JCBPS; Section D; May 2018 – July - 2018, Vol. 8, No. 3; 197-224 E- ISSN: 2249 –1929

[DOI: 10.24214/jcbps.D.8.3.19724]

Journal of Chemical, Biological and Physical Sciences

An International Peer Review E-3 Journal of Sciences

*Available online at*www.jcbsc.org

Section D: Environmental Sciences

CODEN (USA): JCBPAT Research Article

Neoproterozoic Dindéfélo waterfall geosite (DCNR, Bassari country, Eastern Senegal): biodiversity and geodiversity between conservation and valorization

Cheikh Ibrahima YOUM[1], Ezzoura ERRAMI[2], El Hadji SOW[1]

[1]Département de Géologie, Faculté des Sciences et Techniques, Université Cheikh Anta Diop, Dakar-Fann, Sénégal.

[2]Equipe de Géodynamique, Géo-éducation et Patrimoine géologique, Faculté des Sciences, Université Chouaïb Doukkali, B.P. 24000, El Jadida, Maroc

Received: 26 April 2018**; Revised:** 28 May 2018; **Accepted:** 08 June 2018

Abstract: The Dindéfélo Community Natural Reserve (DCNR), created to preserve the biodiversity and to ensure the sustainable development of the territory, is especially famous for its waterfalls of which the best known and the most visited is the Dindéfélo waterfall. The latter is hosted by the Neoproterozoic Dindéfélo formations in the current Kédougou region, between the Niokolo Koba National Park and the mountainous Fouta-Djalon massif in Guinea-Conakry. This latter offers a great abiotic diversity or geodiversity that consist of various rocks of differents natures and ages and geomorphological landscapes made of waterfalls, caves and plateaus, compatible with the installation of a particular biological community (biodiversity) that it is strongly threatened in Senegal and some of which are in process of disappearance. A dozen associated to the Dindéfélo waterfall geosites, which deserve to be valued and protected, have been inventoried. The Dindéfélo waterfall geosite was chosen to promote the

geodiversity as a support of the biodiversity and the geoheritage as a tool for human and socio-economic local sustainable development in the region. The integration of this geoheritage in the biodiversity protection and enhancement program of the DCNR and of the cultural heritage of the Bassari Country could help promoting a new touristic niche in Senegal, the geotourism and adoption of a new label, the geopark.

Keywords: Dindéfélo waterfall, DCNR, Bassari Country, Senegal, biodiversity, geodiversity, sustainable development, geotourism, Geopark.

1. INTRODUCTION

The Dindéfélo commune is located in the south-east of Senegal, in the region of Kédougou, between Niokolo Koba National park and the Fouta-Djalon mountainous massif in Guinea-Conakry. The latter offers a large geological and geomorphological diversity (geodiversity) which supports an important biological diversity (biodiversity) unique in Senegal. This geodiversity and the quality of its outcrops have made this region a popular destination for the field schools of students of the Department of Geology and the Earth Sciences Institute of Cheikh Anta Diop University of Dakar.

To preserve the biodiversity and ensure the sustainable development of this territory, the state of Senegal, in collaboration with numerous national and international agencies, created in 2010 the DCNR[1] which is a part of the Bassari Country territory declared in 2012 a World Heritage Site (WHS) [2]. The latter is composed of three geographical regions with specific geomorphologic and ethnic characteristics: the Salémata region with the Bassari people, the Bandafassi region with the Bédik people and the Dindéfélo region, that hosts the DCNR, with the Peul people. These people settled in the region since the XIth century [3], offer an original multicultural landscape respectful of its environment and extremely well preserved, structured in villages, hamlets and dense groups of thatched-roofed huts. The listing of the Bassari Country as a UNESCO WHS is based exclusively on cultural criteria without taking in consideration its geodiversity. The area has become a touristic destination, with rich and diversified cultural activities, due particularly to the Dindéfélo waterfall located ca 1,5km from the village which bears the same name. The waterfall is of more than 110m height with a swimming pool of 2 to 3m of depth around with a microclimate characterized by a relatively high humidity and low temperature which have led to the settlement of a flora consisting of a much diversified woody and herbaceous plants [4] and a rich microflora of diatoms [5]. The fauna consists of various species of reptiles, amphibians, birds and mammals such as chimpanzees which are threatened with disappearance [6].

This work aims to demonstrate the importance of the geodiversity of the Dindéfélo waterfall and its surrounding geosites as a support of the biodiversity, and highlight its scientific, educational, economic and socio-cultural values by calling the selection criteria VIII and X of UNESCO World Heritage Convention to strengthen the status of Bassari Country WHS. The purpose of this work is to raise the awareness of the local population of the Dindéfélo commune at all levels of the importance of this geoheritage in the conservation of animal and plant species, and of the necessity to preserve and valorize it at the same level of the biodiversity in view of a human and socio-economic sustainable development of the region, because the survival of the fauna and flora passes necessarily through the sustainability of the

geodiversity. This will be particularly important to women, the most vulnerable layer of the population of this region, to have additional income through the development of a new touristic niche, the geotourism.

The Dindéfélo waterfall, by the diversity of its geoheritage, its diverse micro-ecosystems, and the socio-economic activities conducted on its territory, deserves to be erected as a protected and valued geosite in order to preserve its flora and fauna (biodiversity). The management of this geosite will create the start of a geopark in the region. To meet this challenge, a preliminary inventory of the related DCNR geosites has been conducted in the frame of this work.

According to the African Geoparks Network (AGN) [7], a geopark is a territory where the geological and the geomorphological heritage (geoheritage) and all other heritage components (archaeological, ecological, historical, tangible and intangible cultural heritages) should be used to*: i)* strengthen the infrastructures of the rural areas through the development of geotourism; *ii)* strengthen the human development and; *iii)* promote sustainable peace in Africa and Middle East. The AGN, created in 2009 by the Association of African Women in Geosciences (AAWG) [8], aims; *i)* to identify, promote and inform on the importance of the geoheritage in Africa and the Middle East and the necessity of its preservation and valorization; *ii)* to strengthen the capacity of researchers, professionals and general public in the field of geoheritage, geotourism and geoparks and *iii)* accompany the regions to create their geoparks.

To meet these objectives, numerous conferences, roundtables, workshops and short courses were organized in several African countries and numerous national committees were set up [9, 10]. Despite this dynamic, the establishment of geoparks slows to emerge in Africa in general and in Senegal in particular. The continent count only two geoparks, however numerous projects are in progress.

This study is the beginning of a vast multidisciplinary scientific research work, in this part of Senegal naturally rich and socially poor, to promote the geodiversity through its ecological, scientific, educational and economic roles.

II - GEOGRAPHICAL SETTINGS OF KÉDOUGOU REGION

2.1 Geographical setting: The Dindéfélo commune is located in the south-east of Senegal, in the Kédougou region, Department of Kédougou, sub-prefecture of Bandafassi. The Kédougou region extends on an area of 16896km^2 and is limited to the west and to the north by the Tambacounda region, to the east by the Republic of Mali and by the Republic of Guinea to the south **(Figure 1**).

It hosts the DCNR, created in 2010 [11], which covers an area of 14000ha[6] between Tépéré and Walidiala. Oriented NE-SW, the DCNR is located between the latitudes 12°18'24"N and 12°25'51"N and the longitudes 12°11'35"W and 12°23'28"W. The village center, Dindéfélo, which means "at the foot of the mountain" in Fulani language, was founded between 1921 and 1923 by a hunter of the name of Manga Dian Pathé Traoré. It is located ca 37km from the Kédougou city. Its geographical coordinates are 12°22'58.64"N/12°19'22.32"O.

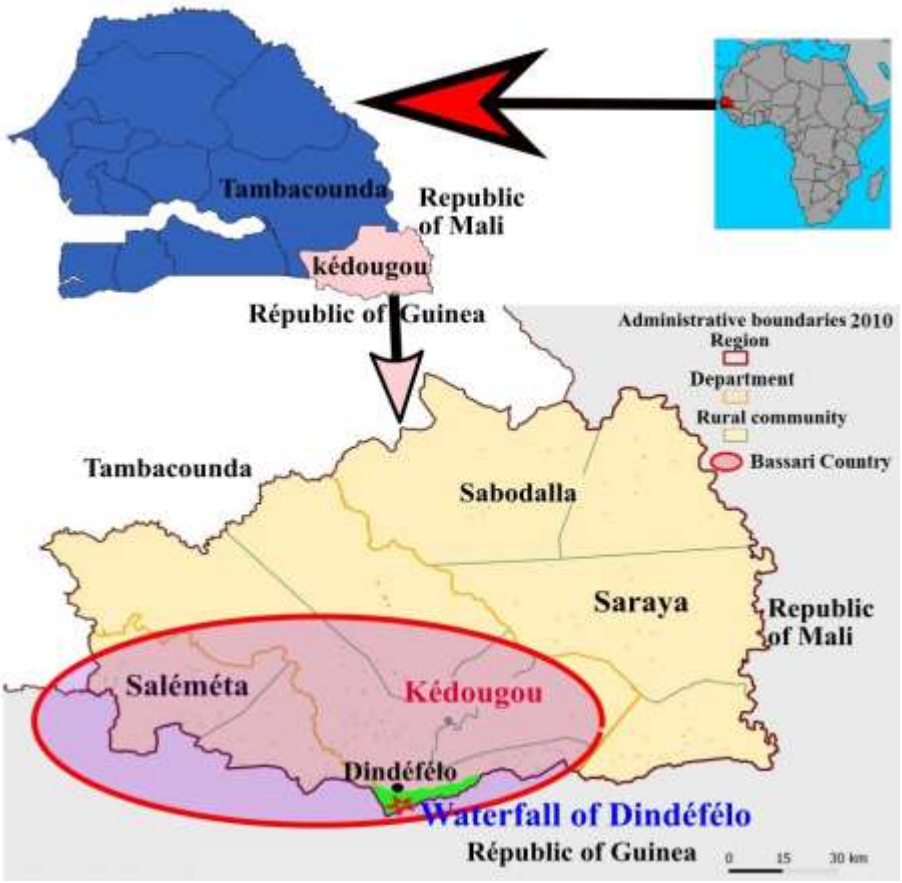

Figure 1: Location map of the DCNR (green coloration)

2.2 Climate and rainfall: the Kédougou region has a climate of Sudano-Guinean type with a rotation of dry and wet seasons. Located between the isohyets 1000 and 1300mm, it is one of the wettest regions of Senegal. The rains begin between April and May, peak during August and stop in October. The annual average temperature is 28°C, with an average of the maxima that can reach 40°C between April and October. The days may be of an acceptable heat between November and February and then they become very warm with thermal peaks in April and May before the first rains that lower the temperature [6].

2.3 Geomorphology and hydrography: The geomorphology of Kédougou region is quite particular compared to that of the rest of Senegal. Near the border with Guinea, stand up the Neoproterozoic sandstone plateaus of Fouta Djalon foothills with a culminating pic at 578m of altitude (Mont Sambagalou). NNE-SSW volcanic hills dominate the region. Most of the reliefs are covered by laterites, colluvial deposits and soils with clay dominance in the lower slopes and foothills.

The hydrographic network is represented by Gambia River and its tributaries (Thiokoye in particular) and the Falémé which take their source in Guinea.

2.4 Flora and fauna: The Kédougou region hosts a vegetation (*i*) of gallery forests of Guinean affinity which occupy the shallow places with big trees, (*ii*) of Savannah with species of Sudanian affinity, (*iii*) and of clear forest with a mixture of dominance of Sudanian essences and Guinean species [4].

The fauna is marked by a variety of species among which the antelopes, most of the African carnivorous species (lions, hyenas…) and hippopotamus in the Gambia River. It is common to encounter warthogs, monkeys and groups of Cynocephalus, and many avian species. The reptiles are represented by snakes, lizards and varans.

2.5 Population and economic activities: The Kédougou region is one of the less populated areas of Senegal with a density of ca 7 inhabitants/km^2. The most important cities are the regional capital Kédougou, Saraya and Salemata. Elsewhere, they are villages populated by few tens to a few hundreds of inhabitants and are linked by tracks. During the last years, we are witnessing the erection of new anarchical living areas close to the gold washing areas. The population is composed of a majority of Malinke and related ethnic groups (Soninke, Diakhanké, Diallonké and Bambara) and Fulani. These two ethnic groups are of Muslim faith. There is also the Bassaris and Bedicks ethnies which are of Christian confession and sometimes animists in the villages located on the mont Bassari. The cultural expressions of the people show original traits in their agropastoral, social, ceremonial and spiritual practices.

Economically, despite its young population (55.9% with less than 20 years), its numerous mineral resources and a good rainfall, the Kédougou region is the poorest area of Senegal with 86% of the population who live below the poverty threshold [1,12], The economic activities are dominated by the cattle and goats, agriculture generally organized in terraces and in rice paddies and the gold washing. The area of Dindéfélo houses three camps to local decor (boxes) managed by the young people of the village. The latter receives all Sundays the most important weekly market of the Kédougou region.

III - GEOLOGICAL SETTING OF THE KÉDOUGOU REGION

Several previous works have been carried out in the Kédougou region (Eastern Senegal). The authors who participated in the knowledge of the history of regional geology are very numerous. Among which we can mention: F. Adeguelou et M. Fall [13]; Arnould *et al*... [14, 15]; J.-P. Bassot [16-18] et J.-P. Bassot *et al*... [19-23]; J. Brinckmann *et al*... [24]; F. Buscail *et al*... [25, 26]; L. P. Chtocolov and V. V. Korj [27]; S. J. Culver and D. Hunt [28]; P. Debat *et al*... [29], C. Delor *et al*... [30, 31]; M. Deynoux *et al*... [32]; A. Dia [33, 34]; D.P Diallo [35, 36]; E. Dioh [37, 38] and E. Dioh *et al*... [39]; T. Fullgraf *et al*... [40-42]; J. -C. Goujou, [43, 44]; M. Gueye *et al*... [45]; P. M. Ndiaye [46-49]; W. Hirdes and D. W. Davis [50]; J. Kaisin *et al*... [51, 52]; D. Lahondère *et al*... [53]; A. Le Page [54]; P. Ledru *et al*... [55]; M. Morisseau *et al*... [56, 57]; J. P. Milési [58]; P. M Ngom [59, 60]; S. Pawlig et al. [61]; Y. Péronne [62]; J. Pons *et al*... [63]; G. A. Shields *et al*... [64]; G. Sustrac [65]; M. Villeneuve [66-68]; J. Walter and J. Chantraine [69]; F. Witschard [70, 71] ; A. Wuilleumier *et al*... [72, 73]; M. Dabo and T. Aïfa [74-76].

The geological history of the Kédougou region extends from the Paleoproterozoic (Birimian) to the Paleozoic era. The Birimian formations, -2.25 to -2.2Ga, consist of mafic and ultramafic rocks of the Mako Group, witnessing the existence of an old oceanic crust in the area. The partial melting of these basic rocks, as a result of a subduction, leads to the formation of predominantly dioritic rocks between -2.17 and -2.14Ga, constituting the Sandikounda-Soukouta Suite. Around -2.1Ga, extensive tectonic phenomena allow the formation of the silici-clastic basin of the Dialé-Daléma Group followed, in the interval -2.1 to -2.06Ga, by a N-S shortening episode characterized by an Eburnean sinistral NE-SW shear zone, and a dominant granitic magmatism (Saraya and Boboti Suites).

The Birimian basement is cross cut by numerous generations of doleritic dykes and sills of Mesoproterozoic to Neoproterozoïc ages emplaced between -1.5 and -0.8Ga. The dolerites are of Ectasian (-1.3Ga, Kédougou Suite) and Stenian ages (-1.15Ga, Sambarabougou Suite)[30] as the successive stages of an extensive cycle which led to the creation of a large basin where the Ségou/Madina-Kouta Supergroup represents the first sedimentary deposits. The latter constitutes two deposits sequences that record two cycles of flooding and progradation of silico-clastic sediments. The first sequence (Ségou Group), the most represented in Senegal **(Figure 2)**, begins with fluvial deposits (Kafori Formation) supplied by the weathering and erosion of the Birimian basement followed by a low transport, covered locally by post-Birimian rhyolitic effusions[30]. The basis of the transgressive formations (Pélel Formation) is characterized by the locally creation of a carbonate platform (oolithes, stromatolites) with fluvial silico- clastic recurrences in a shallow marine environment. The summit of the transgressive series is marked by the appearance of a silt-sandstone component which will suffocate quickly the carbonate platform. These silico-clastic deposits continue, reinforce and lead to the progradation of a fluvio-deltaic system (Dindéfélo Formation) in a shallow marine environment in a tidal and swell dynamics. The second sequence, Madina-Kouta Group, less complete in terms of deposit processions, records a similar evolution of the deposit environment **(Figure 2).**

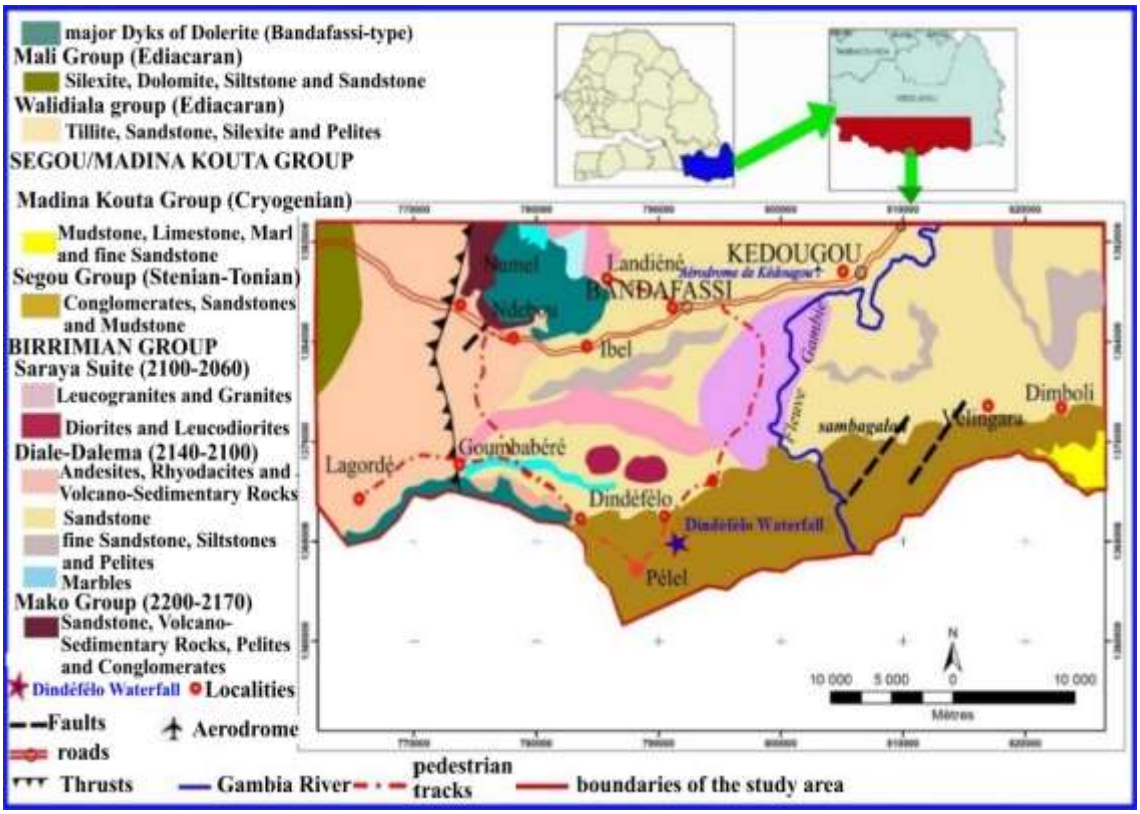

Figure 2: Geological map of Kédougou region

This long and rich geological history, which lasted approximately 2000Ma, has given rise to many geological and geomorphological sites (geosites) which, in addition to their scientific, educational and socio-economic importance, are important ecological ramparts constituting the last refuge for biological species highly threatened in Senegal. The choice in this work of the Dindéfélo waterfall geosite, the best known and most visited site, will facilitate the promotion of the importance of the conservation and valorization of the geodiversity in the preservation of the biodiversity and the human and socio-economic sustainable development of the region.

IV - THE DINDÉFÉLO WATERFALL GEOSITE

4.1 Introduction: The Dindéfélo waterfall geosite is located in the DCNR which has been created with a strategic objective to contribute to alleviate poverty by creating additional revenues for local population through the promotion of an integrated, decentralized and participatory management of the natural resources of Kédougou region, in particular in the Dindéfélo commune [77]. This initiative is the result of the actions carried in 2003 by the Program Agriculture - Management of Natural Resources "Wula Nafaa" and the Department of Water and Forests of the Ministry of Environment of Senegal and USAID, in collaboration with the Jane Goodall Institute of Spain and the Biodiversidad Fundación interested in monitoring and protecting the chimpanzees that are threatened with disappearance [78,79]. This program has provided a technical and financial support to the creation of the DCNR which is located between two important natural areas, the Niokolo Koba National Park (PNNK) situated in the north-west of Senegal and the Badiar National Park in Guinea-Conakry. Although, it occupies only a small part of the area between these two national parks of high fauna value, the DCNR has a great value as a wildlife corridor between the two parks. The installation of this unique biological community in Senegal, which led to the establishment of the DCNR, is due to its rich and diverse abiotic diversity (geodiversity) that it is offering habitats, havens and food necessary to their development and maintenance.

4.2 Management of the Dindéfélo waterfall, as geosite with ecological, scientific and socio-economic values:

4.2.1 The Dindéfélo waterfall, a geosite with ecological values: The relief in the vicinity of the waterfall is constituted by a belt of rocky hills essentially made of sandstones constituting havens for species that are very rare in the surrounding flat areas and plateaus (large diurnal and nocturnal raptors, small carnivores…etc).

The DCNR houses a very diverse fauna (biodiversity) consisting mainly of mammals, birds and reptiles. Mammals are dominated by Primates among which the chimpanzee of West Africa (Pan troglodytes verus Schweinfurthii) (**Figure 3A),** an endangered species[6]. The avian fauna **(Figures 3B & C),** consist of mountainous birds of rocky areas and of Guinean forests some of which are unique in Senegal. The DCNR houses also the populations of a few avian species seriously threatened in western Africa, such as of vultures and other raptors **(Figure 3D).**

The chimpanzees are followed by the Jane Goodall Institute of Spain since 2008. The information provided by this Institute on the avifauna [80] led the BirdLife International, an international organization of reference in birds conservation, to register the DCNR on the list IBA (Important Bird and Biodiversity

area). This recognition comes to reinforce the importance of the DCNR for biodiversity. Lizards (**Figure 3E**) and hives of bees (**Figure 3F**) are also very frequent in the DCNR.

The well-developed forests-galleries, situated around the waterfall, are offering a habitat particularly valuable to wildlife due to its richness in food, havens, shelters and water. The well preserved semi-deciduous forests, occupying the slopes bordering the valley leading to the waterfall, constitute another habitat that generates favorable conditions for numerous plant and animal species.

Accessing to the DCNR is complicated because there are no paved roads leading to the reserve, and the plateau area is accessible only on foot; therefore, poaching is much reduced.

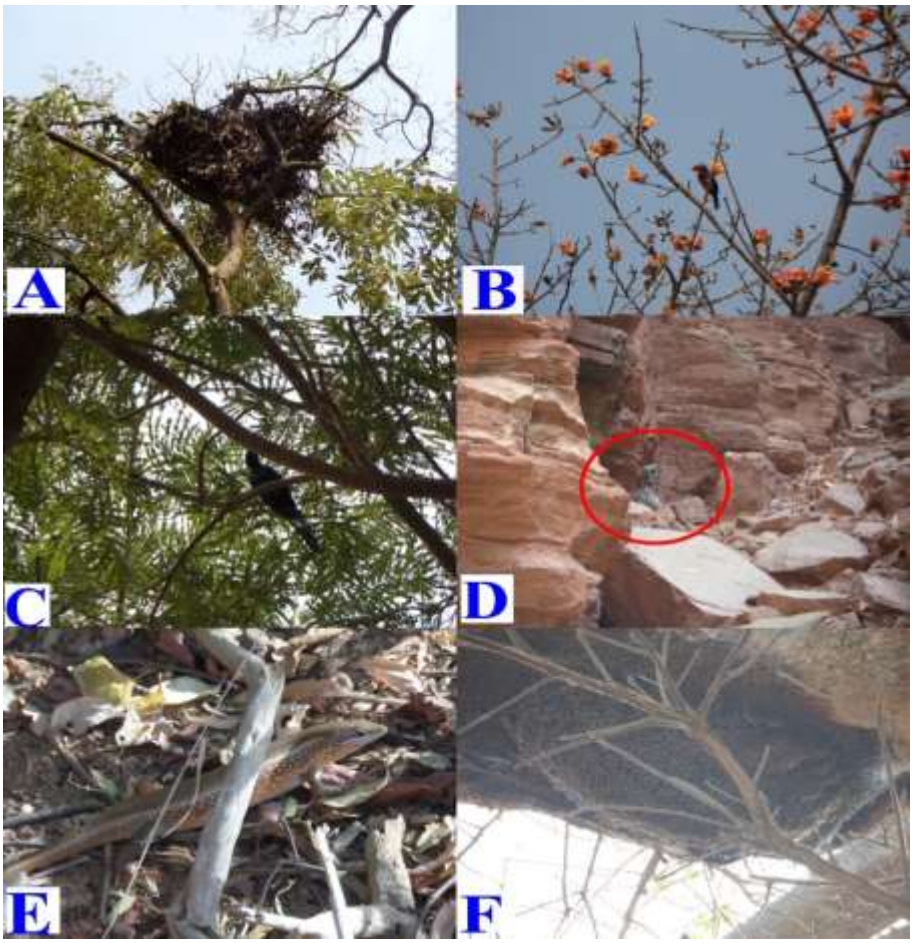

Figure 3: Wildlife of the DCNR; (**A**): Nest of Pan troglodytes verus schweinfurthii (chimpanzee); (**B** and **C**): Birds; (**D**): Raptor; (**E**): Lizard; (**F**): Hive of bees**.**

4.2.2 The Dindéfélo waterfall, a geosite of socio-economic and tourism values: the DCNR is especially famous by its waterfalls, of which the best known and most visited is the Dindéfélo waterfall. Nestled at the bottom of the Fouta Djalon foothills, 739km from Dakar, the Dindéfélo waterfall, bearing the same name as the commune (10473 inhabitants), is cut in the lower Neoproterozoic Dindéfélo formation. The water of the fall comes from sources of resurgence located on the Dandé plateau, village

which overlooks the waterfall, at the level of the historical Cave of Dandé, in the Republic of Guinea on a height of the order of 110m **(Figure 4).**

The Dindéfélo waterfall is the highest in the Senegal and the most accessible compared to the other waterfalls of the DCNR, Ségou, Pélel, and Afia. It also has a large swimming pool, of 2 to 3m of depth, which is serving as bathing place for visitors and local populations. The water of the fall flows toward the north along a stream of surface drainage on 1100m followed by a groundwater runoff before joining the Thiokoye, tributary of the Gambia. Its source flows, without discontinuity throughout the year. It is a trough for animals and a place of bathing rituals for the children of the village and visitors.

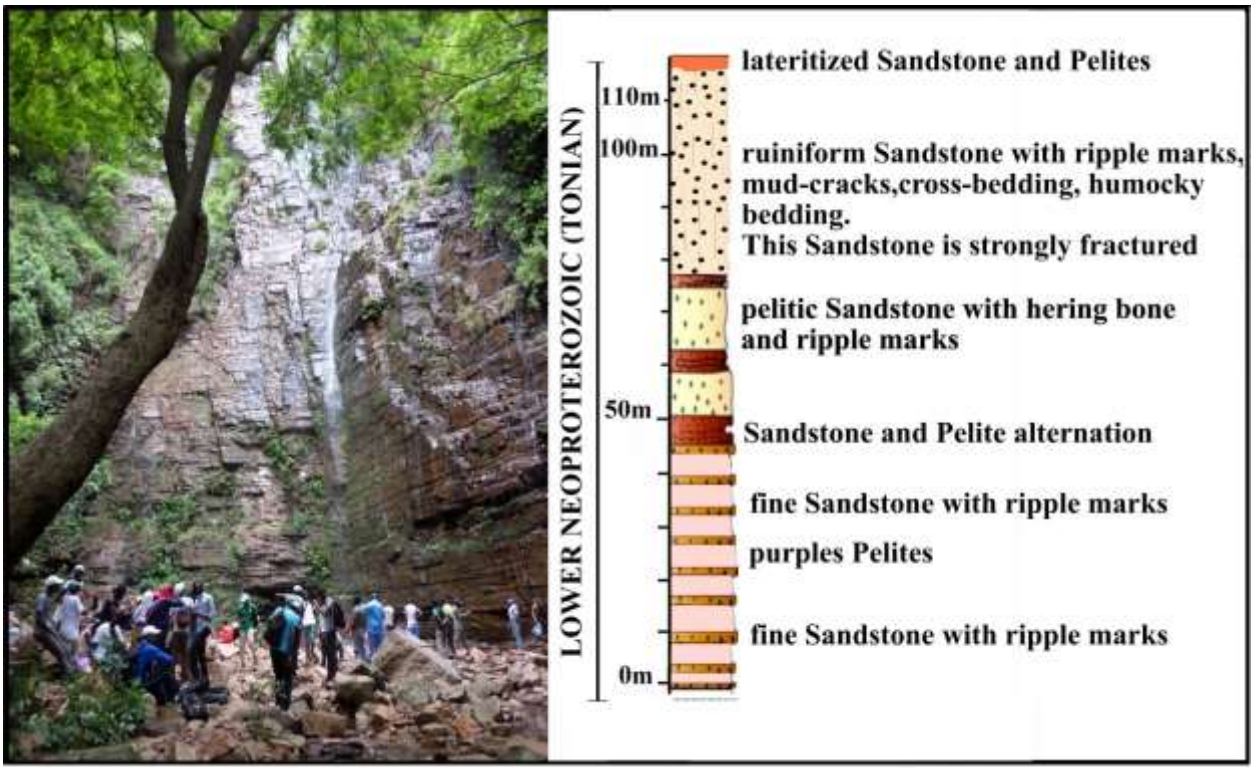

Figure 4: Dindéfélo waterfall and corresponding stratigraphic log

Kédougou region is reachable from Dakar, both by land using private or public transport or by air via the Kédougou aerodrome. From the city center of Kédougou, we can access Dindéfélo by car via a track. A half-hour walk is necessary to arrive at the Dindéfélo waterfall, but the show at the end of the effort is worth of all sacrifices. The place is of a breathtaking beauty that defies all taboos and annihilates all legends.

The spray of a part of water into fine droplets, during its fall along the cliff, creates a mist of spray that humidifies the air [81]. This process creates a wet microclimate in a region with climatic conditions marked by a long dry season. The encashment of the valley in a gorge shape increases the relative humidity and decreases the temperature in the vicinity of the waterfall. The water in the fall is nowadays exploited as water source by local population and marketed everywhere in Senegal allowing both the creation of additional incomes and jobs for the local population.

The Dindéfélo waterfall is receiving an increasing number of visitors, tourists, students and researchers for its water, its microclimate and its rich biodiversity. Adding to its touristic importance, the Dindéfélo waterfall plays a very important role in the economy of the community. Purveyor of jobs, it has enabled several young people of the community to invest in their territory by setting-up camps to accommodate tourists.

At its beginning, the visits of the waterfall were free, but, being aware of the enormous economic potential that it abounds, the municipal authorities have decided to make most of the activities related to it profitable. The visits are now paying, which allows the Town Hall to recover 3 to 5 million FCFA per year, depending on the number of foreign visitors, which varies between 1200 and 2000, despite the emergence of the hemorrhagic Ebola virus that impacted negatively the touristic influx.

This site has become, since a few years, an important touristic destination with rich and diversified sports and cultural activities. The Dindéfélo village is now equipped with a reception center and the DCNR consists of six tourist camps, two of which are community managed. Local materials were used in the construction such as bamboo, straw or mud, and the traditional architecture Fulani has been respected. In this way, the camps are very well integrated into the landscape.

Tourism is one of the most important economic activities in the reserve. It allows creating employment and are financing projects to improve the life standard of the local population such that the investment in public services such as clinics, sanitary facilities or schools, pay rural taxes, help the sick poor, repair of wells, to ensure the meals served during religious ceremonies. The infrastructure, consisting of ten boxes and a large meeting room, serves as a hotel for visitors of the waterfall and surrounding géosites.

Dindéfélo is also known for its monkey's bread, its fonio, its shea, its palm oil, its local bread, its honey and many other local products, which constitute the main economic resources of the community especially for women, the main actresses of rural development.

The population composed mainly of the Peuls and Malinke, living essentially from agriculture, breeding and tourism, is dedicating a real respect to the waterfall because it owed it almost everything. If today the Dindéfélo village is internationally known, this is because of its waterfall that allows the installation of a biological diversity rare in the rest of the country, as a result of which the area was erected a rural community and then a commune. The future of the commune and its development are linked to this geoheritage.

4.2.3 The Dindéfélo waterfall, a historical value geosite: Manga Dian Pathé Traoré, a brave hunter, went into the depths of the kédovine forest in the quest of bushmeat. The place is shady and the sun breaks through the places intermittently. Far away, the graceful hiss of water flowing stirs up his curiosity. He lends an ear and continues his walk. What will be his surprise when after 20 to 30 minutes, he falls on a source of clear water supplied by a waterfall that fails at the foot of the Fouta Djallon foothills and called it "Dindéfélo" that means "at the foot of the mountain in Fulani". The name will remain. At the beginning, the wild game was abundant and the grazing very green. But today, many species disappeared or are highly threatened. This story shows the historical importance of the Dindéfélo waterfall as a support of the biodiversity in the region.

4.2.4 Women groups and cereals processing: the Dindéfélo commune has welcomed its center of support to local self-promotion on February 22, 2016, due to the support of the Rotary Club Passau-Dreiflüssestadt of Germany in partnership with the Support to Local Initiatives and Environment Association. The center will enable women and young persons to learn trades such as dressmaking, hairdressing, restaurant services and initiate them to computing and to the processing of local products. The center aims also to promote the insertion of girls and boys that abandoned the school, in the economic fabric through a professional training.

In the Dindéfélo commune, several groups of women are active in various branches (Production and transformation of fonio and harvesting wild products (Monkey bread, tamarind…), market gardening, rice growing, production of peanuts, small trade, livestock…) in order to improve their life conditions. The establishment of a federation of transformative technologies and the construction of a transformation complex in Dindéfélo will contribute to the harmonization of the manufacturing process for a better quality of products and to facilitate their collection. Several national and international agencies help women diversifying their activities. They support women associations in the market gardening, in rural female entrepreneurship in order to increase the added value and their income.

4.2.5 Weekly market: Since 1980, in a context of disengagement of the state consecutively to the application of the Structural Adjustment Programs, the border areas of West Africa are experiencing an intense merchant traffic. In effect, the border areas between Senegal and Guinea Conakry in particular are of an intense trading activity by merchants and consumers. This spatial transboundary connection reflects the sub-regional integration between West Africa countries. The inhabitants of Dindéfélo, the region of Kédougou in general and of Guinea Conakry met each Sunday in the market place to exchange their local products but also to get supplied in manufactured products which came from the interior of the country. The weekly market constitutes an opportunity for local women to sell their products.

4.2.6 The Dindéfélo waterfall, a scientific and pedagogical values geosite: Geologically, the DCNR consists of a wide variety of rocks, including sedimentary rocks belonging to two supergroups (**Figure 5**), Ségou/Madina Kouta of Meso-Neoproterozoïc age and Mauritanides of Neoproterozoic age ([32]M. Deynoux *et al*..., 1993; [30]C. Delors *et al*..., 2010; [40]T. Fullgraf *et al*..., 2010). The basis for the Supergroup 1, Group of Ségou, discordant on the birimian basement, is observable in the valley of Walidiala. It is constituted by dominant sandstone and conglomerates facies with sand-silty-limestone matrix covered by oolitic limestone and red silty-lime-mudstone with stromatolites and intercalations of calcarenites (Pélel Formation) and ends by ruiniform sandstone with cross-bedding stratifications, ripples marks and lenticular bedding (Dindéfélo Formation). The upper part of Madina Kouta group, is absent in this part of the basin.

The Supergroup 2 or Supergroup of Mauritanides begins in the valley of Walidiala by a glacial conglomerate matrix-support to clast-support, the tillite discordant, on the Group of Ségou followed by an alternation of argillites more or less silty with dropstones and lenticular fine sandy siltstones with hummocky cross stratification (HCS) and plurimetric sandstone strata. This set is covered by, the dolomitic limestone or dolostone described as "cap carbonate / dolostone" in the literature, the strata of silexites with Jasper facies and then the mudstones and siltstones covered by greywackes.

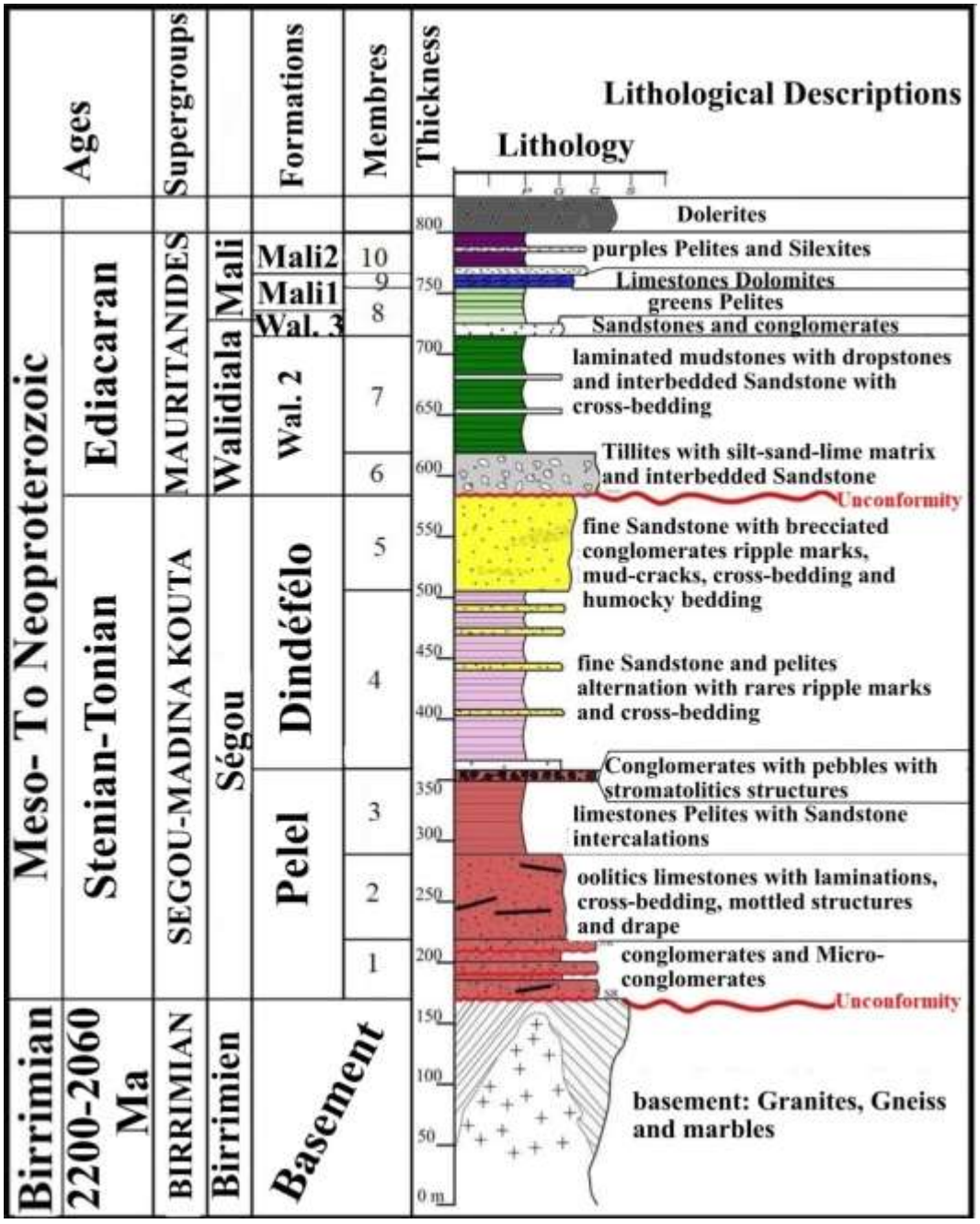

Figure 5: Synthetic lithostratigraphic Log of Dindéfélo

The deposits of the cliff at the level of the waterfall belong to the Dindéfélo formation of lower Neoproterozoic age [30, 32, 82], subdivided into two members: a lower member that consists of sandstone at lamins purple pelites, an upper member composed of sandstone highly fractured "ruiniform" with interbedded sandy-pelite that are becoming rare at the top. This formation is covering unconformably the sandstone, limestone pelites and stromatolites bearing conglomerates and basic rocks, that outcrop 1km in the west where they are covered by fluvio-glacial formations showing the existence of a former glacial

period in the area. The Dindéfélo sandstones formation [83] are affected by a combined NW-SE, WNW-ESE, NNE-SSW fracturations between Dindéfélo and Pélel and NNW, NE, ENE between Dindéfélo and Ségou. These fracturations are very marked and cause bulk rhombic flow and ruins aspects named "ruiniform sandstone".

This geodiversity, which encompasses the geology and the associated landscapes, facilitate the formation of waterfalls, caves and the biodiversity installation with specific flora and fauna that make the popularity of this area on the ecological level.

The microclimate in the vicinity of the cascade allowed the installation of a diversified woody flora with a Guinean predominance [4]. The various micro-ecosystems around the waterfall are home to a rich diatoms microflora of 62 species belonging to 28 genera [5] illustrating the various habitats of these micro-algae: (*i*) aquatic algae fixed on rocks in the ponds and along the streams, (*ii*) aerial humid on the flank of the waterfall and on ferns and (*iii*) dry aerial in the cave. The DCNR and particularly the Dindéfélo waterfall receive visitors for relaxation and pupils from numerous schools of the Kédougou and Tambacounda regions to study the biodiversity and the geological phenomena (**Figure 6A).** The students of Department of Geosciences and the Earth Sciences Institute of Cheikh Anta Diop University of Dakar **(Figure 6B)** organize each year their field schools in the area related to outcrops of good geological formations.

Figure 6: Dindéfélo waterfall, relaxation and pedagogical spaces (**A** & **B**)

4.2.7 Myths and legend of Dindéfélo region: the Fouta Djallon foothills, constituting the "walls" of the Kédougou region, are rich of stories. The waterfall has always been surrounded by certain mysticism and the circumcised were grouped during the ceremonies of initiation. Semi-closed, difficult to access with a mild micro-climate, the waterfall was once prohibited to visit on Monday and Thursday. The "forest of termites", which surrounds the site, contains a lot of spirits and mystics according to the indigenous people.

Among the numerous myths and legends figure the "trunk" of Pélel, located in the DCNR seven kilometers from Dindéfélo, trunk mystically suspended on the flanks of the mountain by the nature. Local people say that it contains wealth and precious stones such as gold or diamond. This trunk is the subject

of several lusts and curiosity, but nobody dares to come close to it. This suitcase still resists to time. Nobody dares to open it, because there are bees which ensure its protection. According to local populations, those who approach it do not find the key to open the padlock. If they found the keys, the padlock becomes invisible; never both at the same time according to the legend. The Dandé cave and the source of the waterfall are also surrounded by myths and legends.

4.2.8 The associated Dindéfélo waterfall geosites (Figure 2 and 4): In addition to the Dindéfélo waterfall geosite, object of this study, the preliminary inventory has allowed to identify a dozen of geosites in the DCNR. They are: *i)* the Ségou waterfalls, located southwest of Dindéfélo and Pélel in the Kondoodji valley at approximately 5 km from the Dindéfélo and Afia villages **(Figure 7**); *ii)* the Gambia river which crosses the DCNR in its southern and east parts; *iii)* The basement showing structural and sedimentary geosites **(Figure 8);** *iv)* Ribbon marbles of Koukoudji **(Figure 9);** *v)* structures and sedimentary figures of the Pélel sandy-carbonate formation and the Dindéfélo sandstones (**Figure 10)** (draping in the form of flaser and wavy-bedding), soft rollers and chips of mud clayey silty-reformulated within the banks of the thicker, lenticular bedding, oblique bedding, mud crucks, ripple marks, erosive surfaces…etc. The "Dandé Teeth" are carved in the ruiniform sandstone overlooking the plain of Dindéfélo **(Figure 11);** *vii)* the large valley of Nandoumari located between Nandoumari and Pélel, place of grouping of primates during the night and the very hot periods; *viii)* the stromatolites of the Ségou-Madina Kouta supergroup **(Figure 12**) which outcrop in Walidiala valley in the form of balls of overhauled granular limestone, packaged in a matrix of carbonate argillites which cover the Pélel limestone of Ségou group. They are also found in Afia and in the basal conglomerate of Pélel; *ix)* the glacial formations (tillites) in Walidiala valley **(Figure 13);** *x)* several unconformaties of different ages are observable in DCNR **(Figure 14):** The unconformity between the Supergroup 1 of Meso-Neoproterozoic age and the Birimian basement where outcrops the Stenian basal conglomerate deposited directly on the Birimian granitic basement in Pélel **(Figure 14a),** the unconformity between the Supergroup 2 of Neoproterozoic age and the Supergroup 1 of Meso-Neoproterozoic age where outcrops the lower Ediacaran tillite covering unconformably of gully erosion of Pélel Stenian-Tonian calcarenites Formation **(Figure 14b),** the unconformity between the Supergroup 2 and the Birimian basement where the lower Ediacaran tillites are deposited directly on the Birimian marbles in Walidiala and Koukoudji (Figure 14c), and the unconformity between Mali and Walidiala Groups where the calcareous dolostones of Upper Ediacaran age are covering the quartzose arenites of lower Ediacarian age (**Figure 14d**); *xi)* Dandé cave: the village of Dandé was founded in 1945 by the brothers Manga Kouladio Diallo and Manga Binté Vero Diallo who came from Douari in the Republic of Guinea Conakry. These Aboriginal people were fled the colonial yoke who took their animals. Later, others arrived from the same country. The high plateau presents caves among which the historical Dandé Cave (**Figure 15**) that is receiving numerous visitors. These places were first inhabited by the Bedicks and Bassaris, animists who lived in these caves to escape the Islamization of Karamokho Alpha Yaya (king of Labé in Guinea); *xii*) footprints of Tépéré Diang Tung on the Paleozoic ferruginous crust that covers the birimian granitic formations **(Figure 16),** corresponding according to the legend, to the footprint of a hunter and the print of the game hoof he was pursuing which remained engraved on the laterite at the level of the mythical village of Tépéré Diang Tung. The visitor is surprised by this image that last for a long time.

Figure 7: Afia waterfall (**A)**: and ripple marks at the base of the waterfall (**B**).

Figure 8: Birimian basement and deformations; **A**: Birimian calc-shists of Hassana Diallo hill; **B**: folding in the Birimian shists of Walidiala valley; **C**: Fault filled with recrystallized calcite in the calc-shists in the Guinea ravine; **D:** listrique fault and recrystallization affecting the calc-shists in the ravine of Guinea in Walidiala valley.

Figure 9: Walidiala Birimian marbles and schists; **A**: recrystallized vein of Walidiala Birimian ribbon marbles; **B** and **C**: Folding of dykes of recrystallization in the Walidiala ribbon Birimian marbles; D: strongly locally folded Walidiala schists**.**

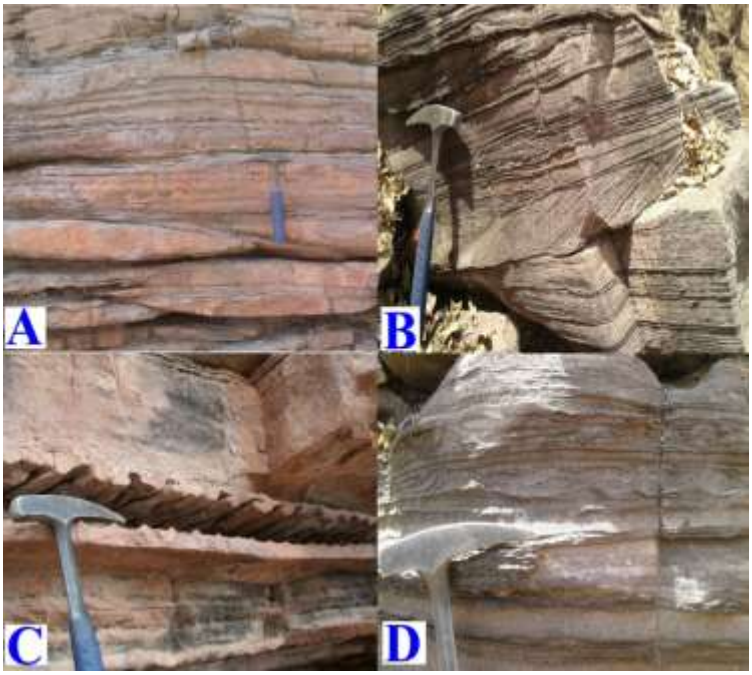

Figure 10: Sedimentary structures in the Dindéfélo Tonian sandstone formation and in the Pélel Stenian-Tonian carbonate facies formation; **A:** lenticular bedding in the Dindéfélo Tonian ruiniform sandstones formation, **B:** Flat stratifications, oblique and erosive surfaces in the Pélel Stenian-Tonian calcarenites formation; **C:** Ripple marks in the Dindéfélo Tonian ruiniforme sandstones; **D:** Ripple marks in the Pélel Stenian-Tonian calcarenites formation.

Figure 11: Dandé Teeth in Tonian ruiniform sandstones near the Dindéfélo waterfall

Figure 12: Stromatolites in the sandy limestone Supergroup 1 formations of Meso-Neoprotezoïc age

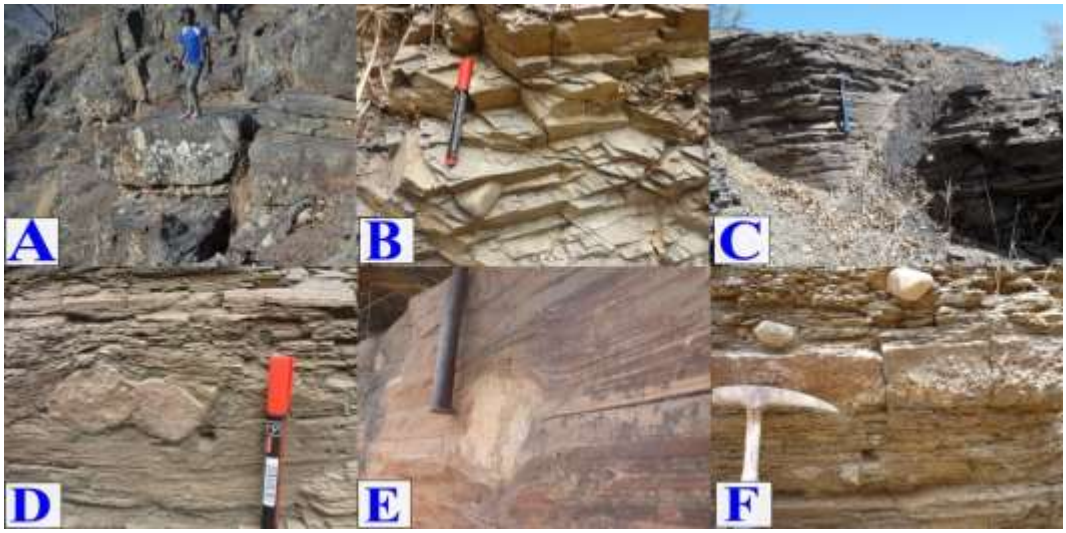

Figure 13: Glacial formations (Ediacaran) of the DCNR; **A**: Massive glacial formations (conglomerate); **B** and **C**: glacial formations with dropstones; **D** and **E**: dropstones in the glacial formations; **F**: intercalated ferruginous micro-conglomerate in the laminated glacial formations.

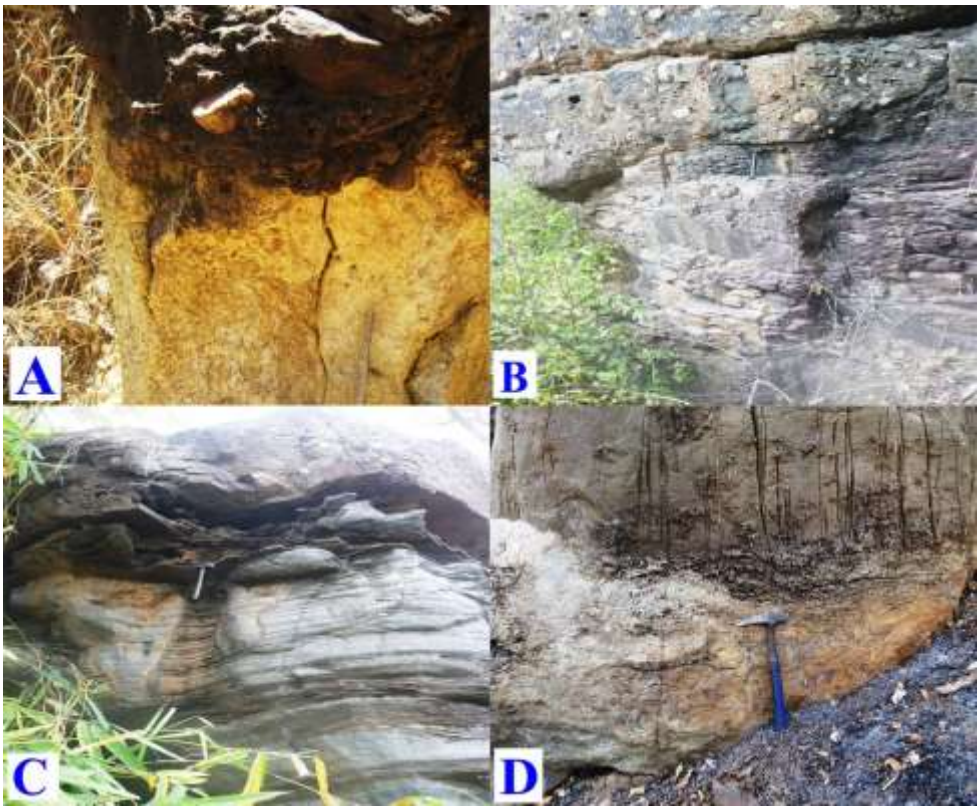

Figure 14: Unconformities in the geological formations of the DCNR; **A**: Unconformity Supergroup1/Birimian basement; **B**: Unconformity Supergroup 2/Supergroup1, **C**: Unconformity supergroup2/Birimian basement, **D**: Unconformity Group of Mali/Group of Walidiala.

Figure 15: Dandé Cave dug in the Lower Neoproterozoic Dindéfélo Formation; **A**: View from above the cave with a waterfall, **B**: Track inside the cave, **C**: Cave in the main cave.

Figure 16: Footprint of the hunter of Tépéré on the Paleozoic laterite covering the Birimian formations (**A**) and the print of a game hoof (**B**).

5. DISCUSSION AND CONCLUSION

The Dindéfélo waterfall geosite is part of the Dindéfélo Community Natural Reserve (DCNR), created to preserve the biodiversity and ensure the sustainable development of the territory. In this context, only the biodiversity has been taken into consideration. This geosite is also part of the Bassari Country which has been classified as World Heritage Site [3], in 2012, based on criteria III, V, VI of the World Heritage Convention. These criteria emphasize especially the cultural heritage of the region without taking into account its geological and geomorphological heritage (geoheritage) which constitutes the natural elements which shaped and preserved this culture while constituting at the same time the support of biodiversity [84], which is participating to keep the local populations and prevent their exodus. According to the Convention of the World Cultural and Natural Heritage of UNESCO [85], is considered as natural heritage "…the geological formations and geomorphological features and areas strictly delimited constituting the habitat of endangered animal and plant species, which are of outstanding universal value from the point of view of science or conservation…". This definition shows very clearly the link between the biodiversity and the geodiversity concepts which has not been clearly taken into account in the classification of the Bassari Country as world heritage site. In other words, the link between the geography, morphological features, cultural expressions and the agropastoral, social, ceremonial and spiritual practices of the local populations with their natural environments have been clearly mentioned. The environment, in this context, includes implicitly all components of the natural heritage including geomorphological diversity but not the geological; even if it is the latter that shaped the geomorphology (nature of rocks, reliefs, fracturations…).

In the framework of this study, we are trying to demonstrate the importance of the geodiversity in the reconstitution of the history of Earth and as a support of the material and immaterial cultural diversity and the biodiversity by taking as an example the Dindéfélo waterfall geosite which is part of the DCNR and of the Bassari Country. This geosite represents in addition to its scenic landscape, a witness of the geological history of this part of our planet, Earth, during the Neoproterozoic era and constitutes a natural habitat of several species of flora and fauna threatened or endangered and which have exceptional value from the point of view of science or conservation. This massif offers also a great abiotic diversity or geodiversity, rocks of various natures and ages and geomorphological landscapes made of waterfalls, caves and plateaus, compatible with the installation of a biotic diversity, particular biodiversity, strongly threatened.

In Senegal, most of the classified sites are prehistoric or historic sites or natural parks or biosphere reserves. On the few classified natural sites, little attention has been given to the geomorphological and geological aspects (geodiversity) which determine the value of the biotic components, biodiversity, which are the subjected to protection. Thus, the geological context which has allowed the formation of waterfalls, caves and landscapes compatible with the installation of a rich and diversified flora and a fauna in the Bassari Country, has retained little attention despite the geological studies carried out in the area. This geodiversity, which constitutes a real reservoir of biodiversity and serves as ecological shelters for numerous endangered plant and animal species, has never been taken into account in the national inventories of the natural heritage. This work aims to promote the geodiversity as a support of cultural and biological diversity and the need for its valorization and its protection and to raise the awareness among local communities and local decision-makers on the importance of this component of their natural heritage. The issues of conservation, of this territory, are also well on the living and non-living

components and the destruction of the second drive automatically the disappearance of the first and requires the action of all local stakeholders including local communities, decision-makers and civil society in the framework of an integrated management strategy where the management authorities of the RNDC and of the Bassari Country should optimize their human and financial means. This integrated conservation strategy will allow in addition to the protection of all the nature components, their valorization in view of a human and socio- economic local sustainable development of the region and the creation of a new label, the geopark that cover the RNDC territory and the Bassari Country and where the geoheritage will be taken into account to create a new touristic niche, the geotourism. This approach, which in addition to the ecotourism, would, along the lines of what is done in the world during the last decades [86-88], to tell and sell the story of the geodiversity in this region of Senegal naturally rich and socio-economically poor. This would promote the territory at the local, national, continental and international level, create and drain funds to strengthen the infrastructure of the rural areas through the creation and the improvement of roads and accommodation infrastructure, supply all the territory including its remote areas with drinking water and electricity, to create new products related to the geoheritage and to all the other components cultural heritage of the territory, and adequate spaces to valorize and sell local products, the creation of museums and centers of information and interpretation to promote the geodivesity and biodiversity of this territory.

Nowadays, geotourism is taking more places in the world, it is imperative to include this concept in the objectives of sustainable development in Senegal, particularly in the rural areas in a context of climate change where the flora and fauna are highly endangered.

REFERENCES

1. USAID/Wula Nafaa, Juillet 2010. Rapport des enquêtes socio-économiques de Dindéfélo. Programme agriculture, gestion des ressources naturelles.
2. FFEM, Appui à la mise en place de la Réserve Communautaire de Dindéfélo. Document interne Programme de Petites Initiatives (PPI) du FFEM, 2010, 1-2.
3. République du Sénégal. Pays Bassari, Paysages Culturels Bassari, Peul et Bédik ; Proposition d'inscription sur la liste de Patrimoine mondial, 2011, 316p.
4. A.T. Goudiaby, B. Bâ, Sambou. La flore ligneuse du site de Dindéfélo, au Sud-est du Sénégal. Annales de Botanique de l'Afrique de l'Ouest, 2001, 00(0), 21-33.
5. E. Sow, C.A.K. Fofana, C. Aw. Diatoms of Dindéfélo fall (upper Basin of the Gambia River, Senegal): floristic inventory. African Journal of Ecology; 2013, 51 (4), 352-362.
6. Ecosénégal Kédougou. Réserve Naturelle Communautaire de Dindéfélo: Programme de conservation du chimpanzé de l'Afrique de l'Ouest au Sénégal, 2011. www.ecosenegal.org/fr/Kédougou/sustainability.
7. E. Errami, G. Schneider, N. Ennih, H. Nirina Randrianaly, A. Bendaoud, A. Noubhani, N Norman, M Allan, L. Vasconcelos, L. Costa, M. Al-Wosabi, A. Al-Subbary, P. Mabvuto-Ngwira, G. Okunlola, S. Lawal Halliru, L. Andrianaivo, S. Siby, B. Ketchemen, M. Gauly, M. Hassine, F. Azki, T. Juliette, K. Lattrache, M. Omulo and P. Bobrowsky. Geoheritage and Geoparks in Africa

and the Middle-East: Challenges and Perspectives. In Geoheritage to Geoparks: Case Studies from Africa and Beyond. E. Errami, M. Brocx, & V. Semeniuk; (eds), 3-23. Springer Verlag. ISBN; 2015, 978 - 3- 319 - 10707 - 3.

8. E. Errami. Pre-congress meeting of the fifth conference of the African Association of Women in Geosciences entitled “Women and Geosciences for Peace”; 2009, Episodes 32 (3), 210-211.

9. E. Errami, L. Andrianaivo, N. Ennih, M. Gauly; The first international conference on African and Arabian Geoparks - Aspiring Geoparks in Africa and Arab World. El Jadida, Morocco, 20-28 November 2011; Episodes; 2012, 35(2) 349-351.

10. E. Errami, N. Ennih, A. Bendaoud, O. Bouzidi, M.C. Chabou, L. Andrianaivo, K. Ben Ismail-Lattrache, M. Hassine. Inventaire du géopatrimoine en Afrique : état des lieux et perspectives. In G. Egoroff, A. Cornée, P. De Wever & A. Lalanne, (eds.); 2013 - Actes du colloque « Géopatrimoine, un lustre d’inventaire en France », Digne-les-Bains. - Mém. H.S. Soc. géol. France; 10-12 octobre 2012, 13, 128-139.

11. UNPD, 2010. Rapport National sur le Développement Humain au Sénégal. Changement climatique, Sécurité alimentaire et Développement humain-, 102p

12. ANSD/SRSD Kédougou: Situation Economique et Sociale régionale; 2012, 16p.

13. F. Adeguelou et M. Fall, 1979. Etude géologique du secteur de Guemedji. Rapport de fin de campagne de sondage, COGEMA, Dakar, 82 p.

14. M. Arnould, J.M. Ayme, et R. Guillaume, 1960. Nouvelle stratigraphie des séries primaires du Nord du Fouta Djalon (Guinée-Sénégal). Bulletin de la Société Géologique de France, Série 7, Vol. 1, p. 631-634.

15. M. Arnould, J.M. Ayme, et R. Guillaume, J.P. Bassot, J. Bois, E. De Chetelat, M. Defossez, R. Giraudon, J. Gravesteijn, R. Guillaume, M. Nickles, Y. Peronne, J. Sagatsky, C. Skawich et B. Tagini, 1963. Carte géologique de la République du Sénégal au 1:200 000, feuille Kédougou. Ministère des Travaux Publics et des Transports. Service des Mines et de la Géologie, Dakar.

16. J.P. Bassot, 1961. Etude géologique du Sénégal oriental. Rapport de fin de campagne 1961. Rapport B.R.G.M.-Dakar, 43 pp., 5 planches hors texte.

17. J.P. Bassot, 1966. Etude géologique du Sénégal oriental et de ses confins guinéo-maliens. Mémoires du B.R.G.M., Vol. 40, 322 p.

18. J.P. Bassot, 1987. Le complexe volcano-plutonique calco-alcalin de la rivière Daléma (Est Sénégal): discussion de sa signification géodynamique dans le cadre de l’orogène éburnéenne (Protérozoïque inférieur). Journal of African Earth Sciences, 6 (4), p. 505-519.

19. J.P. Bassot, J. Bois, L. Kocinski, J. Lehingue, M. Nickles, C. Skawich, D. Soule de Lafont, F. Witschard, 1963a. Carte géologique de la République du Sénégal au 1:200 000, feuille Kéniéba. Ministère des Travaux Publics et des Transports. Service des Mines et de la Géologie, Dakar.

20. J.P. Bassot, L. Baud, J. Bois, M. Nickles, Y. Peronne, C. Skawich, D. Soule de Lafont, F. Witschard, 1963b. Carte géologique de la République du Sénégal au 1:200 000, feuille Kossanto. Ministère des Travaux Publics et des Transports. Service des Mines et de la Géologie, Dakar.

21. J.P. Bassot, J. Bois, M. Dieng, J. Gravesteijn, M Nickles, Y. Peronne, C. Skawich et F. Witschard, 1963c. Carte géologique de la République du Sénégal au 1:200 000, feuille Dalafi. Ministère des Travaux Publics et des Transports. Service des Mines et de la Géologie, Dakar.

22. J.P. Bassot, M. Bonhomme, M. Roques et M. Vachette, 1963d. Mesures d'âges absolus sur les séries précambriennes et paléozoïques du Sénégal oriental. Bulletin de la Société Géologique de France, Série 7, Vol. 5, p. 401-405.

23. J.P. Bassot, J.M. Cantagrel, C. Jamond, et H. de Carvalho, 1986. Nouvelles données géochronologiques sur les dolérites et gabbros de l'est Sénégal et de la Guinée Bissau. Réflexions sur l'âge de mise en place et la répartition du magmatisme tholéïtique « continental » à l'échelle de l'Afrique de l'Ouest. Garcia de Orta, Séria Geologica, Lisboa, 9 (1-2), 1-14.

24. J. Brinckmann et K.D. Meinhold, 2007. La géologie de la chaîne des Bassarides et des terrains environnants au Nord-Ouest de la Guinée. Geologische Jahrburch. Hannover, B, SB1, 446 p.

25. F. Buscail, T. Fullgraf, R. Couëffé, P.M. Ndiaye, D.P. Diallo, R. Caby, O. Blein, J. Le Métour, D. Lahondère, J.C. Goujou, G. Martelet, S. Sergeev et M. Villeneuve, 2010a. Notice explicative de la carte géologique à 1/200 000 du Sénégal, feuille Tambacounda-Dalafi Ouest. Ministère des Mines, de l'Industrie, de l'Agro-Industrie et des PME, Direction des Mines et de la Géologie, Dakar.

26. F. Buscail, T. Fullgraf, R. Couëffé, P.M. Ndiaye, D.P. Diallo, R. Caby, J. Le Métour, D. Lahondère, J.C. Goujou, G. Martelet et M. Villeneuve, 2010b. Carte géologique à 1/200 000 du Sénégal, feuille Tambacounda-Dalafi Ouest. Ministère des Mines, de l'Industrie, de l'Agro-Industrie et des PME, Direction des Mines et de la Géologie, Dakar.

27. L.P. Chtocolov et V.V. Korj (Mission Sénégalo-Soviétique), 1973. Projet de recherches minières Sénégalo-soviétiques (contrat n° 2.000). Rapport final sur les travaux de prospection pour la recherche de l'or filonien et alluvionnaire au Sénégal oriental en 1971-73, 278 p., 48 pl.

28. S.J. Culver et D. Hunt, 1991. Lithostratigraphy of the Precambrian-Cambrian boundary sequence in the southwestern Taoudéni Basin, West Africa. Journal of African Earth Sciences, Vol. 13, p. 407-413.

29. P. Debat, D.P. Diallo, P.M. Ngom, L. Rollet, M. Seyler, 1984. La série de Mako dans ses parties centrales et méridionales (Sénégal Oriental, Afrique de l'Ouest). Précisions sur la série volcano-sédimentaire et données géochimiques préliminaires sur les formations magmatiques post-tectoniques. Journal of African Earth Sciences, 2, p. 71-79.

30. C. Delor, R. Couëffé, J.C.Goujou, D.P Diallo, H. Théveniaut, T. Fullgraf, P.M. Ndiaye, E. Dioh, T.M.M. Barry, J. Le Métour et G. Martelet, 2010a. Carte géologique à 1/200 000 du Sénégal, feuille Saraya-Kédougou Est. Ministère des Mines, de l'Industrie, de l'Agro-Industrie et des PME, Direction des Mines et de la Géologie, Dakar.

31. C. Delor, R. Couëffé, J.C.Goujou, D.P Diallo, H. Théveniaut, T. Fullgraf, P.M. Ndiaye, E. Dioh, O. Blein, T.M.M. Barry, A. Cocherie, J. Le Métour et G. Martelet, S. Sergeev et K. Wemmer, 2010b. Notice explicative de la carte géologique à 1/200 000 du Sénégal, feuille Saraya-Kédougou Est. Ministère des Mines, de l'Industrie, de l'Agro-Industrie et des PME, Direction des Mines et de la Géologie, Dakar.

32. M. Deynoux, P. Duringer, R. Khatib, M. Villeneuve, 1993. Laterally and vertically accreted tidal deposits in the Upper Proterozoic Madina-Kouta Basin, southeastern Senegal, West Africa. Sedimentary Geology, Vol. 84, p. 179-188.

33. A. Dia, 1988. Caractères et significations des complexes magmatiques et métamorphiques du secteur de Sandikounda-Laminia (Nord de la boutonnière de Kédougou). Un modèle géodynamique du Birimien de l'Afrique de l'Ouest. Thèse Doctorat d'Etat, Université Cheikh Anta Diop, Dakar, 350 p.

34. A. Dia, W.R. Van Schmus, A. Kroner, 1997. Isotopic constraints on the âge and formation of a paleoproterozoic volcanic arc complex in the Kédougou Inlier, Eastern Senegal, West africa. Journal of African Earth Sciences, Vol. 24, No.3, p. 197-213.

35. D.P. Diallo. 1994. Caractérisation d'une portion de croûte d'âge protérozoïque inférieur du craton ouest africain: cas de l'encaissant des granitoïdes dans le Supergroupe de Mako (boutonnière de Kédougou implications géodynamiques. Thèse de Doctorat d'Etat, Université Cheikh Anta Diop, Dakar, 466 p.

36. D.P. Diallo, 2001. Lithostratigraphie du Supergroupe de Mako (Paléoprotérozoïque du Sénégal oriental). Implications géodynamiques. Bulletin de l'Institut Fondamental d'Afrique Noire Série A, T. 51, No. 1-2, p. 33-58.

37. E. Dioh, 1986. Etude des roches magmatiques birimiennes de la région de Sonfara-LaminiaMédina Foulbé (Sénégal oriental) Thèse Doctorat 3ème cycle, Université Nancy I (France), 144 p.

38. E. Dioh, 1995. Caractérisation, signification et origine des formations birimiennes encaissantes du granite de Dioumbalou (Partie septentrionale de la boutonnière de Kédougou- Kéniéba, Sénégal oriental). Thèse Doctorat d'Etat, Université Cheikh Anta Diop de Dakar, 446 p.

39. E. Dioh, D. Béziat, P. Debat, M. Grégoire, M. Ngom, 2006. Diversity of the Paleoproterozoic granitoids of the Kédougou inlier (eastern Sénégal): petrographical and geochemical constraints. Journal African Earth Sciences, Vol. 44, p. 351–371.

40. T. Fullgraf, P.M. Ndiaye, F. Buscail, R. Caby, D. Lahondère, J. Le Métour, G. Martelet et M. Villeneuve, 2010a. Carte géologique à 1/200 000 du Sénégal, feuille Linkering/KoldaKédougou Ouest. Ministère des Mines, de l'Industrie, de l'Agro-Industrie et des PME, Direction des Mines et de la Géologie, Dakar.

41. T. Fullgraf, P.M. Ndiaye, R. Couëffé, F. Buscail, R. Caby, O. Blein, D. Lahondère, J. Le Métour, G. Martelet, S. Sergeev, M. Tegyey et M. Villeneuve, 2010b. Notice explicative de la carte géologique à 1/200 000 du Sénégal, feuille Linkering/Kolda-Kédougou Ouest. Ministère des

Mines, de l'Industrie, de l'Agro-Industrie et des PME, Direction des Mines et de la Géologie, Dakar.

42. T. Fullgraf, P.M Ndiaye, H. Théveniaut, D. Lahondère, R. Caby, C. Delor, D.P. Diallo, E. Dioh, J.C. Goujou, F. Buscail, J. Le Métour, G. Martelet et M. Villeneuve, 2010c. Carte géologique à 1/200 000 du Sénégal, feuille Bakel-Semme Sud-Ouest. Ministère des Mines, de l'Industrie, de l'Agro-Industrie et des PME, Direction des Mines et de la Géologie, Dakar.

43. J.C. Goujou, F. Buscail, H. Théveniaut, E. Dioh, C. Delor, O. Blein D.P. Diallo, P.M. Ndiaye, J. Le Métour, T. Fullgraf, R. Caby, R. Couëffé, G. Martelet, S. Sergeev, M. Tegyey, M. Villeneuve et K. Wemmer, 2010a. Notice explicative de la carte géologique à 1/200 000 du Sénégal, feuille Kossanto-Dalafi Est. Ministère des Mines, de l'Industrie, de l'Agro-Industrie et des PME, Direction des Mines et de la Géologie, Dakar.

44. J.C Goujou, F. Buscail, H. Théveniaut, E. Dioh, C. Delor, D.P. Diallo, P.M. Ndiaye, J. Le Métour, T. Fullgraf R. Caby, R. Couëffé, G. Martelet, et M. Villeneuve, 2010b. Carte géologique à 1/200 000 du Sénégal, feuille Kossanto-Dalafi Est. Ministère des Mines, de l'Industrie, de l'Agro-Industrie et des PME, Direction des Mines et de la Géologie, Dakar.

45. M. Gueye, S. Siegesmund, K. Wemmer, S. Pawlig, M. Drobe, N. Nolte, 2008. New evidences for an Early Birimian evolution in the West African Craton: An example from the KédougouKénieba inlier, SE-Senegal. South African Journal of Geology, Vol. 110, p. 179-190.

46. P.M. Ndiaye, 1986. Etude géologique et métallogénique de la partie septentrionale du granite de Saraya : secteurs de Missira, Wassangara, Frandi (Sénégal Oriental). Thèse Doctorat 3ème cycle Université Cheikh Anta Diop de Dakar, 109 p.

47. P.M. Ndiaye, 1994. Evolution au Paléoprotérozoïque inférieur de la région Est Saraya (Supergroupe de Mako, Sénégal oriental) : tourmalinisation, altérations hydrothermales et minéralisations associées. Thèse Doctorat d'Etat Université Cheikh Anta Diop de Dakar, 372 pp.

48. P.M. Ndiaye, B. Robineau, C. Moreau, 1989. Déformation et métamorphisme des formations birimiennes en relation avec la mise en place du granite éburnéen de Saraya (Sénégal oriental). Bulletin de la Société Géologique de France, Vol. 8, p. 619-625.

49. P.M. Ndiaye, A. Dia, Y. Vialette, D.P. Diallo, P.M. Ngom, M. Sylla, S. Wade, E. Dioh, 1997. Données pétrographiques, géochimiques et géochronologiques nouvelles sur les granitoïdes du Paléoprotérozoïque du Supergroupe du Dialé-Daléma (Sénégal oriental) : implications pétrogénétiques et géodynamiques. Journal of African Earth Sciences, Vol. 25, No. 2, p. 193-208.

50. W. Hirdes et D.W. Davis, 2002. U-Pb geochronology of paleoproterozoïc rocks in the southern part of the Kédougou-Kenieba Inlier, Senegal, West Africa: evidence for diachronous accretionary development of the eburnean province. Precambrian Research, Vol. 118, p. 83-99.

51. J. Kaisin, B. Dabo, M. Fall, F. Ndiaye, T.M.M. Barry et E. Diagne, 2010a. Atlas géochimique à 1/200 000 de la prospection géochimique du Sénégal oriental. Ministère des Mines, de l'Industrie, de l'Agro-Industrie et des PME, Direction des Mines et de la Géologie, Dakar.

52. J. Kaisin, B. Dabo, M. Fall, F. Ndiaye, T.M.M. Barry et E. Diagne, 2010b. Inventaire et prospection géochimique du Sénégal oriental. Ministère des Mines, de l'Industrie, de l'AgroIndustrie et des PME, Direction des Mines et de la Géologie, Dakar.

53. D. Lahondère, H. Théveniaut, P.M. Ndiaye, T. Fullgraf, R. Caby, O. Blein, C. Delor, D.P Diallo, E. Dioh, J.-C Goujou, F. Buscail, J. Le Métour, G. Martelet, S. Sergeev, M. Tegyey, M. Villeneuve et K. Wemmer, 2010. Notice explicative de la carte géologique à 1/200 000 du Sénégal, feuille Bakel-Semme Sud-Ouest. Ministère des Mines, de l'Industrie, de l'Agro-Industrie et des PME, Direction des Mines et de la Géologie, Dakar.

54. A. Le Page, 1983. Les grandes unités des Mauritanides, aux confins du Sénégal et de la Mauritanie. L'évolution structurale de la chaine, du Précambrien supérieur au Dévonien. Thèse, Université de Marseille (France), 518 p.

55. P. Ledru, J. Pons, J.-P Milési, J.-L. Feybesse, V. Johan, 1991. Transcurrent tectonics and polycyclic evolution in the lower Proterozoïc of Senegal-Mali. Precambrian Research, Vol. 50, No. 4, p. 139-165.

56. M. Morisseau, J. Kaisin, D.P. Diallo, P.M. Ndiaye, E. Dioh, B. Dabo, T.M. Barry, M. Fall, F. Ndiaye, E. Diagne et F. Diatta, 2010a. Carte gîtologique et abondance Or à 1/500 000 du Sénégal oriental. Ministère des Mines, de l'Industrie, de l'Agro-Industrie et des PME, Direction des Mines et de la Géologie, Dakar.

57. M. Morisseau, J. Kaisin et H. Théveniaut, 2010b. Notice explicative de la carte gîtologique et abondance Or à 1/500 000 du Sénégal oriental. Ministère des Mines, de l'Industrie, de l'AgroIndustrie et des PME, Direction des Mines et de la Géologie, Dakar.

58. J.P. Milési, J. L. Feybesse, P. Ledru, A. Dommanget, M.F. Quedraogo, E. Marcoux, A. Prost, C. Vinchon, J.P. Sylvain, V. Johan, M. Tegyey, J.Y. Calvez et P. Lagny, 1989. Les minéralisations aurifères de l'Afrique de l'Ouest. Leurs relations avec l'évolution lithostructurale au Protérozoïque inférieur. Chronique de la Recherche Minière, Vol. 497, p. 3-98.

59. P.M. Ngom 1985. Contribution à l'étude de la série birimienne de mako dans le secteur aurifère de Sabodala (sénégal Oriental). Thèse 3° cycle, Univ. Nancy, 134p.

60. P.M. Ngom. 1995. Caractérisation de la croûte birimienne dans les parties centrale et méridionale du Supergroupe de Mako. Implications géochimiques et pétrogénétiques. Thèse Doctorat d'Etat Université Cheikh Anta Diop, Dakar, Sénégal, 243 p.

61. S. Pawlig, M. Gueye, R. Klischies, S. Schwarz, K. Wemmer, S. Siegesmund, 2006. Geochemical and Sr-Nd Isotopic Data on the Birimian of the Kédougou-Kenieba Inlier (Eastern Senegal): Implications on the Palaeoproterozoic Evolution of the West African Craton. South African Journal of Geology, Vol. 109, p. 407-423.

62. Y. Péronne, 1967. Mission « Prospection Kédougou » - Campagne 1966. Prospection de trois secteurs du bassin de la Haute-Gambie. Rapport BRGM DAK 67 A 4, 90 pp., 16 pl. hors texte.

63. J. Pons, C. Oudin and J. Valero, 1992. Kinematic of large syn-orogenic intrusions: example of the Lower Proterozoïc Saraya Batholith (Eastern Senegal). Geologische Rundschau, Stuttgart, Vol. 81, No. 2, p. 473-486.

64. G. A. Shields, M. Deynoux, S.J. Culver, M.D. Brasier, P. Affaton and D. Vandamme, D., 2007. Neoproterozoic glaciomarine and cap dolostone facies of tje southwestern Taoudéni Basin (Walidiala Valley, Senegal/Guinea, NW Africa). C.R. Geoscience, Vol. 339, p. 186-199.

65. G. Sustrac (coord.), 1984. Plan minéral de la République du Sénégal. Bureau de Recherches Géologiques et Minières, Orléans, 3 volumes.

66. M. Villeneuve, 1984. Etude géologique de la bordure SW du craton ouest-africain – La suture panafricaine et l'évolution des bassins sédimentaires protérozoïques et paléozoïques de la marge NW du continent de Gondwana. Thèse de doctorat, Université d'Aix-Marseille III, 552 p.

67. M. Villeneuve, 1989. The geology of the Madina-Kouta basin (Guinea-Senegal) and its significance for the geodynamic evolution of the western part of the West African Craton during the Upper Proterozoic period. Precambrian Research, Vol. 44, p. 305-322.

68. M. Villeneuve, 2005. Paleozoic basins in West Africa and the Mauritanide thrust belt. J. Afr. Earth Sci., Vol. 43, p. 166-195.

69. J. Walter, J. Chantraine, 1974. Rapport de fin de mission Daléma, Campagne 1973-1974. BRGM, Rapport 74-DAK-005, 38 p.

70. F. Witschard, 1962. Mission est-SARAYA. Rapport de fin de campagne 1962. BRGM, Rapport DAK 62 A 26.

71. F. Witschard, 1965. Contribution à l'étude géologique, pétrographique et métallogénique du massif granitique du Sénégal oriental. Mémoires du B.R.G.M., Vol. 44, 171 p., 2 cartes annexes à 1/100.000.

72. A. Wuilleumier, I. Mall et P.M. Ndiaye, 2010a. Carte hydrogéologique à 1/500 000 du Sénégal oriental. Ministère des Mines, de l'Industrie, de l'Agro-Industrie et des PME, Direction des Mines et de la Géologie, Dakar.

73. A. Wuilleumier, H. Théveniaut, I. Mall et P.M. Ndiaye, 2010b. Notice explicative de la carte hydrogéologique à 1/500 000 du Sénégal oriental. Ministère des Mines, de l'Industrie, de l'AgroIndustrie et des PME, Direction des Mines et de la Géologie, Dakar.

74. M. Dabo et T. Aïfa, 2010. Structural Styles and Tectonic evolution of the Kolia-Boboti sedimentary basin, Kédougou-Kéniéba inlier, eastern Senegal. C.R. Geoscience, 342, 796-805.

75. M. Dabo et T. Aïfa, 2011. Late Eburnean deformation in the Kolia-Boboti sedimentary basin, Kédougou-Kéniéba inlier, Sénégal. J. Afr. Earth Sci.

76. M. Dabo et T. Aïfa, 2013. Architecture tectonique des formations paléoprotérozoïques de la Daléma (Sénégal oriental): apport des linéaments d'images landsat-7 ETM+/SRTM et aéromagnétiques. J. Sci. Vol. 13, N°1, 32-45.

77. L. Pacheco, S. Fraixedas, A. Fernández-Llamazares, N. Estela, R. Mominee, F. Guallar. Perspectives on Sustainable Resource Conservation in Community Nature Reserves: A case study from Senegal. Sustainability, 2012, 4, 3158-3179.

78. C. Camara. Le petit Chimpanzé. Bulletin d'information de la réserve naturelle communautaire de Dindéfélo; 2016, 4p.

79. Programme USAID/Wula Nafaa. Dindéfélo, Sénégal; Plan de Gestion de la Réserve Naturelle Communautaire de Dindéfélo, 1st Ed.; Institut Jane Goodall Espagne, 2012-2016, 3p.

80. M.F. Fernández-García, N. Ruiz de Azua and L. Pacheco; Birds of Dindéfello Nature Reserve, south-east Senegal; Bull ABC; 2013, 20 (1), 49-59.

81. 81 J.G. Adam. Tourisme et flore du Fouta Djalon au Sénégal, Notes Afr., Dakar; 1965, 105, 12-15

82. 82 C.I. Youm. Révision lithostratigraphique de la Formation de Dindéfélo-Bassin de Madina Kouta Mémoire D.E.A de Géosciences, option environnements sédimentaires. Dakar, 43p.

83. 83 D. Sarr, M. Fall, P.M. Ngom, M. Ndiaye, C.H. Kane, M. Ba. Geomechanical Characterization of Sandstones Cliffs of Segou (Senegal, West Africa) in the Madina Kouta Basin. International Journal of Geosciences ; 2012, 3, 166-174.

84. 84 F. Bétard, J.P Peulvast, M.A d'Oliveira. Biodiversité, géodiversité et enjeux de leur conservation dans les montagnes humides du Nordeste brésilien (Biodiversity, geodiversity and conservation challenges in the humid mountains of Northeast Brazil). In: Bulletin de l'Association de géographes français, 88e année. Montagnes tropicales. 2011,1, pp. 17-26; http://www.persee.fr/doc/bagf_0004-5322_2011_num_88_1_8201.

85. UNESCO (1972), Convention concernant la protection du patrimoine mondial culturel et naturel adoptée par la conférence générale à sa dix-septième session, Paris, 16 novembre 1972, 15p.

86. T. A. Hose. Telling the story of stone – assessing the client base. Geological and Landscape Conservation. London. 1994.

87. T. A. Hose. Selling the Story of Britain's Stone. Environmental Interpretation, 1995, 10-2, 16-17.

88. T. A. Hose. Geotourism – selling the Earth to Europe. Engineering Geology and the Environment. Rotterdam. 1997.

*** Corresponding author: Cheikh Ibrahima YOUM**

[1]Département de Géologie, Faculté des Sciences et Techniques, Université Cheikh Anta Diop, Dakar-Fann, Sénégal. Email : **youma.ramou@hotmail.fr**

Online publication date 08.06 2018