Petrographic and geochemical characteristics of Cretaceous formations of Nkara region and surrounding area (Kwilu province, DRC)

Pétrographie et caractéristiques géochimiques des formations crétacées de la région de nkara et ses environs (province de Kwilu, RDC)

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ABSTRACT: Geological investigations in the Nkara region of Kwilu Province, DR Congo, have identified seven lithofacies: pudding, argillite, quartz arenite, feldspathic arenite, greywackes, micaceous arenite, and soft fine-grained quartz arenite. This study presents the petrographic and geochemical compositions and paleo-environmental conditions for the first time. Chemical analyses show slight variations in SiO2, Al2O3, and Fe2O3, linked to mineral composition. The quartz grains indicate extensive transport under strong hydrodynamic conditions, and iron oxides suggest deposition in an oxidizing environment, highlighting the need for further geological research in the area.

KEY WORDS: Petrography, Geochemistry, Lithofacies, Cretaceous formations, Paleoenvironmental conditions of deposition.

RÉSUMÉ: Des investigations géologiques dans la région de Nkara, province du Kwilu, en RD Congo, ont permis d'identifier sept lithofaciès : poudingue, argilite, arénite quartzique, arénite feldspathique, grauwackes, arénite micacée et arénite quartzique tendre à grains fins. Cette étude présente pour la première fois les compositions pétrographiques et géochimiques ainsi que les conditions paléoenvironnementales. Les analyses chimiques montrent de légères variations de SiO2, Al2O3 et Fe2O3, liées à la composition minérale. Les grains de quartz indiquent un transport important dans des conditions hydrodynamiques fortes, et les oxydes de fer suggèrent un dépôt dans un environnement oxydant, soulignant la nécessité de recherches géologiques plus poussées dans la région.

MOTS CLÉS : Pétrographie, Géochimie, Lithofaciès, Formations Crétacées, Conditions Paléo-environnementales de dépôt.

1. Introduction

Given the current state of knowledge, it is very difficult to accurately estimate the geological resources present throughout the Congolese territory, due to insufficient data, thus necessitating a real need for investment in geological exploration work (De Putter and Decrée, 2012). The Kwilu province (DRC) in general, and the Nkara region under study in particular, are no exception. The geology of this region is still unresolved.

From geological point of view, Kwilu province in general, and the Nkara region under study in particular belong to the ''Kwango Group'' of the litho-stratigraphic of the large central sedimentary basin of DRC (Figure 1). This litho-stratigraphic column results from the compilation of outcrop data, boreholes and the interpretation of seismic reflection's profiles (Lepersonne, 1951, 1975,1977; Cahen, 1984; Kadima, 2007; Delvaux, Fernandez-Alonso, 2015; Delvaux, 2021).

The level of knowledge about this Kwango Group from a petrographic and geochemical point of view varies from one part of Kwilu province to another, with only the kikwit, Bulungu and Kipala regions having been investigated. Passau's work in the first half of the 2Oth century (1920), followed by that of Henry (1986) obtained from the data of two boreholes drilled by the DRC's water authority in Kikwit area in 1983, and Bulungu region in 1984 established that : (1) the Kwango Group is represented in these regions by a fairly monotonous succession of coarse grain, sometimes conglomeratic sandstones, soft fine grain sandstones with varying degrees of clay and occasional silicified levels, ad at the base argillites, mainly red in color, known as the ''Inzia layers''; (2) the ''Inzia layers'' lie at a depth of around 250 to 300 m on a Precambrian bedrock which, unfortunately, does not outcrop in the region; and (3) all the geological formations in the region have an azimuthal direction varying from N170° to N180°, and a dip varying from10 to 20° towards the WNW (Lukosi et al., 2014).

More recently, three types of lithofacies have been defined in the Kipala area (Munene et al., 2023): soft fine-grain sandstone, argillaceous sandstone and organic-rich shale divided into two micro-facies, one bold and black, with a Total Organic Carbon (TOC) content of 9.3-15.8%, and the other brownish-grey (TOC: 6.7-8.7%). Still in the Kipala region, Passau (1920), Lepersonne (1975) and Taverne (1976) focused their research on the discovery of fish fossil site. The fossils were those of fish whose origin would later become the subject of controversy: continental origin for some authors (Lepersonne, 1977), and mixed for others.

The last authors see it as a mixture of fish of marine and continental origin, specific to the lagoon environment (Taverne, 1976). For the Nkara region under study, the tabular geological structure of these Kwango cretaceous series and the existence of a thick Cenozoic sandy-loam cover makes their outcrops very rare. As a result, the lithology of the Kwango cretaceous series in the Nkara region is poorly understood, to the extent that even on the 1:2,000,000 geological map of the DRC, the formations in this region are loosely grouped under the term "undifferentiated Cretaceous" (Lepersonne, 1974).

This review of the geological literature clearly shows a hiatus in the knowledge of the lithology of the Kwango cretaceous series in the Nkara area.

This gap has motivated us to undertake this study that will deal with the determination of petrographic and geochemical compositions of the different lithofacies outcropping in the studied area. The lithofacies characteristics will be related to paleoenvironmental conditions of deposition, with a view to placing them in the regional geological context.

2. Study area

The study area is located in the territory of Bulungu (Kwilu Province) in the Central Basin of the DRC. It is bounded by longitude 18°39'00'' to 19°8'30'' east and latitude 4°19'30'' to 4°51'30'' south. It lies within the Kwilu-Kamutshia gap, a left tributary of the Kasai River (Figure 3).

2.1. Geological setting

As mentioned above, the geological formations in the target area are part of the Kwango Group (or Kwango Formation). The Groups of Kwango, Bokungu, Loia and Dekese constitute the ''Cretaceous series'' of the lithostratigraphic subdivision of the DRC's Central sedimentary Basin (Lepersonne, 1974 and 1977; Daly,1992; Kadima,2007;Delvaux, Fernandez-Alonso, 2015; Delvaux,2021) (Figure 1). It is necessary to recall that the main lithofacies constituting this Kwango Group Formation in Kwilu province in general are listed in the introductory part of this note; but for the Nkara region under study, in particular, no available data exists.

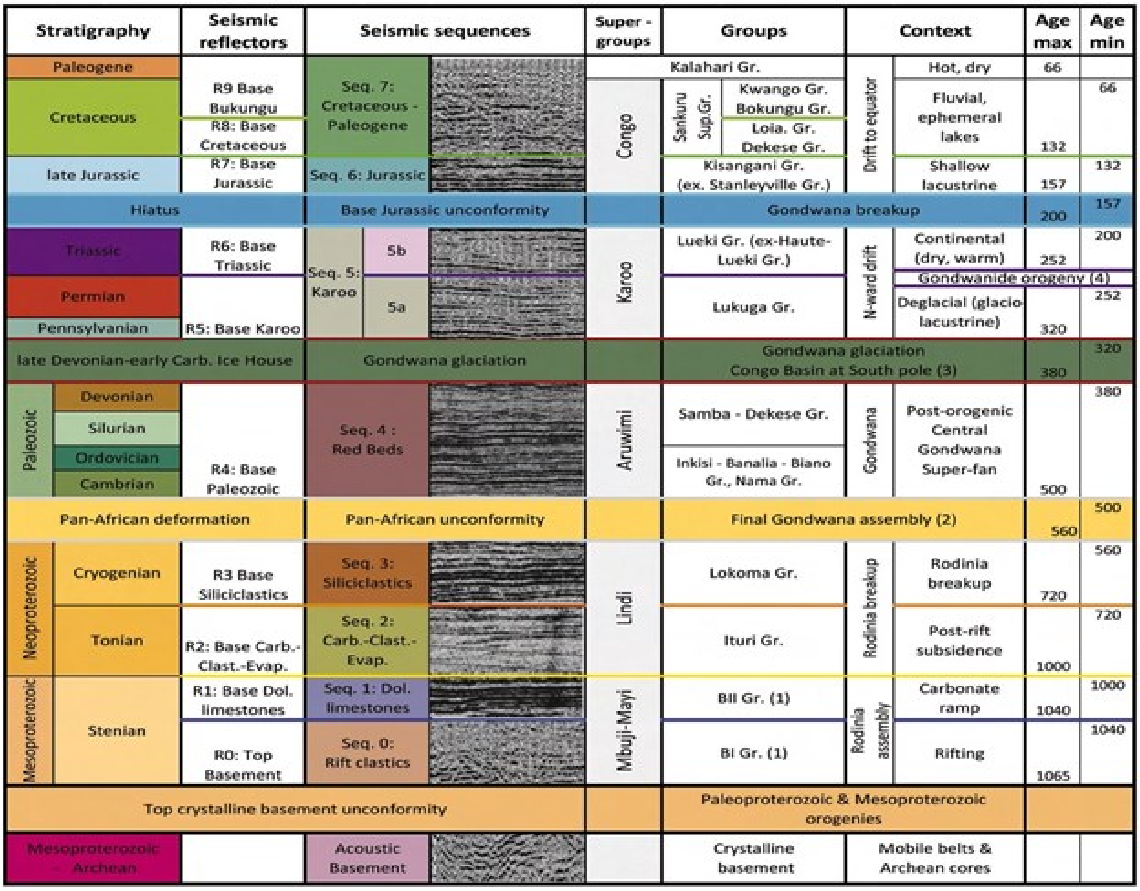

Figure 1 Composite seismo-stratigraphic model integrating well and outcrop data and seismic reflection profiles, Age estimations of the Central sedimentary Basin of DRC. The thick coloured lines refer to the interpreted sequence boundaries in the profiles (Delvaux D. et al., 2021).

Overall, the geological structure is almost tabular, with the layers sloping 10° to 20° to the NW (Ibanda and Kamizele, 2021), with formations located beneath a sometimes very thick Cenozoic sandy-loam cover. This structural slope, which also affects the post-Cretaceous overburden and flattening levels, is thought to have resulted from the progressive uplift of the southern edge of the DRC's Central Basin during the Quaternary (Henry, 1986).

3. Materials

Except the documentation phase, this work went through the following two stages:

3.1. Field research stage

An exhaustive geological survey was carried out in the region, in particular along the main watercourses (Lukwa, Duem, Lukob, Ndobo, etc.) and at the level of artificial cuts (quarries), in order to maximise the chances of encountering in situ outcrops, as the region is covered by a thick sandy-loam blanket. During this field phase, the outcrops were described and located on a 1:400,000 topographic map of the study area (Figure 2); a total of 18 rock samples were taken for laboratory analysis, 12 samples for petrographic analysis, 4 samples for geochemical analysis, and structural measurements (azimuth of the directions and dips of the layers and fracture planes) were also recorded.

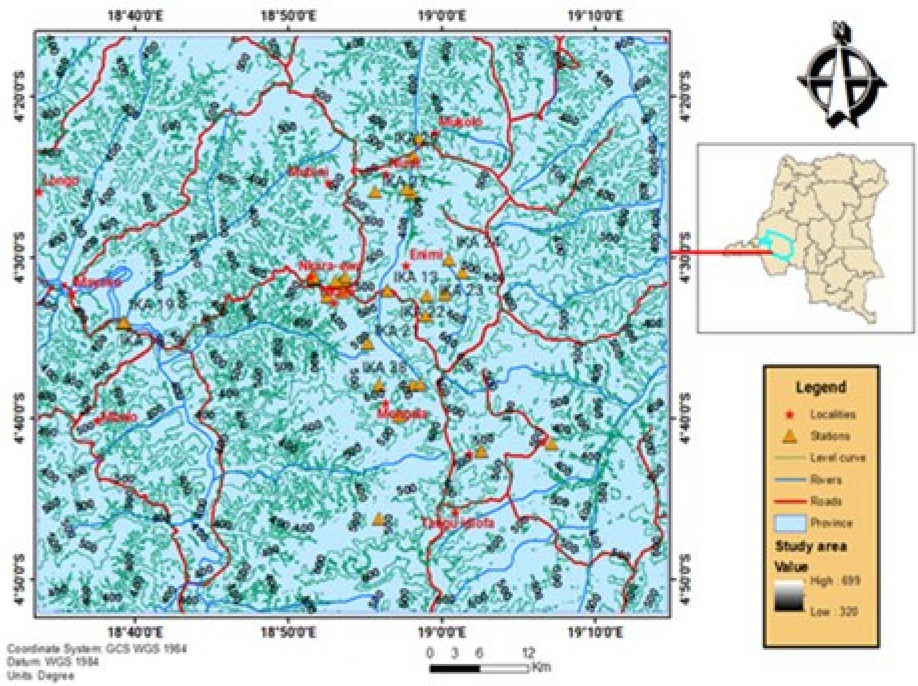

Figure 2 Location map of the observation and sampling stations.

3.2. Laboratory research stage

Laboratory research included: (1) selection of representative samples for the making of thin sections, at the Laboratory of Mention Géosciences of the University of Kinshasa. Thin sections were analysed under a polarizing microscope. Determination of minerals was based on the specific criteria established by Roubault et al. (1963) and Beaux et al. (2016), using both Cross Polarized

Light (CPL) and Plane Polarized Light (PPL). (2) geochemical analysis (major and trace elements) of selected rock samples using spectroxepos fluorescence spectrometry at the Centre de Recherche Nucléaire de Kinshasa (CRNK).

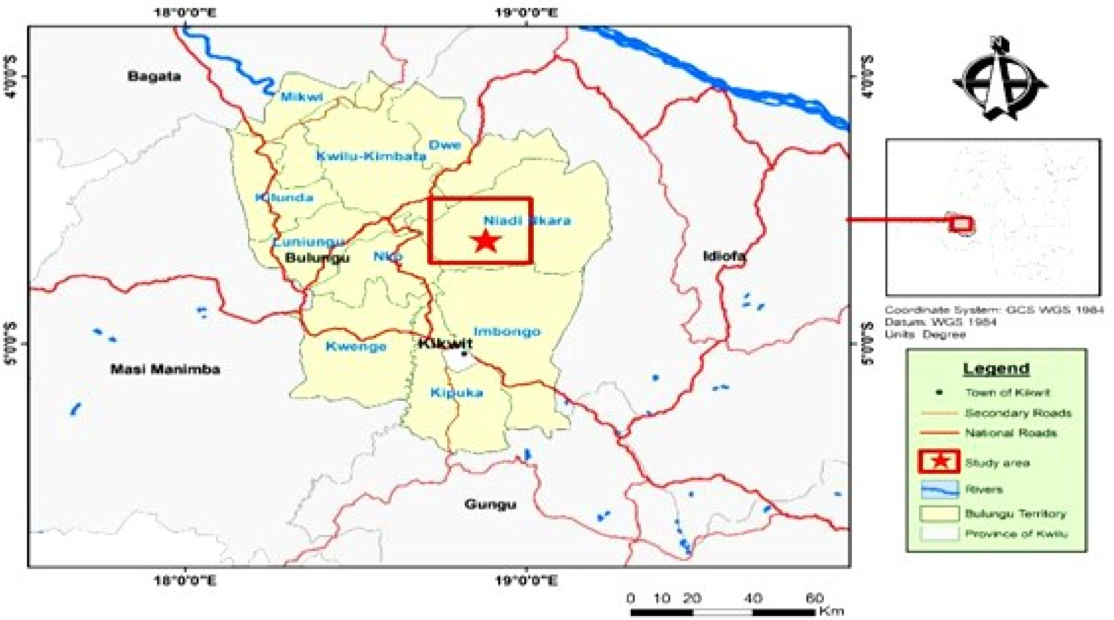

Figure 3 Location map of the study area in Kwilu Province (DRC).

4. Results and discussion

4.1. Geological survey

The field survey led to the creation of the observation and sampling station location map (bearing the initials IKA) shown in Figure 2.

4.2. Lithofaciès characteristics

From a lithological point of view, seven lithofacies have been defined in the study area; their characteristics are presented below:

4.2.1.Feldspathic arenite

The best outcrops of this lithofacies is found on locations IKA06 (Figure 4a), at the foot of a hill near the village of Nkara. This outcrop is cut by a normal fault with a displacement of around 50 cm, direction 249° and dip 68° to the SE, and at location IKA34 (Figure 4b), in the village of Kiakia.

Macroscopically, this is a brown to whitish-coloured, fine- to medium-grained, moderately dense rock, rich in quartz accompanied by feldspar (Figure 5 A, A'). It has an azimuth direction of N38°E, with a dip of 13° towards the NW.

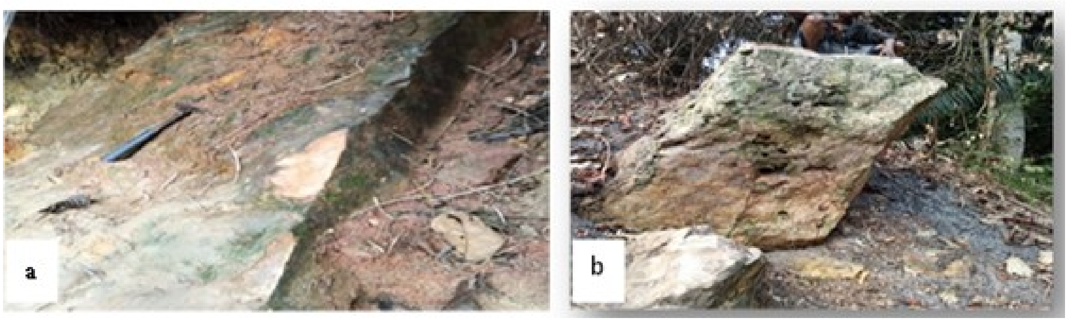

Figure 4 Outcrop view of the feldspathic arenite; a: station IKA 06; b: station IKA34.

Microscopically, the rock shows a joined texture and is mainly constituted by whitish-grey quartz crystals (~ 80 %), accompanied by rare leached feldspar crystals (~ 20%). The quartz grains are joined, rounded to sub-rounded shape and packaged in siliceous cement (Figure 5B, B' and C, C'). The high percentage of the quartz and small amount of feldspars range this lithofacies in the feldspathic arenite class (Pettijohn et al., 1973).

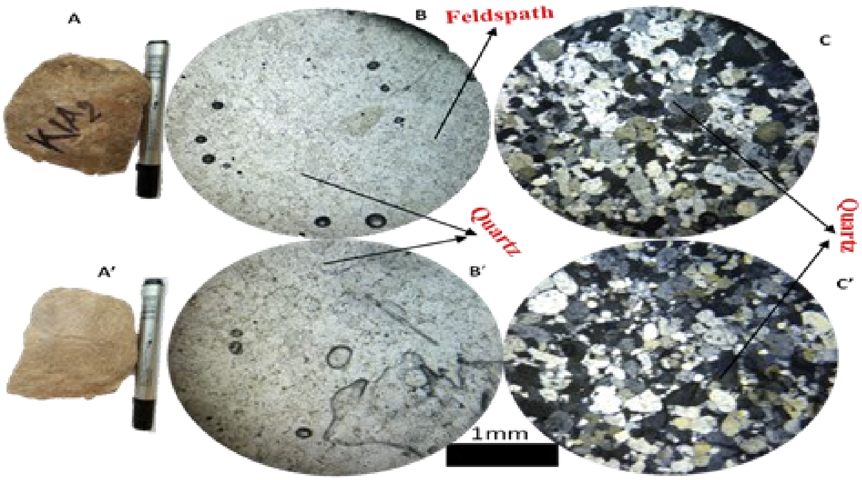

Figure 5 Sample view (A:IKA06 and A':IKA34) and microscope views of the feldspathic arenite (B and B':In CPL; C and C': in PPL.

4.2.2.Polygenic Pudding

Its typical outcrops are found in the Kisieta artisanal quarry, in the village of Kimbao (station IKA14) (Figure 6a), and 2 km from the village of Kimbau (station IKA15) (Figure 6b).

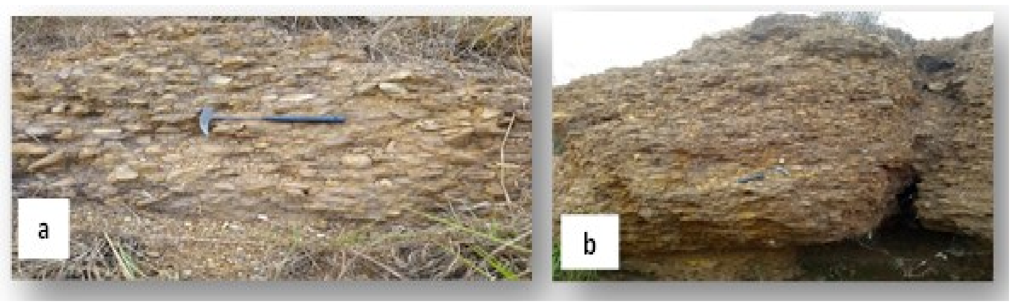

Figure 6 Outcrop view of the pudding; a: station IKA14; and b: station IKA15.

The rock, massive in appearance and yellowish in colour, is dense and composed of rounded to sub rounded shaped elements (pebbles) larger than 2 mm; the lasts are of various types (quartz arenite, feldspathic arenite, argillite, etc), aligned and bound together by a siliceous-clay matrix. The shape of the elements and their varied nature are typical of a polygenic pudding (Prothero and Schwab, 2004).

Furthermore, the aligned nature of this pudding's elements suggests strong hydrodynamic conditions of their transport and deposition (Vatan, 1978).

4.2.3.Greywackes

Its best outcrops are in the Nkara village (station IKA07) (Figure 7a), and at the Nto Nkom Okol river, in the village of Mbila 1 (station IKA28) (Figure 7b).

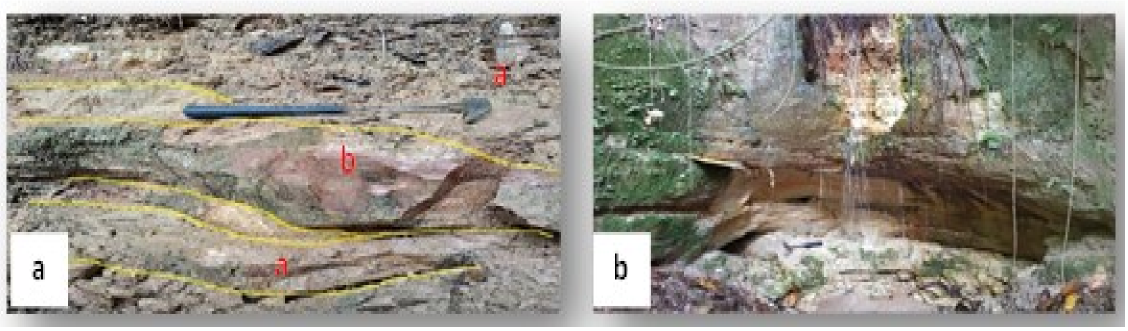

Figure 7 Outcrop view of the greywackes(a) with intercalation of micaceous arenite(b) a: station IKA07a; b: station IKA28.

Macroscopically, the rock is yellowish-pink in colour, rough to the touch, friable, and stratified (stratum thickness: approximately 1.5 cm); it is sparse fine-grained and composed of quartz (Figure 8A, A'). This formation has an azimuth direction of N82°E, with a dip of 14° towards the NW.

Microscopically, the rock has a pasty texture, and formed of approximately 50-60% rounded to sub-rounded quartz crystals and lithic fragments (argillite?) embedded in a clay- siliceous matrix (Figure 8 B, B' and C, C'). With the percentage of the matrix of this sandstone being greater than 15%, and the presence of lithic fragments, this rock can be considered, in agreement with Pettijohn et al. (1973), as a greywacke.

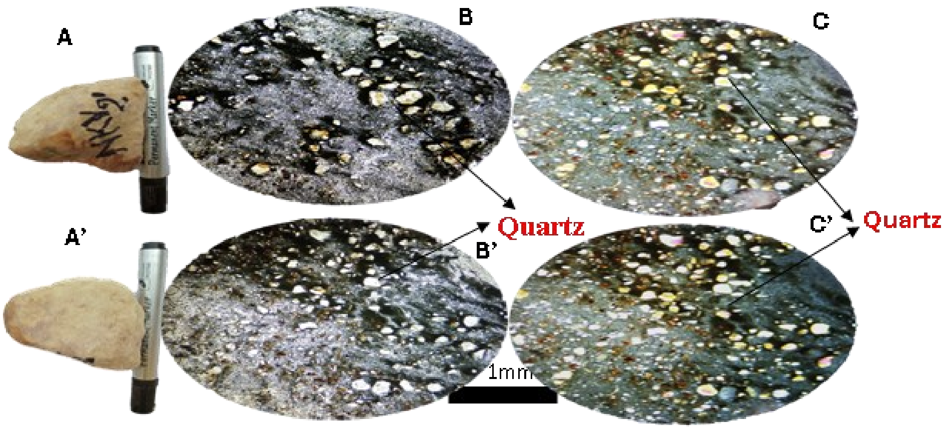

Figure 8 Sample views (A: IKA7b and A':IKA28) and microscope views of the greywacke (B and B': in CPL; C and C': in PPL).

4.2.4. Micaceous arenite

This formation was observed intercalated in the greywackes at the station IKA07a (see Figure 7a).

Macroscopically, the rock is reddish in colour, sparse fine- to medium-grained, with a massive flow, smooth fracture and rich in quartz, accompanied by flakes of muscovite (Figure 9 A, A'). His azimuth direction is N82°E, with a dip of 14° towards the NW.

Microscopically, it is of joint texture, with the main components being quartz (87%) in rounded and sub-rounded crystals, rare leached feldspar crystals (2%) and muscovite (10%); accessory minerals are opaque oxides. All these elements are bound together by a siliceous cement (Figure 9 B,B'and C,C'). With this composition, the rocks can be considered as a micaceous arenite (Pettijohn et al., 1973).

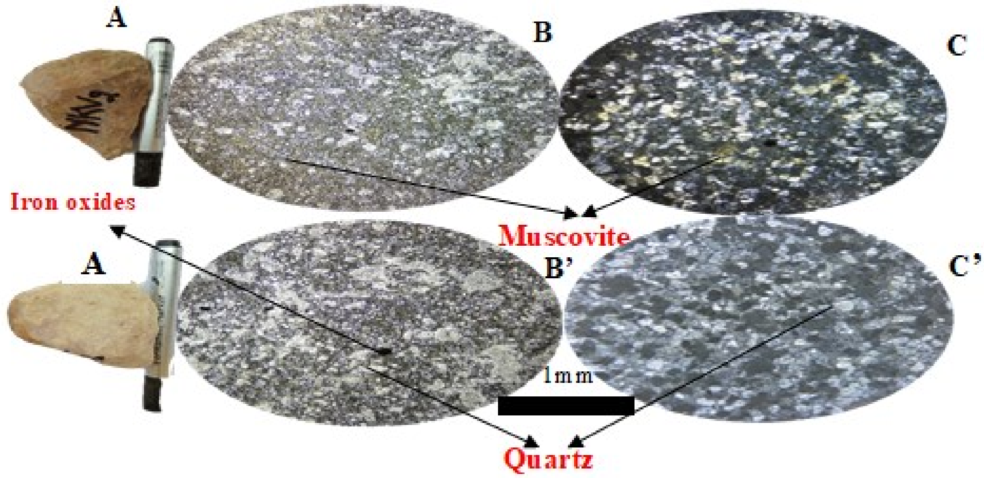

Figure 9 Sample views (A: IKA7a and A': IKA7c) and microscope views of the micaceous arenite (B and B': in CPL); (C and C': in PPL).

4.2.5.Quartz arenite (Samples IKA33 and IKA35)

Typical outcrops of this lithofacies are located near the village of Kiakia (stations IKA33) (Figure 10a), and IKA35 (Table 1).

Figure 10 Outcrop view of the quartz arenite; a: station IKA33; b: station IKA35.

Macroscopically, this is a yellowish-grey, sparse, compact, medium-grained, and cavernous rock composed of quartz, accompanied by feldspars (Figure 11 A, A').

Microscopic observations reveal that the rock is of joint texture, almost entirely formed of fine- to medium-grained quartz (99%); the last are rounded to sub rounded in shape, and accompanied by rare fine grains of opaque minerals bound together by a siliceous matrix (Figure 11 B, B' and C, C'). With these characteristics, this sandstone falls into the class of 'quartz arenites' defined by Pettijohn et al. (1973) and Folk (1974), and similar to those of the Ranverscar, in Great Britain, studied by Marshal (2006).

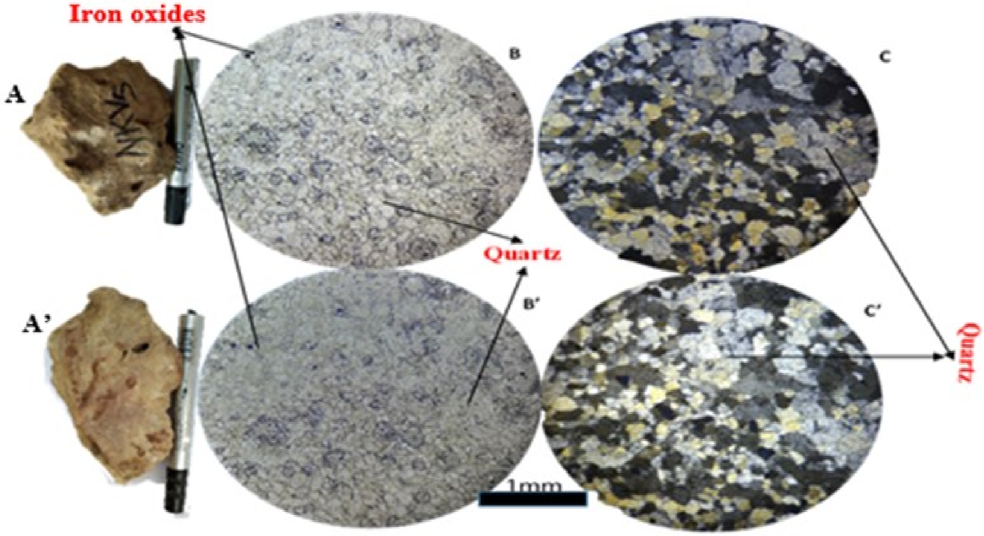

Figure 11 Sample view (A: IKA33 and A': IKA35) and microscope views of the quartz arenite (B and B':CPL; C and C': PPL).

4.2.6.Soft fine grain quartz arenite

Typical outcrops of this formation are located near the village of Kimbao (station IKA17) (Figure 12) and station IKA18 .

Macroscopically, the rock is reddish-brown in color, sparse fine-grained, with a massive flow and smooth fracture. It is rich in quartz (Figure 13 A, A'). Microscopically, the rock has a joint texture and is fine-grained; it is very rich in quartz (95%), almost rounded to sub-rounded in shape; Opaque minerals with rare biotite are also present, but in fine crystals. The different constituents are weakly linked together by a siliceous cement. (Figure 13 B, B' and C, C'). This lithofacies rangers in the quartz arenite class (Pettijohn et al., 1973; Folk., 1974).

Figure 12 Outcrop view of the soft fine grain quartz arenite at the station IKA17.

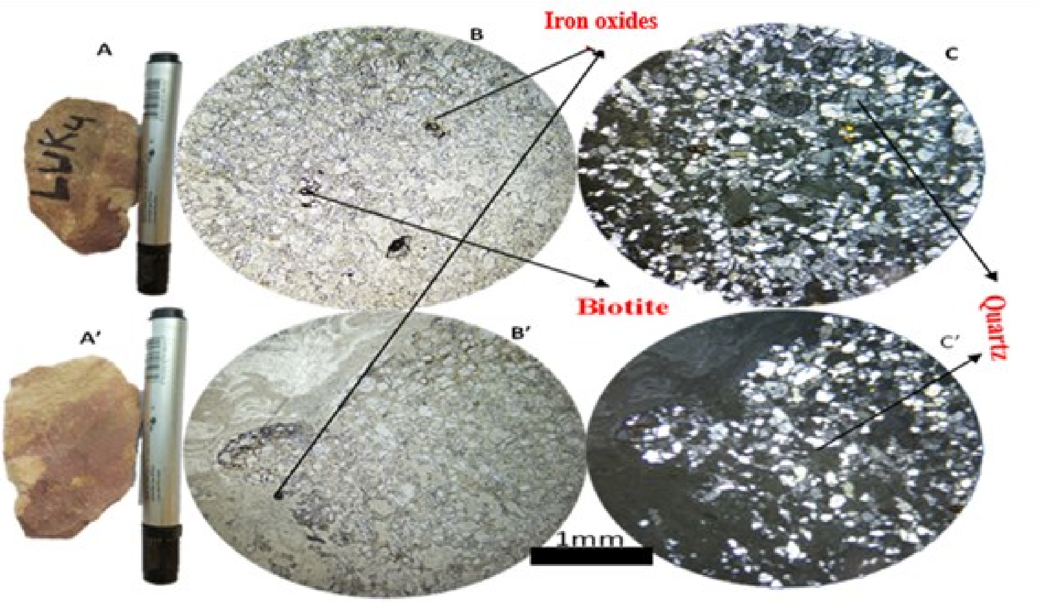

Figure 13 Sample view (A: IKA17 and A': IKA 18) and microscope views of the soft fine grain quartz arenite (B and B': in CPL; C and C' in PPL).

4.2.7. Argillite

Its most remarkable outcrops are located at the Milimi river (Musenge-Mukulu village) (station IK32) (Figure 14a), and along the Lepera river at Nsama village (station IK37) (Figure 14b).

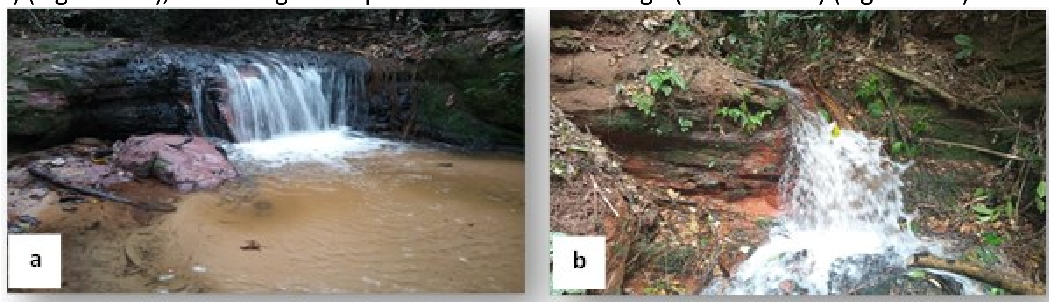

Figure 14 Outcrop view of the Argillite; a: station IK32; b: station IK37.

To the naked eye, the rock is reddish in colour, sparse, friable, bedded and fine-grained (Figure 15 A, A'). It has an azimuth direction of N75°E, with a dip of 11° towards the NW.

Microscopic observations show that the rock has a pasty texture; it contains about 30% of fine-grained, angular to subangular quartz, and 60% of clay. The rest of mineralogy consists of opaque minerals (Figure 15 B, B' and C, C').

All these elements are encased in abundant clay matrix. This composition seems far removed from that of the Tournemire argillite (France), and of the Upper Jurassic argillite from the Meuse-Haute Marne boundary (France). In the latter two regions, in addition to the minerals mentioned above, there is a small amount of calcite, dolomite and iron sulphides (Pyrite) and carbonates (Siderite) (Moreau-Le-Golvan, 1997; Lenoir, 2006).

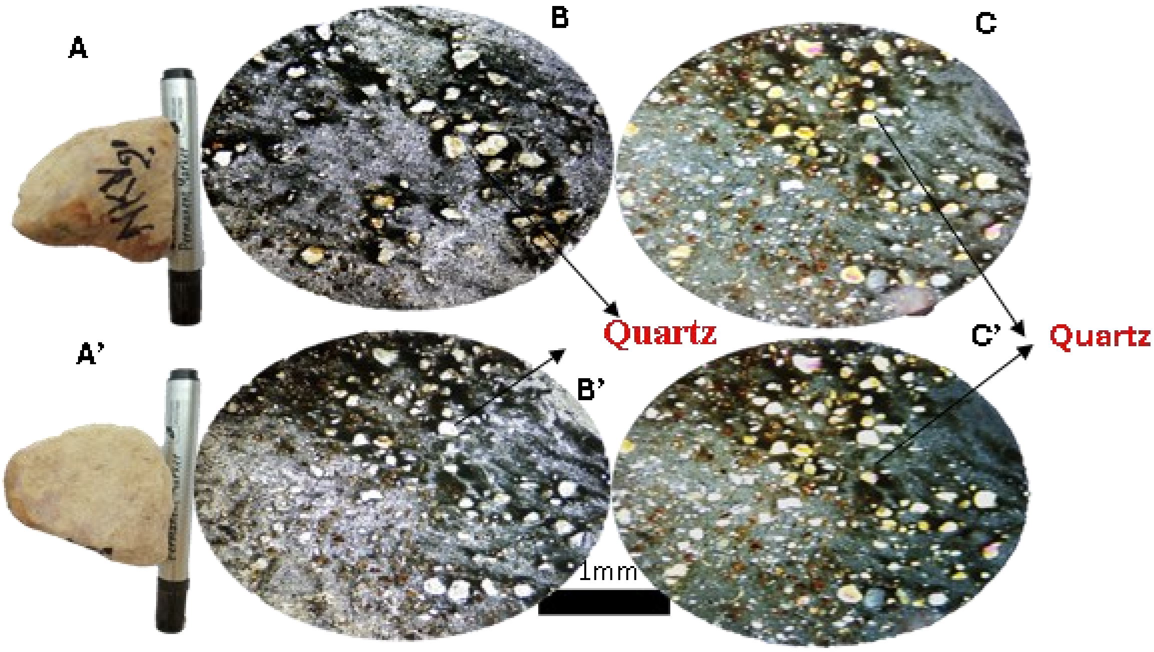

Figure 15 Sample view (A: IKA32 and A': IKA37) and microscope view of the argillite (B and B': in CPL; C and C': in PPL).

4.3. Chemical analysis

Only four rock samples were subjected to chemical analysis, two of them grauwackes and two argillites, and the choice of these two lithofacies was dictated by the fact that the two were not easy to distinguish.

The results of the chemical analyses for the major elements are presented in Table 2 and the diagrams (Figures 16, 17, 18), so that comparisons can be made between the different lithofacies analysed.Results reveal that the four samples analysed are made up of the following major elements: SiO_2, Al_2O_3, Fe_2O_3, K_2O, MgO and TiO_2, with a relatively high percentage of SiO_2 in the four rock samples analysed, followed by Al_2O_3, Fe_2O_3, K_2O, TiO_2 and finally MgO.

Alumina shows a decrease in content from the argillites (Al_2O_3 > 12%) to the greywackes(Al_2O_3 < 10%); the relatively high Al_2O_3 contents in the argillites may be explained by the argillaceous nature of the host rocks (Cullers, 1994; Belhannachi, 2013).

Relatively higher iron contents were also noted in the argillites (Fe_2O_3 > 5%) than in the greywackes (Fe_2O_3 < 3%); this may be explained by the fact that, as is well known, in certain geological environments, Fe^{3+} is a faithful geochemical companion of Al^{3+} (Vidal, P., 2003). This element would thus have accompanied alumina in argillites.

It is noted a difference of SiO_2 content between the two greywackes samples analysed (53.04% SiO_2 vs 35.70%); this difference can be attributed to that of their amount of quartz content. Similarly, the difference in SiO_2 (58.01% vs 35.12%) noted between the two Nkara argillite samples analysed could be attributed to the discrete presence of fine silica grains in the matrix of the sample IKA32. Furthermore, a comparison of the chemical composition of the argillites studied with their counterparts at Tournemire in France shows striking similarities regarding the content of certain major elements. Indeed, the contents of SiO_2, Al_2O_3, Fe_2O_3 and K_2O are in the same order.

Except for the MgO and TiO_2 which are respectively higher and lower in the Tournemire argillites than in those of the study region (Table 1). The difference of MgO content between the two groups of argillites is probably due to the fact that the Tournemire argillites contain dolomite which the Nkara argillite do not (see Lithofacies characteristics).

With regard to trace elements, only Ta, Ge, Br, Ag, Cd, Eu and U were determined in the analysed rocks (Table 2; Figure 18). Of all these trace elements, only Ge, Cd and Br are present in all the samples analysed; albeit with relatively higher contents in the greywackes than the argillites (Ge > 50 ppm vs. Ge < 50 ppm; Cd: 17 - 73 ppm vs. 15 - 93ppm); unlike bromine, which appears to be more concentrated in the argillites than in the greywackes (Br: 23 – 70ppm vs. 0 - 32ppm).

There are notable differences in the content of certain trace elements (i.e. Ta, Br, Ag, Cd) between the two greywacke samples, but also between the two argillites samples analysed. These differences of trace element content between two samples of the same lithofacies can perhaps be explained by the anisotropic nature of the rocks, which do not generally have the same rigorous mineralogical and geochemical compositions in all directions.

The presence of Ge, Br and Ag in the Cretaceous formations of the Kwango Group have recently been reported in the Kakobola sandstone formations in the Gungu region, further to the south-east of the target area (Ndala et al., 2022).

Finally, we note the absence of uranium traces in greywackes, whereas argillite contain up to 35 ppm; this can easily be justified by the fact that uranium is preferentially adsorbed by clays (sediments with a finer granulometry than sandstones) (Vidal, 2003).

It should also be noted that tantalum, bromine and cadmium content in the argillites and greywackes analysed are close to those obtained for sediments from the Lake Nkara-Ewa and the Duem, Lukwa, Luso and Ndobo rivers (Ta: 75-92 ppm vs. 68-78 ppm; Br : 23-70 ppm vs. 48-71ppm; Cd: 15-93ppm vs. 39-61ppm, for rocks and sediments respectively) from the same region (Ibanda and Kamizele, 2021)(Table 2); suggesting that the contents of these two chemical elements in these sediments are probably inherited from the leaching and weathering of the region's argillites and greywackes.

Table 1 Results of chemical analysis of rock samples IKA 21, IK28, IK32 and IK36

Eléments	Grauwackes		Argilites		
	IK21	IK28	IK32	IK36	Unity
SiO_2	53.04	35.70	58.01	35.12	%
Al_2O_3	6.82	7.52	16.52	12.28	%
Fe_2O_3	3.10	0.24	8.74	5.68	%
K_2O	3.25	0.05	3.80	0.74	%
MgO	1.70	0.05	2.14	0.95	%
TiO_2	0.68	0.61	3.22	1.96	%
Ta	0.00	79.50	0.00	91.70	Ppm
Ge	53.00	59.60	46.60	26.60	Ppm
Br	32.50	0.00	70.30	23.10	Ppm
Ag	24.90	0.00	11.10	0.00	Ppm
Cd	16.80	73.50	14.60	93.70	Ppm
Eu	0.00	18.00	0.00	0.00	Ppm
U	0.00	0.00	35.00	16.30	Ppm

Many authors (e.g. Sopuck et al.,1980; Marcote, 1989) consider that the values of various chemical elements observed in sediments of lacustrine and fluvial origin in a region are the results of various factors: lithology, possible mineralisation, particular local conditions. In the Nkara region under study, certain chemical elements found in the sediments of Lake Nkara-Ewa and local rivers were, as mentioned above, linked to the different lithofacies. However, given the current state of geological knowledge, links of these chemical element's values with possible mineralisation cannot be ruled out. More detailed geological research is needed in this region in the future.

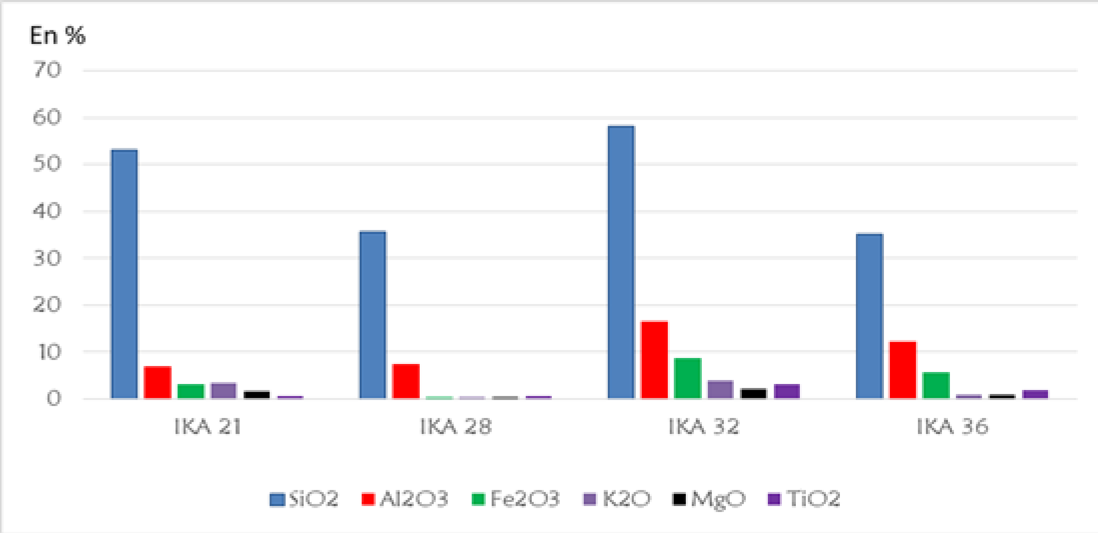

Figure 16 Histogram of the chemical composition (major elements) of argillites and greywackes.

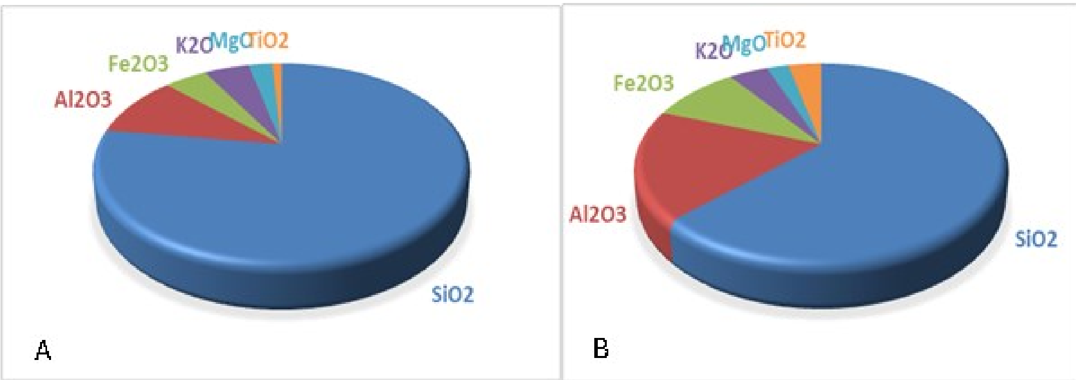

Figure 17 Area diagram of chemical composition (major elements): A for greywackes; B for argillites.

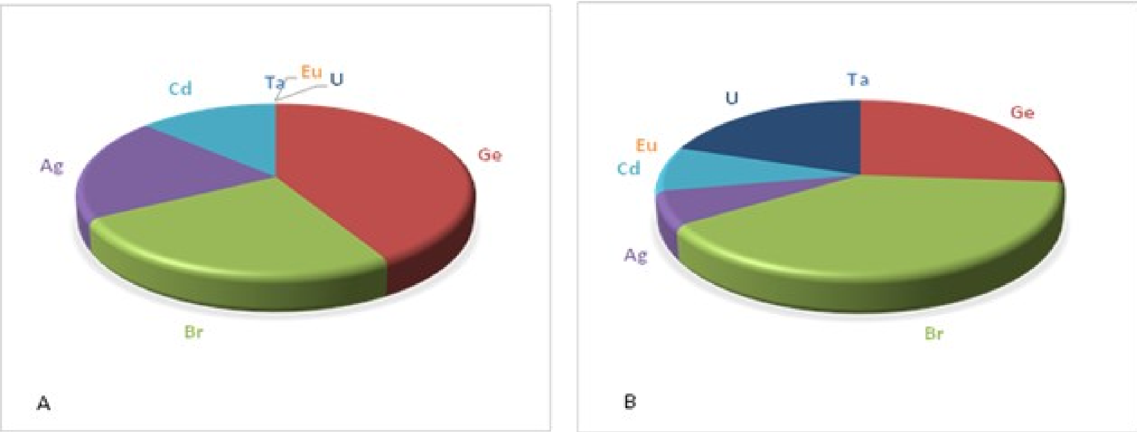

Figure 18 Area diagram of chemical composition (trace elements); A: for greywackes; B: for argillites.

Table 2 Contents of some trace elements in lake and river sediments from the Nkara region (Ibanda and Kamizele, 2021).

Elements	IKA01	IKA05	IKA10	IKA12	IKA24	IKA26
Ta	73.70	59.00	78.40	73.10	68.30	68.40
Br	67.70	48.40	0.00	71.50	57.30	47.90
Cd	61.05	39.00	44.10	41.70	47.70	42.20
Mo	0.094	0.00	0.00	0.00	0.00	0.00
Ga	0.046	0.00	0.00	0.00	0.00	0.00

IK01 and IK05: sediment from the lake Nkara-Ewa; IK10: sediment from Dwem river;IK12: sediment from Lukwa river; IK24: sediment from Luso river; IK26: sediment from Ndobo river

4.4. Paleo-environmental conditions of deposition of the rocks studied

Taking into account the size, shape and degree of roundness of the abundant quartz grains in most of the rocks studied, there is reason to believe that the hydrodynamic regime that transported these grains varied somewhat. Some grains (the rounded ones) underwent long transport, while others (the angular ones) underwent a much shorter transport, their feeding area being in this case close to the sedimentation basin (Boulvain, 2013). The most suggestive case in this regard is that of the roundness of the pudding's elements, as well as their alignment. These two facts attest to the duration of transport and the strong hydrodynamic conditions of the transport and deposition of particles (Vatan, 1978; Boulvain, 2013).

Some of the rocks studied have a clay matrix with discrete silica fine grains. As we know, clay minerals are the product of the alteration of sedimentary, metamorphic and igneous rocks. However, these rocks do not contain pre-existing clay minerals, but one of their constituents, feldspar, is easily degradable into clays (Boulvain, 2013). Burial-related dissolution thus primarily affects the most vulnerable grains, namely feldspars (especially potassic), whose elements contribute to the genesis of clays (Bellair and Pomerol, 1971; Boulvain, 2013).

As for the siliceous cement found in other rocks under study, in agreement with some authors (Cojan and Renard, 1999; Chamley, 2000), it mainly comes from interstitial silica released by the destruction of potassium feldspars and the transformation of smectite into illite (illitization), and less frequently from the effects of quartz dissolution under high pressure. The siliceous cement then organizes itself around the periphery of the original quartz grains in successive layers.

The presence of iron oxide granules in certain samples (i.e. samples IK17, IK18, IK 33 and IK35) suggests, in line with the work of Perrodon (1985), that these rocks were deposited in an oxidizing environment.

5. Conclusion

A geological study carried out in the Nkara region, Kwilu Province (DRC) has revealed seven different lithofacies (pudding, greywackes, soft fine grain quartz arenite, quartz arenite, micaceous arenite, argillite and feldspathic arenite) in Cretaceous formations that were previously undifferentiated in the study area, despite being attributed to the Kwango Group.

Petrographically, some of the rocks studied have a clay matrix and others a siliceous cement, with quartz grains that are sometimes blunt and sometimes rounded to sub-rounded shapes, testifying to long and short transport respectively from the feeder area to the sedimentation basin.

Preliminary geochemical analyses of greywackes and argillites show significant differences in Al_2O_3 and Fe_2O_3 content, due to the nature of their matrix or cement (clayey and siliceous respectively), and of certain trace elements (Cd, Br, Ge and U).

The Cd, Br and Ta contents of the rocks analyzed are close to those of the lake and river sediments in the study area, indicating that the latter are probably inherited through leaching and alteration of the local greywackes and argillites. However, the links between the values of certain chemical elements and probable mineral deposits should be investigated in the future in the region studied.

References

Beaux, J-F.,Fogelgesang, J-F.,Agard, P., Boutin,V.(2012). Atlas de Géologie Pétrologie. Dunod, Paris, 127p.Belhannachi, C.N. (2013). Caractérisation des formations argileuses de la région de Constantine, Thèse de doctorat, Université de Mentouri Constantine, Algérie, p. 205.

Bellair, P., et Pomerol, C. (1971). Eléments de Géologie (3è éd.). Armand Colin, Paris, 527 p.

Boulvain,F.(2013).Eléments de sédimentologie et de pétrologie sédimentaire. Technosup, Liège, 168 p.

Cahen,L.,Snelling, N.J.,Delhal,J.,Vail,J.L.(1984).The geochronology and evolution of Africa. Clarendon Press. Oxford, 512p.

Chamley, H. (2000). Bases de sédimentologie. Dunod, Paris, 178 p.

Cojan, I., Renard, M. (1999). Sédimentologie. Dunod, Paris, 418 p.

Cullers,R.L.(1994).The controls on the Major and Trace element variation of shales, siltstones and sandstones of Pensylvanian-Permian age from uplifted continental blocks in Colorado to platform sediments in Kansas (USA). Geochimica and Cosmochimica Acta, 58, 4955-4972.

Daly, M.C.,Diemu,T.,Lawrence,K., Matouana, B. (1992).Tectonic evolution of the Cuvette Centrale, Zaïre. Journal of the Geological Society, vol. 149, 530-547.

De Putter,T.,Decrée, S.(2012). Le potentiel minier de la République Démocratique du Congo (RDC). Mythes et composantes d'une dynamique minière. MRAC-L'Harmamattan,62p.

Delvaux, D.,Fernandez-Alonso, M. (2015). Petroleum Potential of the Congo Basin, in: M.J. de Wit et al. (eds.), Geology and Resource Potential of the Congo basin, Regional Geology Reviews, Springer-Verlag Berlin Heidelberg.

Delvaux,D.,Maddaloni,F.,Tesauro, M., Braitenberg, C.(2021). The Congo Basin: Stratigraphy and subsurface structure defined by regional seismic reflection, refraction and well data.

Folk,R.L.(1974).Petrology of sedimentary rocks. Hemphill Publishing Company, Austin,182p.

Ibanda,M.J.,et Kamizele, G.D. (2021). Etude pétrographique, géochimique et sédimentologique des Formations de Nkara et ses environs (Province du Kwilu, RDC). Mémoire de Licence, Université de Kinshasa, 78p. (inédit).

Henry, J.(1986). Mise en évidence d'une nappe artésienne jaillissante dans la série crétacique du Kwango (région de Kikwit, RDC). Bulletin de la Société belge de Géologie, Bruxelles, 95(1), 47-53.

Kadima,E.(2007). Sismographie, Structure géologique et prospectivité pétrolière du bassin de la Cuvette Congolaise (RD Congo). Master Thesis, University of Lubumbashi, 162p.

Lenoir, N. (2006). Comportement mécanique et rupture dans les roches argileuses du Jurassique supérieur (limite Meuse-Haute Marne, France) étudiées par micro tomographie à Rayons X. Thèse doct. Université Joseph Fourier-Grenoble I, 238p.

Lepersonne,J.(1974). Notice explicative de la carte géologique du Zaïre au 1/2000000ème. Dpt.des Mines du Zaïre, Dir. Géol. Kinshasa, 67 p.

Lepersonne,J.(1975). La collection paléontologique du Musée Royal de l'Afrique Centrale. Rapport annuel, 1974, du Dépt. Géol. Min. du Musée Roy. Afr. Centr., Tervuren (Belg.), 97-101.

Lepersonne,J.(1977). Structure géologique du bassin intérieur du Zaïre, Bulletin de l'Académie Royale Belge, 914-965.

Lukosi,N.S.et Zampamba, L.J. (2014). Etude pétrographique et structurale de la région de Mbadinga-Bilala (District du Kwango, Province de Bandundu, RDC). Mémoire de Licence, Université de Kinshasa, 70 p. (inédit).

Marcote, D. (1989). Analyse multidimensionnelle de données géochimiques de sédiments lacustres dans la région de Manicouagan (Québec). Rapport du Service de la géochimie et de la géophysique, Ministère de l'Energie et des Ressources du Québec, 60p.

Marshal, B. (2006). Caractérisation et interprétation de la variabilité chimique et minéralogique des grès réservoirs. Implications pour la modélisation numérique de la diagenèse minérale des grès du Ravenscar Group (Yorkshire, Royaume Uni). Yhèse doct., Université Jean Monnet, 253p.

Moreau-Le-Golvan (1997). Traçage isotopique naturel des transferts hydriques dans un milieu argileux de très faible porosité : les argilites de Tournemire (France). Thèse doct., Université Paris XI, 141p.

Munene,A.D.,Simbungu, A.F., Kanika, M.T., Mulaji, I.R., Thijenira, L.A., Makoka, M.F., Makuku,M.L., Opuluku, R., Iyolo, L.J(2023). Contribution of petrographic and geochemical analyses of the Kipala shale (Central basin, DRC) to the assessment of its potential as a hydrocarbon source rock.Journal of Engineering Studies and Research, volume 29, No.4, 24-30.

Ndala, T.I., Kalanga, K.B.,Musitu,M.J., Nzau, U.C. (2022).Sedimentological and Paleoenvironmental Characterizations of the Kakobola Hydroelectric Power Site and its surroundings (Kwilu Province/DR Congo). Geo-Eco-Trop, 46, 315-328.

Passau, G. (1920). Découverte d'un gite fossilifère au Kwango, Publications relatives au Congo belge et régions voisines, Annales de la Société Géologique de Belgique, T.43, 29-55.

Perrodon,A.(1985).Géodynamique pétrolière.Genèse et répartition des gisements d'hydrocarbures, Masson, Paris, 344p.

Pettijohn, F.J., Potter, P.E., Siever, R. (1973). Sable et grès. Springer Verlag, New York, 618p.

Prothero, D.R., Schwab, F.(2004). Sedimentary geology: an introduction to sedimentary rocks and stratigraphy. Ed. Freeman, 557p.

Roubault, M., Fabries, J., Touret, J., Weisbrod, A. (1963). Détermination des minéraux des roches au microscope polarisant. Lamarre-Poinat,Paris, 366p.

Sopuck, V.J., Schreiner, B.T., Smith, J.W.J. (1980).Interpretation of reconnaissance lake sediment data in the Precambrian shield area, Saskatchewan Research Council G78-10a, 53p.

Taverne, L. (1976). Les téléostéens fossiles du Crétacé moyen de Kipala (Kwango, Zaïre), Annales du Musée Royal de l'Afrique Centrale, Sciences géologiques, vol.79, no. 8, 1976, p.1-50.

Vatan, A. (1978). Histoire des sables et des grès à travers leur environnement minéral. Document Laboratoire de Géologie, Faculté des Sciences de Lyon, hors- série, 4, 46p.

Vidal, P. (2003). La géochimie (2è éd.). Dunod, Paris, 190p.