allow to establish a link with the probable mineralization of niobium. The comprehension of the setting up of these pegmatites will need an investigation on the geochemical nature of the different pegmatitic, granitic, amphibolitic and gneissic facies. More generally, it brings us to the question of the origin of TTG-gneiss of the WAC.
Keywords: *pegmatite, rare metals, mineralization, columbite, West African Craton*

Contribution of the static and chemical study of waters: case of great SebkhaBasin,Oran

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Oran is relatively a city with the worst quality of the waters. Recently, the growing populations may put stress on natural waters by impairing their quality. Unfortunately, certain stretches of the watershed are polluted. It has scarce physico-chemical data on its water resources that could assist in making robust decision in mitigating the impact of human societies on natural waters. This may not only preserve natural areas, but improve the quality of life of the growing population. In an attempt to study the environmental impact on water quality, an investigation was carried out to monitor the water quality over a period from 04 to 20 July 2011. So fifty samples were collected and analyzed.
The physico-chemical study of such samples were consistent with previous studies addressed in this area.

Higher values of the physico-chemical parameters of water obtained in the present study sites indicate that the results obtained fell within the maximum allowable limit set by the World Health Organization for drinking water.

***Keywords**: Sebkha, water, quality, physico-chemical parameters, static.*

Rating quantitative and mapping of landslides in Ouenza quarry, Algeria

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The exploitation of iron ore deposit of Ouenza runs into serious difficulties related to landslides. Among the most important events of sliding, we have those of the Zerga site including lands located above the ore body "north" of Zerga. The overall area of the landslide is 40,000 m^2. Land instabilities are also manifested in other mine workings, thereby destroying the natural and economic resources. Thus, issues of prevention are needed to secure the quarry staff and preserve the resources and assets. Our goal is to determine the stability parameters of the quarry to allow the extraction of ore in good working conditions. This allows us to have a topographic map that puts us in the problem and gives us valuable information to guide us in our work to avoid the slip.

***Keywords:** Operation, landslide, safety, preservation, stability, quarry, pore pressure*

Cartography, lithostratigraphy and structure of the Neoproterozoic formations of the Ouansimi inlier and their Neoproterozoic to the Lower Cambrian cover (western Anti-Atlas, Morocco)

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The geological investigations in the Ouansimi inlier allowed the realization of a 1/10,000 geological map, the development of the lithostratigraphy as well as the identification of the geometrical characteristics of the regional structuring. The results of this study can be summarized as follows:

1- The demonstration of the "lie-de-vin" series which represents a benchmark level separating the lower limestones of late Neoproterozoic (Adoudounian) and the upper limestones of the lower Cambrian (Ediacarian).

2- The structural analysis allowed identifying different styles of folding: (i) plurikilometric folds of NE-SW orientation, with the exception of the Taourirt syncline oriented E-W, due to

its framing by two dextral strike-slip faults: WNW and NE-SW faulting northward and southward, respectively; (ii) Disharmonic folds related to the detachment level of the "lie-de-vin" series; (iii) A style of folding in a staircase which, in the Ouansini mine, developed from surface to depth.
3- The proposal of a tectonic events chronology: (i) synchronous wrinkling of a fracture in the extrados of folds. This phenomenon is identified only in the Azrou area; (ii) an opening of tension gashes of the same orientation as the NW-SE stress responsible for folding. Mineralization is confined in these tension gashes (quartz gangue with dissemination of cupriferous levels); (iii) a brittle tectonic which, depending on the orientation of the lineaments, can generate either dextral or NW vertex overlaps.
These three phases are controlled by the same main stress oriented SE-NW. A reorientation of the stress to the N-S direction has reactivated the NE-SW dextral in sinistral movements and the E-W dextral into reverse faults with south vergence.
Keywords: *Cartography, lithostratigraphy, structural, Ouansimi area, District Mining of Ouansimi, western part of Anti-Atlas, Morocco.*

Irbiben granite (West Anti-Atlas, Morocco), witness of an episode of convergence between oceanic lithosphere northward and West African Craton southward

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The Irbiben deposit, formerly mined for its gold, belongs to Tagragra of Akka inlier. It is located in the western Anti-Atlas, about 260 km south-east of Agadir. South of this deposit is the granite massif, object of this study. The methodology is summarized in macroscopic and microscopic petrographic study and geochemical study. This latter, made from geochemical diagrams, is based on the results of geochemical analyses in major and trace elements. This work shows that it is porphyroid-grained texture granite, composed of quartz, plagioclase phenocrysts, alkaline feldspars sometimes with centimetric size and sulphides. Two generations of quartz have been identified, quartz Q1 with rolling extinction testifying an episode of deformation in the inlier and quartz Q2, witnessing of an intense silicification. Plagioclases and alkaline feldspars are profoundly altered in sericite and epidote. Geochemical analysis showed that it is a calc-alkaline granite rich in potassium, peraluminous, of crustal origin. Its geochemical arc signature, Ba enrichment, as well as negative anomalies in Nb, Ti, and P are typical features of magmas from subduction zones. This subduction would come from an episode of convergence between an oceanic lithosphere located to the north and the West African Craton to the south.
Keywords *: Irbiben granite, west Anti-Atlas, petro-geochemistry, arc signature, subduction zone.*

Nkob Talc deposit (Siroua inlier, central Anti-Atlas, Morocco): Litho-structural and petrographic characterizations

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The Nkob Talc deposit, situated in the central Anti-Atlas (Morocco), is hosted by the Tonian Taghdout group. This latter corresponds to the break-up and rifting of the northern margin of the West African Craton (WAC) which led to the formation of a passive margin sequence. Rifting culminated with the creation of an oceanic crust between the northern edge of the WAC in the south, and an unknown terrane in the north (Ennih et *al*., 2001, Thomas et *al*., 2004). The Nkob massif consists of an allochthonous ophiolite sequence witness of the oceanic crust (El Boukhari, 1991).

The data collected during the various field missions, compiled to the existing data, allow us to realize a detailed geological map of the study area, and to define the various facies in contact with the talc deposit. Within the deposit, there is an alternation of discontinuous, decametric to metric beds of dolomites recrystallized into marble (blackish to greenish rock, with fine grains and heteroblastic texture, dominated by dolomite and calcite) and white talc, chloritite beds and mafic doleritic lavas. Towards the west of the talc deposit, the serpentine concentration is very high (Chrysotile).

The structural study of the area shows that the formations have an average orientation of ENE-WSW, and are affected by an apparent schistosity averagely oriented N100, moderately or strongly deeping towards the north. All these formations are associated to a NW-SE, NE-SW, and E-Wfaults system.

The rocks in the study area were affected by a regional metamorphism that is characterized by mineral assemblages: “quartz, biotite, muscovite, sericite and ilmenite” in the pelitic rocks; “serpentine + talc + chlorite” in the carbonated rocks; “hornblende, plagioclase, ±epidote, ± opaques” in the mafic rocks. These paragenesis indicate greenschist to amphibolite facies conditions. The analysis of the blastesis-deformation relationship shows that the micas, the andalusites and the cordierites are syn- and late- kinematic. The thermo-barometry conditions were estimated between 450 and 500°C and 4 to 5 kbar which increase towards the west of the study area, reaching a temperature higher than 650°C (El Boukhari, 1991). The regional metamorphism is followed by a contact metamorphism related to the emplacement of the Amassine granite. It is characterized by mineral assemblages “biotite + muscovite + cordierite + andalusites” in the metapelites and "serpentine + talc + chlorite" in the carbonated rocks.

Talc are spatially and microscopically associated with carbonate rocks. Talc-carbonate rocks consist of an assemblage “talc ± dolomite ± serpentine ± calcite”. The hydrothermally altered dolomites are successively transformed into serpentine and talc, with late calcite veins that clearly cross the carbonated/serpentinized rocks.

Field relations and assemblage minerals in the talc deposit of Nkob allow us to propose a magnesian sedimentary origin of the parent rock, dolomites, that have been transformed

into marble, talc and serpentine during the contact metamorphism and hydrothermalism related to the Amassine granite emplacement. The transformation of dolomites into talc minerals was carried out by the addition of silica from granite and magnesium from dolomites. The geochemical analyses, which are in progress, will allow confirming the sedimentary origin of talc genesis.

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Preliminary geological data for the Etéké-Gabon deposits

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Etéké is a town located in the province of Ngounié, department of Ougoulou in southern Gabon. It is located in a mountainous area that contains deposits and numerous gold-bearing indices. In this area of Etéké is mainly exposed granitoids and amphibolites, whereas the volcano-sedimentary formations are very small.

The gold mineralization discovered so far, is aligned NE-SW parallel to the direction of the green rocks of Etéké. The deposits where the mining activity has not yet started are classified into three distinct and different age groups:

- Archean mineralization is strictly related to greenstone belts and can overflow as fragments enclosed in granitic terrain. These belts are made up of ultramafic volcanic rocks with felsic metamorphosed into green rocks and gneisses and more or less associated with sedimentary deposits.
- The deposits associated with the sediments and volcanic rocks of the Paleoproterozoic are affected by the Ogooue orogen; similar to the Archean lands,
- The mineralization in the upper Neoproterozoic sedimentary rocks is deformed by Panafrican orogeny.

The highest economic grade mineralization in Etéké is associated with the Eburnean cycle. Alluvial gold production in this zone is the largest in Gabon.

Five primary deposits have been recognized in the region of Etéké:

- Dondo-Mobi: Prospect embedded in the ultramafic rocks of the Etéké Group, located between the bedding plane and the staggered micaschists of the Ogooué Supergroup.
- Dango: the enclosing bearer of the deposit of Dango is formed by sedimentary rocks of the Massima Supergroup. The lithological terms are represented by black muscovite-chlorite schists and recrystallized jasper of massive or banded quartzites.

- Ovala: lodge located in a Palaeoproterozoic syncline wedged between two domes of remobilized Archean migmatites. This synclinal filling is formed by sediments and lavas of the Eteké Group, the Massima and Ogooué Supergroups.
- Massima: deposit encased in the green rocks of the parautochtonous outsole of the Ogooué Front. It is strongly straightened, folded and chipped with a NNE steering. The volcanic rocks are affected by a carbonization, chloritisation and more or less intense hydrothermal pyritization.
- Moukanda: the mineralization is encased in the belts of green rocks which are bordered by the Bapindji granites in the west and by the granites of the Chaillu massif.

Thedistribution of the CentralIapetusMagmaticProvince (CIMP) into West African craton: U-Pb dating, geochemistry and petrology of Douar Eç-çour and Imiter mafic Dyke Swarms (High and Anti-Atlas, Morocco)

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The 615-540 Ma Central Iapetus Magmatic Province (CIMP) was emplaced in multiple pulses during Ediacaran-Cambrian times, and has been linked to the disruption of the Rodinia supercontinent leading to the opening of the Central Iapetus Ocean. It is well represented in Laurentia and Baltica but also present on other formerly attached blocks such as the Congo Craton, the West African Craton (WAC) and Amazonia.In northwest Africa (Morocco), the CIMP occurrences are found particularly in the High and Anti-Atlas of Morocco, as the 600-541 volcano-sedimentary sequences of the Ouarzazate Supergroup (i.e. "XIII" or PIII of Choubert et al., 1963) that covered ca. 2 x 10^6 km^2 with an estimated magma volume of ca. 1 x 10^6 km^3 and volcanic thicknesses greater than 3000 m. It also occurs as dyke swarms and

sill complexes that are the plumbing systems of the Ouarzazate Large Igneous Province. Two CIMP related Ediacaran dolerite dyke swarms cut the Precambrian basement of the Ouzellagh promontory in the High Atlas and the Jebel Saghro massif in the Anti-Atlas: 1) the NNE, NE to ENE-trending Douar Eç-çour mafic dyke swarm and 2) the NE-trending Imiter swarm. The Douar Eç-çour dykes have an approximate zircon/apatite/rutile U-Pb dating age as 554 ± 6 Ma. These Imiter dykes show co-mingling magmatic textures with the Askaoun granodiorite of the Assarag suite dated at 579± 7 Ma (U-Pb zircon, Chevalier et al., 2001).The Imiter dykes yield a crystallization age of 578.8 ± 3.8 Ma (MSWD C+E = 1.3, n = 31; upper intercept age 581 ± 10 Ma; MSWD = 0.83) and have geochemical characteristics of continental tholeiites. Possible equivalents are the continental flood basaltic (CFB) lava flows of the second eruptive cycle of the Ouarzazate Supergroup. The world-class Imiter epithermal vein silver deposits are genetically associated with 550 ± 3 Ma rhyolites, and therefore may also be linked to the CIMP event. The Imiter dyke correspond to the northern extension of the Great Foum Zguid dyke which was recently dated at 201.111 ± 0.071 Ma (U-Pb on zircon; Davies et al., 2017) near Foum Zguid town and at 208.6 ± 3.7 Ma in the Bou Azzer El Graara inlier (this work). So the Foum Zguid belongs to the 201 Ma Central Atlantic Magmatic Province (CAMP) event and is unrelated to the c. 581 Ma Imiter dyke. Geochemically, the c. 581 Ma Imiter dykes were generated in an intraplate setting, and thec. 279-554 Ma Douar Eç-çour dykes have three compositional groups calc-alkaline, tholeiitic and alkaline. We interpret these Douar Eç-çour geochemical groups to represent three distinct pulses that are likely the plumbing system ("feeder dykes") of the Ouarzazate supergroup volcanic pile since the three dyke compositions match the three successive eruptive cycles (synextensional calc-alkaline, tholeiitic CFB and alkaline) of the Ouarzazate Supergroup. The studied dolerite dyke swarms have formed during the fragmentation of Rodina (Pannotia) leading to the opening of the Central Iapetus Ocean and therefore are compared to similar-age, rift-related extrusive/intrusive rocks found in the Siroua Window, Jebel Saghro Massif, Ougnat Inlier and other inliers of the Anti-Atlas. The dykes provide a window into the late Ediacaran mantle, and also shed light on early magmatic processes accompanying the breakup of the WAC region. Links between the CIMP and the Gaskiers glaciation and the Cambrian Bioradiation are proposed: 1) the c. 580 Ma CIMP pulse (mainly silicic) helped trigger a Volcanic Winter and subsequent Snowball Earth conditions ("Icehouse"), i.e. the Gaskiers glaciation. 2) the subsequent c. 570 Ma flood basalt CIMP pulse helped trigger a "Volcanic Summer" and succeeding global warming conditions ("Greenhouse") that ended the ice age and contributed to consequent expansion and diversification of the life on Earth, i.e. the Cambrian Bioradiation.

Evaluation of the degree of metal pollution in the waters and sediments of the Sidi Hsayen Dam (Morocco)

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In the last decades, more and more attention has been devoted to the investigation of heavy metals pollution in the environment, due to the increasing anthropogenic contribution to the natural sources of heavy metals in the environment.
The presence of heavy metals in water and sediment samples is due to a variety of chemical, biological and physical effects: they can be introduced as dissolved or particulate matter, whatever they are due to natural processes (river flow fluctuations, water drainage, runoff from river banks, leaching of bed rocks) or to the anthropogenic contribution (industries discharging into rivers, urban wastes). The examination of the spatial differences of the heavy metals content of water and sediments allows the identification of the presence of anthropogenic effects, possible sources of contamination and effects due to the transport of pollutants from other areas.
In this work, we report and discuss results of distribution of major and trace elements in water and sediment samples collected from Sidi Hsayen Dam in the region of Tanger (Morocco)using different methods. The methodology undertaken during this work is based on:
(i) monitoring of measurements of physico-chemical parameters of water;
(ii) identification of as many metallic elements from neutron activation analyzes;
(iii) standardization of the elements obtained in relation to the upper continental crust;
(iv) processing of the database by principal component analysis (PCA).

Keywords: *Sediments, heavy metals, Sidi Hsayen Dam, neutron activation analyses, principal component analysis, physico-chemical parameters.*

Post-Variscan magmatism of Tighza: mapping and structural study of the Anjdam magmatic complex (south zone of Tighza district, eastern part of central Meseta, Morocco)

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The Magmatism of Tighza Mining District (TMD), as other districts of central Meseta (Zaer, Ment, Oulmès), is essentially Hercynian. This magmatism consists mostly of granitic intrusions cross-cutting the Paleozoic formations in the form of apophyses, and several veins and magmatic dykes.
The Anjdam area is located in the south of the TMD in the eastern part of the CentralHercynianMountains, at the limit of the thrust nappe zone. The Palaeozoic terrains ranging from the Upper Ordovician to the Middle Devonian show a clear diversity, presenting a geometry, in nappes and thrusts with an E to S-E vergence, following a NE-SW trend. The lithostratigraphic study of the different deposits of this area, shows a variation in the depth of depositional environment. It draws an evolution from deep, to turbiditic, and

then to shallow deposits. Furthermore, the eastern sector is marked by a well recorded synsedimentary tectonics during the Paleozoic.
The petrographic study of the magmatic complexes of the Anjdam sector, suggests the identification of three areas with three dominant facies: i) in the northern half: microgranite, ii) in the southern half: microdiorite to microgranodiorite and iii) in the western border: micromonzogranite.
The Palaeozoic terrains are entirely folded, schistosed, then deformed by polyphase brittle tectonics (dominant structural directions are NE-SW and E-W to ENE-WSW) which spreads from the paroxysmal phase, driven by a dextral movement, to late-Hercynian marked by a sinistral movement, related to a stress relaxation which probably guided the emplacement of the microgranites.
Keywords: *Cartography, lithostratigraphy, petrography, structural, Anjdam area, Tighza Mining District, eastern part of central Meseta, Morocco.*

Late orogenic evolution of the Leo/Man shield: a reconstitution using fabrics of granitic plutons

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Granite is the best marker of crustal deformation (Lagarde, 1989; Gleizes, 1992;Bouchez, 1997). Nevertheless in many cases, it is difficult to access to internal fabrics of plutons directly on the field. In this study the technique of anisotropy of magnetic susceptibility (AMS) have been used to highlight fabrics of some plutons of Burkina Faso (Tenkodogo-Yamba, Wayen, Déou, Arbinda,...). The petrographic and geochemical characteristics of these plutons are different, ranging from calk-alkaline to alkaline compositions. Their ages range from 2128 $\pm$ 4 Ma (U/Pb on zircon) for Kouaré calk-alkaline granite to 1889 $\pm$ 27 Ma (K/Ar) for the Wayensyenite (Castaing et al., 2003). The internal structures of these plutons compared to those of their country rocks have allowed to propose different models of emplacement that include diapirism and emplacement along discontinuities created by regional transcurrent shearing.

The main conclusion that can be drawn is that the Eburnean tectonics remained active until the emplacement of the later plutons like the Wayensyenite.
These results show that the best comprehension of the geodynamic of the West African Craton during the Paleoproterozoic needs a best investigation of the internal structures of different plutons of different ages.

Keywords: West African Craton, Paleoproterozoic, geodynamic, fabrics, AMS, granite plutons

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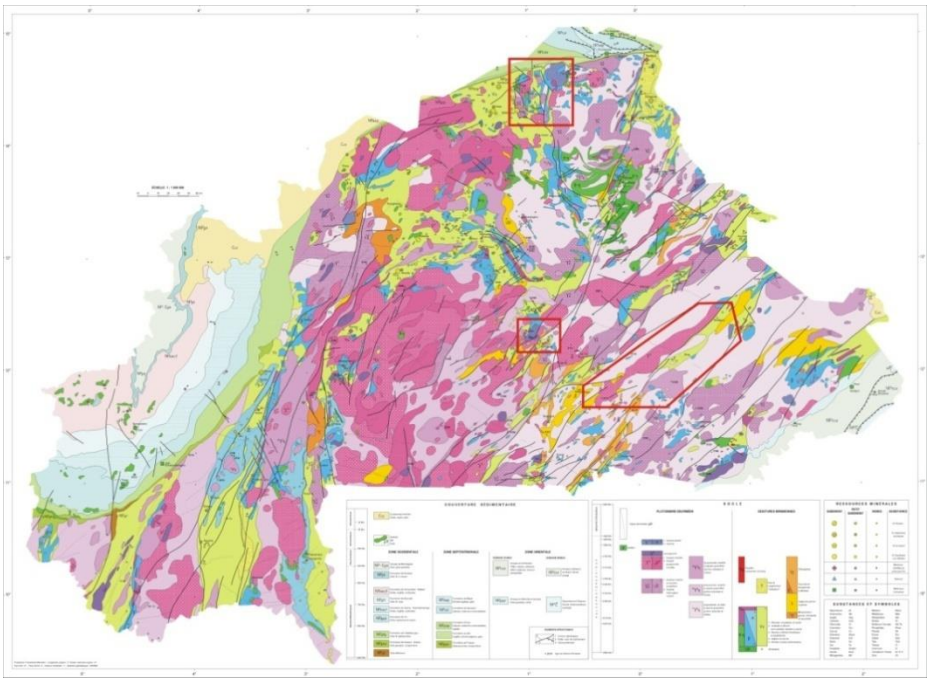

Positions of investigated areas (red framed) on the geological map of Burkina Faso (Castaing et al., 2003)

Architecture of transpressional shear zone systems in the Mako Belt (SE-Senegal): implication for gold mineralization

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The Mako Belt is a segment of a Paleoproterozoic accretionary belt that developed on the western margin of the West African Craton. It is represented by a series of volcanic, volcanosedimentary, sedimentary and igneous assemblages, which belong to the Kedougou-Kenieba Inlier (KKI) of the western Eburnean orogen. This belt is dominantly characterized by folded low grade metamorphic rocks and preserves a polyphase deformation history that is intimately associated with orogeny-parallel sinistraltranspressive shear and emplacement of various granitic and mafic intrusions. Major linear fault such as the MTZ also approximates a north-easterly trend form the eastern boundaries.Transpressional deformation focussed the wrench component along these pre-existing major tectonic boundary.The Mako Belt hosts several orogenic gold occurrences. Two main gold corridors are distinguished and includeSabadala-Niakafiry-Sofia, and Massawa-Deliya-Mandinka. In the Sabodala area, gold occurrences are aligned along the major Sabodala fault and the gold occurs within a complex

wrench dominated, sinistral fault array and associated veins and alteration haloes. The development of this brittle to ductile oblique wrench fault system was associated with the majority of gold mineralization in the Mako Belt. The wrench-dominated transpression strain during D_3-phase, accommodated by the major structures and subsidiary fault zones, is well documented by the geometry and pattern of the associated mesoscale deformation. Structural data confirm that the D_3-deformation postdates the emplacement of late granitic suite (Saraya, Mamakono, Boboti, etc.) and mafic dykes.As with other districts, there is also local evidence of changes in kinematics from dominantly strike slip to more constrictional strain with associated vertical stretching and reverse displacement along mineralized structures, characteristic of progressive strain accommodation during transpressional deformation.

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 syn-kinematic genesis of goldattributed to D_3-wrench dominated transpression throughout the Eburnean evolution.

***Keywords**: Mako Belt, Birimian, transpression, gold mineralization, wrenching.*

Petrographic and geochemical characterization of the Archean fine granitoid: example of the Bakoudou gold deposit in Gabon

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Gabon is a country in central Africa whose geological history is part of the geological context of the African continent. The lands found throughout the country show a great geological diversity which is reflected in formations whose ages range from the Archean to the recent Cenozoic and which contain important natural resources such as Bakoudougold and Comilog manganesedeposits, located in the southeast of the country at the level of the ChailluArchean massif which is an extension of the Congo Craton. The Bakoudou gold deposit, owned by the Moroccan mining group MANAGEM since 2005-2006, is enclosed in Archean finite granitoid (2.7-2.5 Ga) (Cahen et al., 1984).

Macroscopically, these granitoids have a grainy texture and mostly appear dark to clear gray. Visible minerals include quartz, potassium feldspars and ferromagnesian minerals. Some samples show a pinkish color, indicative of altered feldspars. The various minerals observed on a microscopic scale are amphibole (more precisely green hornblende), biotite, feldspar plagioclase (anorthite-intermediate-albite, microcline), orthoclase (orthosis) and apatite. There are also some altered minerals such as chlorite, sericite, muscovite and epidote. Geochemically, these Bakoudougranitoids belong to a highly potassiccalc-alkaline series. The petrographic and geochemical characterization of these granitoids revealed three main facies hosting the mineralization, namely: granites, granodiorites and quartz diorites.

The results obtained, through metallogenic analysis, show that the quartz veins comprise quartz as the main mineral. Then come the gold mineralization, and the sulfides that are included in the quartz or in the muscovite biotite relics contained in the geodes and

fractures filled by the quartz. The presence of a cataclase zone undergone by these quartz veins would have resulted in a recrystallization of the small quartz grains (2nd generation) and created openings allowing the emplacement and/or redistribution of sulfides, gold and calcite. All these results, as well as the presence of gold and sulfides in the biotite relics contained in the quartz, suggest that placing gold within the quartz veins is the result of the circulation of fluids in cracks generated by intense tectonics. The association of sulfides, gold biotite relics and calcite, confirmed that the mineralization phase is genetically linked to a hydrothermal process that affects the rock host. These are epigenetic mineralization poor in sulfides.

Keywords: *Gabon, granitoid, Bakoudou gold deposit, associated mineralization.*

Lithospheric thickness and principal crustal lineaments of southern Algeria: attempt to locate diamondiferous magmatic primary sources

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In Algeria, more than 1500 alluvialdiamonds were found;however in the absence of evidence of the primary source, their provenance remains enigmatic.This study aims to test a model of detection of potentially fertile areas in diamondiferous kimberlites defined by Faure et al.(2004) for the North American Craton. They are: (i) cold and thick lithosphere (175-275 km), (ii) steep slope, (iii) abrupt direction change in mantle morphology.

Thus, several works on geometry and thickness of African lithosphere are obtained thanks to gravity anomalies derived mainly from satellite data, or by regional scale seismic tomography. We compared the results of Faure et al. (2004) with some other models, such those of Artemieva and Mooney (2001) or Artemieva (2006) and Braitenberg (2014), showing the thickness of the lithosphere under the West African Craton (WAC) and the neighbouring south Algerian regions.

Compiling the different results allowed us to identify the areas that best match the geologic conditions and models previously mentioned. In addition, mapping of the most important south Algerian crustal lineaments obtained by inversion of aeromagnetic and gravity data, shows that the large lithospheric faults are within the range of targeted regions.

Most lithospheric thickness models defined for the WACshowthat southern Algeria filled the three main conditions established by Faure's model.For example, this study reveals many favourable zones, such as the southern part of Touat region, which gathers all the conditions to be the seat of a deep magmatic activity which may produce diamondiferous rocks.

In addition, the kimberlites are often associated with structural trans-lithospheric corridors (Jelsma, 2009), which is also considered as a condition leading to ascent of diamonds to the surface (Kaminsky, 1992). So, we mapped the most important southwest Algerian crustal lineaments by inversion of aeromagnetic and gravity data. The results show the presence of large lithospheric faults in the targeted regions.

The region hosts numerous mafic dyke swarms. We mapped them using various datasets such as full resolution Google Earth™ images, multispectral Landsat 8 Operational Land

Imager (OLI) and aeromagnetic data. The spectral response of Landsat Oli 8 allowed the discrimination of the felsic and the potentially diamondiferous mafic dykes. A statistical analysis helped to establish a distribution dykes map which reveals a central concentration of mafic dykes trending N-S and NW-SE, the NE-SW trend comprises a second order orientation with a smaller size.
In addition to confirm the possibility of getting diamondiferous primary sources in southern Algeria, we believe that these preliminary results will also help in the choice of areas to be further explored.**References**

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Post-Variscan vertical movements of the Anti-Atlas Belt (Morocco): Synthesis of the low-temperature thermochronological data

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The northern margin of the West African Craton (WAC) is a mobile zone affected by numerous geodynamic episodes: Pan-African, Variscanand Alpine orogenies. These orogenic phenomenadominantly horizontal are followed by more discreet vertical movements, the restitution of which is often problematic.
The Anti-Atlas Belt occupies a critical position at the northern edge of the WAC. Surprisingly, this ancientVariscan foldbelt is characterized by a relatively high and rough relief with several peaks up to 2000-2500 m above sea level.
Some key points that can help us to better understand the post-Variscan geodynamic evolution of this area and the vertical movements responsible for its high relief have been enlightened using low-temperaturethermochronology.
In this abstract we present a synthesis of low-temperature thermochronology data (fission-track and U-Th/He) obtained over the past decadeby different groups in the different parts

of the Anti-Atlas (Malusà et al., 2007; Missenard et al., 2008; Balestrieri et al., 2009; Ghorbal, 2009; Sebti et al., 2009; Ruiz et al., 2011; Sebti, 2011; Oukassou et al., 2013;Oukassou, 2013; Sehrt, 2014;Gouiza et al., 2016).

The belt, which has for long been interpreted asthe external fold belt of the Variscan orogen is now revealed to have experienced major vertical movements through Mesozoic and Cenozoic times. Thereby, the Anti-Atlas domain appears to be affected by two episodes of exhumation separated by an episode of subsidence. The initial episode began in the Late Triassic and led to the exhumation of 7.5-10.5 km crustal basement by the end of the Middle Jurassic. The following phase resulted in 1-3 km of basement subsidence and occurred during the Late Jurassic and most of the Early Cretaceous.

The basement rocks were then slowly brought to the surface after experiencing 2-3.5 km of exhumation throughout the Late Cretaceous and the Cenozoic.

The timing of these episodes of exhumation and subsidence coincides with major tectonic (reactivation of the Variscan structures) and thermal events (regional mantle anomaly) in relation with the evolution of the Atlantic and Tethys Oceans, indicating that the effects of their rifting and drifting extended beyond their presumed margins.

***Keywords**: Thermochronology, exhumation, vertical movements, fission-track, U-Th/He, Anti-Atlas, Morocco.*

Contribution of remote sensing for geological study of the southeast of Constantine Basin, Algeria

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The main objectives of this work are to map and characterize thefracturenetworksdeveloped in major carbonated deposits ofsoutheast Constantine Basin. It is a contribution to a better knowledge of the geometry of existing surface fracture networks and their extension at subsurface. To achieve this goal, the tools of remote sensing and seismic data were used.

Using remote sensing data, our study enabled us to draw up a lineament map, along with tectonic analysis, where we could draw up a list of 409 lineaments. Such lineaments are divided into 9 classes according to their directions, among whichthe main directions of the NW-SE fracture network are: H (N1300-N1500), G (N1100-N1300) and F (N900-N1100).

These three classes are in agreement with the major faults recognizedin the region, e.g.the Biskra-Outaya, Ouinet-Morsott-Tebessafaultsand the dextral shears.

After the deferential work carried out on the southeastConstantine area, and the results obtained by seismic reflection, as well as the well log data, summarizethat our reservoirs are characterized by a mainly low to medium porosity and low permeability.These carbonated reservoirs are affected by the majority of vulnerabilities detected at surface, but do not contribute to the improvement of the petrophysical characteristics. This can be reported to the clogging of the cracks.

***Keywords:** Algeria, southeast Constantine Basin, remote sensing,fracture network,carbonate reservoirs,petrophysical characteristics*

The geological heritage of the OuedAkrecharea (northwestern part of Morocco): inventory and geotourism

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Geologically, the OuedAkrecharea (Rabat-Tiflet, northwestern part of Morocco) belongs both to southern part of Sehoul exotic Bloc (mainly middle Cambrian metamorphosed quartzo-phyllites) and the north western (unmetamorphosed) moroccanMeseta attached by a strike slip/thrust southward fault where are aligned numerous lenses of upper Devonian deformed granites and "andalusitic" mica-schists.
Diversity, richness and scientific knowledge of the geosites from OuedAkrech are very important. Ranging from the Upper Precambrian to recent Quaternary, the OuedAkrecharea hascontainsmany geosites with a high scientific, educational and touristic value.These geosites display excellent outcrops of various sedimentary, tectonic, magmatic, paleontological, geomorphological phenomena… Some of those geosites are unique, for example: (i) The remains of the Upper Neoproterozoic granitic northern moroccan substratum, (ii) the amphibolites of Rabat (Rheic ocean relicts?), (iii) the Lower Ordovician Pillow lava, (iv)the Lower Viseanundeformedfluviatil red conglomerates, (v) several examples of Tournaisian-Visean debris flows, (vi) the Tortonian/MessinianOuedAkrech GSSP stratotype,(vii) coastal consolidated Quaternary sand dunes structures,...
Pertinent geosites should be conserved, but before that, we need start the inventory process. The preservation and assessment of geosites can be a lever for the geotourism development of the region.
***Keywords** : Oued Akrech area, geologicalgeosites, inventory.*

A synkinematic pluton emplacement along a major shear zone revealed by AMS study, northern Burkina Faso (West Africa)

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Anisotropy of magnetic susceptibility (AMS) study were successfully applied on the granitic pluton of Bousse (GPB), located in the north of Burkina Faso, within Djibo greenstone belt. AMS study were combined with microstructure analyses, airborne geophysics, geochemistryand field observations in order to ensure the complete cartography of the pluton and its host rocks. The main goal of the study is the understanding of the granitic

pluton emplacement mechanisms in relationship with the major shear zone of Djibo-Arbinda (DASZ).
The study allows the following results:
(i) The GPB is a small elliptical body elongate N-S with 10kmlength and 4km width for an area of 35 km^2. It is an I-type granite of syn-collisional granite geodynamic context. It is hosted byamphibolite on its western side and by a biotite bearing gneiss on its other borders.The whole pluton is surrounded by the Djibo-Arbinda regional shear zone (Fig. 1a).
(ii)Spatial distributions of the magnetic scalar data show zoningsin magnetic susceptibilities (K_m), shape parameters (T) and anisotropy degrees (P%) (Fig. 1b,c,d).
(iii)Magnetic foliations and lineations are well organized alongside the DASZ (Fig. 1a,e,f).
(iv)Microstructures are mainly of submagmatic state and high temperature microstructures. The contacts with the DASZ are characterized by mylonitic microstructures.
A 3D model resulting from the whole interpretation allows us to conclude that the GPBhad a synkinematic emplacement, following a “pull apart” system with the sinistral DASZ.

Keywords: *Bousse, magnetic susceptibility, microstructures, shear zone.*

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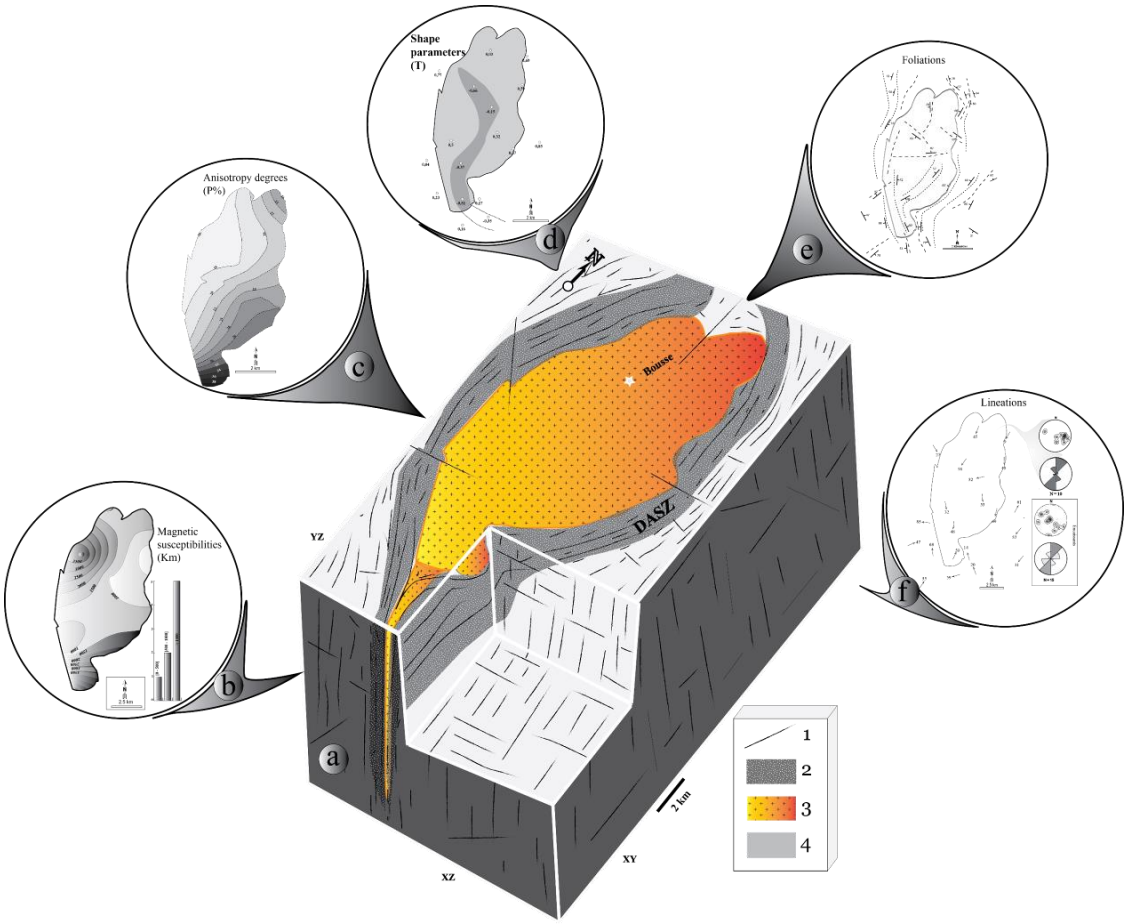

Figure 1 : 3D model of the granitic pluton of Bousse and its host rocks showing relations with Djibo-Arbinda shear zone (DASZ). 1: macrostructures; 2: DASZ ; 3 : granite ; 4:host rocks. (a) 3D block model; (b) magnetic susceptibilities (K_m); (c) anisotropy degrees (P%); (d) shape parameters (T); (e)magnetic foliations and macrostructures; (f) magnetic lineations.

Petrological and mineralogical characteristics of pyroxenites, hornblendite and websterite xenoliths from the JbelSaghro Volcanic Field (eastern Anti-Atlas, Morocco)

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The heterogeneous suite of mantle and crustal xenoliths sampled by the nephelinites from the Saghro area (Anti-Atlas, Morocco) could be divided into three groups: a) spinel-bearing websterites, b) pyroxenites, and c) hornblendites. The websterites (size<3cm), the pyroxenites and hornblendites (4 cm<size<8 cm) could be observed in a same lava flow. Representative samples from those 3 groups have been selected for a systematic petrological and mineralogical study in order to constrain their origin and history. The petrographic and mineralogical features of the investigated upper mantle and crustal xenoliths evidence that: a) websterites contain olivine (89<Mg#<91), orthopyroxene (90<Mg#<91), clinopyroxene (89<Mg#<89) and spinel (74<Mg#<75) with adcumulate textures; b) pyroxenites contain clinopyroxene (63<Mg#<83), phlogopite (66<Mg#<78), kaersutite (63<Mg#<82), titanomagnetite, pyrochlore and rarely olivine (84<Mg#<87) with adcumulate or orthocumulate textures; c) hornblendites contain hornblende (71<Mg#<74), clinopyroxene (43<Mg#<56), biotite (76<Mg#<77) and rarely titanomagnetite. Temperature estimates for websterites xenoliths using the Brey and Kohler (1990) thermometer applied on orthopyroxene, at a fixed pressure of 15 kbars yield temperature ranging from 900 to 993°C.For pyroxenites and hornblendites, we applied the geobarometer of Schmidt (1992) and deduced pressure equilibration ranging from 9 to 10 kbars for the pyroxenites and from 8-8.5 kbars for the hornblendites. Those PT estimates evidence that the three types of xenoliths were probably sampled at different levels of the lithosphere: websterites (upper mantle), pyroxenites (crust-mantle boundary), hornblendites (crust). The websterites probably represent channels of focused melt percolation within upper mantle lherzolite wall rocks while the pyroxenites and hornblendites are cumulative magmatic rocks with alkaline affinities.

***Keywords**: Texture, mineral chemistry, nephelinites, xenoliths, upper mantle, Saghro.*

Granite pebbles in the Lower Devonian conglomerate of ImouzzerKandar (Northwestern Middle Atlas, Morocco): New U–Pb ages and geochemistry

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Lower Devonian conglomerate (more than 100 mthick) of Tournaisian/lower Viseanolistolite of ImouzzerKandarinilier (Northwestern Middle Atlas, Morocco)is generally polygenic, in spite of a microconglomatic tendency towards the summit where the pudding is impoverished in cobbles and passes to coarse microconglomatic and grauwacky sandstones. The cement is of lithic grauwackeuse type with microconglomératic. We can distinguish mainly pebbles of sedimentary rocks and pebbles of volcano-clastites and magmatic rocks (Charrière, 1991). These include: quartzite, sandstone and microconglomerate pebbles, schist pebbles (sometimes with cleavage or low schistosity), argillites and black siliceous rocks (reminiscent of Silurian rocks), pebbles of ignimbrites, volcanic tuffs, and pebbles of granitoid. It is these latter pebbles that have been the subject of the isotopic and geochemical analyzes of this work.

Petrographical and geochemical studies of granitic pebbles in the Devonian poudingue of Imouzzer Kandar inlier allow classifying these rocks asperaluminous and highly potassic calc-alkaline. They also shear manysimilarities with active margin rocks. They are rich in high field strength elements and display anomalies in Ta-Nb.

New U-PbSHRIMP analysis on Zircon for some granite pebbles yield ages of Ediacaran (558 ± 10 Ma) to Cambrian (502 ± 4 Ma; 500 ± 6 Ma) or Ordovician (489 ± 5 Ma).

The unknown (don't outcrop) undeformedgranitoidsmassifs (which was not to be far away considering the rounded pebbles of the puddingstone)probably completely eroded and related with Upper Neoproterozoic/Lower Paleozoic Iberian and/or Avalonian (NE Canadian) terranes (granitoids) is proposed as the initial region of the granites and the pebbles derived from them. Indeed, no granitoid massif of these (Cambrian) ages is known at the outcrop in this NW African (Western Moroccan Meseta) part of Gondwana.

Ordovician magmatismwas reported in the eastern part of High Atlas (Pelleter et al., 2017).

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