

Radiometric mapping of the Tondibia sector, western terminus of the Iullemeden intra-cratonic basin (Niamey, Niger)

Mallam Mamane Hallarou ¹, Mahamane Moustapha Sanda Chékaraou ^{2,*}, Sani Abdoulwahid ³, Lawali Idi Chamsi ¹, Sofiyane Abdourahmane Attourabi ¹ and Gambo Ranaou Noura ¹

¹ Department of Geology, Groundwater and Georesources Laboratory, Faculty of Sciences and Techniques, Abdou Moumouni University of Niamey. Po.Box: 10662, Niamey-Niger.

² Department of Disciplines Didactic, Faculty of Sciences of Education, Djibo Hamani University of Tahoua. Po.Box: 255, Tahoua-Niger.

³ Fossil Energy Department, National School of Engineering and Energy Sciences (ENISE), University of Agadez. Po.Box: 199, Agadez-Niger.

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Abstract

The study area (Tondibia sector in the Niamey region of Niger) belongs to the western terminus of the vast Iullemeden intra-cratonic basin. In this basin, five (5) geological formations rest in major unconformity either on the Birimian basement or on the Pan-African basement. The most recent formation in this basin is the Terminal Continental (Ct) of Oligo-Miocene age. Only the last unit (Ct³) of this formation outcrops in the study area. This terminal unit of the Iullemeden Basin is known for its iron mineralization, most often associated with lateritic facies. The aim of this study is to produce a surface radiometric map of the Tondibia sector (Niamey, Niger) in order to identify laterite facies zones, which are the preferred targets for iron mineralization in the Iullemeden Basin. The methodology used in this study consisted of field and laboratory work. In the field, rock outcrops were described and samples taken. In the laboratory, Surfer software was used to produce a radiometric map of the Tondibia sector. The radiometric data obtained using the SPP2 NF scintillometer in the sandy riverbeds show low values (10 to 30 cps), in contrast to the higher topography areas made up of lateritic facies (armour and carapace), where radioactivity is relatively higher (41 to 80 cps). These lateritic zones are rich in iron oxide, which has a strong affinity with the naturally radioactive elements such as thorium, potassium and uranium. As a result, the study area's high radioactive value zones are the preferred areas for prospecting iron mineralization.

Keywords: Radiometric map; Lateritic armour and Carapace; Scintillometer; Iullemeden Basin; Tondibia; Niger

1. Introduction

The study area is an integral part of the western terminus of the Iullemeden basin. The latter is a vast intracratonic basin covering most of Niger and extending as far as Algeria, Mali, Benin and Nigeria [1]. The sedimentation history of the Iullemeden Basin is mainly marked by marine transgressions and regressions [2]. The sedimentary fill consists of intercalary continental deposits of Permian to Lower Cretaceous age. Significant sedimentation in this region began as early as the Paleozoic, with sedimentation areas confined to the Tin Seririne syncline in Algeria as early as the beginning of the Primary Period. Central deposits shifted from north-east to south-west, in line with the migration of the basin's subsidence pole during the Paleozoic-Lower Cretaceous period [3], resulting in the emplacement of marginolittoral and continental formations [4]. Sedimentary cover in the Iullemeden Basin can exceed 3 km in depth. Its stratigraphy comprises five (5) geological formations that rest in major unconformity either on the Birimian basement or on the Pan-

* Corresponding author: Mahamane Moustapha Sanda Chékaraou

African basement: (i) Paleo-Mesozoic formations (Cambrian to Lower Cretaceous); (ii) continental intercalary formations (CI) (Permian to Lower Cenomanian); (iii) marine formations (Upper Cenomanian to Lower Eocene); (iv) continental Hamadian formations (CH) (Lower Cenomanian to Maastrichtian) and (v) continental terminal formations (Ct) (Oligocene to Miocene). The latter formations are stratigraphically subdivided into three groups (3) sub-names. These are respectively Ct¹, Ct² and Ct³. In Niger, the Continental Terminal (Ct³), constituting the terminal unit of the Iullemeden Basin, is known for its iron mineralization. Researchers [5] have shown that iron mineralization is always associated with lateritic facies rich in aluminum and radioactive elements such as uranium, potassium and thorium. Thus, areas with a significant radiometric signature could be a potential source of iron mineralization. The general objective of the present study is to produce a surface radiometric map of the Tondibia area (Niamey, Niger). Specifically, it aims to:

- Identify the alteration mantles that are the most important sources of laterite production.
- Produce a guide (radiometric map) for future prospecting campaigns.

1.1. General context of the study area

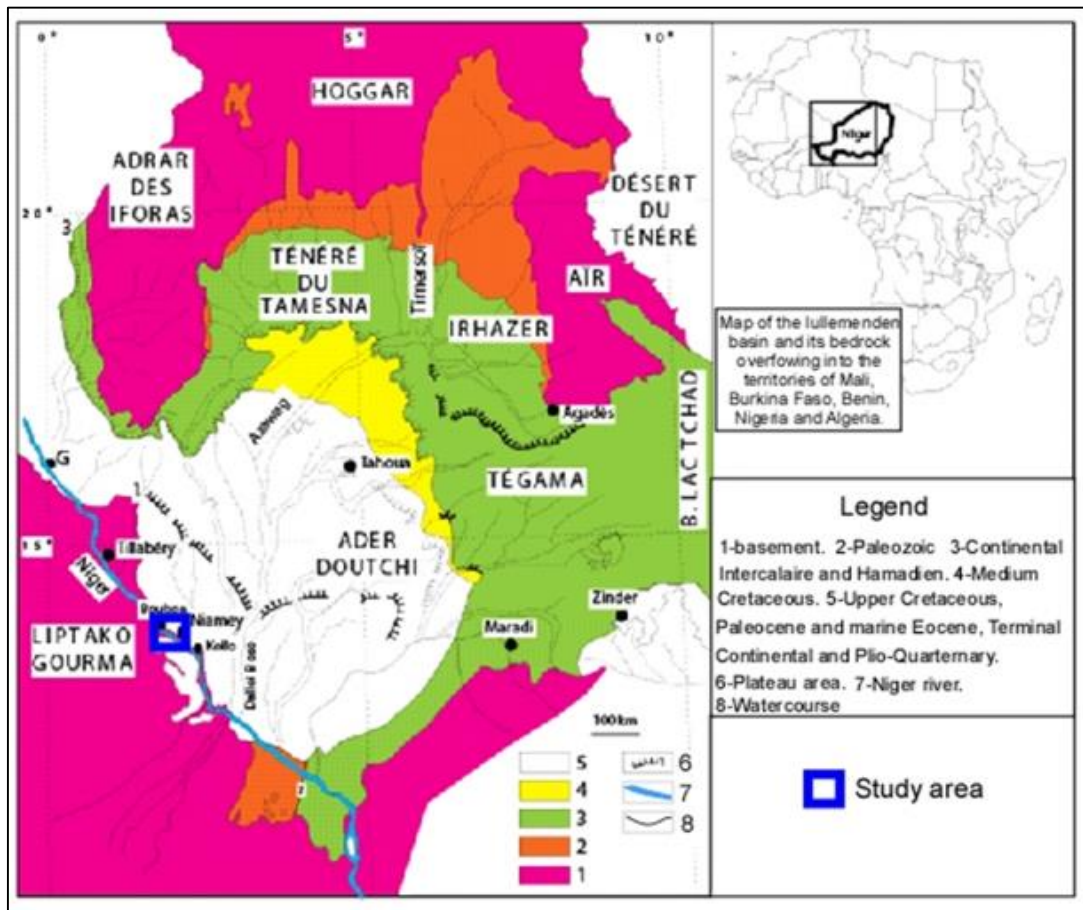


Figure 1 Geological map of Iullemeden basin [8]

The Tondibia sector is located 10 km north-west of the city of Niamey, between the villages of Tondibia and Soudouré, more precisely between Latitudes 1,501,000 UTM and 1,503,000 UTM and Longitudes 391,000 UTM and 394,000 UTM (**Figure 1**). The terrain model is clearly influenced by the nature of the subsoil. Granitic formations with little resistance to weathering have given rise to almost featureless plains in which, more recently, long WNW-ESE alignments of dunes have formed. The rarer volcanic rocks form sets of smaller hills, reaching heights of around 20-30 m. In this sector, laterization has little influence on morphology. However, in places, the Mottled variegated clay is covered by lateritic carapaces whose strong induration slows erosion by forming tabular hills (test mounds) with steep slopes. Hydrographically, the Niger River is the only permanent watercourse in the study area. There is also a highly branched hydrographic network formed by koris. Runoff ceases early on the surface at the end of the rainy season, in November at the latest. Geologically, the study area straddles the southeastern edge of the West African Craton and the southwestern terminus of the Iullemeden Basin (Figure 1). At the base, the Paleoproterozoic basement (2300 to 2000

Ma) [6] comprises granitoid plutons alternating with greenstone belts. At the top, the sedimentary cover, comprising Neoproterozoic deposits known as the "Niamey Sandstone", topped by lateritic clayey sandstones, ferruginous oolitic sandstones of Oligocene age from Terminal Continental 3 and Quaternary deposits (dune and alluvial deposits) [7].

(1) Paleoproterozoic basement formations: Paleoproterozoic (or Birimian) formations are made up of alternating greenstone and granitoid plutons. (i) Greenstone belts are made up of metabasalts, amphibolites, ultramafic to mafic granitic rocks often transformed into talcchists and chloritoschists, sediments and metamorphosed volcano-sediments. (ii) Granitoid plutons are mainly composed of granites, TTG (Tonalite, Trondhjemite, Granodiorite), diorites and quartz diorites, monzonite and locally syenite [6]. The emplacement of these plutons is at the origin of the main greenstone structuring phase in a context of global NW-SE shortening [9, 6, 10]. (2) Overburden formations: Overburden formations in the Niamey region comprise three (3) facies. (i) An older formation that underlines the eastern edge of the West African Craton, essentially made up of Precambrian sediments. These blanket deposits are attributed to the Neoproterozoic and, in the Niamey area, consist of quartzite sandstones, conglomerates and pelites that rest in major unconformity on the Paleoproterozoic basement. These Neoproterozoic formations recorded the Pan-African deformation dated at around 600 ± 50 Ma [11] (ii) Terminal Continental (TC): The Oligocene-age deposits of the Terminal Continental represent the upper terms of the sedimentary deposits of the Iullemeden Basin [3]. The latter defined three sets within this formation, from base to top:

- The Ader Doutchi siderolithic series (Ct¹);
- The sandy-clay lignite series (Ct²);
- The Middle Niger claystone series (Ct³) (Figure 2).

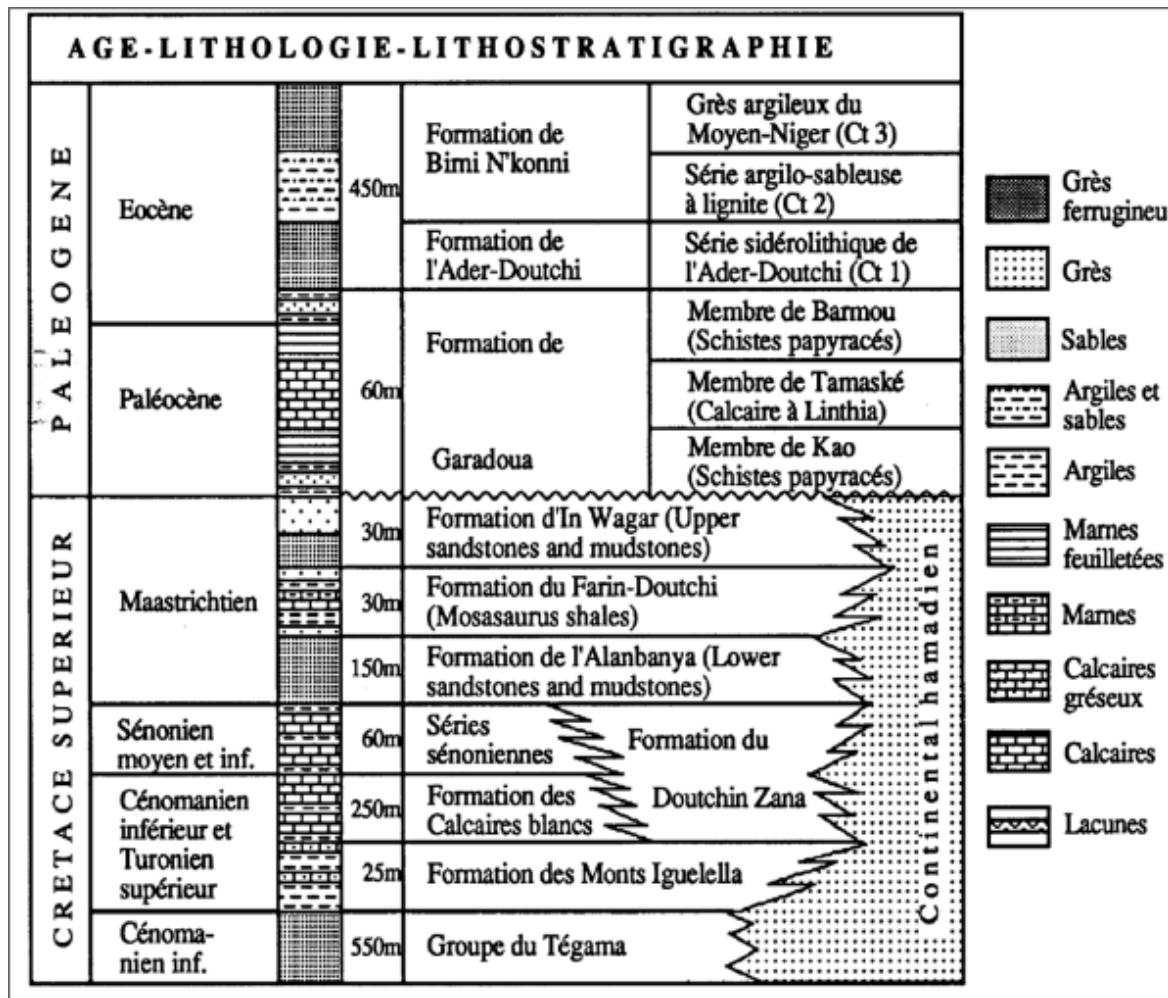


Figure 2 Simplified stratigraphic scale of the Iullemeden basin [17]

In the Niamey area, only the Ct³ formation outcrops [5,7,12]. This Ct³ formation, classically known as the "Middle Niger Sandstone" [3], represents the last deposits to fill the Iullemeden basin. These deposits, consisting of alternating

clayey sandstones and oolitic ferruginous sandstones with indurated levels [5,7,12], rest in major gully unconformity on Neoproterozoic deposits and in major unconformity on the Paleoproterozoic (or Birimian) basement. The Ct³ formation consists of clayey sandstones and ferruginous oolites, more or less associated with [5,7,12] tubules. The top of the Ct³ is generally a ferruginous "lateritic" cuirass, overlain in places by superficial formations. The Ct³ formation forms the broad plateaus that overhang the Niger River on either side [5,7,12]. The age of the Ct³ deposits has long been uncertain. It was considered to post-date the Middle Eocene and predate the Quaternary [13, 14]. Recently, the work of [15, 16], assigns an Oligocene age to these deposits. (iii) Formations of Quaternary to present age, consisting of colluvium, dunes and recent terraces, resting on the terminal Continental or Birimian basement.

2. Material and methods

The methodology used in this study includes field and laboratory work. In the field, a petrographic description, GPS surveys and measurements using the SPP2 NF scintillometer (Figure 3) were carried out. A pre-established grid with 10 m steps covering the entire study area was used. At each grid point, the GPS coordinates (Latitude, Longitude and Altitude) and the radioactivity value (in shocks per second (cps)) were recorded. The scintillometer (SPP2 NF) is a field device for searching for radioactive sources in extreme environmental conditions. It is designed to detect and measure γ and X-rays of energy greater than 30 keV. The device takes the form of a pistol connected by a cable to a box that can be worn on the belt and contains the electronics, power supply and buzzer. The SPP2 NF is an all-terrain precision device designed to detect radioactive sources or products. Probable radioactive sources are Uranium, Potassium and Thorium. In the laboratory, field data were processed into an Excel database. Outcrop, topographic and radiometric maps were produced using Mapinfo and Surfer software.



Figure 3 SPP2 NF Scintillometer used in the field

3. Results and discussion

3.1. Weathering profile of the study area

A detailed petrographic description of the sedimentary formations in the Tondibia area was carried out. As these formations are the result of supergene alteration, an alteration profile (regolith) was established (**Figure 4**). The different parts of the profile from top to bottom are: Cuirass, Carapace, Mottled variegated clay, Saprolite and Roche mère.

- Cuirass: This part of the regolith, belonging to the Continental Terminal (Ct³), is characterized by iron oxide and magnesium. It occurs in metric blocks, filled with fine earth and ferruginous nodules. Tubules are found at the periphery and especially at the base of the blocks.

- The carapace: The carapace is made up of large ferruginous nodules, with a structure of armour elements packed in fine earth. It is on this that the cuirass rests.
- ATB: Below the carapace, we find the Mottled variegated clay. This is a horizon of mottled clays with a variegated sandy-clay matrix and a rock structure recognizable by gray patches towards the base.
- Saprolite: This is a diaclose granitic arena with a low clay content in two levels: The saprock or lithomarge, which consists of fine saprolite. Below the saprock is coarse saprolite (the first stage in the alteration of the parent rock), which is very important for the search for gold.
- Bad rock: This is the sound rock (granite). All the other layers mentioned above rest on it.

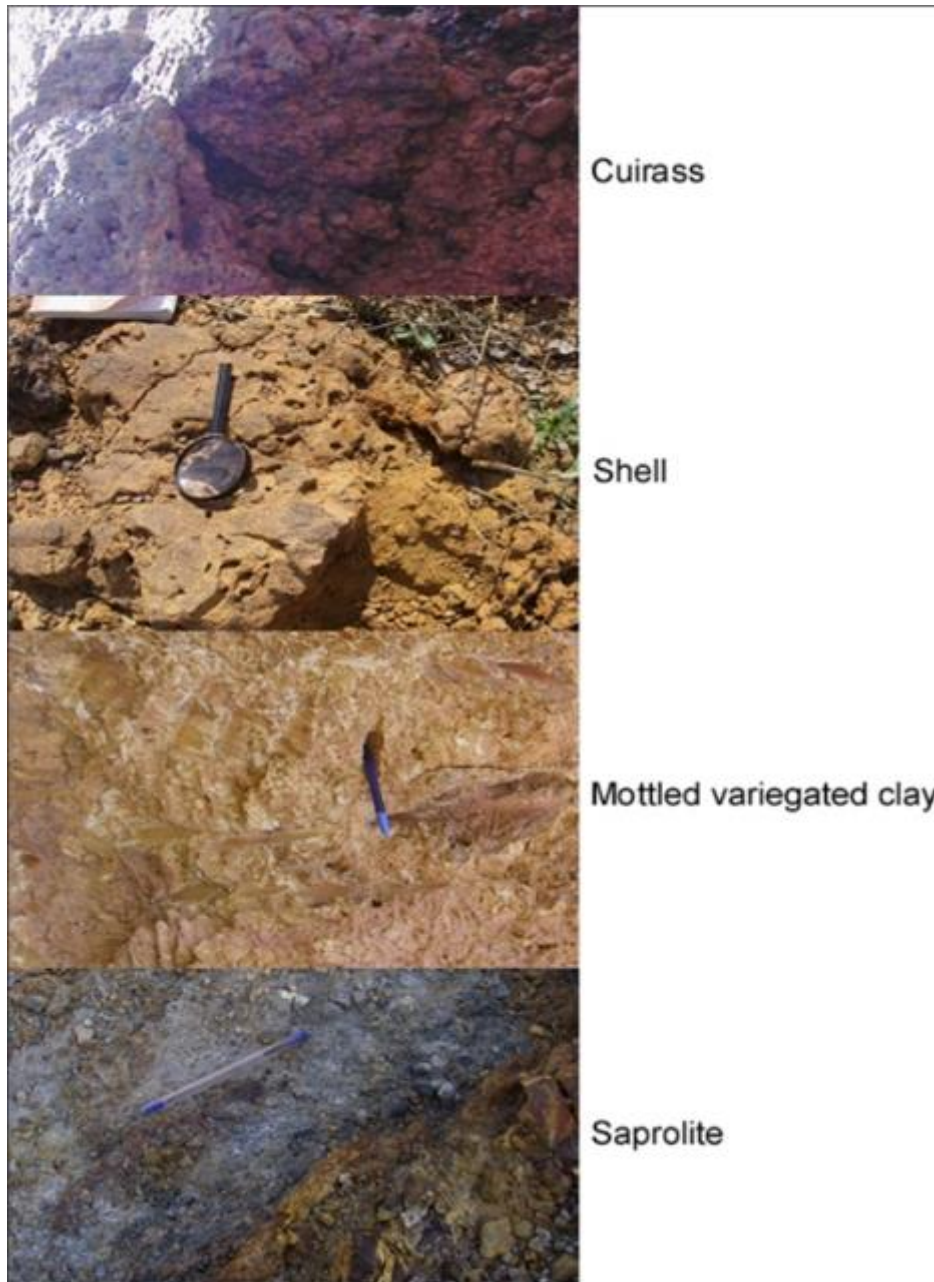


Figure 4 Alteration profile (regolith) in the Tondibia sector

3.2. Map results

The results of this study are maps of relief features, topography and radiometry. All these maps were produced from a database (**Table 1**).

Table 1 Partial database used to produce the maps

Geochemistry Outcrop 2				
Points	Longitude (m)	Altitude (m)	Altitude (m)	Radioactivity (Cps)
AF2/001	392 688	1 502 204	215	30
AF2/002	392 698	1 502 215	216	30
AF2/003	392 698	1 502 229	214	45
AF2/004	392 703	1 502 245	217	40
AF2/005	392 686	1 502 250	215	55
AF2/006	392 676	1 502 252	213	50
AF2/007	392 666	1 502 264	214	50
AF2/008	392 657	1 502 284	219	45
AF2/009	392 649	1 502 301	219	40
AF2/010	392 576	1 502 321	219	45
AF2/011	392 676	1 502 318	222	50
AF2/012	392 689	1 502 304	221	60
AF2/013	392 700	1 502 287	220	50
AF2/014	392 713	1 502 270	220	50
AF2/015	392 730	1 502 257	221	45
AF2/016	392 722	1 502 243	219	45
AF2/017	392 711	1 502 233	216	55
AF2/018	392 708	1 502 211	213	50
AF2/019	392 708	1 502 191	213	60
AF2/020	392 708	1 502 166	215	50
AF2/021	392 703	1 502 147	212	30
AF2/022	392 713	1 502 111	216	40
AF2/023	392 703	1 502 096	215	35
AF2/024	392 694	1 502 084	215	45
AF2/025	392 682	1 502 082	214	45
AF2/026	392 686	1 502 069	214	40
AF2/027	392 700	1 502 056	213	50
AF2/028	392 702	1 502 068	214	50
AF2/029	392 709	1 502 079	215	35
AF2/030	392 721	1 502 080	213	55
AF2/031	392 714	1 502 091	212	40
AF2/032	392 728	1 502 108	209	25
AF2/033	392 744	1 502 100	206	30
AF2/034	392 752	1 502 093	203	30

AF2/035	392 740	1 502 074	206	45
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3.2.1. Relief features map

This map shows the various relief features identified in the study area. These include hills (test mounds) (lateritic cuirasses), a valley (koris), buildings (roads, firing range) and small granite outcrops (**Figure 5**).

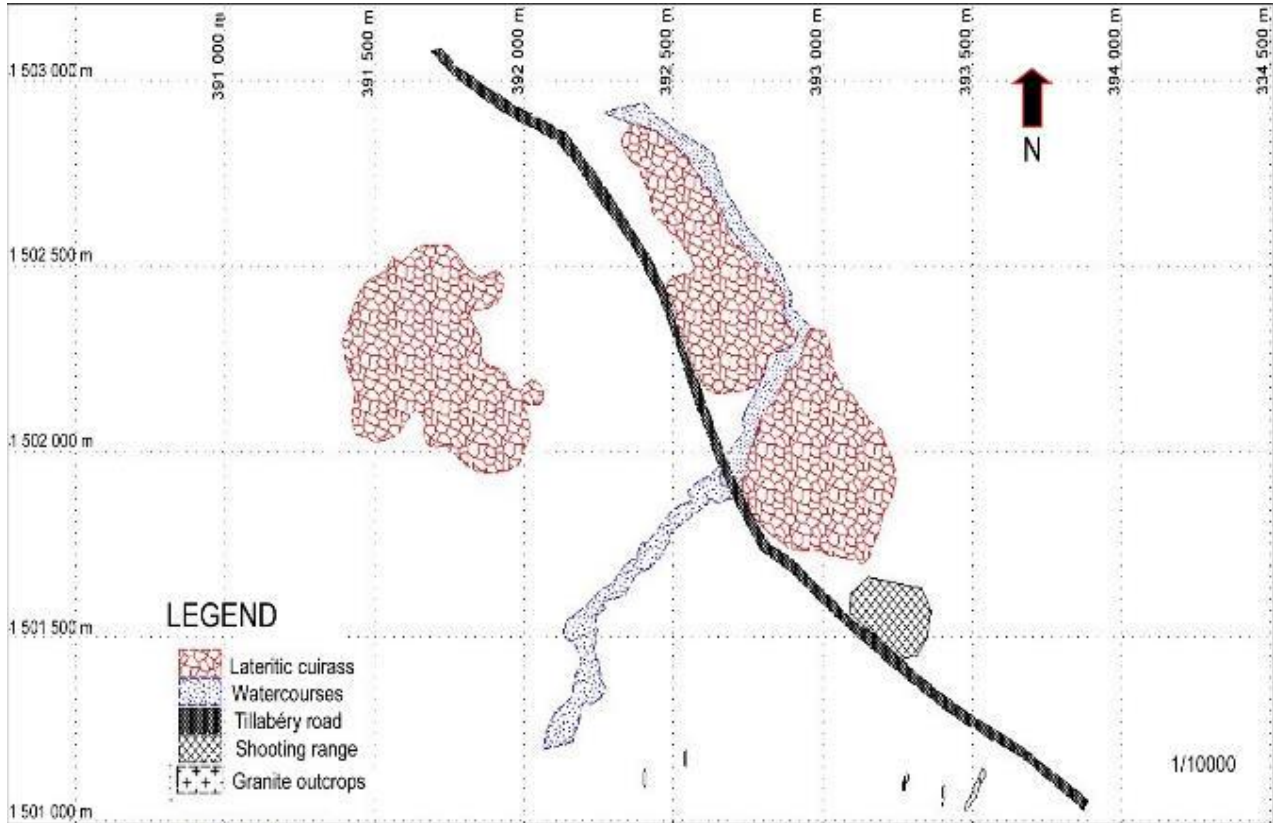


Figure 5 Relief features map of Tondibia area

The parts made up of lateritic cuirasses represent the control mounds. These are the three (3) The koris is one of the northern tributaries of the Niger River. The Koris is one of the northern tributaries of the River Niger. It flows into the river to the south. The road is the RN3 national highway linking the cities of Niamey and Tillabery. A few small granite outcrops sporadically appear in the Tondibia sector.

3.2.2. Topographic map

On the topographical map (**Figure 6**), the areas coloured pink to reddish correspond to the higher-altitude points in the study area, i.e. the interfluvies, while the areas coloured blue and white correspond to the lower-altitude points, i.e. the talweg.

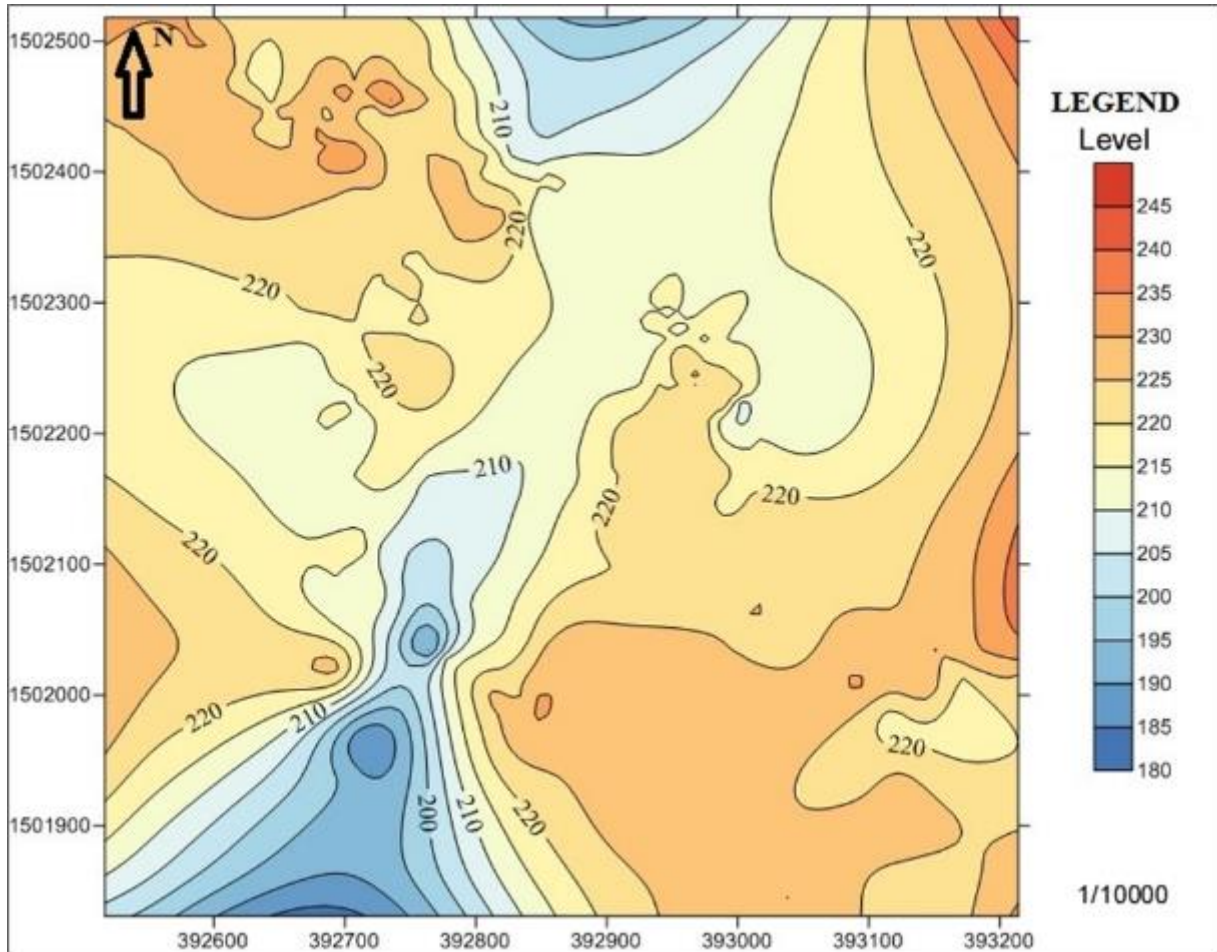


Figure 6 Topographical map of the study area

3.2.3. Radiometric map

Radioactivity values across the study area were specialized in Surfer software to obtain the radiometric map (**Figure 7**). The map shows radioactivity values (in cps) ranging from 0 to 80 cps. The low values correspond to the blue and green areas. These are the values measured in the bed of the koris, which is essentially sand, while the high values correspond to the yellowish to reddish patches measured on the control mounds corresponding to lateritic cuirasses (weathering mantles).

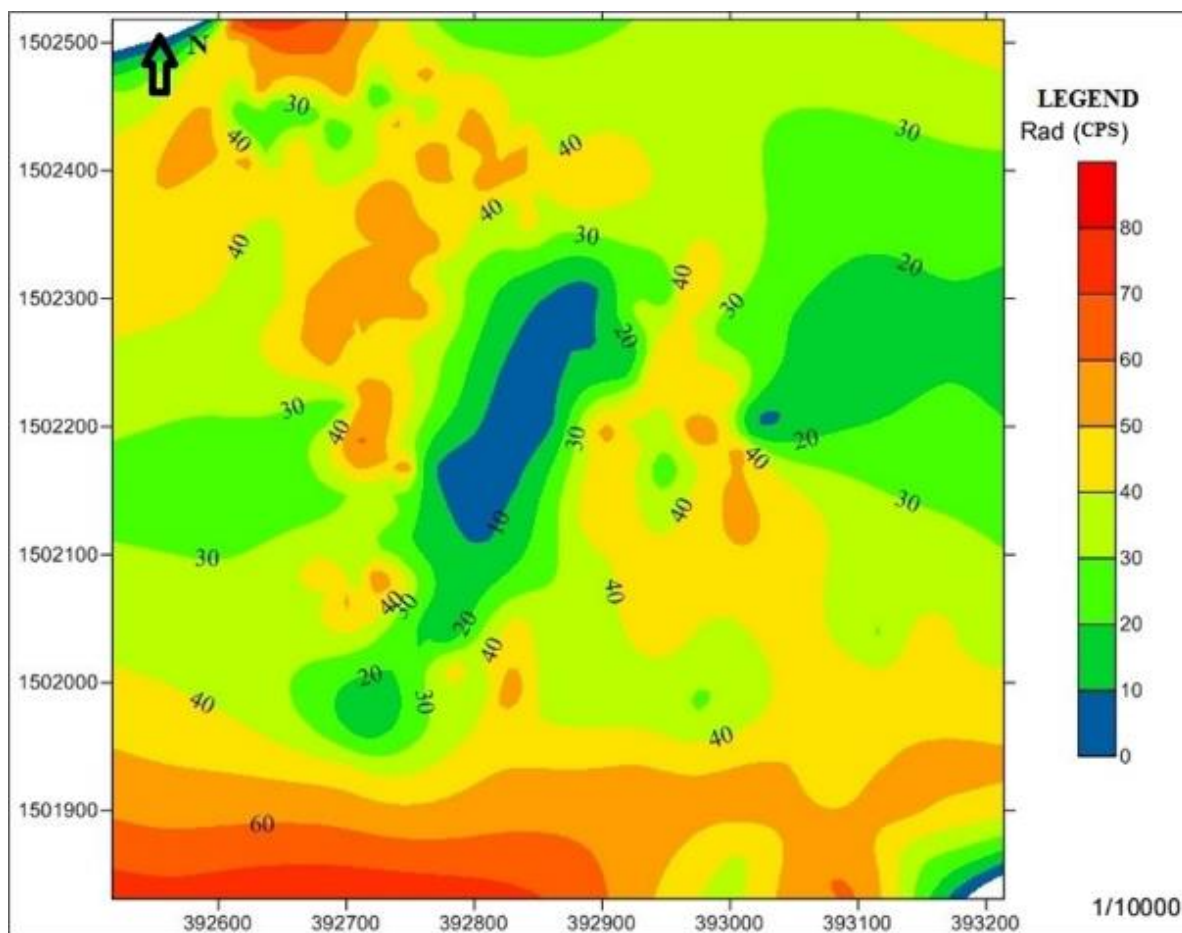


Figure 7 Radiometric map of the Tondibia area

4. Discussion

The radiometric data obtained during this study (Figure 7) show low values (10 to 30 cps) at low altitudes (180 to 210m). These correspond to the river beds, made up mainly of alluvial sand. This leached sand, consisting mainly of quartz and potassium feldspars, contains little or no radioactive elements [18, 19]. Average altitudes (211 to 220m) correspond to average radioactivity values (31 to 40 cps). These mid-altitudes are where saprolite and/or mottled clays outcrop. These two (2) facies are directly derived from the weathering of granitoids and/or volcanosedimentary rocks. These origins give saprolite and clays the presence of more or less radioactive minerals, such as clay minerals [20]. The relatively higher radioactivity (41 to 80 cps) corresponds to the highest altitudes (221 to 240 m) in the study area. These relatively higher topographic levels correspond to lateritic carapace and/or cuirass facies. These are mainly characterized by iron and aluminum oxides, quartz and kaolinite, in addition to neoformed minerals (limonite, goethite, gibbsite, boehmite, pyrolusite, manganite, imogolite, halloysite) that are relatively radioactive [18, 19, 21, 22]. Iron oxides also tend to bind highly radioactive elements such as potassium, thorium and especially uranium [23]. However, kaolinization helps to remove potassium [24].

5. Conclusion

The investigations carried out in the Tondibia sector of the Niamey region first produced maps of relief and topographic features, enabling a topographic characterization of the study area using GPS coordinates. Next, measurements of total surface radioactivity values, taken using the SPP2 NF scintillometer according to a pre-established grid, were used to produce a radiometric map of the Tondibia area. Analysis of this map shows that radioactivity in the study area varies between 10 and 80 cps, depending on whether one leaves the low-lying areas towards the high-lying areas. Low levels of radioactivity are found in washed-out areas (watercourses), while high levels of radioactivity are found in high-altitude, lateritic facies (armour and carapace). These high levels of radioactivity are due to naturally radioactive elements (potassium, thorium, uranium) being assimilated by iron oxide and alumina, the main constituents of lateritic armour and carapace. As a result, the study area's high-radioactive zones are ideal for prospecting iron mineralization.

Compliance with ethical standards

Acknowledgements

In memory of Dr Kargné Hamado, during his lifetime, he was the head of the Geosciences department at the School of Mining, Industry and Geology (EMIG) of Niamey (Niger). He provided unfailing support for field missions. May Allah have mercy on him. Amine.

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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