

1 **AT THE CROSSROADS OF NATURAL AND HUMAN SCIENCES:**
2 **THE EVALUATION AND PROSPECTS FOR THE DEVELOPMENT OF THE**
3 **GEOSITES OF BAKEL CITY (TAMBACOUNDA REGION, SENEGAL).**

4 **Abstract:**

5 Bakel, located in the Tambacounda region, is the capital of the department of the same name.
6 It lies in the far east of the country on the left bank of the Senegal River, which separates it
7 from Mauritania. The relief is generally flat but dotted with a few hills and small depressions
8 formed by streams. The exposed geological formations date from the Paleoproterozoic to the
9 Pliocene epochs. The presence of the river has facilitated settlement in the area since the Late
10 Pleistocene, and navigation has furthered the arrival of colonists since the early 19th century.
11 It is connected to National Route 2 (RN2) by a 5 km stretch and is located 65 km from Kidira.
12 This study aims to identify and assess the geosites within the municipality and propose
13 strategies for their development. Based on our observations and the results of previous work,
14 we carried out an evaluation of the criteria used by the authors for the creation of geosites in
15 this municipality. Thus, the scientific, cultural, ecological, aesthetic, and economic values
16 were assessed for nine geosites, eight of which were anthropogenic and one hydrological. To
17 promote geodiversity as a support for biodiversity and geoheritage as a tool for sustainable
18 local human and socio-economic development in the region, some of these geosites deserve to
19 be valued and protected. This could allow for the delimitation of a geopark within the
20 municipality and contribute to promoting geotourism.

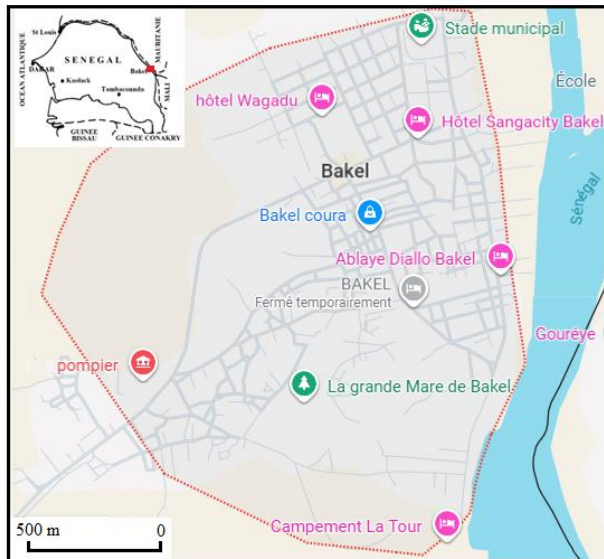
21 Keywords: Senegal River, geosite, geodiversity, geoheritage, geotourism.

22
23 **1. Introduction.**

24 Bakel is the capital of the department of the same name. It is located in the Tambacounda
25 region, in the far east of the country, on the left bank of the Senegal River, which separates it
26 from Mauritania (Fig. 1). It is connected to National Road 2 (RN2) by a 5 km stretch and is
27 65 km from Kidira, a town crossed by National Road 1 (RN1) and the Dakar-Niger railway.
28 The presence of the river has facilitated human settlement in the area since the Late
29 Pleistocene.

30 The Ndiaye aristocrats, who came from Djolof, settled in an area they named Ndiayega in the
31 village of Bakel. This latter name also originates from them (Diallo, 2021; Cissokho, 2017;
32 Willane, 2019). This departure of the Ndiaye from Djolof is linked to the collapse of the
33 Djolof Empire, which occurred between 1549 and 1575 (Boulègue, 2013). Their settlement in
34 Bakel took place before the official French presence in 1818, although their presence has been
35 documented since the 17th century (Diallo, 2021). Logically, the Ndiaye settlement in Bakel
36 falls within the period from 1549 to 1818. This territory was under the control of the Bathily
37 family when they settled within the Kingdom of Galam. The relationships between Bathily
38 and Ndiaye, Ndiaye and Kébé, Ndiaye and the French, French and the inhabitants of
39 Modinkané, French and Bathily, among many others, testify to a multitude of interactions,
40 beginning before the official French settlement and continuing with their arrival to the present
41 day, with other forms of adaptation, the most striking of which is the tendency towards

42 emigration. The desire to reduce Bakel's heritage to the colonial period alone stems from an
43 unsuccessful attempt at ideological manipulation and coercion. Relationships that sometimes
44 converged with the interests of the colonizers, and sometimes diverged, sometimes exhibiting
45 resistance, are visible in the spatial configuration.



46
47 **Fig. 1:** Location map of the municipality of Bakel
48

49 Among the older neighborhoods of Bakel are Ndiayega, Guidimpale (“behind the stones or
50 hills”), and Liberté-Faidherbe, while those of HLM (Habitations à Loyer Modéré – low-
51 income housing), Bakel Coura, Darousalam, and Fandale date from after 1960 (Diallo, 202).
52 Bakel was established as a municipality in 1960.

53 The area boasts a rich geological and geomorphological diversity (geodiversity), which,
54 through its varied ecosystems, supports significant biological diversity (biodiversity) and a
55 rich cultural heritage based on archaeological sites, places of worship, and traditional
56 ceremonies. The preservation and enhancement of this natural and cultural wealth requires the
57 establishment of several geosites within this municipality.

58 According to Reynard (2004) and Skibiński et al. (2021), “geosites are defined as portions of
59 the geosphere that are of particular importance for understanding Earth’s history, geological or
60 geomorphological features that have acquired scientific, cultural/historical, aesthetic and/or
61 social/economic value due to human perception or exploitation.” Geosites are therefore key
62 elements in the development of geotourism and education, and inventorying and assessing
63 them is the first step towards establishing a geopark (Skibiński et al., 2021).

64 Another key concept is geoh heritage (geosites and geomorphosites), which must be assessed
65 (Brilha and Reynard, 2018), managed (Erikstad, 2013), subject to conservation (Brocx &
66 Semeniuk, 2019), promoted through geoparks (Xu & Wu, 2022; Zouros, 2004), and be central
67 to geotourism (Ehsan et al., 2012; Hose & Vasiljevic, 2012), geoscience museums, and
68 mapping (Coratza et al., 2021). Preserving geoh heritage means safeguarding the natural

69 diversity of elements within major geomorphological and geological sites, that is, geoheritage
70 sites, also called geosites (Mariotto et al., 2020).

71 This study is a continuation of a large-scale, multidisciplinary research program currently
72 underway in Senegal to promote geodiversity. It follows on from the work carried out by
73 Youm et al. (2018) in the Dindéfélo Community Nature Reserve (RNDC), Youm et al. (2022)
74 at Lac Rose, and Gueye et al. (2023) in the Bamboung Community Marine Protected Area,
75 located 700 km, 30 km, and 150 km from Dakar, respectively. The present study aims to
76 identify and assess the geosites in the area and propose strategies for their development.

77

78 **2. Geographical, geomorphological, and geological context of the study area**

79 **2.1. The geographical context**

80 The commune of Bakel is located in the east of the country, on the border with Mali and
81 Mauritania, more than 500 km upstream from Saint-Louis on the left bank of the Senegal
82 River and nearly 800 km from the capital, Dakar. Situated at the mouth of a bend in the
83 Senegal River, the town of Bakel lies between latitudes 14°53' and 14°55' North and
84 longitudes 12°26' and 12°27' West (Gassama, 2025). The climate is Sudano-Sahelian,
85 characterized by a dry season (November to June) and a wet season (July to October).
86 Temperatures are high, with an annual average of approximately 27°C. The average annual
87 rainfall is approximately 539.9 mm.

88 The town of Bakel is traversed by the Senegal River, which forms a natural border with
89 Mauritania. This river is formed by the confluence of the Bafing (its main branch) and the
90 Bakoye at Bafoulabé. It originates in Guinean territory in the high altitudes of the Fouta
91 Djallon highlands, within the Guinean climate zone, which is very rainy. Near Aroundou, it is
92 joined by the Falémé, a powerful tropical river. At Bakel, the Senegal River flows over a hard
93 bedrock composed of quartzite sandstone and schist. It drains a catchment area covering
94 218,000 m², and its average annual flow is 648 m³/s. It's very gentle gradient at Bakel (0.03
95 on average) results in a very small drainage network, which limits erosion and sediment
96 deposition (Gassama, 2025). During the winter, temporary backwaters called "Kharé", formed
97 in the schist lowlands, are flooded by the river.

98 The distribution and density of vegetation are linked to geology, topography, rainfall, and soil
99 type (Diakité 2018). Thus, the commune of Bakel is located in the Guinean savanna region,
100 characterized by the appearance of pre-forest species. In the valleys, homogeneous stands of
101 fan palms and sometimes bamboo appear. The presence of water allows for crops such as rice.
102 The streams and rice paddies harbor aquatic and semi-aquatic fauna typical of humid Sahelian
103 environments, potentially including fish, amphibians, and water birds. The presence of water
104 near the town may also attract fauna adapted to Sahelian conditions from the surrounding
105 areas.

106 The town of Bakel owes its existence to the establishment of a military post. Indeed, a former
107 river port, the town is situated on a system of rocky hills around which the entire urban fabric
108 was organized. According to the 2023 census, the population of the commune of Bakel was
109 estimated at 18,939 inhabitants, covering an area of 5.858 km², resulting in a population

110 density of 3,233/km². Women represent 54.6% of the population. The Soninke, comprising
111 52% of the population, are the dominant ethnic group in the commune. The other ethnic
112 groups present in the town are primarily the Toucouleur (20%), the Wolof, the Fulani, and the
113 Bambara (Gassama 2025). Bakel abounds with authentic traces of the colonial era. A visit
114 reveals magnificent sites worthy of admiration. This is the case with the René Caillé Pavilion,
115 the Faidherbe Fort, the three military towers, and the circumcised cemetery, which were listed
116 as historical monuments in 2003 and represent a treasure capable of bringing this town out of
117 obscurity. Unfortunately, all this heritage, which could have made Bakel a true destination for
118 historical and cultural tourism, is being left to decay. Its disappearance could constitute a
119 major loss of a part of the collective memory. The town has a high rate of emigration,
120 particularly of men to Europe. This phenomenon primarily affects the Soninke people,
121 followed by the Toucouleur.

122 In addition to its role as an administrative center, Bakel is also the economic hub of a vast
123 geographical area. Agriculture and livestock farming remain the main economic activities
124 within the municipality. In each neighborhood, more than a third of the inhabitants are
125 engaged in agriculture. This sector has experienced significant growth with the development
126 of land in the river valley by SAED (the local agricultural development agency). Cultivated
127 crops include millet, corn, market garden produce, and to a lesser extent, peanuts (Gassama,
128 2025). Livestock farming is, in many respects, an activity that engages the majority of the
129 population. Urban livestock farming is extensive, encompassing the main breeds of domestic
130 ruminants. Poultry farming, primarily practiced by women, provides a supplementary source
131 of income. Support is provided by the departmental livestock service and a private veterinary
132 clinic (Gassama, 2025). The city offers real potential for cultural tourism and exploration.
133 Indeed, the available attractions include the Bakel Cultural Days and historical sites and
134 monuments such as the René Caillé Pavilion and the Bakel Fort. Despite these opportunities,
135 the tourism sector has not benefited from large-scale promotional campaigns. In fact, the lack
136 of dynamism in this sector limits Bakel's appeal as a destination. Only three accommodations
137 are available to visitors: the Hotel Islam, the Djikké Camp, and the guesthouses run by the
138 delegation of SAED (Société d'Aménagement et d'Exploitation des Terres du Delta du fleuve
139 Sénégal - Senegal River Delta Development and Management Company) and CFPE (Centre
140 de Formation Professionnelle de l'Entreprise - Business Professional Training Center,
141 Gassama, 2025). Remittances accompanying these international migrations are a crucial
142 component of Bakel's economy. The allocation of these remittances to meet household needs
143 appears to be a deliberate and premeditated strategy undertaken by the migrant in consultation
144 with their family and community (Cissé, 2023). The emigrant is concerned with the well-
145 being of their loved ones. The sums of money sent by emigrants generate significant changes
146 in the socio-spatial configuration of Bakel. The acceleration of urbanization and the
147 development of housing in Bakel's urban area are inextricably linked to the migratory
148 phenomenon (Cissé, 2023).

149 **2.2. The geomorphological and geological framework**

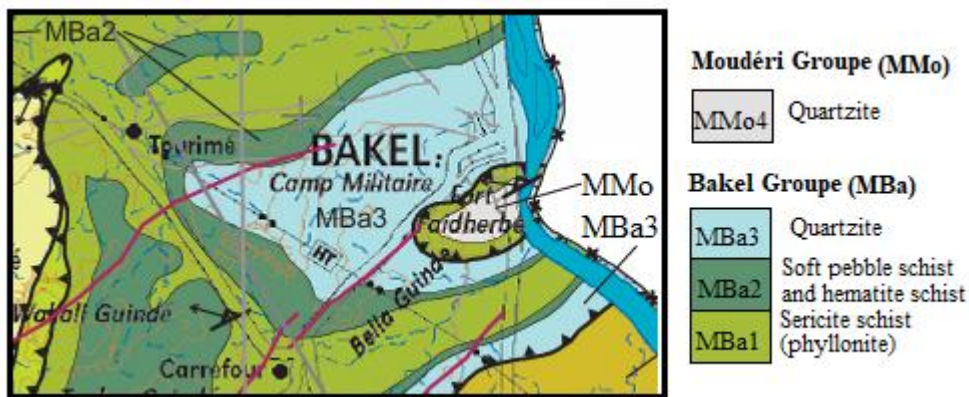
150 **2.2.1. The relief of the municipality of Bakel.**

151 The relief is generally flat but dotted with a few hills overlooking the Senegal River and small
152 depressions formed by streams and ponds. Specific hills named Grimpalé Montagne,
153 Ndiayega, Dar Es Salam, Bakel Coura, Modinkané, and Yaguiné are present in the landscape.

154 2.2.2. The geological context of the municipality of Bakel

155 The outcropping rocks in the commune of Bakel belong primarily to the Mauritanides
156 Supergroup, which is composed of Precambrian and Paleozoic formations deformed and
157 metamorphosed during the Pan-African and Hercynian orogenies (Lécorché, 1980; Lécorché
158 et al., 1989; Le Page, 1983). This north-south trending chain forms the western boundary of
159 the geological formations of the West African Craton and the Taoudeni Basin. It disappears in
160 its western part beneath the sedimentary formations of the coastal basins of Western Sahara,
161 Mauritania and Senegal.

162 The Mauritanides have been subdivided into three structural zones: the northern section
163 located north of the Aouker River, the central section from the Aouker to the Senegal River,
164 and the southern section, south of the Senegal River (Dia, 1984; Lécorché, 1980; Le Page,
165 1983; Lille, 1967). Our study area is located on the southern branch. The latest updates
166 carried out by Lahondère et al. (2010), which we refer to below, have allowed us to
167 distinguish four major geological domains: autochthonous to parautochthonous,
168 allochthonous in an external position, a Central Complex, and an allochthonous unit in an
169 internal position. The Bakel rock outcrops belong to the Bakel and Moudéri Group (Fig. 2),
170 both of which are part of the allochthonous unit in an internal position.



171
172 **Fig. 2:** Geological map of the study area (after Fullgraf et al., 2010, modified)

173 - **The Bakel Group (MBa)** corresponds to a vast unit that constitutes, in and around the town
174 of Bakel, numerous hills reinforced by sandstone-quartzite bars. It corresponds to the southern
175 continuation of the El Harach Group defined in Mauritania (Pitfield et al., 2004). The
176 quartzites of the Bakel Group are affected by a penetrative foliation of locally protomylonitic
177 to mylonitic nature. This foliation is generally associated with an elongation lineation,
178 sometimes highlighted by long fibrous quartz crystals. Measurements show that the S1
179 foliation has a generally shallow dip ($< 40^\circ$) towards the West or Northwest. The elongation
180 lineation is always close to the line of steepest descent (Lahondère et al., 2010). The Bakel
181 Group is divided by Lahondère et al. (2010) in three formations: - MBa3 consisting of white
182 quartzites with mauve patches on which the old agglomeration is built; MBa2 represented by

183 schists with soft pebbles and hematite schists located below and surrounding the white
184 quartzites and - Mba1 consisting of sericite schists (phyllonite) surrounding, in the locality,
185 the MBa2 and MMo4 formations (Fig. 2).

186 - **The Moudéri Group (MMo)** is composed of conglomerates, greenschists, quartz-sericitic
187 schists, ferruginous schists, meta-arenites, and quartzites, forming a sedimentary stack whose
188 stratigraphy remains largely unknown. The distinction between the MMo1 to MMo4
189 formations within the group is therefore based primarily on the predominance of certain facies
190 within each unit (Lahondère et al., 2010). In the municipality of Bakel, only the MMo4
191 formation outcrops as an ENE-WSW trending quartzite hill overlooking the river (Fig. 2). In
192 thin section, these quartzites consist of heterogranular quartz grains, very tightly interlocked,
193 without any preferred orientation. Iron oxide veins, sometimes folded, appear to be associated
194 with micro-shears. The recrystallization of quartz is subsequent to the folding of the iron
195 oxide veins.

196 These Precambrian and Paleozoic formations are partly covered by superficial formations
197 represented by some lateritic crusts.

198 **3. Methodology for evaluating geosites**

199 We conducted a quantitative and qualitative evaluation using the criteria proposed by Lima et
200 al. (2010) and Mariotto et al. (2020). According to Lima et al. (2010), most geosite evaluation
201 methods use scientific value, which can be subdivided into four sub-criteria:
202 representativeness, integrity, rarity, and also the degree of scientific knowledge about the
203 geosite, as evidenced by the number and quality of scientific publications focused on it
204 (Brilha, 2016). Each of these sub-criteria is evaluated independently with a numerical score
205 ranging from 0 (none) to 1 (very high) in 0.25 increments; the final scientific value of the
206 geosite is obtained by averaging the four criteria. In addition to scientific value, other, so-
207 called "supplementary" values (Coratza & Giusti, 2005) can be identified and assessed:
208 cultural, ecological, economic, aesthetic, and educational (Mariotto et al., 2023). Like
209 scientific value, these additional values are established by a score ranging from 0 to 1 in
210 increments of 0.25. A table is created in which the average values obtained are entered, along
211 with the overall average value, which is the mean of the data, with the scientific value
212 weighted twice.

213 The data used comes from our observations and surveys conducted among the population,
214 notably Mr. Abdoulaye Diallo, Curator of Bakel's heritage. It is supplemented by work carried
215 out in previous programs based primarily on geology, biodiversity, history, archaeology, and
216 tourism.

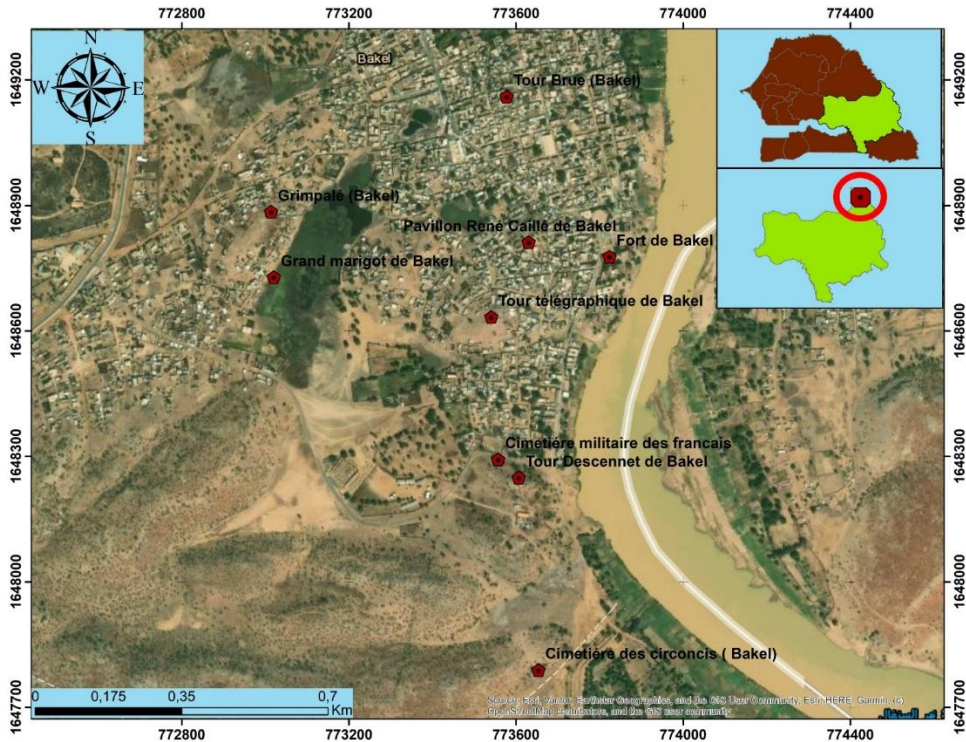
217 **4. Geosites in the Municipality of Bakel: Prospects for Development.**

218 Based on our observations and the results of previous studies, we evaluated the criteria used
219 by authors for the creation of geosites in this municipality. Thus, the scientific, cultural,
220 ecological, aesthetic, and economic values were assessed for nine geosites, eight of which
221 were anthropogenic and one hydrological (Table 1, Fig. 3). Of these identified geosites, only
222 four obtained a score greater than 0.50 and will be described in detail. These are, in

223 descending order of score: Pavillon René Caillé (René Caillé Pavilion), Fort de Bakel (Bakel
224 Fort), « Tour Brue » or Tour du « Mont aux Pigeons » (Tower of Pigeon Hill) and Tour
225 Descennet (Descennet Tower) or Tour du Mont aux Singes (Monkey Mountain Tower). All are
226 colonial remains falling under the category of anthropogenic geosites, which, according to
227 Rădulescu et al. (2019), encompass historical, cultural, archaeological, artistic, sporting, and
228 economic geosites. They have all been listed as historical monuments of Senegal (Willane,
229 2019).

230 **4.1. The Pavillon René Caillé** (Fig. 4).

231 The building is perched on a hill offering a picturesque view of the entire town and the
232 Senegal River. It is the highest point in all of Bakel. It served as a sanatorium for patients
233 from French Sudan (Cissokho, 2016-2017). The French explorer René Caillé, during his
234 voyage to Timbuktu in 1824, is said to have stayed there as a patient, and the building,
235 although older, eventually came to bear his name. The pavilion's location was later used as a
236 training ground for adults in the area when the number of learners grew significantly. Initially,
237 classes were held at Fort Faidherbe, and it was later, with the increasing number of students,
238 that the area around the pavilion was used by the French to train tax collectors (Willane,
239 2019). It was also used as a rear base and lookout point by the Senegalese military during the
240 Senegal-Mauritanian conflict of 1989 (Cissokho, 2016-2017; Willane, 2019). This pavilion
241 also served as temporary housing for refugees from Mauritania during the conflict. It was also
242 used, in turn, as accommodation for the district chief, the Gendarmerie, and the deputy
243 prefect. It was converted into a reading center in 1997 by the town hall, but this did not have
244 the desired effect due to a lack of readers (Cissokho, 2016-2017). The site is currently used as
245 a children's playground, a garbage dump, and also as a public urinal and defecation area.
246 Geologically, it is located on a hill composed of quartzites from the MMo4 formation and
247 sericite schists from the MBa1 formation.



248

249 **Fig. 3:** Location map of the geosites identified in the municipality of Bakel

250 **Table 1: Geosites identified in the municipality of Bakel, classified by type and in**
 251 **descending order of score.**

N°	Geosite	Geographic coordinates	Scie	Cult	Ecol	Aest	Econ	Moy
A1	Pavillon René Caillé of Bakel	X = 773629.9 ; Y = 1648812.2	0,75	0,67	0,13	0,88	0	0,69
A2	Fort of Bakel	X = 773823.3 ; Y = 1648777.6	0,8	0,5	0,63	0,5	0,25	0,66
A3	Tour Brue (Bakel)	X = 773577.2 ; Y = 1649160.4	0,75	0,5	0,13	0,88	0	0,63
A4	Tour Descennet of Bakel	X = 773606.2 ; Y = 1648249.5	0,75	0,5	0,13	0,88	0	0,63
A5	French Military Cemetery (Bakel)	X = 773556.9 ; Y = 1648293	0,5	0,5	0,25	0,75	0	0,5
A6	Telegraph Tower of Bakel	X = 773540.5 ; Y = 1648633.3	0,55	0,5	0,13	0,5	0	0,45
A7	Cemetery of the Circumcised (Bakel)	X = 773653.3 ; Y = 1647789.5	0,65	0,13	0,13	0,63	0	0,44
A8	Grimpalé (Bakel)	X = 773013.6 ; Y = 1648884.8	0,3	0,13	0,13	0,63	0	0,29
H1	Large marsh of Bakel	X = 773020 ; Y = 1648728.6	0,4	0,13	0,13	0,63	0	0,36

252 Scie = scientific value; Cult value = cultural value; Ecol = ecological value; Aest = aesthetic
 253 value; Econ = economic value; Moy = average value; A = anthropogenic geosite; H =
 254 hydrological geosite.

255 The highest score for this geosites is its aesthetic value (0.88), followed by its scientific (0.75)
 256 and cultural (0.67) value. The high aesthetic value is due to the site's open layout, its visibility

257 from afar, and its expansive size. The high scientific value is linked to its rarity, with
258 exceptional characteristics unique within the reference area, and its international recognition.
259 The cultural value is a combination of its international historical importance and its lack of
260 religious importance. Ecologically, the site has very low biodiversity and receives no
261 protection. The site also generates no income.

262 **4.2. Fort de Bakel** (Fig. 5).

263 Fort de Bakel (also called Fort Faidherbe) was founded between 1818 and 1820 by the French
264 (Diallo, 2021) and primarily served to supply "Douaïch Maures gum," gold, and ivory to
265 merchants in Saint-Louis (Bah, 1981). It is built on the quartzite hill of the MMo4 Moudéri
266 formation, bordering the left bank of the Senegal River. The basic building materials came
267 from the same hill. It offers a panoramic view of the landscape (the Senegal River and the
268 surrounding plain) and the city, with cannons aimed towards the river. The Compagnie du
269 Galam was the main trading company, followed by merchants representing the trading houses
270 of Saint-Louis. The fort underwent modifications in the 1850s under Faidherbe. It served
271 political, administrative, legal, commercial, and military purposes. It currently serves as the
272 prefecture. The fort currently serves as the prefecture. It also served as a school for adults in
273 its early years, around 1919-1920. The construction of three towers near the fort between
274 1855 and 1860 made Bakel the most important military post in all of Upper Senegal. This is
275 what led to the failure of Mamadou Lamine Dramé's attack in 1886 (Bah, 1981). The three
276 watchtowers, built on hills, allowed for control of the surrounding area.

277 Geologically, the dominant facies are the same as those of Pavillon René Caillé, with
278 quartzites from the MMo4 Formation of the Moudéri Group and sericite schists (phylionite)
279 from the base of the Bakel Group (MBa1 Formation). In front of the prefecture building,
280 brittle faults and associated structures, including tectoglyphs (striations, re-entrant surfaces,
281 crush surfaces, and detachment surfaces), are visible on the quartzites. On the phyllonite,
282 descending the hill, folded quartz veins with long and short limbs and boudinage of the limbs
283 are found. The folds have a curved axis, with the curvature of the axis in the direction of the
284 stretching lineation (Lahondère et al., 2010).



285

286 **Fig. 4:** Pavillon René Caillé. A: Building perched on a hill of sericite schist from the MBa1
287 formation; B: Detail of the main entrance.

288 The highest score for this geosite is its scientific value (0.80), followed by its ecological value
289 (0.63). The high scientific value is due to the following: - it is highly representative of the
290 regional geomorphology and exhibits truly exemplary qualities; - it is rare and possesses
291 exceptional characteristics unique within the reference area; - it is of exceptional importance
292 for education and training and - it is internationally renowned. The high ecological value is
293 supported by ecological diversity and protection related to its occupation by the prefecture

294 and its listing as a historical monument. The cultural value is shared between its international
295 historical importance and the absence of religious significance. The aesthetic value is average,
296 and the site does not generate any income.



297
298 **Fig. 5:** Fort Faidherbe of Bakel. A: General view; B: view of the main entrance; C: Detail of
299 the main entrance showing the cannons; D = Wall of the fort bearing the plaque of the
300 Prefecture; E = Outcrop of sericite schists of the MBa1 formation visible at the bottom of
301 the wall of the fort which is deteriorating.

302 **4.3. Tour Brue or Tour du « Mont aux Pigeons » (Fig. 6).**

303 The Tour Brue, or Tour du « Mont aux Pigeons », stands to the north, which is why it is also
304 called "Tour du Nord" (North Tower). It is built on a hill in the Diabé Giddé district
305 (Cissokho, 2017). Construction of this tower dates back to the 1820s. Its purpose was to
306 monitor traffic to and from the villages of Tiyabu and Modinkané. The latter word means
307 "dwellings of the marabouts" (Diallo, 2021). The tower has metal stairs leading to the top.
308 From the summit, one can see the Pavillon René Caillé, the Tour Descennet and the Bakel
309 water tower. It is an excellent vantage point. The site is currently inhabited by two men. The
310 tower is built on the quartzite hills of the MBa3 formation of the Bakel Group.

311 The highest score for this geosites is its aesthetic value (0.88), followed by its scientific value
312 (0.75). The high aesthetic value stems from the site's open layout, its visibility from afar, and
313 its expansive size. The high scientific value is linked to its international recognition and its
314 visibility within the landscape, possessing exceptional, though not unique, characteristics
315 within the reference area. Ecologically, the site exhibits very low biodiversity and receives no
316 protection. Furthermore, the site generates no revenue.



317
318 **Fig.6** : Tour Brue in deterioration

319 **4.4. Tour Descennet or Tour du Mont aux Singes (Fig. 7).**

320 It is perched on a hill south of the city (in "Montagne Centrale" district). It was built to control
321 the passes leading to Boundou and Kounghany in order to defend against attacks from these
322 areas. Upon reaching the tower, one can see the Cimetière Militaire des Français on the plain
323 (Cissokho, 2017). A camp is noted near this tower. It is also built on a quartzite hill of the
324 MBa3 formation of the Bakel Group.

325 The scores are the same as for the Tour Brue.

326 **4.5. Geosites with a score of 0.50 or less (Fig. 8).**

327 In descending order, we have:

328 **4.5.1. Cimetière militaire des Français (French military Cemetery, Fig. 8A).**

329 It is located not far from Fort Faidherbe. It contains the remains of French nationals who
330 succumbed to war or malaria.



331
332 **Fig.7 :** Tour Descennet or Tour du Mont aux Singes perched on "Montagne Centrale".

333 **4.5.2. Tour télégraphique** (Telegraph Tower, Fig. 8B).

334 The Jauris Tower, or telegraph tower, is located west of Fort Faidherbe. Its ruins can currently
335 be seen in the area known as "Central Mountain" (Cissokho, 2018). It served as a
336 communication relay point for the colonial administration.

337 **4.5.3. Cimetière des circoncis** (Cemetery of the Circumcised, Fig. 8C).

338 This is a space where circumcised boys who had died after sucking on tamarind fruit, a
339 forbidden act, were buried. Subsequently, it became a gathering place for boys about to be
340 circumcised. It is an important place for young men of the local ethnic groups before their
341 circumcision, which constitutes an essential step in their passage to adulthood (Interview with
342 Mr. Abdoulaye Diallo, Curator of Bakel's heritage). It is located in a plain at the foot of a
343 quartzite hill of the MBa3 Formation of the Bakel Group. Today, the cemetery has become a
344 garbage dump; the waste is even burned there.

345 **4.5.4. Grimpalé or Sacred Hill of Ngoundéiny Guidimpalé**(Fig. 8D).

346 It is a historical and cultural site located in the present-day in Darou Salam district. It offers a
347 panoramic view of the entire river. From there, one can see the René Caillé Pavilion, the
348 Descennet Tower, and the SDE water tower. People live in the immediate vicinity of the site,
349 with all the associated risks of rockfalls. It is listed among the historical monuments and sites
350 of the Tambacounda region. It is currently being used as a garbage dump.



351
 352 **Fig. 8:** Geosites with a score of 0.50 or less: A: Overview of the Cimetière militaire des
 353 Français (French Military Cemetery); B: Tour Télégraphique (Telegraph Tower); C: Cimetière
 354 des Circoncis (Cemetery of the Circumcised); D: Grimpalé; E: Grand Marigot de Bakel
 355 (Large Bakel marsh).

356 **4.5.5. Grand Marigot de Bakel** (Large Bakel marsh, Fig. 8E).

357 It is a temporary pond occupying a clay depression. During periods of high water on the
 358 Senegal River, it acts as a retention basin, posing a risk of drowning. Pollution is severe,
 359 increasing the risk of contracting diseases. During the rainy season, it shelters aquatic and
 360 semi-aquatic fauna typical of humid Sahelian environments. Market gardening activities are
 361 practiced all around it.

362 As with the previous geosites, the highest score for this geosite is its aesthetic value, which
 363 exceeds 0.50 everywhere, followed by their scientific value. Economically, the site also
 364 generates no income.

365 **5. Discussion**

366 The geosites identified in the municipality of Bakel are not very diverse. Only two types were
367 found: anthropogenic (8 geosites) and hydrological (1 geosite). Since the objective of this
368 work was to inventory and conduct a qualitative and quantitative assessment of the geosites in
369 the department, we used the methodology proposed by Brilha (2016). Our approach could not
370 be the same as that of the RNDC (Youm et al., 2018), the Lake Rose (Youm et al., 2022), or
371 the Bamboung Community Marine Protected Area (Gueye et al., 2023), which primarily
372 focused on a single geosite. As Sallam et al. (2018) did on the Fayoum oasis in the Western
373 Desert of Egypt, and Marescotti et al. (2022) in the UNESCO Global Geopark of Beigua
374 (Liguria, Italy), we carried out a quantitative and qualitative assessment of the most
375 representative sites (having a score exceeding 0.50). This allowed us to select four geosites,
376 all anthropogenic (historical) and all listed as historical monuments of Senegal. They are
377 distinguished primarily by their aesthetic and scientific value, followed by their cultural and
378 ecological value. The only hydrological geosite identified is the Grand Marigot de Bakel
379 (Bakel's Great Marsh); its low score (0.36) is dominated by its aesthetic value, followed by its
380 scientific value.

381 The highest average scores obtained for aesthetic and scientific values across all the studied
382 geosites indicate remarkable natural and geological richness, undeniable scenic beauty, and
383 proven educational value. Conversely, only the Fort de Bakel geosite exhibits low economic
384 value (0.25); all the others have none. This low, or even nonexistent revenue is primarily due
385 to the underdevelopment of tourism activities, linked to insufficient and poor-quality tourist
386 infrastructure. Added to this are the inadequacy and poor quality of transportation routes.
387 Indeed, in the past, navigation on the Senegal River flourished between Saint-Louis in
388 Senegal and Kayes in Mali, over a distance of 948 km. Unfortunately, the severe drought of
389 1973-1975, along with a lack of dredging, hampered this development, and today only the
390 "Bou El Mogdad" ferry provides regular service, transporting tourists from Saint-Louis to
391 Podor. This disruption of river transport was followed by a slowdown and then a stoppage of
392 the Dakar-Bamako railway line, which crossed the Bakel department.

393 This rich historical, cultural, geological, and hydrological heritage deserves to be preserved,
394 promoted, and made economically viable. The solution involves several approaches:

395 (i) Opening up the city through the rehabilitation of the waterway. The SOGENAV (Société
396 de Gestion et d'Exploitation de la Navigation - Navigation Management and Operations
397 Company) of the OMVS (Organisation pour la Mise en Valeur du fleuve Sénégal - Senegal
398 River Basin Development Organization) launched a call for tenders in September 2025 for
399 dredging and improvement works of the navigable channel of the Senegal River from Saint-
400 Louis (Senegal), to Ambidédi (Mali). The work is scheduled to take 30 months;

401 (ii) Preserving the Falémé River environment, threatened by pollution from upstream mining
402 and by flooding; this requires a cooperative and cross-border approach;

403 (iii) Promoting the rich and diverse geological heritage by emphasizing the close relationship
404 between geology and human history. Examples include historical sites built on geological
405 formations and using subsoil rocks as construction materials. This will allow for the creation
406 of detailed geotourism and road maps and make this heritage more visible;

407 (iv) Modernizing and strengthening tourist accommodations. Only six accommodations are
408 listed in Bakel, three of which are generally the preferred choice for visitors: the Hotel Islam,
409 the Djikké camp, and the guest rooms of the SAED and CFPE delegations;

410 (v) Rehabilitating and protecting historical monuments. Although four sites in Bakel are listed
411 as historical monuments of Senegal, only the Bakel fort is functional because it houses the
412 prefecture. The others are in a state of advanced disrepair and have sometimes become
413 garbage dumps. The local community bears a heavy responsibility in this management.

414 The preservation and enhancement of this natural and cultural wealth will allow the erection
415 of several geosites in this city, the first step towards the establishment of geoparks.

416

417 **Conclusion**

418 In the municipality of Bakel, we identified nine geosites, eight of which are anthropogenic
419 and one hydrological. For each geosite, we conducted an evaluation based on the criteria
420 established by the authors for the creation of geosites. These criteria are based on scientific,
421 cultural, ecological, aesthetic, and economic values. For each geosite, we performed a
422 quantitative and qualitative evaluation of the most representative ones (those with a score
423 exceeding 0.50). The highest average scores were obtained for aesthetic and scientific values
424 across all the geosites studied. This indicates remarkable natural and geological richness, as
425 well as undeniable scenic beauty and proven educational value. In contrast, only the Fort de
426 Bakel exhibits economic value, and even then, it is very low. The low revenue is mainly due
427 to the underdevelopment of tourism activities related to the inadequacy and poor quality of
428 tourist infrastructures, as well as the inadequacy and poor quality of transportation routes.

429 The enhancement and protection of this rich historical, cultural, geological, and hydrological
430 heritage must involve all stakeholders, both state and community. This requires opening up
431 the area by rehabilitating the railway and river routes; restoring and protecting historical
432 monuments; adopting a cooperative and cross-border approach to protect the Falémé River
433 environment from mining-related pollution; promoting the rich and diverse geological
434 heritage; and strengthening and modernizing tourist facilities. These efforts will enable the
435 city of Bakel to become an attraction that could potentially become a future geopark.

436

437 **CRedit authorship contribution statement**

438 **SOW Ibrahima Sory:** Conceptualization, Data curation, Formal analysis, Investigation,
439 Methodology, Writing - original draft, and Writing - review & editing. **YOUM Cheikh**
440 **Ibrahima:** Conceptualization, Data curation, Formal analysis, Investigation,
441 Methodology, Writing - original draft, and Writing - review & editing. **SAMBOU Bernard**
442 **Siguendibo:** Writing - review & editing. **GUEYE Adama:** Formal analysis, Writing - review
443 & editing. **Dione Mamadou:** Data curation, Software, **SOW El Hadji:** Supervision,
444 Validation, Writing - original draft, and Writing - review & editing.

445 **Declaration of Competing Interest.**

446 The authors declare to the Quaternary International that they have no direct or indirect
447 financial or non-financial interests related to the work submitted for publication.

448 **Funding.**

449 The authors received no funds, grants, or other support for the preparation of this
450 manuscript.

451 **Ethical Compliance.**

452 This article does not contain any studies involving human participants or animals
453 conducted by any of the authors.

454 **Acknowledgments.**

455 The authors express their gratitude to Mr. Abdoulaye Diallo, Curator of Bakel Heritage,
456 for the interview he kindly granted us and for his on-site support. We also thank
457 Géopatrimoine Sénégal et service (GPSCS) for their constructive feedback on previous
458 versions of this work.

459 **Data Availability.**

460 All data used to perform this analysis are available in the manuscript and were acquired
461 by the respective authors.

462 **Declaration on the Use of Generative AI.**

463 All geological, paleobiological, and cultural data presented derive from fieldwork,
464 validated bibliographic references, and the authors' critical analysis. The authors assume full
465 responsibility for the content, accuracy, and interpretation of the data.

466

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