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Organize

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# Posters





## Geological and Geochemical Controls of Gold Mineralization in the West African Craton: A case study from the Kunche deposit, Wa-Lawra belt, NW Ghana

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The Kunche deposit is one of the largest gold deposits discovered so far in the Wa-Lara Belt in NW Ghana and the eastern edge of the Paleoproterozoic West African Craton. Gold in Kunche is confined within N-NNW trending and steeply dipping DK1 anastomosing shear zone and Type-1 quartz veins. The gold can be inferred to have occurred around 2110- 2105 Ma and the ore body consists of a single lode with a strike length of 1.1 km. The ore zone is characterized by an alteration assemblage of calcite + chlorite + sericites + quartz + sulphides, which occupy an entire width of 20 to 150 m. Gold in the Kunche deposit is associated with arsenopyrite. Two types of gold occurrences have been identified in the Kunche deposit. (1) The invisible gold formed as nanoparticle or solid solution with the crystal lattice of the arsenopyrite and (2) the visible gold formed within the fractures formed in the arsenopyrites or in the quartz veins. SEM imagery on arsenopyrite reveals that the arsenopyrite carrying the gold mineralization was formed via hydrothermal processes. LA-ICP-MS show that the gold in Kunche is associated with trace elements such as Ag, Pb, Cu, and Zn.

**Keywords** - Gold mineralization - Kunche deposit - Wa-Lawra belt - NW Ghana.

## Geological context of Pb-Zn mineralization of the Damagaram Pan-African basement (Southeastern Niger)

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The study area corresponds to the Pan-African province of the Damagaram (Southeastern Niger), which is a part of the Northeastern Benin-Nigerian Shield. The main formations of this Pan-African basement are represented by quartzites, micaschists, schists, gneisses and more or less deformed granitoids (Greigert and Pognet, 1967; Mignon, 1970).

These Pan-African formations are intruded by a set of alkaline granites which ages range from Carboniferous to Permian. These latter are well-known as «Younger Granites» (Moreau, 1982). The Pb-Zn mineralization have been highlighted in microgranites and quartzites, in which they are associated with quartz veins of 1-3 cm thickness and 1 to 10 m long.

The methodology implemented consisted of a field study followed by a polarizing microscope analysis of thin section of the rocks bearing mineralization in Pb-Zn.

The preliminary results of this study show that:

- Lead-Zinc mineralization consist of Zinc oxides and lead sulphides;
- The structural evolution of the study area is marked by two deformation phases. The first one, ductile, is characterized by the formation of rather tight folds associated with the development of a schistosity/foliation sometimes refolded, which is more or less affected by ductile shear zones. The second phase of deformation is brittle. It is marked by the formation of brittle deformation structures such as fractures and strike-slip faults.

**Keywords** - Damagaram - Pan-African - Benin-Nigerian Shield - Pb-Zn mineralization.

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## Characterization of fluorite mineralization in North Hameimat by fluid inclusions and stable isotopes

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The Mineralization of North Hameimat is a link of 1700 m long and 600 m wide, oriented NW-SE. It is located 17 km NNW of the city of Tebessa and 13 km south of Morsott village. The sedimentary lands that outcrop in this massif are of Cretaceous and Triassic ages. They consist mainly of reef limestones and friable marls that are in contact with the multicolored marl of the Triassic formations located on the southern flank of the massif which is characterized by the mineralization of fluorite, barite and galena.

The Triassic formations consist of a chaotic set composed of breccia with dolomite elements, very silicified with sometimes small fragments of eruptive rocks which are probably brought to the surface during the ascent of the diapir.

Mineralization appears mainly in two types: 1) a first type of mineralization with breccia appearance rich in barite, fluorite and incidentally in galena. It is outcropping in the western part of the massif. It is related to the Triassic-cover contact; 2) a second type of vein mineralization outcropping in the eastern part of the massif, in the abnormal contact between the Albo-Aptian and the Vraconian.

The study of fluid inclusions focused on fluorite. Inclusions are essentially two-phase primary inclusions (Aqueous + Vapor). However, the brownish fluorite type in North Hameimat shows two-phase primary inclusions containing (Hydrocarbons + Vapor) and three-phase inclusions (Hydrocarbons + Vapor + Aqueous).

The microthermometric studies carried out on the fluid inclusions contained in the Fluorites shows a ternary system composed mainly of H<sub>2</sub>O-NaCl-CaCl<sub>2</sub>. Homogenization temperature "Th" ranges between 104°C and 152°C with almost the same range of salinity from 20 to 25 wt % eq. NaCl.

Stable isotopes study of O, C and S performed in two samples of calcite galena shows that  $\delta^{13}\text{C}_{\text{‰}}$  vs. VPDB is -1;  $\delta^{18}\text{O}_{\text{‰}}$  vs. VSMOW: 17 and  $\delta^{34}\text{S}_{\text{‰}}$  vs. VCDT: 2.2 to 10 which is in perfect correlation with the results presented recently by Laouar *et al.* (2016) studying Mesloula district: "sulphide and sulphur were likely derived from Triassic sulphates through thermochemical sulphate reduction and residual sulphate in such a system would have been enriched in  $^{34}\text{S}$ ; this is reflected in the barite deposition. The  $\delta^{13}\text{C}$  VPDB values of calcite minerals, indicate an inorganic carbon origin which is the case too for Hameimat North".

The mineralizing fluid would be a hot water high salinity fluid that would have undergone a dilution phenomenon during its evolution. The origin of the mineralization deposition that

replaced the limestone and filled the open spaces was hydrothermal fluids which were conducted by diapir intrusion at the favour of various tectonic accidents.

The genetic model for the emplacement of polymetallic mineralization of North Hameimat is similar to the model of the Mississippi Valley Type Formation (MVT)

**Keywords** - North Hameimat - Stable isotopes - Microthermometry - Fluorite - Diapir Triassic - Mississippi Valley Type.

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## Impact of trace elements on brines: Chotts and Sebkhass of the Algerian Low Sahara

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The brines in the Chotts and Sebkhass of Algerian Low Sahara are solutions characterized by a salinity that far exceeds that of the sea waters (120 to 440 g/l). Over the past three decades, these lacustrine systems become an estuary for all types of urban discharges, highlighting the environmental impact of these discharges on such systems.

The chemical analyzes show very high concentrations of certain trace elements, in particular Zn, Cu and Pb, with respective contents of 2.2, 1.6 and 0.03 mg/l. These trace elements are micropollutants that cause nuisance even when they are released in very small quantities.

**Keywords** - Brine - Chott - Sebkhass - Low Sahara - Trace element - Impact.

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## Study of the variability of annual rainfall series in the Isser Wadi (East of Algiers)

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Any development program in hydraulic planning uses a study of the variability of annual rainfall as this parameter conditions the completion of the project.

Our study is based on the application of statistical methods to analyze rainfall time series in order to characterize the spatiotemporal variability of the rainfall regime within the O. Isser watershed.

Located in the northern part of Algeria, this watershed is equipped with twenty (20) rainfall stations managed by the National Hydric Resources Agency of Algiers which was kind enough to make available to us the measurements of these stations which spread from 1975 to 2014 for all series.

The period considered was arbitrarily divided into four decades (or episodes) namely 1975-1984, 1985-1994, 1995-2004 and 2005-2014 in order to illustrate the chronological evolution of annual rainfall totals. It shows that the general trend has been declining since the 1970s. It worsened in the following decade (1980 or even 1990).

The database is used under the ArcGIS10.2 software where kriging interpolation was used to generate the thematic maps. The analyzed series all show breaks, the majority of which are localized during the 1970s and 1980s.

Isohyets mapping of annual rainfall calculated per decade over the period 1975-2014 shows that the 1970s and 1980s appear to be in deficit throughout the watershed.

However, we notice a trend towards a return of precipitation during the period 2005-2014.

**Keywords** - Watershed - Isser wadi - Rainfall regime - Failure - Mapping.

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## Study of hydrosystems dam-groundwater: case of the Beni Haroun dam (Oued El Kebir) and the surrounding groundwater bodies

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The study deals with an assessment of the impact of setting water of Beni Haroun dam on the underground water resources of the Constantine region. The geological site consists of complex formations of carbonates and marls, strongly tectonized, in the Neogene basin between Constantine and Mila. The dam was thus built on a limestone bed in the form of a syncline, set between two marly formations (Eocene downstream, Paleocene upstream). This synclinal, flared in trough on the right bank, tightens in direction of the left bank where the layers become vertical at the same time as its axial plane undergoes an incurvation towards the South. The tectonics affected this structure by a system of faults, passing south of the dam (in the reservoir), diving towards the NW, as well as a system of tensile fractures roughly oriented NS. The few outcrops of Triassic age, namely gypsum facies, observed upstream of the dam, on the slopes of the basin, injected into Cenozoic rocks, are associated with the existence of weakness zones.

The large-scale reservoir (1 billion m<sup>3</sup>) on Oued El Kebir, downstream from the Rhumel-Endja confluence and a few tens of km north of Constantine, is one of the most important in the East. This hydraulic structure is located in an area with high potential in surface water (Oued Rhumel, Oued Endja, etc.), and underground (karstic aquifer, alluvial Oued Endja, etc.). This set of water bodies is reminiscent of a systemic functioning, a classic case of exchanges between surface and underground waters, and the various risks they incur or cause in the environmental context.

The objective of the study thus consists of the hydrosystems knowledge in order to establish the different risks incurred by the underground environment and the reservoir. These facts will be sought through the piezometric measurements of water bodies during high water periods.

Piezometric measurements of the aquifer in recent wet years have shown a close relationship between the impoundment and the groundwater laden.

In addition, the result of the piezometric monitoring at the level of the piezometers installed at the dam site gives an insight into the infiltration of dam water towards the karst representing the seat of the dike. It appears that the water flow is concentrated on the left bank following two drainage axes: the contact between the limestones and the Paleocene marls in the NW part and the discontinuities network of breach and fracture. The piezometric observations on the left bank of the dam have demonstrated anisotropic permeability of limestones, highly parallel than transverse



to the layers, thus implying circulations parallel to the stratification. These observations prove the risk of water loss from the reservoir into the karstification voids of the rock.

It is clear that the exchanges made between the water bodies expose the Beni Haroun dam to the risk of instability due to the choice of the geological site. Indeed, fractured and karstified carbonates are likely to benefit from a concentrated infiltration of subsurface waters downstream of the dam. It constitutes a loss for constraint. Also, the fault under the bed of the Oued Rhumel and the overlap of Sidi Merouane, West of Oued El Kebir, corresponding to a flexure zone developed during the Lower Miocene compression, constitutes a more important source of water loss from the reservoir into the karst. This state of facts is accentuated by active tectonics with earthquakes reaching a significant threshold.

Finally, from an environmental point of view, the introduction of surface water into groundwater may cause serious issues threat to the chemical quality of the aquifer, the karst aquifer is less concerned because of the mobile water which drains into its ducts.

**Keywords** - Hydrosystem - Beni Haroun dam - Aquifer - Karstification.

## Paleoenvironmental study of the Messinian series of Djediouia, Lower Chelif Basin, Algeria

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Since a long time ago, the Messinian series of Djediouia located in the Southeastern part of the Lower Chelif Basin, were the subject matter of a lithostratigraphic, systematic, paleoecological and palaeoenvironmental study.

Based on this, our work was carried out on the section of Sidi Abdelkader Tazghat, and thereafter five lithostratigraphic units of Messinian age were identified, from bottom to top: marly unit, marly-diatomitic unit, alternation of sandstone and sandy marl unit, alternating unit of limestones and marly sands and finally the massive limestone unit.

The systematic study of fossils has allowed us to identify 3 species of echinides, 10 species of bivalves, a species of gastropods, a species of scaphopods and 41 species of foraminifera (benthic and planktonic) of more bryozoans, annelids and melobesias.

Moreover, the Paleocological and palaeoenvironmental studies revealed that the Sidi Abdelkader Tazghat series is a regressive series.

**Keywords** - Messinian - Lithostratigraphy - Systematic - Palaeoecology - Palaeoenvironment.

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## Extraction of uranium from an unconventional deposit by the radiometric emission method: Application to the phosphate deposit of Dj. Onk, eastern Algeria

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Uranium is an element that exists in the phosphate deposits of Dj. Onk. It turns out that this radioactive element replaces the calcium ( $\text{Ca}^{2+}$ ) cations in the apatite network of the phosphated material, as it can precipitate directly because of the reducing nature of the phosphate medium. The determination of uranium in phosphates allowed to demonstrate its presence with an average content of 48 ppm. Its existence in phosphates may cause an environmental problem, following the formation of phosphogypsum heaps from the industrial production of fertilizers. Radioactivity, which is a physical property appropriate to this unstable chemical element, and its characteristics can be used to recover it by optimal selection: radiometric separation. This method is based on the emission of radiation using the natural radioactivity of a chemical element. It is ecologically clean with secondary production of uranium from a phosphate deposit that can exceed 25,000 tons.

**Keywords** - Uranium - Radiometric emission method - Dj. Onk deposits - Eastern Algeria.

## Characteristic features of the In Abeggui gold deposit (Hoggar Shield, South Algeria)

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The In Abeggui gold deposit is located in the Eastern part of the Laouni terrane (Hoggar, South Algeria). Our studies lead us to distinguish two shape kinds of gold mineralization i/ big quartz-tourmaline veins hosted in gabbro-diorite massif; ii/ stockwerk and veins hosted in microgranite-aplite dikes.

These felsic rocks are the latest and crosscut all the structures. All is incorporated in the frame of a Neoproterozoic volcano-sedimentary basin. The mineralization is characterized by intensive hydrothermal alteration where microgranite-aplite is transformed into quartz-muscovite association (greisen).

Mineral association encountered in this deposit is : quartz-tourmaline-muscovite-rutile-topaz-wolframite-molybdenite-pyrite-arsenopyrite-pyrrhotite-chalcopyrite-bismuthinite-native bismuth-galena-sphalerite-native gold-calcite-dolomite and iron oxides. Yet, In Abeggui is a gold deposit characterized by the presence of topaz  $\pm$  molybdenite  $\pm$  wolframite linked to greisens stage; as well as by plenty of rutile.

**Keywords** - Hoggar - Native gold - Quartz-tourmaline - Stockwerk - Gabbro-diorite - Aplite - Greisen.

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## Artisanal exploitation of gold in the Birimian Guinee Basin (Siguiri).

Cissé I.

The Republic of Guinea is an agricultural country whose basement is full of important mineral resources (bauxite, iron, gold, diamond, limestone, graphite) and occurrences (uranium, nickel, copper, manganese, etc.) greatly underexploited. The mineral resources currently in production are : bauxite, gold, diamonds and building materials. The state regulated the exploitation and marketing of gold and diamonds and these reforms were improved upon the advent of the Third Republic.

The implementation of the reform in artisanal and small-scale gold mining is done through the Union Nationale des Orpailleurs de Guinée (UNOG), which in turn brings together groups and cooperatives. Guinea has over four decades of experience in the field of Diamond handicrafts, and the Office of Technical Guidance for Diaminiers works in partnership with CONADOC and UNADOR.

This level of organization makes this sector a lever of the national economy and a tool for development and pacification between companies , research projects, the oil sands on the one hand, and the riparian communities on the other.

However, artisanal exploitation of gold is not only beneficial to people, but also a source of health and environmental problems. Environmental problems include deforestation and mercury contamination of soil and water. In terms of health, silicosis and sexually transmitted diseases (STDs), including AIDS, are examples. Mercury, for its part, is a major health and environmental hazard. The amount of mercury lost in the environment from artisanal and small-scale mining (EMAPE) is estimated to be over 30% of all emissions to the atmosphere. In Guinea, only 73% of sites use mercury and the amount of mercury lost to the atmosphere is estimated at 19.10 tons (AGC Inventory, 2016), and in leaching the release from ore washing cyanide is used by craftsmen.<sup>1</sup> This activity is not without impacts on water, deforestation, landscape and human density.

**Keywords** - Gold - Artisanal mining - Mercury - Environment - Guinea.

## Hydrochemical characterization of water resource in the southeastern part of Senegal. Impact of mining in the Kedougou region

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In the Kedougou region, basement of Senegal, the establishment of mining companies has led to a rapid development of some villages through a massive influx of people from all regions of Senegal and neighbouring countries seeking employment in traditional industries or gold mines. In this context, the demand and use of water are increasing due to the large amount of water used by the extractive industry and traditional miners for ore processing. However, the latter could seriously affect the quality of this resource, as mercury is widely used in processing, such as gold washing and leaching of metallic trace elements.

This study aims to assess the chemical quality and geochemical processes of water mineralization as well as the impact of mining activities in surface waters and crystalline rock aquifers in Kedougou.

The methodological approach is based on geochemical investigation and GIS tools in relation to the geological background. Two field campaigns were carried out in May 2017 and June 2018 to measure physicochemical parameters and water sampling. A total of 66 water samples collected at boreholes, dug wells, stream and waste water from mining, were analysed at Graz University of Technology in Vienna to determine major elements and 21 traces elements concentration.

Binary plots between major ions show that the main mechanism of groundwater mineralization is rock/water interactions with: (1) hydrolysis of silicates of higher magnitude in the metasedimentary and granitic reservoir; (2) silicate minerals from the hydrolysis of sodium-potassium to potassium feldspar mainly control the geochemical processes in granitic reservoirs; (3) basic plagioclases, feldspathoids, amphiboles and pyroxenes control mineralization in the basic volcanic domain with more pronounced cationic base exchange. The piper diagram highlights the Ca/Mg-HCO<sub>3</sub> chemical facies that characterizes the majority of the samples. However, pollution is linked to urban waste in the case of nitrates and sulphates; and discharges and leaching from mining areas for iron, mercury, aluminium, cobalt, manganese, nickel, lead and arsenic. Regarding surface waters, silicate alteration appears to be the major geochemical process that controls mineralization with an additional supply of anthropogenic sulphate and/or chloride ions. As a result, the health of local populations is endangered, with risks of congenital, heart, respiratory and dermal diseases as well as a multitude of cancers.

**Keywords** - Geochemistry - Kedougou - Basement aquifer - Mining - Pollution.

**Petro-structural and geochemical characterization of the mineralization  
of the El-Gir deposit (Bou Azzer-El Graâra inlier,  
Central Anti-Atlas, Morocco)**

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The El-Gir sector is located in the western end of the Bou Azzer El Graâra inlier in the Moroccan central Anti-Atlas and precisely in the Northwestern edge of the Bou-Frokh serpentine massif.

From the lithostratigraphic point of view, the El-Gir sector is made up of Lower (PII) and Middle (PII-III) Neoproterozoic lands, namely: serpentinites, quartzic diorites, green rocks, which are covered in unconformity by Late Neoproterozoic (PIII) lavas facies. In addition to the quartz-carbonated and quartzous structures sits the mineralization.

Structurally, the work area reveals brittle tectonics and ductile tectonics that are related to pan-African orogenic phases; B1: characterized by flow schistosity at the level of serpentinites, B2: marked by fracture schistosity at the level of green rocks (dacites), and finally the late-Pan-African phase responsible for the emplacement of the quartzo-carbonated structure oriented ~N5°, seat of the mineralization with a variable dip.

Microscopic examination of the facies has made it possible to specify the nature and the texture of the rocks and shows the existence of serpentinites of meshed and reticulated texture, quartz diorites, green rocks (dacites) and PIII lavas which are andesites and ignimbritic andesites.

The metallographic study of mineralization revealed a paragenesis composed of löllingite and chalcopyrite as primary minerals, covellite as a secondary stage, malachite, azurite and hematite as oxidation minerals.

Geochemical analyses of the samples showed a polymetallic character of the mineralization, of which cobalt (0.19%), arsenic (3.12%), iron (3.36%) and copper (2.9%) are the major constituents.

The made geochemical maps, allowed us to highlight several mineralized zones: (1) a zone mineralized in Co (löllingite), it is the SE contact of the quartzo-carbonate case with the serpentinites, (2) a copper mineralized zone, this is a PIII lavas intraluminal shear corridor PIII and serpentine located in the center of the study area, (3) a hematite mineralized zone represented by intra-green rock quartz veins (dacite).

**Keywords** - Cobalt - Cartography - El-Gir deposit - Bou Azzer El Graâra inlier - Central Anti-Atlas

## Current situation of the mobilization of water resources by the large dams in the northern-central part of Algeria

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Aware of the challenges in the management of water resources, Algeria took important measures to try to go out and to attenuate the situation of water stress which touches the country. With a view to palliating water stress and satisfying needs in water to assure the socio-economic development of the region, big means were implemented to mobilize new resources in water.

With a focus on sustainable development-based management, we have undertaken a study on the impacts of dams in northern-central part of Algeria. This can serve as an assessment to the sustainability of sprayed solutions, following by a proposal resource mobilization strategy in the region, by the major hydraulic structures.

The Isser watershed area is 4 148 km<sup>2</sup> including the largest watercourse that are the Isser and its tributaries, Mellah, Kherza, Bouhamoud and Djemaa, where several large dams have been planned. The assessment of the current situation of hydraulic system in the region shows great inter-year storage potential of 649.41 million m<sup>3</sup> through three dams in operation. These works allow to regular 236.7 millions m<sup>3</sup> annually for mean annual flow in the order of 410 millions m<sup>3</sup>. However, the loss of water caused by evaporation, leakage and spill lose an equivalent of 61% volume of water inputs at dams. According to hydraulic plan in the region a part of deficits can be reabsorbed by putting into service new projects of dams.

Nonetheless, the question of efficient of projected solutions are required, especially for adaptation the planning water resources to climate change and socio-economic development in the region.

**Keywords** - The Isser watershed - North Central Algeria - Water stress - Resource mobilization strategy - Dams impact.

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## Geology of Triassic complex of Koudiat Djebassa area, El Mhir, Bordj Bou Arreridj, Algeria

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Koudiat Djebassa area corresponds to a Triassic gypsum blade which geographically belongs to the opposite flank of Mzita anticline "sub-bibanic area, Biban". It corresponds to a section of the Meridional Tellian Atlas.

Macroscopic and microscopic observations of the Triassic complex reveal the existence of six major types of textures: massive, banded, drusy, veined, disseminated, and crested.

The Petrographic study of this Triassic complex allowed us to inventory the minerals which are associated to the Triassic drilling: gypsum, anhydrite, celestite, barite, dolomite, calcite, quartz, albite, pyrite and native sulfur.

Microthermometric results of primary fluid inclusions of the Koudiat Djebassa celestite associated to the Triassic complex show that the fluids which are responsible of celestite crystallization have a deep origin, rich on pure water and drained by the contacts diapir/cover during halokinesis, which would explain the high homogenization temperatures obtained (118°C to 280°C). These fluids would have been enriched in Ca and Mg due to the presence of carbonate rocks.

All the results obtained confirm the hypothesis of a slightly salty hot fluid that acquires its salinity during its ascension.

**Keywords** - Triassic - Koudiat Djebassa - Gypsum - tellian Atlas - Salinity.

## Experimental study of the geochemical behavior of mine tailings

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The extraction of sulphides and their processing generate waste stored as tailings which can reach several millions tons. These residues, composed of sulphides and heavy metals, are associated with a carbonate, sulphated, siliceous or clayey gangue and give rise to a phenomenon known as acid mine drainage.

Our study focus on the characterization and geochemistry of mining waste from three deposits of different types and regions: residues of El Abed (Tlemcen), Boucaid (Tissemsilt) and Sidi Kamber (Skikda). Because of the free storage for several years, these sulphides are partially oxidized. They present a certain physical and chemical instability which is at the base of the degradation of the nearest surrounding environments (watercourse, underlying soils, groundwater, etc.) following the migration and dispersal of elements metal traces such as arsenic, cadmium, cobalt, copper, lead, zinc, etc.

To study the geochemical mechanisms that govern the migration of heavy metals and to assess the risk of contamination by these metals, batch-leaching tests were carried out.

**Keywords** - Mining - Environment - Leaching - Geochemistry - Heavy metals - Tailings.

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## Assessment and mapping of the water quality of the Terminal Complex groundwater using GIS interpolation techniques (Oued Souf, Southeast Algeria)

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This study was designed to evaluate the groundwater quality of the Terminal Complex (TC) for drinking purpose, in a rural area (Oued Souf Valley: part of the Northern Sahara Aquifer System (SASS)), and the production of their spatial distribution maps. For this reason, twenty-four groundwater samples were collected and analyzed. Various assessment tools have been used to quantify water quality status, The WQI is one of the most effective tools for obtaining a more complete and accurate picture of water quality. Spatial variation maps have been derived and integrated using ARCGIS10.5 software. The groundwater quality values observed are minimum and maximum values of pH (7.00-7.69), electrical conductivity (3390-4470 S/cm), bicarbonate (143.96-207.4 mg/l), chloride (414.80-985.59 mg/l), nitrate (0.95-23.79 mg/l), calcium (220.44-316.63 mg/l), magnesium (58.33-199.30 mg/l), sodium (320- 420 mg/l), potassium (27-42 mg/l), sulfate (494.3-1334.4 mg/l). The Hydrochemical mapping indicates a gradual increase in the mineralization northwards and northeastwards and designates Taghzoute as a very mineralized zone. The calculated WQI values can be divided into two categories: overall, 41.67% of the measuring points sampled in the study area had «poor water quality», while 58.33% of the samples indicate «very poor water quality».

**Keywords** - Oued Souf Valley - Terminal Complex - Groundwater quality - IQE - GIS.

## Draïssa barite deposit (Ougarta chain, SW of Algeria): geology and geology

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The Draïssa region is the most famous barite extraction area in southwest Algeria and the entire Ougarta chain. The latter forms a large anticline bulge with a central outcrop of the Neoproterozoic basement namely an inlier, topped unconformably by a folded Paleozoic sedimentary cover. In the West, it marks the continuity of the Moroccan Anti-Atlas chain with an ENE-WSW orientation.

The outcrops of the Draïssa anticlinal structure are marked by a volcanic (rhyolite, ignimbrite) and volcano-sedimentary nucleus discordantly covered by Cambrian, Cretaceous, Neogene, and Quaternary sedimentary terrains. Mafic rocks are injected after Neoproterozoic conglomerates. This region is known for its commercial barite veins of up to 4 m thick and 7 km long. The overall direction of these veins is NE-SW and EW with a sub-vertical dip.

It appears that the barite-quartz deposits were formed in two stages. Endogenous fluids deposited the primary vein materials, consisting of quartz associated with copper sulfides. Exogenous fluids (cold seawater) became heated during ascendant fluid movement. Mineralization was governed by convective motions and the barite and galena fillings were deposited in openings created by normal faulting.

**Keywords** - Draïssa - Ougarta - Barite - Hydrothermal.

## Petro-structural and geochemical characterization of magmatism of the mining district of Tighza (Central Massif, Morocco)

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The Paleozoic magmatism of the Tighza Mining District (TMD) is a polyphase emplacement ranging from Upper Carboniferous to Middle Permian. It is expressed overall by kilometeric extension dykes oriented in the direction of NE-SW regional structuring. The complex is part of the large Late Variscan magmatic corridor that runs along the Zyar-Mrirt anticlinal zone east of the Moroccan Central Massif. The study of structural petrology applied to this magmatic complex makes it possible to distinguish three eruptive groups:

An early hypovolcanic complex with intermediate and felsic dykes of microgranites, micro-granodiorites and rhyolites, with a mineralogical composition similar to quartz, biotite, orthoclase and plagioclase. Apatite, zircon and iron oxides form accessory minerals. The whole is affected by a strong hydrothermal alteration, particularly chlorite-micaceous with parallel development of oxides and carbonates.

Granitic stocks of hectometric size, circumscribed, and independent, outcrop in a submeridian alignment within a contact metamorphic aureole generated by buried granite, revealed through gravimetry. The two Northern stocks at Mispickel and that of the mine are particularly fresh and show a medium granular texture size with biotite, plagioclase (An<sub>25-40</sub>) with granodioritic homeogenic enclaves and alumina residues. They are larded with stockwork of quartz veins with scheelite and mispickel.

Lenses of microleucogranites, set up in subequatorial sinistral shear corridors. The texture is porphyritic micrograsp to rhyolitic white quartz, plagioclase (An<sub><15</sub>) and primary muscovite shows plastic deformation structures. Veinlets of quartz and muscovites in secondary flakes intersect by shifting the primary phases.

Microtonalites, porphyritic micrograsp, with biotite and plagioclase (An<sub>30-55</sub>) intersect the granite of the mine and are relatively little altered. They are presented as vein occurrences oriented in two NW-SE conjugate directions at WNW and NE-SW.

The first chemical analyzes in major elements and traces, carried out on 13 samples, collected in the different petrographic groups of TMD, allow us already to specify the aluminous character of this magmatism ( $A/CNK > 1$  and  $A/NK > 1$ ) with a strong crustal contribution. The hypovolcanic group with the granitic stocks describe a calc-alkaline signature which tends towards an alumino-potassium trend well underlined by the microleucogranites. The microtonalites which are the last ones to be put in place at the Middle-Upper Permian limit fit into the calc-alkaline line. The focus of this magmatism in a zone of deep crustal rupture activated as soon as the end of the Variscan compression, allows to explain the syncollisional character of this magmatism as reproduced in the geotectonic diagrams.

**Keywords** - Tighza - Magmatisms - Geochemistry - Geodynamics.

## Iron ore mineralization of Chaabet El Bellout (Tablecloth area, Souk Ahras - Algeria)

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The Chaabet El Bellout mine is located about 600 km east of Algiers, 30 km from the city of Souk Ahras, 8 km east of Aïn Zana and 20 km from West of the Algerian-Tunisian border. It is part of the mountains of the high Medjerda which represents the southern area of the Tellian range. This iron deposit is located at the boundary between two distinct domains; the Tellian domain in the North and the Saharan Atlas in the South.

These mountains are bordered on the north by the Seybouse wadi, on the east by the Algero- Tunisian borders, on the west by the Constantinian domains and on the south by the Saharan Atlas (Mont Mellègue W. Tebessa).

This region is very tectonized and linked to a thrusting sheet structure, of which two major sub-latitudinal major tectonic crashes subdivide this sector into three main blocks: northern, central and southern.

Ferriferous mineralization is hosted by upper Cretaceous facies and is also carried by Miocene formations. Two main morphologies of the mineralized bodies were observed: cluster and vein.

The paragenesis of the Chaabet El Bellout deposit is quite simple, it is composed of the following minerals: hematite, siderite, goethite, limonite, gray copper and barite.

The presence of siderite in the paragenesis, in limited quantity, suggests that the mineralization of Chaabet El Bellout is of the metasomatic type. The emplacement of this mineralization is related to the interaction of iron-rich hydrothermal solutions with the surrounding rocks (sandstone and limestone) and which allowed in the first stage for the transformation of calcium carbonates into iron carbonates (siderite) by the process of substitution of  $\text{Ca}^{++}$  cation by  $\text{Fe}^{++}$  to result in the formation of siderite. In the second stage, the siderite will undergo a chemical alteration in hematite and limonite.

**Keywords** - Chabet El Ballout - Souk Ahras - Iron ore mineralization - Thrusting sheet.







# **Oral Communications**



## Holocene spatio-temporal evolution of Oueme Delta in Benin in response to the variations of the eustatic level

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The deltas are transitional sedimentary environments whose morphology and stratigraphic architecture of deposits depend on several factors including eustatism, submarine slope, subsidence, tectonics, sedimentary inputs, etc. The present work aims to reproduce the Holocene spatio-temporal dynamics of the Ouémé delta in the face of sea level variations. Low and medium depth geological sections (3.4-10 m) from the holes were subjected to sedimentological, pollen and geochronological analyzes. Sedimentological analyzes have made it possible to specify the origins of the sediments and to describe their environments of their deposit; pollen analyzes provided information on vegetation, and 14C peat-level dating helped to date the sediment.

It appears that, around  $7200 \pm 67$  BP, the sea entered the Ouémé valley and accumulated fine to coarse sand. Due to a slowdown in the seaward rise, it is noted a fluvial spreading and the development of vegetation consisting of *Rhizophora*, *Alchornea* lagoon border. A positive impulse from the sea was recorded around 4980 BP years. After  $3885 \pm 50$  BP, the sea retreated, sedimentation evolved into a fluvio-lagoon and deltaic context. Species of marshy meadow including *Cyperaceae*, *Poaceae* and *Eriosema griseum* testify to an open environment under anthropic influence.

**Keywords** - Ouémé Delta - Eustatism - Holocene - Sedimentary environments.

## Petrographic and geochemical features of low to medium grade birimian metasedimentary rocks of the Comoe Basin (North of Alépé - Southeast part of Ivory Coast)

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The Comoe Birimian Basin outcrops in three different countries (Ivory Coast, Ghana and Burkina Faso). The Southern part of this basin located the Ivory Coast, precisely close to Alépé consists of metasedimentary rocks, affected by the low (greenschist) to medium (upper amphibolite) grade metamorphism. Petrographic studies of those rocks highlighted the presence of paragneisses, micaschists, mylonites, metawackes and schists. Paragneisses and micaschists are evolving according to the mineral composition from west to east and from South to North, respectively.

Using major elements, two main sedimentary units have been distinguished: shales group (micaschists, mylonites and schists) and sandstones group (paragneisses and metawackes). Rocks affected by medium metamorphism grade (in majority sandstones) located in the southern part show low PIA and CIA indexes. While PIA and CIA indexes are high for rocks located in the north part affected by greenschist metamorphism grade (in majority shales). PIA, CIA indexes with A-CN-K interpretation indicate that probably chemical weathering in the source area and recycling processes have been more important in the northern rocks (lower metamorphism) relative to the rocks affected by medium metamorphism grade (most of paragneisses). Shales samples have undergone a post-depositional K metasomatism.

Geochemical data suggest that the metasedimentary rocks come from intermediate to mafic igneous provenance, with the Archean greenstone sediments signature. The low ratio of Th/U below 3.5, for Comoe Basin metasedimentary rocks indicates that the source is mantle-derived volcanic rocks. Trace and major elements features suggest that the deposition of those rocks took place in island arc setting.

**Keywords** - Petrographic - Geochemistry - Metasedimentary rocks - Birimian - Comoe Basin.

### Late orogenic structural evolution of auriferous formations of Atacora unit from the Natitingou area (Pan-African Dahomeyides Belt, West Africa)

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Along the Eastern margin of West African Craton (WAC), the Dahomeyides Belt is made from West to the East by external suture and internal zones. It resulted from the continental collision between the WAC and the Benino-Nigerian block after the closure of oceanic domain. The external zone of this belt is made by the called Buem and Atacora lithostructural units.

In order to better understand the structural evolution of the external zone and the stage of emplacement of auriferous quartz veins and dykes, field structural observations and measurements and petrographic studies have been performed in Natitingou area that know gold exploitation.

The Atacora structural unit is made of auriferous geological formations consisted in quartzites associated with chlorite-sericite schist, micaschist and quartzo-feldspathic amphibolite. These lithologies are crosscut by generations of quartz as veins, lenses and dykes.

Structural study reveals four compressional events (D<sub>1</sub>, D<sub>2</sub>, D<sub>3</sub>, and D<sub>4</sub>) during the late Pan-African orogeny. The first D<sub>1</sub> phase is expressed by P<sub>1</sub> isoclinal folds, an S<sub>1</sub> foliation or schistosity plane which bears an L<sub>1</sub> stretching lineation. The centimetric to decimetric-scale auriferous quartz veins and lenses genetically associated to the schists and micaschists were formed during this phase. The D<sub>2</sub> deformation episode is characterized by the refolding of the

S<sub>1</sub> and asymmetric P<sub>2</sub> folds with lightly plunging axis. To this phase is also associated an S<sub>2</sub> schistosity and C<sub>2</sub> dextral shear planes generated by NW-SE stresses. P<sub>3</sub> upright open folds with SW-NE axes and a low northwards plunge have been recorded during the compressional D<sub>3</sub> phase. This third deformation showing NNW-SSE stress, took back P<sub>1</sub> and P<sub>2</sub> folds in quartzite and their geometric relations revealed they are almost coaxial. The decametric to metric thickness dykes and veins of quartz crosscutting the quartzite, schist and micaschist are related to the D<sub>2</sub>-D<sub>3</sub> phases. The D<sub>4</sub> folding phase is represented by large scale virgations, materialised by kilometric structures with NW-SE trending axial plane. All these rocks and quartz veins and dykes underwent late fracturing episodes localized along fault zones.

**Keywords** - Benin - Structures - Auriferous formations - Atacora unit - Dahomeyides Belt.

## Two styles of primary gold mineralization in the Atacora Structural Unit from the Natitingou area, Northwestern Benin (Pan-African Dahomeyides Belt, West Africa)

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Syn-genetic and epigenetic gold mineralization in Natitingou area occurs in poorly documented metallogenic zone belonging to the Atacora Structural Unit of Pan-African Dahomeyides Belt. The syn-genetic mineralization is disseminated in the quartzites, schists, micaschists and amphibolites, and the epigenetic mineralization is hosted by the small quartz lode and kilometric NW-SE, NE-SW quartz veins (dykes) crosscutting the metasediments. The highest gold contents are obtained in the strongly deformed area along kilometric-scale faults where the metasediments are sheared, folded, brecciated. They contain abundant lentils and dykes of quartz lode bearing calcite ± sulphides. This underlines the structural control of the gold mineralization in the study area. In the lodes and quartz dykes, gold is rarely visible macroscopically, but is invisible in the metasediments and amphibolites.

Trace element geochemistry shows that the invisible gold grade in quartz vein samples varies from < 5.0 to 147.4 ppb. Gold content in amphibolites ranges from 49 to 1760.9 ppb whilst it varies from < 5.0 to 9586.8 ppb in metasediments.

Lithophile elements (K, Rb and Ba) show a co-enrichment suggesting that potassium metasomatism have accompanied the gold mineralization, and was probably resulted from hydrothermal ore fluids. The chondrite-normalized REE patterns displays LREE enrichments and HREE depletions with a negative Eu anomaly. Such configurations express an extensive interaction of mineralizing fluids with metasedimentary host rocks and/or ore fluids were likely derived from metamorphic dewatering of host rocks.

Primary gold mineralization origin in the Atacora is inferred to be of (i) remobilization processes of gold contained in the host rocks during the late Pan-African metamorphic and tectonic processes and/or (ii) hydrothermal phenomena related to the Pan-African granitoids

setting up in depth under these metasediments. Similar geotectonic setting of the Atacora gold mineralization is described in Ghana, Nigeria gold fields and many areas of Precambrian in the world.

**Keywords** - Primary gold mineralization - Hydrothermal - Structural control - Dahomeyides - Benin.

## Are there any correlations between West African Craton and Rio de la Plata Craton?

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The difficult reconstruction of «Atlantica» Paleocontinent may remain in the game of irreconcilable ideas of tectonic evolution, which are permanently controversial, if there is not enough geological (Hartmann *et al.*, 2002) and paleomagnetic (Franceschinis *et al.*, 2019) data of good quality. However, since correlations between cratons are based on paleogeographic hypotheses only valid for relatively small-time intervals, some far-field relationships between cratons can be established. They allow to reconcile the available information by simply establishing a temporal link between rocks of the same nature, age, and coherent lithotectonic units. This includes the roots of large igneous provinces (dyke swarms) but also granitic magmatism of specific characteristics. For example, post-orogenic high-K rapakivi granitic magmatism, Statherian in age (ca. 1.8-1.7 Ga), could be used as a valid argument to correlate cratons.

The lithospheric architecture of Africa and the Brazilian Shield in South America consist of several Archean cratons and small juxtaposed craton fragments, differentially transformed into mylonitic belts, and faulted blocks tectonically interspersed with younger folded belts. The similarities of ages, tectonic styles and mineralizations suggest a connection between the structure and the Eburnean tectonic evolution of the West African Craton (WAC) with respect to the Paleoproterozoic terranes of the Rio de la Plata Craton (RPC) from Argentina and Uruguay, as well as its tectonic evolution.

The WAC is made up of two Paleoproterozoic-Archean shields that seem to belong to the same and only great pre-Panafrican craton: (i) Reguibat Shield, in Northern Mauritania, Southern Algeria and Mali, (ii) Man-Leo Shield, in Ivory Coast, Sierra Leone, Liberia and Togo. The Taoudeni Basin comprises Neoproterozoic and Paleozoic formations unconformably deposited on both shields, in its center. The Man-Leo shield contains a central Archean domain unaffected by the Eburnean tectonics (Man Craton) but well deformed in its periphery. In the Reguibat shield, even if the intense Eburnean deformation occurred, some preserved Archean terranes outcrop (Jessell and Liégeois, 2015).

Archean migmatitic orthogneisses (~3.5 Ga) as well as metabasalts (3.3-3.1 Ga) in the western part of the WAC are affected by granulite facies metamorphism at 2.9-2.7 Ga. Above these migmatites and metabasalts, the Birimian Supergroup were deposited, folded and injected



by Rhyacian granites (2.1-2.0 Ga) during the Eburnean Orogenesis. Furthermore, the evolution of Paleoproterozoic magmatism of the most affected Archean regions by Eburnean tectonics (eg, Yetti and Eglab; Leo-Rise and Burkina Faso) indicates the presence of high-K post-orogenic granites, whose ages are consistent with ca. 1.8-1.7 Ga (Peucat *et al.*, 2005).

On the other hand, the RPC is of 850,000 km<sup>2</sup> craton, small compared to the WAC. It is made up of a western block, i.e. Buenos Aires-Piedra Alta (BAPA), separated by Paleozoic faults from pre-Andean terranes, and an eastern block made of multiple pieces of an Archean craton, shredded and recycled by Paleoproterozoic tectonics, the Nico Pérez Terrane (NPT) Uruguay (Oriolo *et al.*, 2016).

Since both blocks are geologically different, some models consider that they were newly docked in the Neoproterozoic, during the Brasiliano Orogenesis. However, given the recent geophysical findings (gravimetry, magnetotelluric survey) it is likely that the RPC already had a common inherited structure between them, since there are no differences in the lithosphere thickness (200 km) (Dragone *et al.*, 2017; Bologna *et al.*, 2019). The nature of the discontinuity that separates them would be misleading, since it was considered as a very long ductile strike-slip shear zone. However, structural evidence suggests that there exists an edge of conjugate faults of brittle-ductile behaviour, which reactivate an ancient dextral strike-slip shear zone, during the Neoproterozoic and causing a sinistral strike-slip inversion with drag folds.

The RPC geology in the BAPA block, westward to this strike-slip shear zone, consists of migmatitic orthogneisses, in amphibolite facies, and late-orogenic juvenile granites, dated at 2.1-2.0 Ga. The Rhyacian fold-belts contain metavolcano-sedimentary rocks, reaching the amphibolite facies, with rather the same ages. The PAT is cross-cut by the Florida dyke swarm, which yields an age of ~1.79 Ga (U-Pb on baddeleyite) (Halls *et al.*, 1999). On the other hand, the NPT contains ortho- and para-derived granulitic gneisses older than ~2.2 Ga and a granulite metamorphism with a thermal peak dated at ca. 2.0 Ga. This domain is subdivided into five sub-domains, each of which has its own tectonic history and geological framework. For example, the Pavas Block stands out for the presence of Archean TTG suites (~3.4-3.1 Ga) but with an amphibolite facies at 2.7 Ga. The Rivera and Valentines blocks contain older metavolcano-sedimentary successions that reached the granulite facies during the Rhyacian Orogenic event (ca. 2.0-1.9 Ga). The high-K Statherian granites of Illescas (rapakivi) and Campanero of the NPT are post-orogenic and yield ages U-Pb LA-ICPMS in zircon of  $1768 \pm 11$  Ma and  $1754 \pm 7$  Ma, respectively (Oriolo *et al.*, 2016 and references therein).

Finally, the intrusion of tholeiitic metagabbros yielded  $1479 \pm 4$  and  $1482 \pm 6$  Ma ages. They could have emplaced during a pre-Panafrican extensional event that produced an intra-continental rift.

Excellent exposition in mineralized old terranes are located around Minas de Corrales, northern Uruguay, Isla Cristalina Belt, where metavolcanic-sedimentary sequences are associated to granite and gneiss bodies and gold was mined during the last century. Mineralization is restricted to dextral shear zones or granite borders and the main mineral assemblages are gold, pyrite, galena, and chalcopyrite associated to quartz veins. Other mineralization examples exist in southern Uruguay, and especially near Minas, Lavalleja, where the main mineral assemblages are sphalerite, pyrite, chalcopyrite, galena but no longer mining.

**Keywords** - Terranes - Geochronology - Shear zones - Mineralization.

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## Mineral exploration in Algeria: current state and perspectives

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Algeria territory is still underprospected. On the basis of the geodynamic evolution, we can define three metallogenic domains from South to North of Algeria : Eglab and Hoggar shields, Saharan Platform and Alpine chain. In this work we will expose for each domain, the

existing mineralization and then by means of the predictive metallogeny and our field work, we attempt to predict the promising areas that deserve exploration

## **1. Eglab and Tuareg shields**

*1a. Mineralization of the Eglab shield (West African Craton):* The main mineralization which is formed during the Eburnean Orogeny and prospected by the ORGM (National Bureau of Mining and Geology of Algeria) in this shield are :

- orogenic gold veins hosted in greenstones formations and linked with shear zones;
- Cu-Mo-Au veins and disseminations hosted in monzonite–syenite structures;
- Ni-Cu sulfides  $\pm$  PGE showings linked with ultramafic rocks;
- Cu-Zn-Pb-Au-Ag of VMS type;
- placers and paleoplacers of gold, diamond, rutile, ilmenite and zircon.

*Perspective:* the junction zone that separates the Yetti from the Eglab domain is highly promising for the anorogenic-alkali granites (Nb, Ta, Zr, U, P), carbonatite-syenite complexes (REE) and REE pegmatites.

*1b. Mineralization of the Hoggar shield;* The Hoggar is composed of reworked Archean-Paleoproterozoic terranes and juvenile Pan-African terranes (750-550 Ma). The ORGM has discovered the following deposits :

- gold: orogenic gold deposits linked to the trans-lithospheric faults;
- Rare Metals mineralizations (W–Sn–Ta–Nb–Li–Be) spatially associated with evolved Li–F granites (latest stage of Pan-African felsic magmatism);
- REE bearing carbonatites and metacarbonatites;
- Cr, Ni, Cu ( $\pm$  PGE) mineralization within the mafic-ultramafic rocks seeming without economic importance.
- Cu-Zn of VMS type.

*Perspective:* the Hoggar Shield is part of several metallogenic panafrikan belts. Our Works allowed us to reveal the existence of a Tantalum sub-province in the Iskel terranne. Besides, more detailed prospecting should be achieved for the following promising targets: (i) REE bearing panafrikan pegmatites, (ii) F-Nb-Ta-REE bearing alkali granites, (iii) Cu-Mo-Ag-Mn-Au porphyry linked to the hypo-volcanic granites, (iv) Rare Metals skarns and Paleoskarns, (v) Rare Metals and Au-Ag-Sb linked to the rhyolite–ignimbrite calderas, (vi) REE-Nb-Zr linked to the Cenozoic-Quaternary alkali volcanism (syenites phonolites) and the residual REE resulting from the alteration of these rocks.

## **2. Mineralization of the Saharan platform**

This domain constituted by a series of sedimentary Paleozoic to Cenozoic basins represent a huge hydrocarbon reservoir and contain other metalliferous mineralization.

*2a. Mineralization of the Ougarta range:* the Ougarta range is constituted by a Proterozoic volcanic basement crowned by a Paleozoic sedimentary detrital formation. Exploration work carried out by ORGM has revealed:

- Cu mineralization of VMS type linked to the Neoproterozoic andesite-basalt formation;
- Mn veins, layers and lenses linked to the Neoproterozoic rhyolitic formation;
- Cu (Ag, V) mineralization of red beds type and U-V silcrete;
- baryte veins hosted in Cambro-Ordovician sandstones.

*Perspective:* when replacing the existing mineralization in the Mitchel & Garson model, it flows from that it would be wise to explore the following mineralization (i) syenites - carbonatites (Nb, P, REE, U and Th), (ii) anorogenic granites Sn, Nb, REE and U, (iii) U-V silcrete, (iv) Zr, Nb, Ta, Ti placers, (v) Li, B and K bearing sebkhas.

*2b. Mineralization of the Bechar and Tindouf basins:* the Bechar Basin, constituted by Proterozoic to Quaternary sedimentary formations, contains various mineralization: coal layers, manganese lenses, Cu-Ag VMS mineralization. The Tindouf Basin contains large layers of oolitic iron hosted in Devonian sandstones (reserves > 4.109 tons).

*Perspective for the Saharan platform:* several placers resulting from the weathering of crystalline basements (Egla, Hoggar and Ougarta) must be prospected. Some occurrences of Zr, Nb, and Ta are found by the ORGM in the Cambrian-Ordovician boundary; predicting the possibility to discover important reserves. Silurian black shales formations (Co, Cu, Ga, Ge, Ni, PGE, Tl, Th, U and V) are spread out throughout the Saharan platform. Moreover, the numerous sebkhas are promising for important Li, K, B and Rb resources.

### **3. Alpine Chain**

The Algeria Alpine chain (Maghrebides) is formed during an oblique collision between Africa and Europe. We can define three metallogenic districts from North to South of Algeria: (i) crystalline massifs (Kabylides) domain, (ii) Tell domain, (iii) High plateau and Saharan Atlas domain.

*3a. Crystalline massifs domain: Greater Kabylia, Lesser Kabylia and Edough*

*3a1. Mineralization strongly linked with the crystalline basement (Hercynian to Eo-Alpine phases) :*

- Fe (magnetite)-Ba, Pb, Sb and Au : as layers hosted in amphibolites, gneiss and marbles;
- gold mineralization (stockwerk) hosted in metagabbros and amphibolites;
- Pb-Zn-Ba-Ag hosted in micaschist-marble formations;
- Cr ( $\pm$ PGE) lenses hosted in metaperidotites and serpentinites.

*3a2. Mineralisations linked with the basement cover:*

- Hg, Sb, As, Au, Ag hosted in the cover and partially in the basement;
- Ba, Pb, F especially hosted in the “dorsale calcaire”.

*Perspective:* (i) Nb-Ta-Sn-W linked with the Hercynian granites, pegmatites and metagreissens; (ii) Au, Zr, Ti, Ta, etc. placers.

*3b. Tell domain:* the mineralizations occurring in this domain remain understudied. In the Mouzaïa-Guerrouma district exist Cu-Pb-Zn and Fe-Cu-Ni occurrences hosted in Cretaceous marls. In the Babor-Berrouaghia district stay a non economic mineralization: Cu, Pb, Zn, As, F, Fe veinlets and Fe-Cu-Pb-Ba of MVT type. The Biban district holds the Beni Mansour strontianite deposit linked with an evaporitic diapir emplacement.

### *3c. High Plateau and Saharan Atlas*

#### *3c1. Mesozoic-Cenozoic cover*

- Meseta and Hodna domains: Pb-Zn-Ba-F of MVT type;
- Constantine Neritic and parautochthonous domains : Sb-Zn-Pb-As-Hg-Au deposits (MVT, and Hot springs types);
- Eastern part of the Saharan Atlas: Fe-Cu-Pb-Zn linked with Triassic evaporitic diapir and huge reserves of Phosphates at Djebel Onk;
- Western part of the Saharan Atlas: Cu-Pb-Zn-Ba and Mn occurrences hosted in clastic sediments.

*Perspective:* gold deposits of Carlin type and Au-Ag-Sb of Hot spring type must be prospected in the neritic and parautochthonous domains.

*3c2. Paleozoic Inliers (uplifts):* by uplifts, the Hercynian basement outcrops as Palaeozoic inliers through the Atlas and high plateau domain. Late Hercynian magmatic events were accompanied by Sn-W-Ta-Nb -Au and Cu-Pb-Zn-W occurrences. Later, Eocene and Miocene events have favored Cu-Pb-Zn-Ba veins.

## **4. Magmatic and hydrothermal events**

During the Alpine orogenesis, Miocene, Pliocene and Quaternary distension phases are responsible of magmatic and linked to mineralization emplacements.

- W-Fe (Au, Bi, Te) of skarn type.
- Cu- Pb-Zn-(Au, Ag, Nb, Ta) veins and Sn-W-Nb-Ta linked with Miocene granites.
- Au-Ag-As-Sb deposits (HS and LS types) and Cu-Pb  $\pm$  Ni-Co (stockworks) linked with late volcanic events.
- Cu, Zn, Pb, F, Ba, Au, Ag of VMS type.
- Kaolinite and bentonite deposits resulted from hydrothermal alteration of magmatic and volcanic rocks.

## **Conclusion**

Algeria hold a very big potentialities in various conventional mineral resources (Au, Ag, Cu, Pb, Zn, Sb, Sn, W Fe, Mn, P, etc.), but the strategic elements (Ga, Ge, In, Se, Te, Tl, etc.)

who exist at the diffuse state in the minerals are unnoticed or unknown. Moreover the hydrocarbons, oil field brines, coals and black shales constitute also an important source for the following elements: He, Se, Te, Ge, Ga, In, V, Tl and U.

**Keywords** - Algeria - Metallogenic domains - Mineralization - Perspective.

### Valorization of Moroccan bentonite deposits : adsorption and stabilization of phenol by bentonite

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Morocco is one of the most olive oil producing Mediterranean countries. This industry, which is so beneficial to the national economy, leaves two toxic and non-biodegradable residues (liquid/solid). “Margines” is a current liquid pollutant that has been listed by the United States Environmental Protection Agency (EPA). Among the priority pollutants. The classical methods used for phenol removal are expensive or limited to large-scale applications such as biological and thermal decomposition methods. The main objective of this work is to contribute to the reduction of contamination of phenolic compounds contained in “margines” by the adsorption process on bentonite. The “margines” used in the studies were collected from a semi-modern oil mill located in the Nador-Morocco region. The results of the physico-chemical analyses showed that the effluents of the oil mills are highly polluted, in particular the suspended solids, COD, and iron and copper contents are around 154.82 mg/l and 31.72 mg/l, respectively. Through XRD the mineralogy of bentonites studied reveals the existence of two types of montmorillonites. Theoretically, the diffraction peaks (001) of the montmorillonite appear at 15 Å and at 12Å, corresponding to calcium and sodium pole, respectively. The specific surface area of the bentonite used is characterized by a large area varying between 127.62 m<sup>2</sup>g<sup>-1</sup> and 693.04 m<sup>2</sup>g<sup>-1</sup> which is due to the presence of hydrated interleaved cations. This surface is likely to increase in aqueous solution depending on the solid/liquid ratio that modulates the degree of hydration. Samples of “margines” mixed with raw bentonites at different percentages vary between 5% and 100%. The potential of Moroccan bentonite for the adsorption of 9.17 g/l phenol from aqueous solutions was investigated. Adsorption tests have confirmed the effectiveness of these natural minerals in reducing phenolic compounds ranging from 8.72 to 76.23% contained in the “margines”.

**Keywords** - Phenol - Bentonite - EPA - Specific surface - Adsorption - Margins - Morocco.



## Use of high resolution 2D electric resistivity tomography for mapping of the geological structures of the north-western portion of Benin: case of the department of the Donga

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The exploration of the tectonic structures in the basement area is very complex and requires a state-of-the-art geophysical approach to complete and validate the results obtained by the use of remote sensing techniques. The aim of this study is to use high resolution electrical tomography to discriminate and characterize the geological structures of the Donga Department. The spatial-directional Sobel and gradient filtering methods applied to satellite images led to the development of the detailed linear map. The validation of these lineaments was made during several geophysical prospecting works. The results of the image processing allowed the development of the fracture map within the study area. It has 745 major fractures ranging in size from 9 to 71.5 km. The TRE applied to a portion of the Northwest segment of the Panafrican chain of the Dahoméides in Benin has shown, up to 55 m depth, several linear structures and aquifer corridors likely to be potentially active reservoirs. These structures may be fractures, geological contacts and vein zones. Indeed, all the linear structures identified on the electrical panels are oriented NS, NE-SW, EW. The average thickness of the saprolite of these structures on all electrical panels is between 10 and 40 m. The most important layers of saprolite were recorded at the sites of Bariénou, Bodi and Diépani at 40 m, 35 m and 25 m depth, respectively. As for the thickness of the fractured horizon, it has been estimated between 5 and 35 m. In general, all the data acquired on the fracturing of the Donga department contributes to a better knowledge of the geometry of the fractured system.

**Keywords** - Major fractures - Geophysics - Tectonic structures - Remote sensing - Basement area.

## Stockwork exhibiting polymetallic occurrences in the Neoproterozoic sediments of Firgoun area, West Niger, Eastern border of West African Craton

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The presumed Neoproterozoic sedimentary deposits of the Firgoun region, staking the Eastern border of the West African Craton, represent the equivalent of the basal deposits of the

Taoudenni and Gourma basins to the North (Bertrand-Sarfati et al. 1991; Miningou et al., 2017, Reichelt, 1972) and the Volta Basin to the South (Affaton, 1990). According to Konaté et al. (2018), the uppermost levels of Firgoun deposits present strong similarities with the Cryogenian «Triad» of the Taoudenni, Gourma (Béli region) and Volta basins.

The aim of this preliminary study is to determine the mineralogical composition of the polymetallic stockwork highlighted in the quartzitic sandstones. This kind of outcrop is widespread in Neoproterozoic formations in the Gourma (Béli region) and the Volta basins (Blot, 2002). The same author attributed them to a gossan (iron hat) likely to contain polymetallic concentrations. As mentioned by Miningou et al., (2017), the latter would probably be enriched during the different tectonic episodes of the Pan-African event.

The microscopic analysis of the thin and polished sections show that the stockwork includes different kinds of minerals such as hematite, magnetite, pyrite, malachite, etc. Radier (1956), Sougy (1957) and Dietrich (1959) pointed the presence of copper mineralization indices in three sectors, notably Firgoun, Donkolo with rare flecks and veins of chalcocite, and malachite and azurite coatings in dolomites (Radier, 1956; Sougy, 1957) and Koutougou (malachite coatings associated with chrysocolla and arranged on the surface of schistose planes (Dietrich, 1959).

However, the presence of accompanying minerals in the stockwork facies could be related to a probable hydrothermal source of the Firgoun area copper mineralization. This is consistent with the observations made by Blot (2002) and Miningou et al., (2017) who consider that the wide distribution of stockwork outcrops paves the way for the research of metalliferous deposits rich in Cu, Pb, Zn, Mo, As, Cd, and Co.

**Keywords** - Polymetallic concentrations - Stockwork - Neoproterozoic sediments of Firgoun - Gourma Basin.

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### Lithological mapping using pure pixels from Sentinel 2A multispectral images: Example of Issalane region in Central Hoggar (Algeria)

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In the last two decades, satellite multispectral imagery has been largely used in a wide range of domains and for several purposes. In particular, remote geological mapping has been greatly developed to the point of competing, in some cases, with the classic methods of mapping, often time and money consuming.

Lithological mapping using multispectral data consists on the identification and classification of geological bodies following one or more methods. Our work focuses on testing the Spectral Angle Mapper (SAM) method which evaluates the spectra similarity between an image pixel spectrum and a reference spectrum. We exploit this criterion of similarity by using multiple spectra as reference spectra to improve the class separability, the discrimination of geological units in this case. For this matter, we use the pure pixel spectra derived from Sentinel 2A satellite images considered to be holding the most representative spectral properties which will help decrease the variability within the same class. We, then, proceed to a multidimensional

visualization of these pixels to increase the variability between the different classes. This will allow a higher accuracy for a more consistent lithological mapping.

The Proterozoic Serouenout and Assodé-Issalane terranes in Central Hoggar present a variety of geological formations which offer a descent range of spectral responses to work on. In this study, we take the example of the Issalane region where we observe outcrops of metabasites, metapelites, migmatitic gneisses, granites, rhyolites carbonate rocks, serpentinites, ophites, whiteschists, chlorite schists and other alteration rocks.

The lithological discrimination of these rock types is confirmed to be possible using the class separability improved SAM method. The preliminary results are rather satisfying when compared to our observations from previous field works and to the existing geological map. The resulting SAM-map not only exhibits a more or less well delineated geological units but also helps to detect some major structural trends. Testing this method has proved it to be a reliable lithological remote mapping tool to use prior to any geological field investigation.

**Keywords** - Sentienl 2A – Multispectral – Spectral Angle Mapper – Issalane – Hoggar.

### **Application of gravity methods to the exploration of Pb-Zn-Ba deposits, case study: Fej Lahdoum mine, Northern Tunisian Atlas**

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This study investigates the benefits of using gravity, structural and drilling data for mineral exploration around abandoned Fej Lahdoum Pb-Zn-Ba mine, in northern Tunisia. The analysis of gravity and microgravity data calibrated by field and drilling data highlights four major directions: NE–SW, NS, EW and NW–SE. The NE–SW lineaments are essentially related to the direction of the structures, while the NS, EW and NW–SE lineaments seem to correspond to faults. Indeed, the mineralization in the study site is mainly concentrated in areas where the land is dense, located at the intersections of the density discontinuities, essentially in the NS and EW directions. Positive anomalies close to the Triassic–Cretaceous contact zone and the NS lineament, highlighted on the residual anomalies map and well-marked on the vertical gradient map, require particular attention. The results of this study provide a notable step forward in the knowledge of the regional structures and the mineralization pattern of the Fej Lahdoum Pb-Zn-Ba mine, and will constitute a solid basis for mineral exploration.

**Keywords** - Northern Tunisian Atlas - Fej Lahdoum mine - Gravity data - Mineral exploration.

**L'évolution géodynamique de l'In Ouzzal depuis le Paléoproterozoïque :  
Étude Géochronologique (U-Pb sur zircon et monazite),  
Géochimie et métamorphique**

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Le terrane de l'Ouzzal, situé dans la partie nord-occidentale du bouclier touareg, est un bloc allongé N-S, de plus de 400 Km de long et d'une largeur maximale de 80 Km dans sa partie Nord. Il correspond à de la croûte continentale archéenne remobilisée lors d'un épisode granulitique paléoproterozoïque (2 Ga) de très haute température (>1000°C, Ouzegane et *al.*, 2003 et références incluses). L'histoire de ce terrane a essentiellement été reconstituée à partir de l'étude de sa partie nord. Il est formé de deux unités majeures: la première correspond à des orthogneiss charnockitiques à composition de TTG, datés entre 3.3 et 2.7 Ga, structurés en dômes; alors que la seconde est constituée de métasédiments et de roches basiques et ultrabasiques, similaires aux ceintures de roches vertes archéennes. Cette seconde série a été datée à environ 2.65 Ga (Bernard-Griffiths et *al.*, 1996, Bendaoud, 2008). Elle est synchrone de la mise en place de charnockites alcalines dont la composition est similaire à celle des granites de rift (2.65 Ga, U-Pb sur zircon, Peucat et *al.*, 1996). L'ensemble est intrudé par des charnockites calco-alcalins datées à 2.50 Ga interprétés comme résultant de la fusion de la croûte inférieure au cours d'un épaississement crustal (Peucat et *al.*, 1996). L'ensemble des formations gneissiques (TTG, alcalines et calco-alcalines) présente des âges modèles Nd entre 3.1 et 3.5 Ga. Le magmatisme paléoproterozoïque est limité à des anorthosites, des carbonatites et de rares leptynites.

L'objet de ce travail est de présenter de nouveaux résultats géochimiques, géochronologiques et métamorphiques obtenus sur des roches orthodérivées mafiques et felsiques d'âge paléoproterozoïque échantillonnées essentiellement dans la partie sud de l'In Ouzzal.

Ces données montrent que le magmatisme paléoproterozoïque est plus important que ce qu'on pensait et qu'une partie de l'In Ouzzal sud est en fait constituée de charnockites à affinité de TTG et d'un complexe basique et ultrabasique lité (complexe d'Amesmssa) dont l'âge de mise en place est entre 2.1 Ga et 2.04 Ga (U-Pb sur zircon). La géochimie de cet ensemble suggère un environnement d'arc pour la première fois reconnu dans cette région.

La présence de zircons hérités archéens et les travaux antérieurs confirment la présence d'un soubassement plus ancien archéen. Par ailleurs, dans ce même terrane de l'In Ouzzal, des données U-Pb sur Monazite suggèrent un métamorphisme de haute température à 2.5 Ga, y compris au sud, ce qui est cohérent avec l'origine du magmatisme calco-alcalin datée à 2.5 Ga interprété comme le résultat d'une fusion de la croûte (Peucat et *al.* 1996, Ouzegane et *al.* 2003

Nos données géochronologiques U-Pb sur zircon et monazite montrent que le métamorphisme paléoprotérozoïque de très haute température est à environ 2 Ga mais que les températures sont restées élevées sur plus de 100 Ma. Elles révèlent également un second événement thermique à environ 1.8-1.7 Ga qui est synchrone avec du magmatisme sub-alkalin qu'on connaît tous les terranes qui entourent l'In Ouzzal.

Alors qu'on considérait jusqu'à récemment que l'In Ouzzal avait connu une évolution cratonique depuis 2.0 Ga, des travaux récents montrent que les granites néoprotérozoïques, datés à 600 Ma (Fezaa et *al.*, 2019) qui recoupent ce terrane, témoignent d'une importante remobilisation de la croûte de l'In Ouzzal puisque les données géochimiques montrent que les roches archéennes ont contribué à plus de 40% dans leur genèse. Cette remobilisation pourrait être le résultat de l'implication de l'In Ouzzal en tant que marge active au cours de l'orogénèse panafricaine comme le suggèrent les zircons hérités à 650 Ma dans ces granites et la présence du massif basique-ultrabasique d'In Allarène, au sud de l'In Ouzzal, qui présente une nette affinité avec les massifs lités d'arc (Talbi et *al.*, 2007).

Enfin, au cours du Crétacé, une phase tectonique extensive a coupé en deux le terrane d'In Ouzzal, sans du tout l'affecter par ailleurs, permettant le dépôt de plusieurs centaines de mètres de sédiments.

**Keywords** - Bouclier Touareg - Terrane In Ouzzal - Données géochronologique U-Pb sur Zircon et monzonite - Paléoprotérozoïque.

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## New soft-sediment deformation structure in the Miocene of Ouarsenis (Algeria), paleoseismic evidence

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The active Algerian zone margin is affected by numerous earthquakes due to the convergence of two tectonic plates. The Ouarsenis is structurally related to the external Tellian domain. This domain includes large pellicular structural sheets with mainly Miocene marl and/or sandstone sedimentary material and Cretaceous-Paleogene limestones which have been thrusts hundred kilometers southwards. Sedimentologically, the outcrops of the Miocene are «*terra incongnita*». sediments of alluvial and coastal transgression to the deep marine deposits of Ouarsenis have undergone seismic activity during the Miocene based on the recognition of seismites in the sedimentary infills. From a morphological point of view, various types of earthquake-induced soft-sediment deformation structures (SSDS) formed as a result of plastic deformation, liquefaction and/or fluidization have been found in the study area. They include (1) load structures of sagging, load-casts and drop structures, which would have formed in a sediment with an inverse density gradient, ball-and-pillow and flame structures, (2) pillow structures dominating specific beds, (3) slump folds, (4) boudinage structures, (5) syn-deformational faults, (6) sedimentary dikes and veins, (7) fluid-escape structures, contorted structures, and other structures. These structures have been interpreted as the result of liquefaction and fluidization processes induced by earthquakes, of magnitude larger than 5, being the minimum value for producing such processes, according to Ambraseys (1988).

Among these figures we have described a new thixotropic structure generating a parallelepiped geometry, from 20 to 30 cm long and 10 to 15 cm width, well structured and not distorted by the slope. The center is sometimes in swelling, limited by the same lithological nature. A deformation that can be described as seismites (Seilacher, 1984), is henceforth called «thixotropic polygon-like», TPL. It is interpreted as seismite, after which it would have been considered and eliminated any other possibility of genetic mechanisms that are specific to the sedimentary environment. This new deformation structure is never mentioned in bibliographic references. This deformation figure bears strong resemblance to «polygonal soils», which are typical formations of the glacial and periglacial regions that are found on flat-to subhorizontal spaces and related to the segregation of materials under the effect of freeze and thaw action (cryoturbation effect). In contrast, the modelling of the TPL figures in question are observed on a slope of the bathyal zone, and could be maintained by a simple after-shocks of seismic events. The environment is identified by sedimentological evidence and traces of organic activities (ichnofacies).

**Keywords** - Marl - Miocene - Seismite - Comparison - Seismic shocks - Ouarsenis.



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## Geochemistry of micas and accessory minerals in P-rich NYF pegmatites at Mangodara, Burkina Faso and West Africa

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The Mangodara district consists of a dome-shaped granodioritic orthogneiss, including amphibolite and paragneiss septa, intruded by a series of granodiorite, leucotonalite and granite plutons. All units are cross-cut by pegmatite dykes, which show a regional variation in accessory mineralogy moving away from the leucotonalitic pluton. Type-I pegmatites form veins within the leucotonalite showing gradational contacts. In addition to quartz, feldspar and biotite, common to all pegmatite types, they contain accessory magnetite, apatite, zircon, epidote and allanite. Type-II pegmatites intrude the granodioritic orthogneiss; they contain muscovite, garnet, accessory apatite, tourmaline, zircon, monazite, xenotime, colombo-tantalite, thorite and Zr-U-Th metamict phases. Type-III pegmatites intrude the orthogneiss and granites in the eastern part of the studied area. They contain garnet, ilmenite-pyrophanite, and accessory amounts of altered Nb-Ti-Th oxides.

The mineralogy and trace composition of accessory minerals are typical of NYF pegmatites (Nb>Ta, affinity with Zr, U, Th and REE) except for low F (no topaz) and high P contents. The geochemical signatures of mica and plagioclase (Fe vs. Mg content, and An<sub>19-26</sub>) point for an origin of the Type-I pegmatites from fractional crystallization of the leucotonalite. The presence of K-feldspar and U-Th-Zr-bearing phases in Type-II pegmatites suggests an origin by partial melting of orthogneiss and paragneisses, which could account for their rare metal content. Type-III pegmatites could either correspond to differentiated pegmatites, or derive from partial melting of an unidentified protolith. Alternatively, the differences between these pegmatite types might be induced by interaction with different host rocks.

**Keywords** - Mangodara district - Geochemistry - NYF pegmatites - Origine - Burkina Faso.

## Paleomagnetic and magnetostructural study of Jurassic formations of Gara Djebilet (Tindouf Basin, Southwestern Algeria)

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Recent geochemical analyzes and <sup>40</sup>Ar/<sup>39</sup>Ar datings of dolerite sills and dykes and basaltic lava flows from Southwestern Algeria (Tindouf, Reggane, Bechar and Hank basins) have shown that these rocks are related to the Central Atlantic Magmatic Province (CAMP). The CAMP is one of the largest among the Mesozoic basaltic provinces identified and formed about 200 Ma ago as a preamble to the breakup of Pangea. These data were solid arguments for undertaking geological observations and sampling for paleomagnetic studies and magnetic fabrics on the CAMP formations. A network of three long doleritic dykes ( $198.9 \pm 1.8$  Ma) located in the Tindouf Basin were targeted to clarify the structural context of their emplacement (magnetic fabrics) and to determine a new reliable Mesozoic pole.

The magnetic fabric, in almost all the sections sampled, is defined mainly through grouping of k1 and k2 axes on the dyke plane whereas axis k3 is almost perpendicular to the dyke plane. This fabric can therefore be interpreted as the magma flow direction. The new Jurassic paleomagnetic pole, of excellent quality, is very close to those obtained on detrital formations of the Algerian Sahara and close to those recently determined on igneous formations of Morocco. This new pole is also very close to the North African pole at 200 Ma. These results represent a new contribution for a better knowledge of the geodynamic context during this period.

**Keywords** - Jurassic dykes - CAMP - Magnetic fabric - Paleopole - Geochemistry - Sahara.

## Synthesis on the metallogeny of Tlemcen Mounts

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The Tlemcenian domain forms the north-western margin of the Algerian highlands. They are characterized by a horst and grabens structure, delimited in the North and South by large faults almost parallel to EW direction. It includes a Paleozoic basement of schists and quart-

zites, folded and metamorphosed during the Hercynian movements, and then injected by the Visean granites of the Tairret and Bou Abdous outcropping to the NE of Ghar Roubane. On the unconformity, lies partially Triassic conglomerates and Jurassic limestones and dolomites, the former hosted a vein mineralization of barite (Pb-Zn) and stratabound of Pb-Zn.

Late Hercynian deformation generated NE-SW and NW-SE fractures, most of them form gold-bearing quartz or greisen and tourmaline veins.

The deposits of barite are mainly hosted in the Lower Jurassic marine limestones but also in the schist-quartzites and granites of the Paleozoic basement.

Veins are the most common type of infill. In the Beni Snouss the veins are hosted in the basement, partly overlapping the Jurassic of Ghar Roubane. The Pb veins (incidentally Zn) of Ghar Roubane and Beni Abir are hosted in Paleozoic schists. Those of Menchar and Beni Bahdel extend for several kilometers and fill NS to NE-SW fractures. They are hosted in limestone and are dominant barite with incidentally Pb and Zn. The coexistence of barite pebbles at the base of the supposed Triassic (non or poorly cemented conglomerates covering the basement and at the base of the Liassic limestones) makes it possible to assume the emplacement of a post-Hercynian and ante-Triassic barite. In the stratabound mineralization of Deglen and El Abed, the dominant textures are open space filling and disseminations of sphalerite and galena hosted in the Aaleno-Bajocian dolomites. In addition, there is a karstic mineralization at El Abed ore deposit, probably resulting from the reworking of the previous one.

The microthermometric study of fluid inclusions trapped in barite, quartz, calcite, fluorite and sphalerite from the basement and the cover is carried out to identify the number of mineralizing stages which contributed to the deposition of these concentrations and finally to characterize the mineralizing fluids.

In the Mounts of Tlemcen, the existence of various concentrations of contents and natures, characterized by distinct parageneses and geochemistry, leads to propose several metallogenic events. These events are related to the geodynamic evolution of the region.

**Keywords** - Tlemcen Mounts - Ghar Roubane - Barite veins - Pb-Zn stratabound - Microthermometry.

## Stratigraphic and sedimentary evolution of the Paleocene-Eocene in Cheria region (Tebessa, SE Algerian)

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The Tebessa region belongs to the Eastern Atlas Domain, which is marked by the coexistence of large NE-SW folds and collapse ditches (Zerdazi, 1990 and Addoum, 1995), accom-

panied by several fault directions. Several works have shed light on this region among these authors; Dubourdieu, Joleaud, Laffitte, Vila and many others thereafter, but it became known thanks to these rich deposits of phosphates which were discovered in the 19th century, and put into exploitation (El Kouif, Djebel el Ounk) subsequently, it was coveted by petroleum geologists.

Our work will be held in the Cheria region. It is located in the western part of Tebessa map, which is the object of a current project, carried by the department of geological mapping.

The outcrops are on a large stratigraphic stretch, ranging from Cenomanian to Quaternary, with some unconformities that are visible, especially between the Maastrichtian-Paleocene and Eocene-Quaternary. We will be interested to the evolution of carbonated deposits of Cenozoic time, which layes on limestones with *Inoceramus regularis* of Maastrichtian time.

The Paleocene formation is composed of green to black marl and then green marl interbedded with phosphatic levels rich in coproliths and fish teeth, some authors attribute the first outcrops of marl to the passage late Maastrichtian - lower Paleocene. The formation of the Eocene is represented by alternations of marls and nodular limestones rich in bioclasts and large kidneys of flint. This formation is especially present in the center of the maps Cheria and forms hills at the level of all the plain of Cheria-1 et cheria-2, it is attributed to the Eocene more precisely to the Lutetian-Ypresian.

**Keywords** - Tebessa - Cheria - Paleocene - Eocene - Alternations of marls and nodular limestones and phosphate.

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## First evidence of Late Permian alkaline magmatism at the edge of the Sahara Platform (North of the West African Craton) : geochronological/geochemical data and geodynamic significance

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Numerous mafic dykes, sills and laccoliths of lamprophyric dolerites and camptonites with minor gabbros and syeno-diorite crop out in the southern part of the Late Devonian-Early Carboniferous Tafilalt Basin (Eastern Anti-Atlas belt, Morocco). These rocks intrude the mildly folded Paleozoic series (from Ordovician to Early Carboniferous). Geochemically, the Tafilalt magmatism shows sodic-alkaline affinity, being produced by low degrees of partial melting from a metasomatized deep mantle source within the garnet stability field. Biotite <sup>40</sup>Ar/<sup>39</sup>Ar and zircon <sup>206</sup>Pb/<sup>238</sup>U dating of gabbros and syeno-diorite provide the first robust geochronological evidence of the age of the South Tafilalt magmatism. Results of <sup>40</sup>Ar/<sup>39</sup>Ar dating of biotite give plateau ages of 264.16 ± 2.72 Ma, 262.61 ± 4.5 Ma and 259.04 ± 6.31 Ma, whereas <sup>206</sup>Pb/<sup>238</sup>U dating of zircon yields a mean age of 255 ± 3 Ma. These ages coincide within the dating error, and indicate that this magmatism occurred during the Late Permian. Our U-Pb and Ar-Ar results demonstrate for the first time the occurrence of a Late Permian alkaline magmatism at the edge of the Sahara Platform where only CAMP intrusions were known.

The geochemistry of the Tafilalt magmatism is similar to the lamprophyres of the same age and other alkaline dolerites and lamprophyres of Triassic age emplaced in central Pangea in both sides of the Atlantic Ocean (i.e., Morocco, South-Western Europe and Eastern North America). These rocks, including the Tafilalt ones, would reflect an early-rift magmatic activity that preceded the Triassic rifting heralded by the Central Atlantic Magmatic Province. This magmatic activity is recorded in both sides of the future Atlantic Ocean by small-volume alkaline magmatism that started in the Late Permian and extends into the Triassic. The alkaline magmas are probably generated in response to an increase in the mantle potential temperature (global mantle warming) underneath the Pangea supercontinent. This precursory magmatism was controlled locally by the extensional/transtensional reactivation of zones of crustal weakness located at the junction between two branches of the Variscan Orogen, i.e., the ENE-trending Anti-Atlas belt and the NW-trending Ougarta belt.

**Keywords** - Gondwana margin - Late Permian - Alkaline magmatism - Pangea supercontinent-Morocco.

## Revisiting the Huepac chert: mineralization of a non-marine Late-Cretaceous microbial population deposit

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Late Cretaceous domical stromatolites are well-exposed in the Tarahumara formation in Central Sonora, Northwestern Mexico, within a volcano-sedimentary succession of continental origin. This succession includes not only stromatolites, but a well-preserved silicified microbiota, among which diatoms frustules record one of the first emergence of continental diatoms reported since almost two decades. Since then, silica mineralization has been an open question.

The results of this work present a diverse microfossil assemblage that includes rest of cyanobacterial, insects, invertebrates and plant tissues and pollen. Among cyanobacterial morphotypes well-preserved are filamentous remains from *Eomycetopsis*, *Calothrix*, *Sphaerophycus* and *Spirulina*, all of which have their fossil counterparts in Precambrian strata. In addition to their biological content, the mineralogical and geochemical features of the Huepac chert suggest a non-marine setting, and very similar to Rhynia chert.

In the vicinity of the limestone and chert deposits it is possible to observe hydrothermal alteration halos in volcanic rocks, especially in the NW-SE trend of base metal mineralization and precious metals of the Ermitaño, Durazno and De Barrios ore deposits. These mineralizations consist of veins and stockworks associated with NW-SE fractures and faults. The mineralizations in these areas are representative of fissure and cavity-filling, and replacement hydrothermal processes. Authigenic minerals encountered in the sedimentary rocks of the Tarahumara formation consist principally of pyrite, cinnabar, galena and barite. The authigenic minerals can be understood and interpreted successfully by hot spring activity with hydrothermal fluid interacting within a transitional continental environment. According to geochemical data, the results of this original work points to a biotic and abiotic silica sources for the mineralization of microbiota remains. The fossilization conditions bear a taphonomic resemblance to other Precambrian deposits.

**Keywords** - Central Sonora - Northwestern Mexico - Tarahumara formation - Late Cretaceous - Huepac chert - Microbiota remains mineralization.



## Mineralogy and formation of the Nkob talc deposit (Central Anti-Atlas, Morocco)

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The Nkob talc deposit is located in the Pan-African Anti-Atlas Belt, South of the Siroua inlier, 25 km NW of Taznakht city. It is hosted in the Precambrian metasedimentary formations of the Proterozoic Taghdout group.

The deposit is delimited to the West by the Amassine monzogranite ( $614 \pm 10$  Ma) and to the East by the rhyolitic lava of the Ouarzazate group. It is limited by metapelites in the North and South, which are marked by large crystals of cordierite and andalusite resulting from the contact metamorphism generated by the granite.

The formations are generally EW oriented with a dip to the North. They are affected by a foliation of major direction ESE-WNW sloping towards the North. Within the deposit, there is an alternation of beds, decimetric to metric of dolostones recrystallized into marble and beds of talc (white, metric and friable), associated with small chloritite beds. The whole being straightened with a subvertical dip to the North.

Three types of marbles have been identified within the deposit. A blackish marble very rich in dolomite with minor quantities of calcite, talc and chlorite. The second is greenish and very rich in serpentine associated with calcite and minor amounts of talc and chlorite. As well as a reddish marble due to concentration of oxides. Veins containing calcite, serpentine, phlogopite, talc, chlorite intersect all the carbonate formations of the deposit. In talcites, talc is associated with calcite, dolomite being totally absent. Chlorite and phlogopite are very rare (even absent). Chloritites are totally blackish or composed of an alternation of dark and clear green layers. This alternation is mainly due to the presence or absence of phlogopite (dark layers) and chlorite (green layers) phases.

Talc crystals grow in carbonates. They have an elongated prismatic shape, sigmoidal and sometimes star-shaped in association with calcite and dolomite residues. Serpentine occurs as nucleases or irregular masses within carbonates and rarely contains preserved olivine residues (forsterite). Another type of serpentine is also distinguished by its fibrous shape and light green colour (chrysotile). This second variety is only found in the western limit of the deposit in direct contact with the granite. Chlorite comes in the form of elongated prisms, associated with phlogopite, and small tremolite crystals.

The mineralogical study of the rocks in the deposit identified an early mineral assemblage consisting of «dolomite + calcite + olivine + phlogopite», and a secondary mineral assemblage consisting of «calcite + talc + serpentine + chlorite  $\pm$  sulphides  $\pm$  oxides».



The magnesium required to form talc would have been released by destabilizing pre-existing carbonates (dolomites) under the effect of silica-rich hydrothermal fluids from Amassine granite. Serpentine crystallized as a substitute after olivine (formed by decarbonation reactions during contact metamorphism) and was replaced by serpentine by the effect of circulating hydrothermal fluids. Chlorite is mainly formed by the replacement of phlogopite. Iron oxides and sulphides (pyrite, chalcopyrite, etc.) are added late to the previously formed assemblage.

The Nkob deposit has been affected by at least two metamorphic conditions. HT minerals such as cordierites and andalusites in metapelites, as well as the dolomite-olivine-phlogopite assemblage in marbles, indicate that the contact metamorphism has reached the amphibolite facies associated with the emplacement of Amassine granite. While the association of talc, serpentine, chlorite, tremolite indicate a retrograde metamorphism of greenschist facies.

This study suggests that the source rocks of the Nkob deposit were magnesium carbonate rocks (dolostones) that would have reacted with a fluid of magmatic origin rich in silica extracted from the Amassine granite. This reaction is responsible for the appearance of a primary paragenesis with dolomite + calcite + olivine + phlogopite. The minerals in this paragenesis were transformed into talc + serpentine + chlorite during the cooling and percolation of fluids from the granite.

**Keywords** - Anti-Atlas - Taghdout Group - Mineralogy - Talc-carbonate - Serpentine - Metamorphism - Hydrothermal circulation.

## The Aptian of Kef Gouriret (Oum El Bouaghi): lithostratigraphy, biostratigraphy and palaeoenvironment

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The Kef Gouriret study area is located in the SW section of the Oum El Bouaghi city in the High Constantine Plains region. We carried out a lithostratigraphic, biostratigraphic and palaeoenvironmental study at the level of Djebel Kef Gouriret.

The raised section represents essentially carbonate-like formations interrupted by some levels of marl or clayey limestones rich in macrofauna where Gastropods of centimetric to pluricentimetric size are frequent and a rare dolomitic ocher interposition. Samples were collected for the manufacture of thin sections and the washing of marl for the purpose of determining the microfauna.

The results of this study made it possible to recognize the different palaeoenvironments that characterized the Aptian of this predominantly carbonate massif deposited in a shallow, perireciful sedimentation environment. It is an internal platform with a very slight variation of facies.

**Keywords** - Aptian - Kef Gouriret - Lithostratigraphy - Biostratigraphy - Palaeoenvironment.

## Characterization of the gold mineralization of the Tondabo gold prospect in the Brobo region (Ivory Coast, West Africa)

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The Brobo region in central Côte d'Ivoire, located in the north of the Hiré-Toumodi-Fet-tékro volcano-plutonite greenstone belt, has been the target of gold mining research by several mining companies. Despite these numerous works, no mine has been identified, unlike the southern part of this greenstone belt which has three active mines. Our work aims to better characterize the mineralization. The metallogenic study of the Tondabo prospect is based on the detailed study of the mineralized zones and their surrounding areas, using diamond drilling and the 12 reverse circulation holes. The study combines lithostructural analysis, alterations and gold analysis results to better identify the characteristics of the mineralization.

Regarding the gold mineralization of the Tondabo prospect, it is mainly hosted by rhyodacites and to a lesser extent by mafic volcanics (volcanic lava and volcanoclastics). These rocks were affected by hydrothermal alteration marked by quartz veins and veinlets associated with carbonates, sericite, epidote and sulphide crystals. This hydrothermal alteration induced a pervasive alteration of the surrounding areas with chloritization, carbonation, hematization and sericitization of feldspars. This mineralization presents a lithological control. The mineralized beds are generally affected by a foliation S1 oriented mainly N000-010° and in a minority N040-050° with a general dip of 60-80° westwards; with however rare NS orientations with a dip of 60-80° eastwards. The sampling intervals showing the highest gold grades are related to quartz veins and veinlets, which are located in deformed areas. These veins are of three types that are chronologically: (i) transverse veins that intersect the flow foliation; (ii) planar veins subparallel to each other and to foliation, sometimes presenting an extrusion; and (iii) late planar veins which intersect the whole complex (veins i, ii and foliation).

The metalliferous paragenesis consists of pyrite (main sulphide), pyrrhotite and rarely chalcopyrite. We note in this prospect a first phase of pyritization, disseminated, and which seems to be contemporaneous with regional foliation. The second phase of pyritization is recent, and associated with the emplacement of quartz veins associated with sericite-carbonate crystals that would have favored mineralization.

**Keywords** - Gold mineralization - Hydrothermal alteration - Lithologies - Deformations - Tondabo.

## Tectonique paléoprotérozoïque dans le terrane de THT de l'In Ouzzal et réactivation postérieure (Hoggar occidental, Bouclier Touareg)

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L'évolution thermomécanique du terrane paléoprotérozoïque de l'In Ouzzal permet de retracer une histoire de déformation éburnéenne (2.0 Ga), ductile, diffuse et synchrone des conditions granulitiques et une déformation au Protérozoïque moyen (0.82 Ga), fragile, co-séismique et très localisée.

L'analyse des déformations ductiles éburnéennes permet de définir un continuum de déformation transpressive, combinant deux principaux stades successifs, réalisé totalement dans les conditions de haute température du faciès granulite, depuis les conditions progrades culminant à plus de 1050 °C jusqu'aux conditions en dessous de 700 °C.

Le stade précoce, synchrone des conditions thermiques progrades de très haute température ( $T = 800 - 1050^{\circ}\text{C}$  et  $P = 10 \pm 1.5 \text{ Kbar}$ ), est caractérisé par un raccourcissement homogène horizontal, marqué par une foliation à fort pendage, de direction NE-SO à ENE-OSO et portant une linéation d'étirement fortement plongeante ( $70-85^{\circ}$ ). Elle est associée à des zones et des réseaux de cisaillements anastomosés, fortement pentés, portant des lignes de glissement à forts pitches. Les microstructures de ce stade traduisent un mécanisme de déformation dominant par fluage-diffusion.

Le second stade de déformation, synchrone des conditions rétrogrades, est accommodé par des déplacements horizontaux, parallèles à la direction principale du plan d'aplatissement régional fortement pentée. Cette déformation est caractérisée principalement par la migration du glissement de la verticale vers l'horizontale, la localisation de la déformation dans des couloirs de cisaillement mylonitiques et ultramylonitiques. Les mécanismes de déformation de ce stade sont de type transition haute-moyenne température et combinent le mode cassant et le glissement intracristallin.

Les déformations post-granulitisation éburnéenne se manifestent par des déformations fragiles qui sont accompagnées de formation de pseudotachylites à microlithes de pyroxène vers 820 Ma ( $40\text{Ar}/39\text{Ar}$ ), en conditions du faciès granulite. Ces pseudotachylites tapissent les surfaces des cisaillements et occupent aussi des structures en pull-apart et des fentes de tension accommodant un étirement de direction NE-SO.

L'évolution orogénique au Paléoprotérozoïque du terrane de l'In Ouzzal, peut être interprétée dans le cadre de la tectonique de collision ou la transpression, a joué un rôle important mais sans engendrer d'épaississement. Ce dernier serait stoppé par un fluage latéral de la croûte, très chaude et donc molle, dans la direction perpendiculaire au raccourcissement régional.

**Mots-clés** - In Ouzzal - Bouclier Touareg - Déformation éburnienne - Tectonique paléoprotérozoïque.

## Evolution néoproterozoïque du terrane de Laouni, LATEA, Bouclier Touareg, Algérie

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

L'analyse des déformations et des structures migmatitiques, couplés aux données géochronologiques permettent de retracer trois événements panafricains postérieurs aux conditions de haute pression (rétro-éclogites), équilibrées à une pression de 17 Kbar et une température de  $750^{\circ}\text{C}$  et datées à  $654 \pm 5\text{Ma}$  dont les structures ont été totalement oblitérées.

Le stade précoce est marquée par une foliation anatectique en conditions de faciès granulite ( $800^{\circ}\text{C}$ ), datée à  $577 \pm 11\text{Ma}$ , associée à des cisaillements normaux, faiblement obliques et tapissés de leucosomes à grenat, des plis d'entraînement intrafoliaux, des plis en fourreau orientés NE-SO à N-S et parallèles aux linéations minérale et d'étirement. L'ensemble de ces déformations sont générées par des détachements crûstaux qui ont exhumés des roches ramenées antérieurement à des profondeurs crûstales. Il se succéderait à un stade d'exhumation précoce par flottabilité ou par extrusion tectonique.

Les structures du stade précoce sont reprises par une tectonique transpressive ayant formé les principaux trends structuraux NO-SE et N-S à NE-SO où coexistent des structures décrochantes, décro- chevauchantes et chevauchantes. Ces structures sont géométriquement et cinématiquement cohérentes et compatibles avec un raccourcissement de direction Est-Ouest. Au cours de ce stade, se développent des structures extensives ou transtensives qui donnent une extension de direction Nord-Sud.

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

**Keywords** - Bouclier Touareg - LATEA - Panafricain - Exhumation.

## Nickel mineralizations of the Birimian greenstone belt of Makalondi (Liptako Province of Niger, West Africa)

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The Birimian greenstone belt of Makalondi is located in the western part of the Liptako province of Niger. It represents the Northeastern part of the Man Shield. Several nickel occurrences have been highlighted (Dion, 1973) in the Eastern part of the Makalondi greenstone belt, which is characterized by a strong aeromagnetic anomaly.

The methodological approach implemented consists of a field study followed by a polarizing microscopic analysis in transmitted and reflected light.

The nickel-bearing rocks are mainly represented by talc-chlorite schists, sericite schists and silicified ultramafic rocks. Three types of nickel mineralization were distinguished: disseminated, stockwork and enclave.

Macroscopic analysis, combined with microscopic observations, shows that nickel mineralization is the result of serpentinization of ultramafic rocks, which is caused by a late hydrothermal silicification. This serpentinization, especially of olivines, would have released nickel. The latter has been concentrated by hydrothermal processes leading to high grades of nickel reaching 4000-5900 ppm (Dion, 1973; Hassan and Marcos, 1987). Exceptionally, a sample analyzed by Dion (1973) gave a grade of 8400 ppm.

**Keywords** - Makalondi - Nickel mineralization - Liptako Province - Nickel-bearing rocks.

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## Estimation of the pollution risk induced by the mining wastes of the El Abed mine, Tlemcen, Algeria

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The post-mining, rehabilitation of mine sites and estimation of the risk of pollution caused by mine tailing, is one of the current environmental challenges.

It is important to study the risk of pollution in order to reduce, eliminate or even prevent them.

The El Abed mine opened in 1952 for the exploitation of Pb-Zn. It is shut down in 2002 without any rehabilitation plan. Our work consists of estimating the pollution risk induced by the El Abed mine basin tailing using kinetic tests (ASTM standards), especially since static tests give neutral results concerning to basic pH (absence of acid mine drainage, AMD) in a site where sulfur supply (PbS, ZnS) is substantial. At the end we will discuss some ways of valorization of the contents of the basin tailing.

**Keywords** - Environment - Pollution - AMD - Kinetic tests - Valorization.

## Environmental characterization of mine waste at the Pb–Zn Sidi Kamber abandoned mine (NE Algeria)

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The mining wastes coming from Sidi Kamber mine stored at the surface are exposed to weathering conditions, which favour the leaching of toxic metals into the environment. This situation presents serious risks for humans and ecosystems. To better understand this problem,



eight representative samples of Sidi Kamber mine tailing were taken from the surface along two vertical trenches and tested using static and dynamic leaching tests. The studied samples present a wide diversity in terms of particle size distribution, mineralogical and chemical compositions. These parameters may greatly affect the reaction rates. The mineralogical investigations show the presence of various sulphide minerals, such as pyrite, galena, sphalerite and chalcopryrite which are present in either free and/or associated with gangue minerals (i.e. quartz, albite, chlorite and muscovite). Moreover, the presence of only minerals with low neutralizing potential such as silicates, promotes the acid mine drainage generation, which is characterized by high concentrations of metals and sulphates. Leaching tests showed an acidic pH and the release of some toxic contaminants (i.e., Pb, Zn and Cu), which exceed the recommended limits (Algerian regulation law for industrial wastewater and US EPA thresholds).

**Keywords** - Mine tailings - Acid mine drainage - Static tests - Leaching tests.

### Sporo-pollenic content survey of the Oligocene ironstones of the Continental Terminal formation, Kandi Basin (North-East Benin)

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The sporo-pollenic study of the oolitic ironstones of the Kandi Basin in the Northeastern part of Benin allowed a paleoenvironmental reconstitution during the Oligocene and Miocene periods. The Taxonomic diversity is characterized by grasses including «graminidites neogenicus» and arecaceae represented by «Hyphaene Thebaica», characteristic of «hot and dry tropical environments». These species also characterize a grassy savannah. While the medium has long been considered azo, microscopic analysis has revealed plant fossils made up mostly of fruits. The oolitic iron ore of the Kandi Basin took place in a reducing lacustrine environment in which plants such as gramineae (*Graminidites neogenicus*) and arecaceae (*Hyphaene Thebaica*) lived.

**Keywords** - Pollenic - Kandi Basin - Continental Terminal - Paleoenvironment.



## Using mobile GIS applications to support mineral resource investigations in the Eglab region, Algeria

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The Algerian Geological Survey Agency – U.S. Geological Survey (ASGA-USGS) mineral resource assessment project in the Eglab region, Algeria, comprises the Eastern part of the Reguibat Shield bounded by the Tindouf, Reggane, and Taoudeni basins to the North, East, and South, respectively. The use of mobile GIS applications on handheld tablets facilitated team coordination and ease of transition from field planning and preparation, to data collection and integration, and transfer into project GIS databases. Mobile GIS applications facilitated collaboration between teams collecting disparate data types to support the geologic, geochronological, geochemical, field spectral, and geophysical investigations. This technology was used in parallel with traditional field investigation methods. These tailored applications on GPS-enabled tablets provided a platform for utilization of GIS data in the field and allowed for standardized data collection, picklists, fewer transcription errors, and the ability to store photos, coordinates, and field notes together in an integrated system. The suite of Environmental Systems Research Institute, Inc. (Esri™) mobile applications allowed for customized use on multiple platforms (Android/Windows/iOS) to streamline data collection, analysis, and storage.

The Eglab region GIS data from the ASGA National Bank of Geological Data (BNDG) were used for the project and an Esri ArcGIS Online (AGOL) working map was prepared. An AGOL group was set up to allow access only to ASGA-USGS team members. GIS layers included planned site locations, infrastructure, geology, known mineral occurrence locations, detailed basemap imagery, and other data critical for field mapping and mineral resource assessment. The imagery was from a 2016 compilation of best available data by Esri ArcGIS Online World Imagery basemap (Esri, 2019). The map was downloaded in the Esri Collector Classic application for offline planning, field navigation, data collection, and documentation of various types of geologic samples as well as spectroscopy and geophysical measurements. Navigation was improved using the tablets with access to detailed basemap imagery, infrastructure where available and in existence, and characteristics of features in the map. The application, Survey123, which is a digital form of field notes, was used to document rock, sediment, and soil samples. A sample collection form was customized for use in the field by the ASGA-USGS team. The form contained required location and descriptive fields as well as optional picklists of various sample characteristics for consistency. Each sample location with field notes and photos of both sample and site were tied together in a data layer.

Field work was conducted by having as many as three teams operating independently on a daily basis to focus on different thematic interests: geology and economic geology, geochronology, geochemistry, geophysics, and spectroscopy. Each team collected data on tablets recording field notes, measurements, and sample information. At the end of the field campaigns, the data collected from multiple tablets were uploaded to the AGOL cloud and a file geodatabase was exported and downloaded for integration into the local project GIS databases.

Tablet-based data collection in the field assisted in data management during the field campaigns and the Esri Collector and Survey123 applications provided flexibility to accommodate

the needs of the various disciplines of research. A primary objective of the project was updating and compiling a geologic map of the region (Buffière et al., 1965). The applications aided examination and validation of as-mapped geologic units in the field. Using the GPS-enabled tablets, mismapped geologic units were identified and locations of lithologic contacts were noted. The field notes with geologic descriptions and suggested modifications were used to inform revisions to the geologic map. Our experience with the ASGA-USGS project demonstrates that the integration of these applications into field operations can successfully help and improve managing team planning, field navigation, data collection, and sample management. With successive testing and incorporation of feedback, these mobile GIS applications can be successfully integrated into field operations.

Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

**Keywords** - Eglab - Algeria - ASGA-USGS project - Mobil GIS applications - Mineral..

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## Non-conventional rare earth element resources from Algerian sedimentary phosphorites (Tébessa, NE Algeria): a comparative study of their abundance and distribution

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Every year, the demand on Rare Earth Elements (REE) increases greatly due to their large applications in the high-tech industry. Typical REE deposits are suffering many problems, such as extensive exploitation and environmental issues. Non-conventional REE resources seem to be a solution for REE supply, such as those from sedimentary phosphorites. This raw material is very suitable because of the possible REE extraction entirely as by-product in a friendly environment (Emsbo, 2015). In this study, Algerian phosphorites from four localities of the Tébessa region (Eastern Saharan Atlas) were investigated. Samples were collected from El Kouif, Dyr

and Tazbent in the north of Tébessa, and Kef Essenoun in the south (Djebel Onk). REE analyses were carried out on both whole-rock and phosphate particles (pellets, coprolites, glauconites and bioclastes) using ICP-MS and LA-ICP-MS, respectively.

The results show that whole-rock  $\Sigma$ REEs contents range from 163 to 906 ppm with a substantial enrichment in the main sub-layer of Kef Essenoun deposit (average =713 ppm) and they are therefore more enhanced relative to regional and global phosphorites. In this deposit, whole-rock REE analyses of 45-125 and 125-250  $\mu$ m particle size fractions yielded the highest REE concentration ( $\Sigma$ REE from 656 to 751 ppm). On the other hand, phosphate particles display  $\Sigma$ REE contents varying between 39 and 1760 ppm. Glauconites show the highest REE contents, ranging from 543 to 1760 ppm. Therefore, this REE enrichment is linked to glauconitization processes which increase with remobilization of preexistent particles during their final depositional environment (Chabou-Mostefai, 1987; Kechiched et al., 2016, 2018). These results could be useful for REE economic extraction based on selective mining methods.

**Keywords** - REE; pellets; glauconite; phosphorites; Tébessa; Algeria.

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## Re-evaluation of Leonian and Liberian events in the geodynamical evolution of the Man Shield (West African Craton)

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It is well-established that Archean domain of the Ivory Coast located to the West of the Sassandra fault is composed mainly of formations of the Leonian age (3400-3000 Ma) and

Liberian age (2900-2700 Ma). The Paleoproterozoic unit of Toulépleu-ity, bordered more to the West by the Birimian rocks of the Nuon complex, is a characteristic of this area. It is all of these Leonian, Liberian, and Birimian formations that are essentially the subject of U-Pb dating in this work. Indeed, the old dating was carried out by direct evaporation on monograin zircon. This method is ineffective when zircon grains have a complex history.

Thus, one of the major assets of this work is the in-situ dating of the zircon of the Archean domain of Ivory Coast by laser ablation (LA-ICP-MS) in systematic U-Pb and Lu-Hf. Our report outlines Leonian and Liberian events to 3273-3010 Ma and 2877-2716 Ma, respectively. The values of  $\epsilon_{\text{Nd}}$  at 3.05 Ga (-2.79 to +4.68) and the values of  $\epsilon_{\text{Hf}}$  of zircons (-9.90 to +0.07) attest that the protoliths of these formations are older without neglecting a juvenile component between 3.5 and 3.2 Ga. However, the zircon grains have high Th/U ratios and give TcDM of 3.32-3.98 Ga. This represents a probable growth and major recycling in the Man Shield at this time.

Birimian formations of Nuon are composed of gneiss and granodiorites whose age is between 2087-2096 Ma. In contrast the oriented granodiorite that borders the unit of Toulépleu-ity to the South, has an age of 2062 Ma. The values of  $\epsilon_{\text{Nd}}$  to 2.1 Ga between +1.48 and +2.35 attest to the juvenile character of these formations. The CAV-1-oriented granodiorite zircons show values of  $\epsilon_{\text{Hf}}$  ranging from +0.59 to +4.39 confirming the mantellic origin of these formations with only slight contamination.

The metamorphic conditions were also constrained by Bloléquin basic granulite thermobarometric calculations using the Teriak Domino software. The metamorphic facies are low-pressure granulite type ( $>800^{\circ}\text{C}$ ;  $>6\text{Kbar}$ ) which undergoes almost isobaric cooling ( $620^{\circ}\text{C} < T < 720^{\circ}\text{C}$ ;  $6.1\text{ Kbar} < P < 7.1\text{ Kbar}$ ).

Finally, the geochemistry of REE reveals the archaic character of the Birimian formations, as well as of the Leonian and Liberian formations, while the isotopes of the Nd and Hf actually reveal the interactions between the Archean and Birimian crusts with even the existence of Archean zircons inherited in the Birimian formations. All this gives us the opportunity to propose a geodynamic model in which we suggest that these interactions took place initially in a context of rifting of the Archean proto-continent between 3.0 and 2.7 Ga. During this period, an oceanic crust and volcanic arcs system associated with subduction zones are generated and are subsequently recycled, after the Archean, by the Burkinian orogenesis that will set up the Dabakalian magmas between 2.5 and 2.2 Ga (early Birimian).

All the data obtained help to re-evaluate the Leonian and Liberian events and to identify the interaction of their formations in the Birimian geodynamics.

**Keywords** - Leonian - Liberian - Birimian - Tectono-metamorphic event - U-Pb Method - Lu-Hf Method - LA-ICP-MS rifting - Volcanic arc.

## The evolution of the metamorphic series of the Serouanout terrane (Central Hoggar): Petrology, Geochronolgy and P-T evolution

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Recent field missions in several sectors of the Sérrouenout block reveal a significant difference between its different components, contrary to what was presumed. Indeed, the region of Ti-N-Eggoleh located in the southern part of this terrane is composed of typical formations of oceanic environments, having undergone eclogite facies conditions of high pressure in a first stage, then high temperature conditions (800 ° C) during the exhumation stage. Phase diagrams indicate that pressure was close to 18 kbar (~ 650 ° C) during the prograde stage which coincides with the development and the stability of quartz-talc-kyanite and omphacite-garnet-quartz parageneses. Further to the North, in the mafic and ultramafic greenstone massif of the Adrar In Imzaden which forms the central part of the Sérrouenout terrane, we observe outcrops of lower metamorphic grades. They are composed of kyanite-staurolite-garnet-bearing micaschists and migmatitic gneisses intercalated with marbles. Garnet-bearing and garnet-free amphibolites, talcschists and serpentinites are also found. Phase diagrams indicate that these metasedimentary series have undergone moderate conditions of amphibolite facies metamorphism (7-8 kbar, 500-600°C) and can even reach green schist conditions.

Geochronological data (U / Pb on zircon and monazite) indicate that the crust of the Adrar In Imzaden massif is juvenile since no age above 630 Ma has been defined in the migmatites and micaschists of the cover. In contrast, in Ti-N-Eggolleh (located only about fifty kilometers south of Adrar Imzaden), detrital products deriving from a 2200 Ma protolith have been deposited and have later undergone an important metamorphic event at about 630 Ma (from a discordia age).

**Keywords** - Central Hoggar - Whiteschist - Eclogite facies - U/Pb on zircon/monazite - Pan-African orogeny.



## Rare Earth Elements in phosphorites from the Bled El Hadba deposit (NE Algeria): concentration, behaviour and depositional environment

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The phosphorites of the Bled El Hadba deposit are located South-Eastern Tebessa region (NE Algeria). They are aged of Late Paleocene to Lower Eocene and are a part of Gafsa-Metlaoui-Onk phosphorite basin. The phosphorite layer, as whole Djebel Onk mining basin, is divided into three sub-layers: lower, principal (or main) and upper sub-layers. The petrographic study of samples from each sub-layer shows high-abundant glauconites in addition to coexisting pellets and coprolites. The geochemical study was carried out on these three types of particles using “in situ” laser ablation technique (LA-ICP-MS). The results show that P<sub>2</sub>O<sub>5</sub> contents are varying between 17 wt% and 24 wt%. The studied particles display high concentration of Rare Earth Elements (REE) with a variation depending on the type of grains and their stratigraphic position relative to the phosphate layer ( $\Sigma$ REE ranging between 194 and 2050 ppm). The REE are enriched in the main sub-layer where the glauconites exhibit contents exceeding 2000 ppm (average= 1346 ppm). This enrichment of REEs could be interpreted by substitutions of several elements by REEs (e.g., Ca, Fe, Mg, V and P) in phosphate minerals of the studied particles.

REE patterns normalized to Post-Archean Australian Shale (PAAS) show a negative Cerium (Ce) anomaly in all particles indicating an oxic deposition environment. They also show a slight positive anomaly of Europium (Eu) which indicates a reducing to sub-reducing conditions. The presence of these two anomalies of Ce and Eu together is probably a result of the “upwelling” phenomenon and the mixing of deep seawater (reducing environment) and shallow seawater (oxic environment) during phosphorite rocks genesis in the deposit basin.

**Keywords** - Phosphorites - Glauconite - Geochemistry - REE - Bled El Hadba - Djebel Onk.

## Two contrasting sources for base-metal mineralization in Northeast Algeria: Evidence from fluid inclusion and stable isotope studies

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Base-metal mineralization, mainly Pb-Zn-Ba, is widely distributed in Northeast Algeria, regardless to the geological petrological and structural complexity of the region. In this part of the country, the Northern area belongs to the Maghreban chain which is composed mainly of Neoproterozoic-Paleozoic metamorphic complex and Middle Mesozoic-Cenozoic terrigenous nappes that are intruded by Miocene igneous rocks. The Southern area, however, is structurally more stable and consists of Mesozoic-Cenozoic mainly marine sedimentary lithologies.

In the Northern area, it is believed that the Miocene igneous activity is responsible for the emplacement of many base-metal deposits, such as those of Oued Amizour giant Zn ores and El Aouana and Ain Barbar Pb-Zn deposits. In the Southern area, the Eastern Saharan Atlas, the halokinesis of the Triassic evaporitic sediments that intruded the Cretaceous to Quaternary carbonate-clay sediments is responsible for the emplacement of base-metal (Pb-Zn-Ba-F) and Fe mineralization. This is observed in several localities, such as Mesloul, Hameimat, Djebissa, and the giant Ouenza-Boukhadra iron deposit.

Fluid inclusion and stable isotope studies carried out on the Northeast Algerian deposits show two different mineralizing fluid. In the Northern area, the fluids are generally hot and saline, with homogenization temperatures (Th) greater than 160°C and can reach 500°C, and salinities between 20 and 25% eq.NaCl.  $\delta^{34}\text{S}$  of sulphide mineralization varies between -7‰ and +5‰ (n=57 samples). These values reflect the major influence of magmatic fluid for the origin of the sulphide mineralization. Magmatic fluid is also reflected when observing  $\delta^{18}\text{O}$ -V-SMOW and  $\delta^{13}\text{C}$ -PDB data of gangue calcite (+11.2‰ to +20.2‰ and -3.7‰ to -11.0‰ respectively) for Oued Amizour.  $\delta^{34}\text{S}$  of sulphates (anhydrite) from Oued Amizour Zn-mineralization show heavier values ranging from +13.2‰ to +20.6‰ (n = 10; mean = +16.3‰) which reflect marine sulphates, more likely Miocene seawater sulphates. The isotopic data indicate that the majority of the ore deposits related to the Tertiary igneous rocks of Northeast Algeria were deposited from mineralized magmatic fluids within seawater environment.

In the Eastern Saharan Atlas, fluid inclusion and stable isotope data show that the fluids are still hot but less than those of the Northern area, with Th between 100 and 160°C and salinities



varying between 10 and 30% eq.NaCl.  $\delta^{34}\text{S}$  of sulphide mineralization varies between -2‰ and +10‰ (n=54 samples); that of the gangue sulphates (barite and celestine) varies between 18 and 32‰ (n=15 samples); and that of the Triassic sulphates (gypsum) range from 14 to 16‰ (n=17 samples). These data coupled with the O- and C-isotope results of gangue calcite indicate that these brines, originating from the compaction and development of deep sedimentary basins associated with Atlasic tectonic events, could have leached metallic cations from post-Triassic sedimentary formations in the basin or even the Triassic rocks.

**Keywords** - Base-metal mineralization - Magmatic fluids - Brines - Fluid inclusion - Stable isotopes - NE Algeria.

### Sedimentary dynamic based on conodont stratigraphy of the Frasnian interval at the northwest Algerian Sahara

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The Ben Zireg anticline belonging to Bechar Basin yields the currently most-important Frasnian succession on the northern margin of the Algerian Sahara. It represents 26.5 m of calcilutites which are attributed to the middle-late Frasnian. As the early Frasnian is not represented, the succession rests conformably on undifferentiated, probably late Givetian, substrate. Our recent studies revealed a high diversity on conodont fauna allowing consequently to consider Ben Zireg as a reference section for the Frasnian interval of the northwest Algerian Sahara. Fine-scaled conodont biostratigraphy reveals a continuous sequence of Montagne Noire Zones 5–13, superseded by the earliest Famennian Lower *triangularis* Zone.

Interbasinal correlation with the South Marhouma section reveals that the middle Frasnian interval is much thicker there than in the studied section. This suggests an important accumulation rate that reflects high subsidence in the Ougarta trough, while the Bechar Basin suffered condensation.

This is presumably due to voluminous fine-grained detrital influx from the far highlands (i.e. Reguibat Shield) into the Ougarta sill. At Ben Zireg, condensation progressively reversed during MN Zones 11–13. This was also the case in Marhouma, the Anti-Atlas, and Meseta domains. At the end of late Frasnian time, deposits tend to homogenize in thickness over wide areas. This may reflect more uniform depositional conditions and less differentiated subsidence rates, in both platform and basin domains.

**Keywords** - Northwest Algerian Sahara - Bechar Basin - Ben Zireg anticline - Conodont biostratigraphy - Frasnian.

## Structural study of Kourki Copper-Molybdenum indices of the Birimian belt of Gorouol (Liptako, North-West Niger)

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The green Gorouol rock belt is located in the Nigerian Liptako which corresponds to the Northeastern edge of the Man Ridge. The West African Birimian outcrops in alternating granitoid and metamorphosed and structured greenstone belts in the Eburnian orogeny (~2.1 Ga) (Milési et al., 1992). The green rock belt of Gorouol (object of this study) is one of the three greenstone belts (Gorouol, Diagorou-Darbani and Sirba) of Liptako-Niger.

Kourki molybdenite (Mo) and copper (Cu) mineralizations are disseminated in a gneiss, embedded in porphyry granodiorites intruding the Gorouol green belt.

The methodological approach adopted consisted in a field study followed by a polarographic metallographic microscope analysis.

The geological environment of the Kourki index consists of lavas of varied nature (mafic and intermediate acid) sometimes in the form of massive flow and sediments (chemical, clastic or pelitic). These volcano-sedimentary formations are intersected by gabbroic, dioritic and granitic intrusions in the form of isolated massifs or dykes. At the metamorphism of localized amphibolite facies, a metamorphism of the generalized greenschist facies appears superimposed by chlorite-carbonate-epidote-quartz hydrothermal alteration in the mafic facies, and quartz-white-calcite mica in the felsic facies.

At the observation stage, four phases of deformation have been evidenced: D1 defined by early syn-schistous ductile deformation underlined by a flow schistosity (S1); D2 which is expressed through syn-schistous folding with schistosity (S2) of axial plane; D3 marked by NE-SW oriented ductile faults; and finally D4 characterized by late NW-SE oriented fractures that sometimes coincide with the direction of the locally mapped doleritic dikes.

The mineral paragenesis of the Kourki deposit is of the molybdenite-chalcopyrite-chalcocite-malachite-pyrite-sphalerite type. Pyrite occurs mostly in the contact gneiss-granitoid.

**Keywords** - Paleoproterozoic - Lithology - Deformation - Alteration - Paragenesis.

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## Iron mines in Algeria

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Given the importance of iron ore in the national economy and in view of the increasing demand for this strategic substance using in the steel and cement industry; The Algerian Iron Mines Company SOMIFER-Spa, specialized in the production and the marketing of ferruginous ores, is concerned to elaborate an iron ore inventory and to update the data and information related to ferruginous ore deposits and occurrences in all the national territory.

The main objective of this work is to locate, identify, classify according to types and importance, and select the potential deposits that would deserve detailed exploration for possible exploitation, and this in order to increase the geological potential and refresh the exploitation of iron mines which would boost the development of the national economy.

To make this possible, it was proceeded to the classification of iron deposits taking into account several criteria, such as the iron content, the size of the deposits, the type of ore, the genesis of mineralization, etc.

**Keywords** - Mines - Iron ore - Deposit - Potentials - Algeria.

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## Factors of copper mineralization in the Gaoua deposit (Southwestern Burkina Faso)

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The copper deposit of Gaoua is located in the Southern branch of the Boromo-Goren greenstone belt. Data from petrographic, geochemical, structural and fluid inclusions studies allow to draw the following main conclusions:

- (1) The main lithologies in the study area are intermediate magmatic rocks (andesites, diorites and microdiorites). Locally, more evolved terms (rhyolites and microgranites) are observed. The end of the magmatic history in the area is marked by andesitic breccia which displays clasts of the other lithologies.
- (2) Geochemical data suggest an emplacement in a volcanic arc context.
- (3) Structural records showed that the Northern part of the study area have been affected by all the phases of deformations whereas the two thirds Southern part is only affected by the second phase of deformation which is brittle-ductile to brittle.
- (4) The copper mineralization seems to be related to the emplacement of the microdiorite and diorite plutons which followed the effusion of andesitic lava. hydrothermal circulation took place at the end of this calc-alkaline magmatism. The hydrothermal circulation occurred when all magmatic materials became more brittle. In the portions where brittle deformation created dilational structures the fluids enrich-copper crystallized in these structures whereas, when these structures do not exist, we observe hydrothermal breccia with several mineralized veins.
- (5) Fluids inclusions studies revealed four types. The investigations on several samples showed that the four types of fluids inclusions can be found in the three types of mineralization at the same time.

Summarizing all this, we can say that the history of the mineralization begin with emplacement of microdiorite and diorite plutons and take end by hydrothermal circulation assisted by brittle tectonic or not. All these events took place in a relatively short interval of time and this can explain why the fluid inclusions natures do not change from one type of mineralization to another.

**Keywords** - Burkina Faso - Greenstone belt - Intermediate magmatic rocks - Volcanic arc - deformation - Copper - Fluid inclusions.

## Mafic and felsic magmatic mingling in the Paleoproterozoic formations of the Mako sector (Kédougou-Kéniéba Inlier, Senegal): geodynamic implications

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The Mako area is composed of a wide variety of greenschist facies metamorphosed rocks (Bassot, 1966; Dabo et al., 2017). These rocks are of mafic, ultramafic, intermediate and felsic nature associated with low sedimentary levels (Ngom, 1995). This ensemble is intersected by Eburnean granitoids which locally contain mafic enclaves.

In the Mako sector these granitoids are composed of Niéméniké pink granite, Lamé microgranite, Soukourtou granodiorite (Bananeraie), Niéméniké leucocratic diorite and mesocratic quartz diorite. The mafic enclaves trapped in these granitoids present varied petrographic and structural characteristics. Indeed, they show microlitic to granular textures, millimetric to multi-centimetric dimensions with elongated, ovoid or even ellipsoidal shapes. Most of the enclaves observed, generally have curvilinear boundaries which are crenulated in the detail. Some rare cases show straight boundaries with their host rock.

The mineralogy of the enclaves is dominated by primary minerals (plagioclase, amphibole and pyroxene) associated with secondary minerals resulting from the uraltization of pyroxenes and the saussuritization of plagioclase.

In view of all these characteristics, it appears that most of these mafic enclaves, which essentially correspond to metagabbros and metabasalts, were not at solid state when incorporated into the granitoids. We argue in this respect that the granitoids and the majority of the enclaves are derived from two contemporaneous magmatic liquids. These liquids have taken the same path during their ascent with one more mafic giving the enclaves and the other more felsic giving the granitoids. In this case, the mafic magma would be less important than the felsic magma. However, the well-defined straight-line enclaves would be linked to an already consolidated magma before being fragmented, ripped and carried away as enclaves in the granitoids.

In the latter case, the mafic enclaves result from the surrounding outcrops of metabasalts and metagabbros, which are locally cross-cut by granitoids (leucocratic diorite of Niéméniké). The alteration of some of these enclaves reveals empty cavities within the granitoids.

The existence of at least two generations of mafic enclaves (ante- and syn-granitoids) within the granitoids suggests a recurrence of at least two mafic magmatism events in the Paleoproterozoic formations of the Kédougou-Kéniéba Inlier.

**Keywords** - Mako - Granitoids - Mafic enclaves - Magmatic mingling.

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## Contribution of remote sensing and hydrographic morphology observation to map Proterozoic rocks in Ivory Coast

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The context of this work is the development of indirect techniques in the recognition of rocks by using remote sensing. The aim is to use hydrographic network legs morphology to discriminate Proterozoic rocks in Ivory Coast. Preliminary processing of Landsat 7 ETM+ data consisted to show the contents of channels which eliminate vegetation and outcrops. The ratio ETM+5/ETM+7 was followed by Laplacian filter to enhance dissonance areas and their internal change. A Principal Components Analysis (PCA) and colored composition of PCA channels have been addressed to see legs morphology. Findings have been validated by field observations. It follows from this methodology that the formation of narrow valleys means that the substratum is granitic. Conversely, under weak vegetation coverage, the formation of wide valleys is an expression of sand schists substratum. Granite outcrop setting is linked to vegetation coverage, while sand schists bedrock levels are only seen in streams. Granitic sands is setting to Northwest. Alluvia which are layered in N'Zi stream are discriminated in mud, sands and gravels. Laterite and clays fill 80% of the study area. This is a good result for geochemical soil prospection.

**Keywords** - Remote sensing - Granitic sand - Laterite - Landsat 7 ETM+ - Field observation.

## Relationship between alteration and mineralization in a mesothermal gold prospect at Akoase, Northeastern Axim-Konongo (Ashanti) belt, Ghana

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A gold prospect at Akoase in the Northeastern flank of the Axim-Konongo (Ashanti) metavolcanic belt in the Birimian of Ghana appears to show distinct relationship between the nature of alteration of the gold bearing rocks and gold mineralization (as per the grade of gold). At the prospect scale, three main types of alteration patterns are present. The first, typified by the minerals chlorite, calcite and minor sericite, is the most dominant but rarely contains Au grades in excess of 0.5 g/t Au. The second most abundant alteration is represented by sericite, dolomite and minor chlorite and is associated with assays >1 g/t but less than 2 g/t Au. The third is usually characterized by sericite, ankerite and pyrite and samples show highly variable but comparatively high gold grades often in excess of 2 g/t Au. Considering that some prospects, separated by about 20-30 km, occur within narrow corridors of the generally northeast-trending shear system, identification of such alteration patterns in the rocks could greatly help narrow down on potentially mineralized zones during further exploration and/or deposit evaluation.

**Keywords** - Axim-Konongo belt - Ghana - Akoase gold prospect - Birimian -

## New reconsideration of the Ouled Maallah geological map based on biostratigraphic data

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The present map is part of the geological map of Sidi M'hamed Benali at 1/50,000 whose surveys were made by Brives (1857), Perrodon (1957) and Welter et al. (1959). The contours of the geological formations are modified and samples taken for new dating purposes. The sector concerned by this study is located in the Dahra massif including part of the northern margin of Chelif plain, extending between the wadis Er Razzaz in the West and Tarhia in the East. Their geological series is characterized by a basement of Cretaceous sandy marls with carbonates and blackish levels; the Cenozoic formations are there represented by mio-plio-quaternary deposits. These localities are well known for their hydrocarbon indices (Ain Zeft) and their mining potential (gypsum-selenite).



Many detailed sections in the Ouled Maallah mounts illustrate the geometric arrangement of the mio-pliocene sedimentation which is marked by a brittle and plicative tectonics (anticline and syncline, folds). These structures are observable since the mouth of the Chelif river, near Mostaganem, to Tenes agglomeration (Derder et al., 2011, Maghraoui et al., 2002). This locality offers a Pliocene transgressive and discordant marine marl series on a pleated massive gypsum-selenite which has acquired its important morphologies during the Messinian and before the beginning of the Lower Pliocene age.

The preliminary data were obtained from the field prospection using biostratigraphic calibration methods, focusing on marine deposits (planktonic foraminifers, calcareous nanofossils).

The pliocène samples have revealed from bottom to top a complete succession of planktonic foraminifera's markers (Belkebir et al., 1996). The same samples subjected to the analysis of the nanofossils revealed the presence of important biostratigraphic markers having to change the previous geological attributions.

These data allow us to reconsider the geological map of this locality and to clarify the well-known mineralization in the region of Ouled Maallah.

**Keywords** - Dahra - Oullad Maallah region - Biostratigraphie - Planktonic foraminifera - Calcareous nanofossils - Mio-Pliocene

### REE-rich minerals in Paleoproterozoic carbonatites from Ihouhaouene -Hoggar

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The Ihouhaouene area is located in the northern part of In Ouzzal terrane (Western Hoggar, South of Algeria) (23°36'14"N, 3°10'32"E) and contains carbonatite bodies associated with syenites that are among the oldest in the world (2030 Ma).

The area of Ihouhaouene (In Ouzzal terrane, NW Hoggar, Algeria) is exceptional by the presence of numerous carbonatite outcrops which are systematically associated with syenites when they occur at the contact of granulites. Syenite and carbonatite complex from the In Ouzzal terrane present a linear shape contrary to what is observed in the other outcrops of continental cratonic regions. Syenites are particular since they are SiO<sub>2</sub>-saturated. As a consequence, the assemblage wollastonite-calcite-quartz is omnipresent in these rocks. All carbonatites are calico-carbonatites and form a continuous range of whole-rock major and trace elements from Si-poor carbonatite (<20 wt.% SiO<sub>2</sub>; 24-36 wt.% CO<sub>2</sub>) to Si-rich carbonatite (20-35 wt.% SiO<sub>2</sub>; 11-24 wt.% CO<sub>2</sub>), white syenite (52-58 wt.% SiO<sub>2</sub>; 0.1-6.5 wt.% CO<sub>2</sub>) and red syenite (57-65

wt.% SiO<sub>2</sub>; 0.1-0.4 wt.% CO<sub>2</sub>). Si-rich carbonatite and white syenite are distinguished both by higher REE content, LREE/HREE fractionation (Ce/Lu= 1690-6182) and high Nb/Ta ratio (>50).

Carbonatites from the Ihouhaouene contain apatite and clinopyroxene set in a matrix with up to 50% of calcium-carbonate and can be defined as calico-carbonatite. Brecciated carbonatites are medium to coarse grained with clinopyroxene (1-20%), wollastonite (< 10%), green or pink apatite (1 to 22%) set in groundmass of pink, gray or white calcite (50 to 70%). Green apatites have quartz, calcite and fluorite as inclusions, whereas monazite, calcite, quartz and allanite occur as inclusions or around pink apatites. Accessory minerals are K-feldspars (4-8 mm, < 1%), magnetite (<1%) as inclusions in clinopyroxenes, allanite (0.5-1%) around clinopyroxene, sphene (<2%), quartz (<1%) and coronitic garnet (<3%).

The pegmatitic carbonatites have large calcite grains (1-3 cm, up to 70 vol.%), clinopyroxene (1 to 5%) and green, pink or yellow apatite (up to 10 cm, 1 to 10%). Green and pink apatites are similar to brecciated carbonatite with the same inclusions. Yellow apatites differ from brecciated carbonatite with britholite exsolutions (up to 40 vol.%). Allanite, fluorite, quartz, wollastonite and alkali feldspar are present as accessory minerals (< 1%).

The most remarkable feature of these complexes is the presence of REE-rich minerals that can also include thorium like monazite (REE: 64-67%), britholite (REE: 60%), apatite (REE up to 9%) and allanite (REE: 14-25%).

**Keywords** - Ihouhaouene area - Hoggar - In Ouzzal terrane - Carbonatite - Syénites - REE-rich minerals.

## Cartography of coastal aquifers in the Essaouira region by application of the geo-electric method (Essaouira, Morocco)

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The region of ace that is given a heavy responsibility in the socio-economic development of Morocco. This development implies a significant increase in water needs in the coming years

for both drinking water supply and for irrigation and industry. This sector, like the other regions of Morocco, has experienced a significant decrease in water intake in quantity and quality. This situation has led to the reduction of agricultural productivity and the degradation of several ecosystems. However, this basin has an aquifer system consisting of a set of uneven aquifers that can offer a natural regulating capacity that makes them valuable to ensure a safe and steady supply. The reserve also makes it possible to meet seasonal needs through temporary overexploitation to the extent that replenishment is possible.

The so-called synclinal study area of Essaouira is part of the coastal zone of the basin with an area of approximately 1418 km<sup>2</sup>. It is limited to the North by Jebb Hadid, to the South by Tidzi River, to the East by the reliefs of South Chiadma, reliefs of North Haha and by the Tidzi slide, and to the West by the Atlantic Ocean.

Geo-electrical prospecting by vertical electrical soundings is a geophysical method that, applied in hydrogeology, will provide information on the geometry of possible reservoirs, their lithological nature and the spatial evolution of these characteristics. The interpretation of the results of this study, in correlation with the mechanical drilling, made it possible to stand out from the quantitative and qualitative maps, the different variations of apparent resistivity of the geological layers constituting the aquifer and aquiclude. The analysis of these maps shows that the area around the Qsob River is of interest from a hydrogeological point of view.

**Keywords :** Qsob River - Geo-electrical - SIG - Coastal aquifer - Essaouira.

### Mineralogical quantitative, cristalline and morphological characterization of siliceous material from the rocks modified by ferric oxide and oxyhydroxide

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The main phases of ferric oxide in nature are in increasing order of crystallinity, ferrihydrite, maghemite ( $\gamma\text{-Fe}_2\text{O}_3$ ), lepidocrocite ( $(\gamma\text{-FeOOH})$ ), hematite ( $\alpha\text{-Fe}_2\text{O}_3$ ) and goethite ( $\alpha\text{-FeOOH}$ ) (Schwertmann et al., 2000). Among these materials is diatomite ( $\text{SiO}_2 \cdot n\text{H}_2\text{O}$ ), also known as diatomaceous earth or kieselguhr, which refers to a soft light rock composed of amorphous silica microfossils of aquatic algae (Lemonas, 1997). The diatomite used in this study comes from the region of Sig (50 km from the city of Oran) in Western Algeria, in the form of a white powder (fig. 1).

45g of raw diatomite of Sig DB were immersed in 300 mL of 6M NaOH at 90°C for 2 hours to partially dissolve the Si (Al-Degs *et al.*, 2001). The mixture was immediately added to 300 mL of 4M concentration  $\text{FeCl}_2 \cdot 4\text{H}_2\text{O}$  ferric chloride tetrahydrate solution and stirred and oxidized in room temperature air for 24 hours. The solid obtained by centrifugation was washed with distilled water and oxidized by air for 24 hours. The mixture was dried at 105 °C in an oven for 24 hours. The product of this process were called DMF4 respectively (figs. 3 et 4).

The mineralogical analysis of iron-modified diatomite «DMF4» shows the predominance of the three oxides which are: iron (III) oxide ( $\text{Fe}_2\text{O}_3$ ) 53.161% ; sodium oxide ( $\text{Na}_2\text{O}$ ) 25.5%; silica ( $\text{SiO}_2$ ) 12.942% and the presence of the oxides of low mass percentages which are: calcium oxide ( $\text{CaO}$ ) 1.19% ; alumina ( $\text{Al}_2\text{O}_3$ ) 0.566% ; magnesium oxide ( $\text{MgO}$ ) 0.198% ; potassium oxide ( $\text{K}_2\text{O}$ ) 0.349% ; 0.066%  $\text{TiO}_2$  and other 6.378%. The X-ray diffractogram of diatomite modified by ferrihydrite «DMF4» is given in figure 5.

Figure 5 shows the evolution of the intensity as a function of the scanning angle. For quartz ( $\text{SiO}_2$ ): the peaks at ( $2\theta=36.8^\circ$ - $50.3^\circ$ - $66.3^\circ$ - $73.5^\circ$ ), with interarticular distances ( $d=2.45$ - $1.81$ - $1.40$ - $1.28$ ) [1]. For hematite ( $\alpha\text{-Fe}_2\text{O}_3$ ): the peak at  $2\theta=35.5^\circ$  with the interarticular distance  $d=2.52$  [1]. For goethite ( $\alpha\text{-FeOOH}$ ): the peak at  $2\theta=21^\circ$  with the interarticular distance  $d=4.19$  [1] (ASTM file 17-536). For magnetite ( $\text{Fe}_3\text{O}_4$ ): peaks at ( $2\theta=43^\circ$ - $57^\circ$ - $62.5^\circ$ ) with interarticular distances ( $d=2.08$ - $1.60$ - $1.47$ ) [1]. For maghemite ( $\gamma\text{-Fe}_2\text{O}_3$ ): the peak at  $2\theta=43^\circ$  with the interarticular distance  $d=2.08$  [1]. Figure 6 shows scanning electron microscopic observation (SEM) of diatomite modified by ferrihydrite with calcination at 600°C.

There are two main types of DMF4 model : the central particles of DMF4 have a diameter of approximately 1.6-8  $\mu\text{m}$  and a thickness of several microns. The pinnate particles of DMF4 have a length of  $\sim 3.3$ -15  $\mu\text{m}$  and a width of  $\sim 1.6$ -7.6  $\mu\text{m}$ .

**Keywords** - Diatomite - Ferrihydrite - Calcination - DMF4.

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## Gitology and Geochemical features of the mineralizing fluids of Es Souabaa Ba-F Pb-Zn prospect (Mellegue Mounts, NE Algeria)

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This sector is located 18 km Northwest of El Aouinet, in the core of the Es-Souabaa (Damous) anticline. The stratigraphic succession of this area may reach a thickness of ~1000 m, consisting dominantly of marls and shales with marly limestones. It extends in age from Cenomanian to Turonian. Structurally, the study area appears as asymmetrical anticline trending NE-SW, with flanks dipping between 15° to 35°. It is crosscut by several diagonal and transverse faults, leading to a tilted block structure. These faults are mostly NW-SE directed and of wrench fault type. Numerous small-scale faults cross-cut the anticline. They are NS and EW trending and are characterized by calcite cements.

The mineralization occurs mainly as veins, veinlets, lenses and infrequent disseminations usually in the rocks near the faults and around the veins.

All sulfide veins are closely associated with calcite veins. Some of them are typical multistage open-fracture fillings. They are characterized by a paragenesis of pyrite, galena, sphalerite, chalcopryrite, tetrahedrite. Traces of oil are associated with this paragenesis. Galena is the most important sulfide mineral. It normally occurs intergrown with calcite and barite or as well-defined single crystals.

The study of the fluid inclusions of fluorite crystals of the sector of Es Souabaa shows that there are three types of inclusions: two-phase aqueous, two-phase to hydrocarbon, three-phase hydrocarbon and aqueous. The hydrocarbon phase is yellow liquid well differentiated from the aqueous and vapor phases.

The diagram makes it possible to locate the aqueous phase of these three-phase hydrocarbon inclusions. This phase has the same homogenization temperatures (60°C to 115°C) and ice melting of the aqueous phase between -5°C to -10°C. This suggests that it would be a fluid with an average salinity of the order of 12% eq. NaCl.

The diagram of the Th vs. T<sub>fg</sub> for both types of two-phase aqueous and three-phase hydrocarbon inclusions clearly shows that it is the same basinal fluid that would be responsible for these types of inclusions. It would be a hot and salty fluid that remobilized during its journey the organic matter contained in the Bahloul facies of the lower Turonian which enriched it in hydrocarbon.

**Keywords** - Cenomanian - Turonian - Bahloul facies - Sulfide mineralization - Fluids inclusions - Es Souabaa.

**Occurrences of heavy minerals and REEs in the Pan-African formations  
of the Mounio Massif, Southern extension of the  
Trans-Saharan Range (Gouré, East Niger)**

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The Mounio Massif is located between the Aïr Massif in the North and the Benino-Nigerian Shield in the South, belonging to the Trans-Saharan Range. It consists of neoproterozoic terrane ( $575 \pm 12$  Ma) dealing with metasedimentary rocks. These rocks are intruded during the Pan-African Orogeny, by calc-alkaline granitoids, then, in the Devonian, by an alkaline ring complex (Black and Liégeois, 1991). This complex, namely Gouré Complex, consists of volcanic terrane represented by rhyolites, cinerites, ignimbrites, breccias and tuffs intruded by plutonic bodies including microgranites, syenites and granites (Black and Liégeois, 1991).

Given to their setting context, the granites of the Mounio Massif could contain porphyry-copper-gold-molybdenum, base metals and rare earth deposits (PRDSM, 2013).

The objective of this study is to highlight the anomalies in heavy minerals and rare earth elements (REE) in the Mounio. The method used consisted of a petrostructural study of the outcrops, a systematic sampling of rocks and weathering zones, a microscopic study and a geochemical analysis.

This analysis shows that mineralization indices in heavy minerals (gold, cassiterite, manganese, Tungsten and tin) and in REE are mostly disseminated in the weathering zones. The bearing facies is the granite. This study is consistent with the work of PAMME (1997-2004) in the Mounio Massif which revealed gold, tin and manganese anomalies in aegyrine and hornblende granites and in granite sodium facies.

**Keywords** - Pan-African mobile zone - Mounio Massif - Heavy minerals - REE - Anomalies.

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## The DASA graben in Northern Niger, a case of a Paleo-Mesozoic basin evolving from uplifting to rifting

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The N70° DASA graben is a closed-rift that seems to be the deepest part of the Tim Mersoï Basin, which is located in the Northwestern part of Niger in West Africa. It contains a pile of more than 805 m of Paleozoic-Mesozoic sediments. The tectonic subsidence and uplifting was calculated using well log data and deducing the variations in sedimentary thicknesses over time. Geological mapping and tectono-sedimentary analysis indicate that the structural evolution of the DASA graben is characterized by two major periods :

- the first period was marked by an uplift stage ranging from Carboniferous to Permian. It was typified by a weak subsidence rate (3.45 m/Ma on average), under a transpressive tectonic regime, with a decrease in the thickness of the sedimentary series along the axial zone of the graben, and an increase of the thickness towards the border areas;

- the second period was characterized by a higher subsidence rate (4.11 m/Ma on average) related to a change in the tectonic regime. It was marked by a rifting stage preserved over a long period, subjected to an extensive tectonic regime, from Triassic to Lower Cretaceous, during which the highest thicknesses of the sedimentary series developed in the axial zone of the graben.

The structural and sedimentological features defined the DASA graben as a particular type of syn-sedimentary basin evolving from a transpressive tectonic regime during the Paleozoic to an extensive tectonic regime during the Lower Mesozoic. Thus, the second period marked by an extensional regime would probably be related to the opening of the first stages of the Atlantic Ocean.

**Keywords** - DASA graben - Tectono-sedimentary - Uplift - Rifting - Polyphasic evolution - North Niger.

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## High-resolution landform-regolith mapping in a greenstone belt context of the Soudanian zone: Implications to mineral exploration

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We present a new protocol of high-resolution landform-regolith mapping that takes into account the specificity of West African morpho-climatic context and allows for the definition of new soil geochemical exploration criteria. Particular attention was given to glacis/pediments that are transportation slopes occupying an overwhelming part of the sub-region. The map is based on extensive fieldwork and complementary photo-interpretation. Field mapping was undertaken at 1:10,000 scale on the basis of Lidar data converted into topographic sheets with 1 m contours. Twenty map units have been defined that are grouped under four main types of landform-regolith association. The first type relates to the relicts of the West African paleo-land surface sequence: (i) paleo-landscape relicts with their pristine capping duricrust (bauxite and/or ferricrete), (ii) paleo-landscape relicts from which the duricrust cap was stripped-off, (iii) erosional paleo-landscape relicts exposing an earlier regolith that it contributed to exhume and (iv) residual hills resulting from the degradation of the paleo-land surfaces. The second type comprises recent erosional landscapes exposing various types of material: (i) bedrock and saprock, (ii) saprolite, (iii) various weathering horizon(s) under scree-capped slopes and (iv) lithosoils. The third type comprises functional land-surfaces and their clastic sedimentary overburden in transit: functional pediment/glacis and alluvial fans. The fourth type corresponds to accumulation landforms that are represented by alluvial terraces along the main mature river drains.

Given the nature of the regolith exposed by each landform-regolith map unit, the twenty map units have been grouped into four categories to produce a soil prospectivity map. This map aims to help interpreting soil geochemical surveys and targeting favourable sampling sites where the regolith is still linked to its underlying parental bedrock. Apart from being key for interpreting surface geochemical anomalies, such maps should further help locating unsuspected resources (concealed under transported regolith) and targeting areas of potential supergene concentration of metals.

**Keywords** - High resolution mapping - Landform regolith map - Mineral exploration - Sudan.

## Granitic pluton of Zorgho: emplacement context and relationship with Markoye Shear Zone (Center of Burkina Faso)

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The Zorgho biotite granite pluton is essentially intrusive in tonalite, trondhjemite and granodiorite (TTG) type granitoids. Only a small Southern portion of this pluton is intrusive in the Birimian metasediments. At the field scale, the difference between Zorgho granite and its TTG shell is clear.

The Zorgho granite is apparently without fabric whereas its TTG shell is often well structured. It contains biotite as the sole ferromagnesian mineral while TTG granitoids contain both biotite and amphibole.

It is in the light of the weak Zorgho granite fabric that we have carried out a total of three hundred thirty six (336) sampling sites that are waiting for Anisotropy Magnetic Susceptibility (ASM) measurements.

The observation of the structures of the TTG casing and the measurements we made there on the compass and the clinometer allow us to distinguish globally three phases of deformation in the study area :

- the deformation phase (D1) corresponds to a regional schistosity (S1) oriented N30°E70NW in the West bank of the PGZ and N40E70SE in the Eastern or South-West part;
- the second phase of deformation (D2) corresponds to a crenulation schistosity (S2) oriented N80°E80°N especially well expressed in the metasedimentary host south of the PGZ whose rheology is favorable.
- finally the third phase of deformation (D3) is characterized by tensile slits, with various filling materials. Many veins of pegmatites and milky white quartz enter this phase.

**Keywords** - Burkina Faso - Granitoids - Metasediments - Anisotropy of magnetic susceptibility - Deformation phases.

## Geochemical characterization of oils discovered from Offshore Benin Basin (Benin, West Africa)

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In order to establish the origin of the discovered oils in relation to their potential source rocks, 4 oil samples and 2 rock extracts samples from wells R16, R17, R24, R24, G20 and G21 in the offshore of the Benin coastal sedimentary basin constituted the main part of the study material. This is based on the chromatographic study of saturated and aromatic hydrocarbons in the samples. Chromatograms of the saturated fraction and geochemical ratios (CPI, Pr/Ph, Pr/nC17 and Ph/nC18) of the corresponding aliphatic hydrocarbons revealed that: (1) the oils from the Turonian and Albian reservoirs in the Sèmè oil field (shallow offshore) are virtually identical and would come from a common source rock. However, the oil in the H6 horizon is heavier (API= 22°C) than in the H6.5 horizon (API = 36°C). These oils are relatively mature and thick, but appear to have been washed into the reservoir. Carbon isotope data suggest that these oils are derived from algal organic matter; (2) the oils from the G20 and G21 wells (API = 42.47°C and 34.24°C) in the deep offshore are about the same (but the G21 well is less mature) and come from the same source that can be the source of the rock extract from the G20 well (Albian). The dominance of the Pr/Ph ratio suggests that the organic matter from which these oils originate is mixed: marine and terrestrial. These oils are apparently different from those of the R16 and R17 wells in the Sèmè field, which are much richer in light aromatics. GC-MS analyses will make it possible to specify this origin by studying biomarkers because several factors can affect sampling conditions before laboratory analyses by GC. Without further precision analysis, these changes can make the interpretations resulting from the chromatograms obtained speculative.

**Keywords** - Gas chromatography - Oils - Source rock - Origin - Coastal sedimentary basin of Benin.

## Geophysical data analysis and interpretation of the Tiawa prospect: Samira, Libiri and Boulon Djounga sectors (Liptako, West Niger)

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The gold mineralization exploited in the study area is located in the Sirba Birimian Greenstone Belt, closely to the Torodi Pluton, in the western part of the Liptako Province of Niger. The study area is composed of metabasites, metavolcanoclastites, metasediments and acid magmatic rocks (Ama-Salah *et al.*, 1996 ; Soumaila, 2000 ; Soumaila *et al.*, 2004).

The methodology implemented consisted of a compilation of geophysical and cartographic data, followed by a field analysis of tectonic structures.

The results obtained show five types of geophysical domains related to different lithofacies :

- The first D-1 domain, corresponds to mafic volcanic rocks ;
- The second D-2 domain has been attributed to more or less graphitic metasediments, which seem to be the gold mineralization-bearing rocks ;
- The D-3 domain represents a massive magnetic structure interpreted as granitic intrusions ;
- The fourth domain comprises some linear magnetic structures, oriented NNE-SSW, that cross-cut the three previous domains. They have been attributed to mafic dykes.
- The last domain (D-5) concerns the northern part of the study area. It has been assimilated to volcano-sedimentary rocks.

Structural analysis shows that the study area is marked by two deformation phases. The first one, ductile, is characterized by the development of a schistosity/foliation NE-SW trending, associated with boudinages, particularly in the ductile shear zones characterized by S/C fabric. The second phase of deformation rather brittle, consists of fractures, strike-slip faults and brittle shearing zones with RRC' fabric. This phase of deformation is at the origin of the emplacement of the doleritic dykes (Soumaila and Konaté, 2005).

**Keywords** - Liptako Province of Niger - Birimian Greenstone Belt - Sirba - Gold mineralization - Torodi Pluton - Linear magnetic structures.

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## The In Allaren mafic-ultramafic complex (Western Hoggar, South Algeria)

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The ring-shaped In Allarene mafic-ultramafic complex (Tirek region) is localized in the south of the In Ouzzal terrane. It is considered as a unique mafic to ultramafic pluton that was emplaced during the Pan-African orogeny. Petrological and geochemical observations show that the core of the pluton is composed of dunites and hazburgites that are surrounded by lherzo-

lites, websterites and gabbros with variable amounts of olivine. Low concentration of Cr-spinel was observed in all these lithologies. These mafic-ultramafic rocks were cross-cut by several doleritic dykes.

The continuous processes of differentiation and fractional crystallization combined with low sulphur fugacity inhibit the occurrence of both sulphide liquation and PGE complexation in the magmas. The dolerite and gabbro clinopyroxene composition and whole-rock geochemical data show that the emplacement of this complex was in arc tholeiitic domain. Emplacement style was in relation with the bracketing of the In Ouzzal with the surrounding terranes during the early stages of the Pan-African Orogeny.

**Keywords** - Mafic-ultramafic complex - Cr-spinel - Tholeiitic domain - PGE - In Ouzzal.

### Metallogenic implications of a new geodynamic model for the Eglab, Algeria

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The Reguibat Shield is the Northern part of the Archean-Proterozoic West African Craton. The Algerian portion of the Reguibat Shield is an extensive (~125,000 km<sup>2</sup>), long-lived Paleoproterozoic volcanic-plutonic tract. Previous workers (e.g., Lasserre *et al.*, 1970; Sabate, 1973) have subdivided this basement into the Yetti domain to the west and the Eglab domain to the east, separated by a postulated terrane boundary called the “Yetti-Eglab shear zone.” Our Algerian Geological Survey Agency (ASGA) – U.S. Geological Survey (USGS) study area includes these domains and is known as the Eglab region. Magmatism in the Eglab region spanned more than 150 million years of Paleoproterozoic time during the Birimian (or Eburnian; ca. 2250-1900 Ma; Peucat *et al.*, 2005) orogeny. Latest Birimian to possibly Mesoproterozoic dikes were the last major event in the region until onset of the Neoproterozoic Pan-African orogeny, which resulted in deformation in the Eglab region in the form of faulting and folding but little magmatism and no metamorphism. The youngest widespread magmatic event recorded in the Eglab region was the emplacement of Central Atlantic Magmatic Province (CAMP) mafic dikes and sills at ca. 200 Ma. Within the study area, the Tindouf (Cambrian or Ordovician to Devonian), Reggane (probably late Mesoproterozoic to Devonian), and Taoudeni (Mesoproterozoic to Cambrian or Ordovician) basins form the margins of the Eglab region on the north, east, and south flanks, respectively.

The most widely accepted tectonic model for the Eglab region (Peucat *et al.*, 2005) proposes that a 2.73 Ga relict of oceanic crust formed a cratonic core against which an eastward-dipping subduction zone developed, producing arc magmatism in the Eglab domain from 2.21-2.18 Ga. Closure of an intervening ocean and collision of the Yetti and Eglab domains at 2.09 Ga produced a second active margin magmatic event and deformation along the supposed Yetti-Eglab terrane boundary. Both domains were then intruded by large volumes of high-K, post-orogenic magmas triggered by slab roll-back and asthenospheric upwelling.

Our work defines magmatic episodes at about 2210, 2150, 2090, and 2075 Ma. From ca. 2240 to 2100 Ma, magmatism was the product of east-dipping subduction, with the axis of magmatism migrating from east to west. The composite Paleoproterozoic arcs collided with the Archean craton in Mauritania at ca. 2090 Ma. The Paleoproterozoic Yetti, Akilet Deilel, and Oued Souss basins are intra-arc basins comprising continentally derived sedimentary rocks and dacite-rhyolite volcanic rocks. Oceanic sedimentary and basaltic volcanic rocks are rare to absent. Similarity of detrital zircon age populations and composition suggests absence of a major terrane boundary along the postulated Yetti-Eglab shear zone. Late collisional slab break-off resulted in a voluminous post-collisional igneous flareup and emplacement of early high-K calc-alkaline and later alkaline magmas throughout the Reguibat Shield at 2080-2060 Ma. Our preferred model for the geodynamic evolution of the Eglab region is shown in Figure 1.

Our field observations, as well as igneous and detrital zircon geochronologic studies, do not support the presence of an Archean continental nucleus in the Eglab region. The absence of a significant Archean remnant in the Eglab region is also shown by neodymium model ages (TDM, “mantle separation ages”, 2.5 to 2.2 Ga; Peucat *et al.*, 2005) that decrease from east to west, consistent with our igneous zircon data. All igneous rocks are overwhelmingly calc-alkaline, suggesting formation in an arc-subduction zone environment probably as a series of continental margin arcs. The majority of the intrusive rocks are mixtures of metaluminous to peraluminous (I- and S-type) granites with a minor component of alkaline rocks; few igneous rocks exhibit A-type or peralkaline compositions, i.e., they are post-collision granites, not within-plate granites.

Geophysical data do not show the presence of a major terrane boundary along the postulated Yetti-Eglab shear zone. The observed magnetic low over the Yetti granitic rocks is likely due to lower magnetite content in rocks with a higher component of metasedimentary protolith. This is supported by the slightly more peraluminous character of the Yetti basement compared to the Eglab basement.

Based on our tectonic and metallogenic interpretations of the new data, a wide variety of mineral deposit types are permissible to occur in the Eglab. The most likely deposits include Mo-Cu porphyry deposits in arc magmatic rocks, epithermal base and precious metal vein deposits related to porphyry intrusions, and orogenic Au and Cu-Mo vein deposits in the Birimian



volcano-sedimentary sequences. Also likely are U-Th-Nb-Ta-REE and possibly Au deposits related to alkaline/peralkaline granites, granite-hosted (shear) and calcrete-hosted (Hamada-type) uranium deposits, and Phanerozoic oolitic ironstones. Deposit types that are permissive, but less likely to occur, include PGE-Cr in layered gabbroic intrusions (sulfide-poor reef-type), Cu-Ni-PGE in unlayered mafic-ultramafic dikes/sills (sulfide-rich conduit-type), and iron/magnetite skarn and sedimentary rock-hosted U and Cu deposits in the marginal basins flanking the Eglab.

The absence of a thick cratonic core in the Eglab region has important implications for diamond exploration. Previous studies have suggested that the Eglab may be a source region for headless diamond placers in Reggane, and several studies have noted the presence of a few harzburgitic “G9” and eclogitic garnets (Zerrouki, 2000; Kahoui et al., 2008). During the ASGA-USGS project, 74 regolith samples were collected and processed for kimberlite indicator minerals. Electron microprobe data for ~800 garnets were evaluated using the classification scheme of Schulze (2003). Our samples contained no peridotitic garnets; however, 74 eclogitic and 3 Cr-poor megacrystic garnets were detected. The majority of the eclogitic garnets are “group B”-type; of the remainder, a few are “group-C”-type and grosspydite garnets. While eclogitic garnets are not as prospective for diamond potential as the presence of peridotitic garnets, the Eglab region remains permissive for primary diamonds in “off-craton” kimberlite.

**Keywords** - Reguibat Shield - Eglab - Birimian - Magmatic episodes - Geodynamic model - Mineral deposits - Diamond.

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## Characterization of the morpho-sedimentary dynamics at the scale of Benin coastal lagoon (between Grand-Popo and Togbin)

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The understanding of the hydrodynamic and sedimentary functioning of the lagoons constitutes a preponderant element for the management of these environments as well as an indispensable base in the evaluation of the changes that know their rich biodiversity. The present study is based on sedimentological analyzes and bathymetric surveys to characterize the hydrosedimentary dynamics and the morphology of the coastal lagoon, one of Benin's four main water bodies. The coastal lagoon is part of the Ramsar site n°1017 and the Benin/Togo transboundary biosphere reserve of UNESCO.

From the sampling of superficial sediments from the lagoon using a grab and depth surveys, following the prerequisite transects, we carried out laboratory work such as sieving and also treatments using Folk & Ward formula, via the Excel spreadsheet, Origin software, Arc-GIS10.3.

The morphology of the bottom of the coastal lagoon is not homogeneous with the presence of basin and depths varying between 0 and 5 m. The western sector of the lagoon, in direct relation with the Mono River and the mouth in ocean, records the deepest depths. According to the North-South transects carried out, the morphology of the lagoon bottom shows a scarcity of «U» type profiles, some «V» and a predominance of the intermediate type. In terms of sedimentology, granulometric indices of sandy facies in the coastal lagoon generally indicate average sands of average classification, almost symmetrical with mesocretic acuity. The Passega diagram reveals a transport by saltation or rolling of sands. The combination of Friedman, Moiola and Weiser diagrams indicates that sands are brought by streams and also remobilized from the coastal dune area adjacent to the lagoon.

A hydrodynamic zoning is established, characterized by a weak hydrodynamism of the eastern sector or Ouidah lagoon and a relatively strong hydrodynamism of the western sector or Grand-Popo lagoon, with a speed of the order of 0.78 to 1.4 m/s towards the bottom and a flow of 429 m<sup>3</sup>/s, at the Avlo beach station.

Ultimately, this work highlights the state of hydrodynamic variations of the lagoon, including an opposition between eastern and western sectors, the diversity of sources of sedimentary inputs and the realization of the first maps of lithofacies and bathymetric of this aquatic environment, tool essential to its monitoring in the face of future changes and a constantly changing context.

**Keywords** - Coastal lagoon - Sedimentary dynamics - Bathymetry - Landscaping - Benin.

## Structural Eburnean events in the Massigui Square Degree (Southern Mali, Northwestern Man Shield, WAC): a review

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The convergence between the Paleoproterozoic Baoulé-Mossi domain and the Archean Kenema-Man domain induced a tectonic events in the Massigui Square Degree, located in Southern Mali.

The Massigui region is covered by the Birimian volcano-sedimentary sequences of the Bagoé Basin which are intruded by multiple Eburnean magmatic intrusions (Wane, 2010). It belongs to the Paleoproterozoic of the Northwestern segment of the Man Shield, Southern West African Craton (WAC) and is close to the Archean Kenema-Man domain. It is a key area to study the amalgamation of these two domains.

The Massigui Square Degree shows a strong spatial relationship between magmatism, tectonic and sedimentary processes. It is transected by the major NNE-SSW to NE-SW Banifing Shear Zone (BSZ) which links possibly with the Sassandra Fault Zone, separating Paleoproterozoic and Archean domains in Ivory Coast (Liégeois *et al.*, 1991; Pothin, 1993; Caby *et al.*, 2000). The BSZ extends from Côte d'Ivoire to the Taoudeni Basin is at least 100 km long and 5 km wide. This lithospheric scale shear characterized by heterogeneous deformations played a key role in the structural evolution of the Paleoproterozoic rocks of the area.

The synthesis of the various tectonic works carried out on the Massigui region by groups of different authors (Liégeois *et al.*, 1991; Wane *et al.*, 2007; Wane, 2010; Wane *et al.*, 2018) allows to discriminate four contrasted tectonics stages developed before, during and after the main BSZ. The D1 tectonic phase is poorly constrained and corresponds to a first isoclinal folding. The D2 tectonic phase, main regional deformation, is transpressive. The sense of shearing is sinistral NNE-SSW to NE-SW based on  $\sigma$ , S/C fabrics and asymmetric fold structures (Wane *et al.*, 2007, 2018). The D3 tectonic phase, brittle/ductile in character, is highlighted by fracture cleavage, tension gashes, microfaults and vein arrays. Orientation of extensional cracks filled by quartz indicates a dextral movement (Liégeois *et al.*, 1991). The D4 tectonic phase marked by brittle character affects display directions sub-parallel or oblique to the main NNE-SSW to NE-SW orientation of the BSZ. It is associated with normal to partially transtensive faulting (Wane *et al.*, 2007).

**Keywords** - Massigui - Tectonics - Eburnean - Man Shield - Shear zone - Banifing - Plutonic rocks- Southern Mali - Structural - Phases - Folding.

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### Rheological context of emplacement of the Dori and Gorom-Gorom plutons (Northeast of Burkina Faso)

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The present study, carried out in the North-East of Burkina Faso, is interested in the granites of Dori and Gorom-Gorom which are arranged on both sides of the Tiébélé-Dori-Markoye transcurrent shear zone whose involvement in gold mineralization is demonstrated by previous works (Nikiéma, 1992; Tshibubudze et al., 2016).

Granitoids being good markers of crustal deformation, the ultimate aim is to reconstruct the mechanisms of emplacement of these plutons by deducing their fabrics using anisotropy of magnetic susceptibility (AMS). This AMS study coupled with the examination of microstructures makes it possible to know the rheological context of the acquisition of fabrics.

Through all this information we propose the space-time relationships between the plutons emplacement and the transcurrent shear below:

- the emplacement of the Dori pluton and the central and southern part of the Gorom-Gorom pluton occurs in a context of interference between the diapiric thrust and an EW regional shortening (phase D1);

- the Northern part of the Gorom-Gorom pluton is emplaced in mega-shears EW oriented, consistent with the shortening phase.
- the activity of the Tiébélé-Dori-Markoye fault (phase D2) began at the end of these plutons emplacement, probably in a continuum of deformation.

These results show the quite contrasting rheological behavior of the crust at the time of the plutons emplacement, authorizing at the same time the emplacement by the diapirism and along mega-shears.

**Keywords** - Northeast Burkina Faso - Granitoids - AMS - Microstructures - Shear zone - Gold mineralization.

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## Geological heritage: legal aspects and methodological approach

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In this communication, we suggest: (i) to review the governing laws of heritage in general; (ii) an inventory methodology of geosites and what is recommended by international instances: UNESCO, IUCN, etc.

Algerian law does not have special regulations that specify the content of the geological heritage. This concept is integrated in various laws related to the environment, cultural parks, etc. The geological heritage has never been treated as such.

Heritage is a fairly complex concept: it can be natural or cultural and the ‘Natural’ is subdivided into Biological and Geological heritage.

Protection of heritage (natural and cultural) is until now carried out by cultural parks of the Ministry of Culture. By the interministerial decree of April 19<sup>th</sup>, 2018, these parks are endowed with prerogatives associated to «follow-up of the works of development and exploitation of the sites and geological deposits, etc.».

The geosites are integrated in the mining law of 2014 under the concept of «remarkable geological site» but this law does not mention the geological heritage. Only the mineral heritage which is an exhaustible and non-renewable wealth has been defined (Articles 5 and 6 of Mining Law 14-05).

Also, this law requires the preservation and enhancement of the heritage of the country's geological knowledge, including reference and representative rock samples, including macroscopic and microscopic samples, drill cores and powders. This is a remarkable advancement knowing that our country has ratified all international conventions relating to Heritage, whether natural (geological and biological) or cultural.

It is also noted that the Algerian Geological Survey Agency is endowed, within the institutional framework of its establishment, with structures having the competence to ensure the safeguarding and the promotion of the geological heritage. A structure is dedicated to this patrimonial activity as well as the compulsory legal deposit instituted by the mining law which requires to declare the realized infrastructure works and/or samples.

Geosites can be classified according to several parameters (among others):

**a. Geological/geomorphological (IUCN typology):** 1. Tectonic and structural characteristics; 2. Volcanoes / volcanic systems; 3. Mountain systems; 4. Stratigraphic sites; 5. Fossil sites; 6. Fluvial, lacustrine and deltaic systems; 7. Caves and karst systems; 8. Coastal systems; 9. Reefs, atolls and oceanic islands; 10. Glaciers and ice caps; 11. Ice ages; 12. Arid and semi-arid desert systems and 13. Meteorite Impact

**b. values:** 1. Scientific; 2. Educational; 3. Aesthetic and 4. Additional: economic/tourist, ecological, historical, symbolic.

Selection criteria (10: i, ii, ..., x) have also been defined by the convention of the World Heritage in an attempt to harmonize choices and promote the emergence of the best sites to inventory and classify.

The protection and preservation of remarkable sites impulse a local development dynamic that must be encouraged within the framework of sectoral policies put in place (e.g., SNAT) and sustainable development.

**Keywords** - Heritage - Geosite - Mining law - Classification - Sustainable development.

## Mineral resources of Algeria: state of play and perspectives

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The mining research carried out, since the independence, has made it possible to discover dozens of metallic and non-metallic mineral deposits in both North and South of the country.



The inventory of metal deposits revealed more than 3000 mineralized deposits, showing and occurrences, and as much if not more, for the industrial minerals. These mineralizations have been highlighted in several known structural domains: (i) the Tellian Atlas; (ii) the Saharan platform; (iii) the Hoggar Shield; (iv) Eburnean Basement of Eglab; (v) the Ougarta Hercynian range.

The metal deposits (Fe, Au, Pb-Zn, W-Sn, U, Ta-Nb, Be, etc.) and non-metallic deposits (baryte, bentonite/bleaching earths, calcium carbonate, noble clays, salts, etc ...) discovered, fueled the action campaigns for exploitation and/or exploration launched by the National Agency of Mining Activities.

The discovered resources are important and the potential may be greater if new approaches and exploration techniques are used.

The purpose of this paper is to provide a panorama of these mineralizations, with an outline of the typologies that could be the driving force for their implementation in their environment. Due to the geological and geodynamic evolution contexts, it is necessary to develop research projects for critical (strategic) minerals to face the new niches represented by green or future technologies.

**Keywords** - Exploration - Inventory - Metallic and non-metallic minerals - Typologies.

## Study of physical and petrophysical properties of Hamra Quartzites formation (Hassi Messaoud field, Algeria)

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In the Ordovician reservoir, the formation of Hamra quartzites is considered as a productive reservoir of oil around Hassi Messaoud field (Boudjema, 1987). This formation is little studied compared to Cambro-Ordovician sandstones. The Hamra quartzites, presented as a clean massive sandstone, well developed, but the the reservoir quality is variable because of the diagenetic effects, their position with respect to the Hercynian unconformity and the presence of fractures (Askri et al., 1995). In this work we studied the physical and petrophysical properties of core samples taken from Hamra quartzites formation in different oil wells located in Hassi Messaoud field.

The analysis of different types of fractures obtained by UBI and CBIL well imaging tools and well cores shows the existence of three types of fractures (open, partially open and closed), with the dominance of partially open fractures. The global orientation of these fractures is NE-SW and NW-SE. These fractures are almost at the same direction as that found on rocks outcrop-

ping at Tassili des nAjjers. This type of fractures is considered to be of tectonic origin (Massa et al., 1972). Magnetic measurements were performed, such as (i) magnetic susceptibility vs. temperature giving information on magnetic phases, their thermal and mineralogical carriers, (ii) hysteresis loops and (iii) isothermal remanent magnetization at saturation (ARIs) showing that the high magnetic susceptibility areas are related to several magnetic minerals such as hematite, magnetite and pyrrhotite.

The thermal conductivity (TC) of the studied samples was measured using the optical scanning method (Popov et al., 1999). The studied core samples are cut into two parts: one for thermal conductivity, porosity and permeability measurements, the other for thin section preparation. The samples are dried for 72 hours in an electric oven at 37°C. The plane polarized light microscopy analysis is used to classify samples on cemented and uncemented grain sets. The first set contains 13 samples and the second includes 15 samples. The relation between thermal conductivity and physical parameters shows that the porosity increases with the decrease of the thermal conductivity. These results confirm that the porosity is the main factor controlling the thermal conductivity. Weak correlation coefficients are found between thermal conductivity, permeability and density. The cementation of grains has low effect on the relation between TC and physical parameters. The correlation coefficient between TC, porosity and density increases slightly in uncemented set.

The Radial Basis Function (RBF) neural network proves to be a successful tool to estimate the thermal conductivity from physical parameters. The high value of the correlation coefficient ( $R=0.983$ ) between the thermal conductivity measured in laboratory and that estimated by RBF neural network shows the nonlinear relation between these parameters.

**Keywords** - Hassi Messaoud field - Hamra Quartzites formation - Ordovicien - Reservoir - Physicol and petrophysical properties.

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