

Litho-Stratigraphic Refinement of the Precambrian Rocks in the Kampti-Loropeni Greenstone Belt, South-West Burkina Faso (West African Craton)

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Abstract

The Kampti-Loropeni greenstone belt (KLB) in south-west Burkina Faso forms part of the paleoproterozoic Baoulé-Mossi domain of the West African Craton. Its lithostratigraphic chronology and magmatic sources remain insufficiently constrained. This study integrates field observations, petrography, whole-rock and trace element geochemistry, whole-rock Sm-Nd isotopes and zircon U-Pb geochronology to refine the timing and petrogenesis of the KLB suite. The KLB records a bimodal magmatic succession that comprises tholeiitic basaltic rocks in the lower sequence and subordinate cal-alkaline andesite rocks together with tonalitic to potassic granitoids. The tholeiitic rocks display broadly flat REE patterns comparable to N-MORB like island arc composition, with slight negative ϵNd values at 2.2 Ga (-1.2 to -0.22) indicating a primary magma source from or in interaction with an older reworked crust or previously differentiated mantle component. Their whole-rock Sm-Nd isochron age of 2264 ± 0.1 Ma provides a timeline for the lower volcanic sequence, whereas depleted-mantle ages of 3.86 to 3.22 Ga indicate an older source history. Zircon U-Pb analyses date the crystallization of a muscovite granite at 2161 ± 2.4 Ma and a monzodiorite at 2120 ± 1.8 Ma, defining at least two generations of paleoproterozoic plutonism. These results support a multistage evolutionary model involving early tholeiitic volcanism followed by calc-alkaline plutonism consistent with subduction-related arc magmatism, mantle metasomatism and crustal assimilation during the eburnean evolution of the

southern West Africa Craton.

Keywords

Kampti-Loropeni Greenstone, Sm-Nd Isotopes, U-Pb Zircon, West African Craton, Magmatic Arc

1. Introduction

The rocks within the Precambrian greenstone belts of the southern West African Craton (sWAC) were emplaced over a time span ranging from 3.6 to 1.09 Ga ago, as documented by various studies [1]-[4], with recent investigations refining the chronological framework of crustal growth [5]-[7]. The geological records reveal the presence of Archean Leo-nuclei dating from 3.6 to 2.6 Ga at the western contact of a paleoproterozoic shield spanning 2.3 to 1.9 Ga of the Baoulé-Mossi domain (**Figure 1(a)**). This shield manifests as linear to curvilinear greenstone belts interspersed with Tonalite-Trondhjemite-Granodiorite (TTG) intruded by multiple generations of granitoid bodies [8]-[10]. Geochemical and isotopic analysis of the Baoulé-Mossi domain's source materials indicates a juvenile crust dating back to 2.3 - 1.09 Ga [11]-[13], with complementary zircon U-Pb and Lu-Hf studies revealing heterogeneous mantle sources and crustal components during crustal accretion. Although geochronological data in southwest Burkina Faso are limited, findings from the Houndé and Boromo belts suggest that tholeiitic units at the base of the volcanic pile date back to 2176 ± 4 Ma (zircon Pb-Pb). Additionally, Tarkwaian-type detrital sediment intercalations are dated to 2170 - 2131 Ma [11] [14]. The intrusive suites exhibiting varying chemistries within the thick volcanic pile have geochronological relationships that are currently poorly dated. This paper aims to enhance confidence in the timing of the lithostratigraphic sequence of the KLB through U-Pb and Sm-Nd isotope studies and discuss their source.

2. Geological Setting

2.1. Regional Background

The Precambrian rocks located to the south of the sWAC comprise both an Archean-age nucleus and paleoproterozoic-age volcano-sedimentary bands within the Baoulé-Mossi domain (**Figure 1(a)**). The present structural architecture of these rocks results from the interplay of tectonics: Leonean (3.3 - 3.2 Ga) and Liberian (2.9 - 2.7 Ga) tectonics in the nucleus and Eburnean orogeny in the Baoulé-Mossi domain. This geological activity led to folding, faulting, and partial melting. Subsequent Eburnean tectonics at 2.1 Ga resulted in the recycling and remobilization of ancient Archean rocks, coupled with the generation of juvenile paleoproterozoic magma [15]-[18]. In Burkina Faso, the paleoproterozoic rocks represent 80% of the surface (**Figure 1(b)**), are structured into NNE-trending greenstone belts of volcanic flows and epiclastic rocks [19]. These belts span in age from

2.25 to 1.9 Ga [1], with the pinnacle of volcanic activity estimated between 2.2 and 2.16 Ga [20] [21]. Sediments within the intrabelt region have been dated from 2170 Ma to 2107 Ma [11] [14].

The paleoproterozoic basement underwent NW-SE-oriented crustal shortening between 2150 and 2095 Ma, coinciding with voluminous felsic intrusions [9] [10] [22]. As a result, two major NNE-oriented crustal faults and other minor plurikilometric offsets in the NE direction were established to accommodate the overall shortening [23] (Figure 1(b)).

2.2. Local Geology

Within the study area, the KLB manifests as a narrow belt confined to the southeastern limits of the Houndé volcano-sedimentary trend. The lower sequence consists of basaltic lavas, projections and gabbros of tholeiitic composition at the base, transitioning to an intermediate suite to minor rhyodacite at the top. All are intersected by diorite and granite plutons. Mafic lavas are prominently exposed as mountain ridges in the northern half of the Kampti district (Figure 1(c)). In contrast, andesite pyroclastic products rich in plagioclase megacrysts dominate the southern area [14] [24]. The KLB is flanked by the high-strain Boni fault [25] [26], serving as a domain boundary between the Tarkwaian detritic sediments [26] and the volcanogenic sediment-dominated Bambela basin (Figure 2).

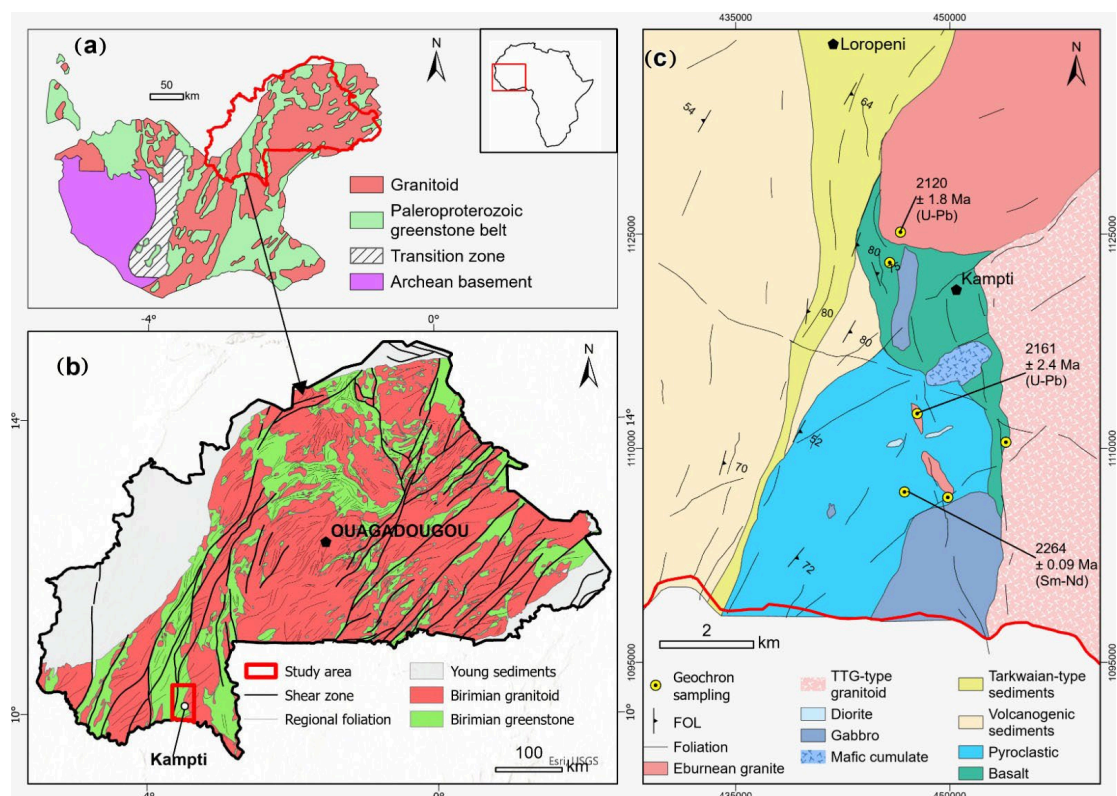


Figure 1. (a) Simplified geological map of the sWAC [1]; (b) Simplified geology of Burkina Faso outlining main lithologies and tectonic features [9]; and (c) Geological overview of the KLB.

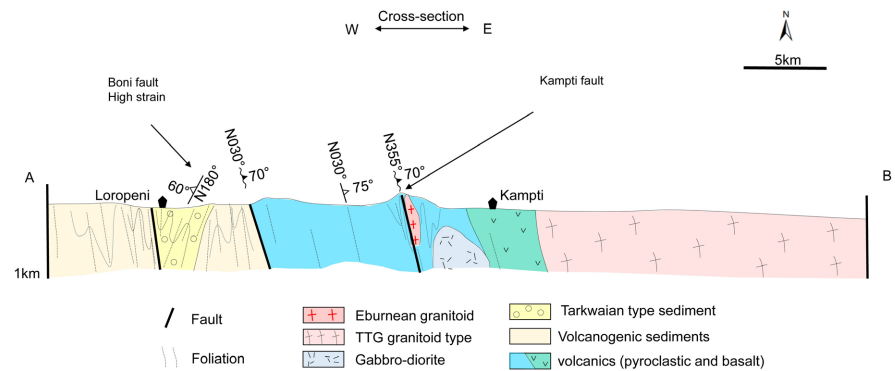


Figure 2. Geological cross-section of the KLB showing the main lithological units and their relationship to faults.

3. Methodology

3.1. Sampling

Petrographic examinations were carried out on systematically collected fresh volcanic materials, including flows and projections, as well as granite facies, with the aim of studying their composition. Major and trace elements were measured by ICP-AES/MS. Sm-Nd and Rb-Sr isotope analyses were performed on total-rock powders. The whole-rock geochemistry (seven samples) was performed at the AcmeLabs facility in Canada, and Sm-Nd isotopes (four samples) at the Geological Sciences Laboratory of the University of Cape Town, Rondebosch (South Africa). Laser ablation techniques were employed to obtain U-Pb isotopes from zircon samples originating from two granite plutons at the Earthlab laboratory of the University of the Witwatersrand (South Africa).

3.2. Analytical Procedure

The whole-rock Sm-Nd protocol follows the procedure by [27], which involved dissolving rock powder in concentrated HF + HNO₃ within closed Teflon beakers at 140°C for 48 hours. Sequential separation and purification of Nd were achieved using a cation-exchange column, conditioned and eluted with dilute HCl to minimize fractionation effects. Isotope ratio analyses were conducted using a Nu Instruments HR multicollector ICP-MS (equipped with a DSN-100 desolvating nebulizer) in the MC-ICP-MS facility, ensuring high-precision measurements of Nd isotopic ratios. Reproducibility of Nd standards JNdi-1 returned a mean ¹⁴³Nd/¹⁴⁴Nd ratio of 0.512115. Normalisation of Nd isotope values to a value of 0.512115 (JNdi-1) followed the method described by [28], with corrections for Sm interference using the measured signal of ¹⁴⁷Sm and natural Sm. Instrumental mass fractionation was corrected using the exponential law and a ¹⁴⁶Nd/¹⁴⁴Nd ratio of 0.7219. For zircon separation, standard procedures involved crushing and pulverising rocks, followed by sieving at <300 µm. Zircons were then separated, mounted in epoxy, and examined using backscatter imaging and cathodoluminescence to identify suitable locations for laser ablation. U-Th-Pb isotopic data acquisition employed a 193 nm resolution ArF excimer system coupled to an ICP-MS. Measurements

were conducted in low-resolution and electrostatic scanning modes, with single-point analysis using a laser repetition rate of 8 Hz and a fluence of 2.5 J cm^{-2} . Laser sampling occurred in a dual-volume ablation cell, with a mixed helium-argon atmosphere and a small volume of nitrogen to enhance signal stability and sensitivity. Calibration utilized zircon GJ1, and certified reference materials (CRMs) like zircon Temora-2 and Plešovice served as unknowns for evaluating measurement accuracy and precision.

Common Pb corrections are applied using the difference between measured and expected $^{207}\text{Pb}/^{235}\text{U}$ and $^{206}\text{Pb}/^{238}\text{U}$ ratios. The corrected ratios were plotted on Wetherill Concordia diagrams [29], allowing the effects of common Pb, radiogenic Pb loss, inheritance, and mixing of zircon domains of different ages to be assessed. For the calculation of crystallization ages, analyses with less than 85% concordance were excluded. Discordant analyses defining a linear trend were evaluated using a Discordia line. Its intersections with the Concordia curve can constrain the crystallization age and the age of a subsequent Pb-loss event or reopening of the isotopic system [29]. Concordia ages were calculated from the retained analyses by combining the two U-Pb systems and accounting for analytical uncertainties. The results are reported with their uncertainties, the number of analyses, the MSWD, and the associated probability. An MSWD below five was considered indicative of an acceptable fit, provided that the result was consistent with the petrographic and geological observations [30].

4. Results

4.1. Petrography of the Kampti Belt

The predominant geological feature in the study area is the volcanic sequence, characterized by green to greyish basaltic lava flows and andesitic projections exhibiting common pseudo-pillow textures (**Figure 3(a)**). The microlitic, glomeroporphyric, and microporphyric textures consist of spherules of actinote and green hornblende. Feldspar microlites, often zoned, display anorthoclase cores rimmed by albite. The feldspars predominantly form a cloudy mass, undergoing metasomatic kaolinization. Porphyritic and vesicular andesite flows are commonly associated with volcanoclastic rocks. The micro-phenocrysts, poorly preserved phenocrysts, and microlitic matrix exhibit zoned plagioclase that has recrystallized to aggregates of secondary epidote, chlorite, carbonate, and quartz. Vacuoles are filled with aggregates of those secondary minerals. The volcanoclastic rocks mainly consist of pyroclastic units with abundant plagioclase and hornblende as lithic fragments and/or minerals embedded in a matrix of andesitic composition (**Figure 3(b)**).

The KLB has a suite of intrusive bodies, notably elliptic plutons and granitoids. Elliptic plutons like Yelonhira and Galgouli are characterized as mafic to ultramafic cumulate complexes [31] and are distinguished by their high magnetic susceptibility, setting them apart from other intrusive bodies in the region. In contrast, the Eburnean granitoid such as the monzodiorite, amphibole and mica-rich

granite are NW elongated boudinaged plutons. It is grey to pinkish due to the abundance of coarse k-feldspar (**Figure 3(c)**). The heterogranular texture contains flakes of muscovite minerals (**Figure 3(d)**), and the main minerals include zoned plagioclase, k-feldspar, perthitic microcline, interstitial quartz, muscovite (derived from ancient biotite associated with chlorite), and accessory minerals such as sericite, epidote, and ilmenite.

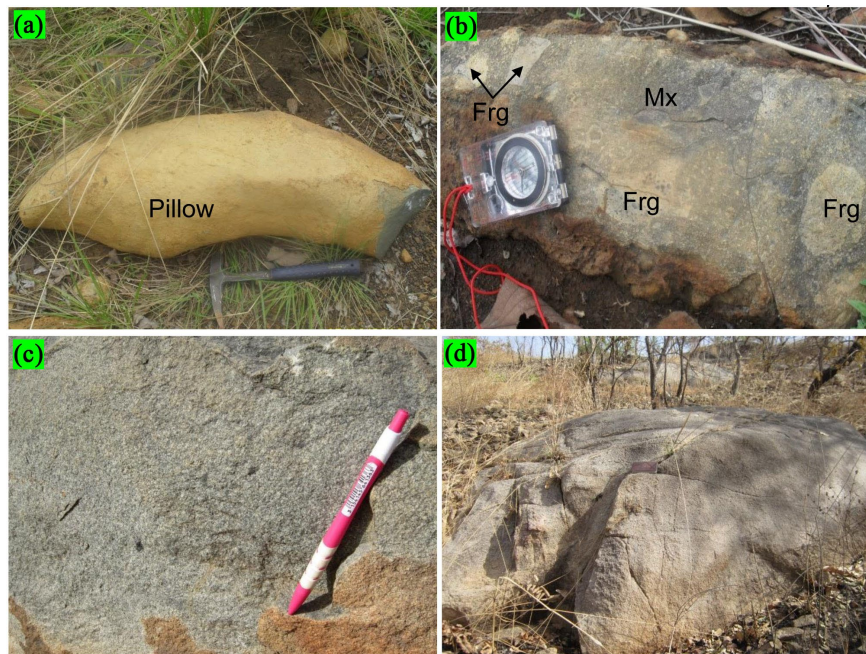


Figure 3. (a) Exposed pillowed basalt showing the internal structure; (b) Volcanoclastic breccia; (c) Outcrop of monzodiorite; and (d) Coarse-grained muscovite granite.

4.2. Geochemistry and Isotopic Studies

The whole-rock geochemistry of the most represented formations discussed in the text is presented in **Table 1**. The KLB rocks expressed a bimodal character (**Figure 4(a)**). The volcanic rocks predominantly manifest as tholeiitic basalts ($Mg\# = 40.5 - 45.2$), with rare magnesian basalts ($Mg\# = 64.2 - 72.8$), and a subordinate calc-alkaline andesite ($Mg\# = 35.2$) suite (**Figure 4(b)**). The tholeiitic volcanics exhibit a significant variation in multi-elements, marked by negative anomalies in P, Ti, and V, alongside positive anomalies in Ni and Cr. These variations are attributed to the fractionation of titanium minerals, spinel, pyroxene, and amphibole. The rare-earth profiles of these rocks exhibit broadly flat characteristics (**Figure 4(d)**), indicative of N-MORB island arc features ($\Sigma TR = 17.6 - 54.55$ ppm and $(La/Yb)_N = 1.5$). Within the KLB, the granitoids (**Figure 4(c)**) include tonalite and various types of potassic granite characterized by diverse compositions (metaluminous and peraluminous granite ($A/CNK = 0.95 - 1.03$) to hyperaluminous granite ($A/CNK = 1.16 - 1.45$)) derived from both igneous and sedimentary sources. These granitoids also exhibit anomalies in specific elements such as Nb, P, Ti, Sr, and Zr, influenced by the fractionation of specific minerals like leucosene, apatite,

and feldspar (Eu/Eu^* : 0.92 - 1.1) (**Figure 4(d)**).

The tholeiitic volcanic rocks span 0.51218 to 0.51253 for $^{143}\text{Nd}/^{144}\text{Nd}$ and 0.16813 to 0.19481 for $^{147}\text{Sm}/^{144}\text{Nd}$ (**Table 2**). These closely clustered isotope ratio values potentially indicate a cogenetic source for these rocks. At 2.2 Ga, the $\epsilon\text{Nd}(t)$ values range from -1.20 to -0.22 , indicating that all analysed samples were slightly less radiogenic than contemporaneous CHUR. This signature is consistent with derivation from, or interaction with, older continental crust and/or a previously differentiated mantle component. Two samples have $\epsilon\text{Nd}(t)$ values close to zero, suggesting compositions broadly similar to the CHUR reference at the time of magmatic crystallization. NK272 has the most negative value ($\epsilon\text{Nd}(t) = -1.20$) and, together with its clastic texture, records the most evolved isotopic signature in the dataset. Negative $\epsilon\text{Nd}(t)$ values are uncommon in the Precambrian rocks of the eastern side of sWAC, with exceptions such as the Dabakala tonalite in Côte d'Ivoire, displaying an $\epsilon\text{Nd}(t)$ value of -2.9 [4], and the Winneba pluton in Ghana, with an ϵNd (2.173 Ga) value of -5.3 [32].

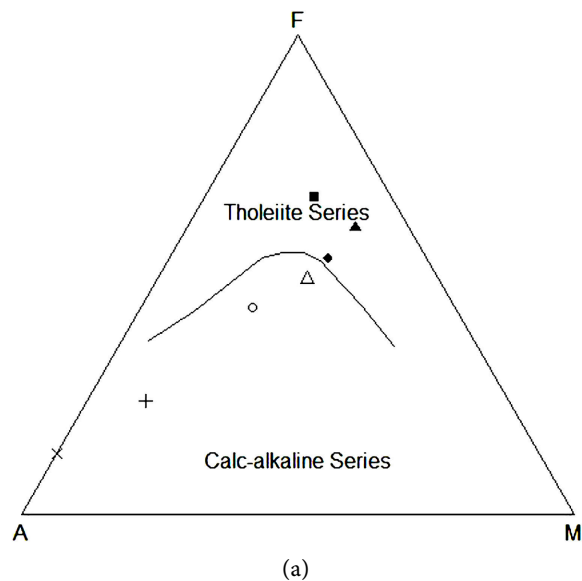
The TDM model ages are consistently older than the corresponding TCHUR ages (**Table 2**). They range from 3.22 to 3.86 Ga and represent approximate model ages for extraction of the crustal source from a depleted-mantle reservoir. Because these are model ages, they should be interpreted as estimates of source residence or extraction rather than direct crystallization ages. Nevertheless, all three TDM values predate the 2264 ± 0.1 Ma Sm-Nd isochron age, indicating that the source material was extracted from the mantle well before the magmatic event recorded by the volcanic rocks. The 2264 ± 0.1 Ma Sm-Nd isochron obtained from the selected tholeiitic volcanic rocks (**Figure 5**) therefore dates the isotopic closure or emplacement-related event of the analysed suite, whereas the older TDM ages indicate an inherited source history. Taken together with the slightly negative $\epsilon\text{Nd}(t)$ values, the data support derivation from, or assimilation of, an older and mildly evolved crustal component during emplacement of the tholeiitic volcanism.

The zircons extracted from granite samples exhibit zoning, taking on prismatic, bipyramidal, stubby, or acicular forms, and occasionally xenomorphic, with sizes ranging from 50 μm to 600 μm (**Figure 6(a)**, **Figure 6(c)**). SEM images reveal pronounced resorption pockets in certain magmatic grains, mineral inclusions, and evidence of recrystallization (**Figure 6(b)**, **Figure 6(d)**). The population of U-Pb laser data exhibiting isotopic homogeneity ($>85\%$ agreement) selected for this study comprises 35 measurements were integrated to calculate the crystallization age, as detailed in **Table 3**.

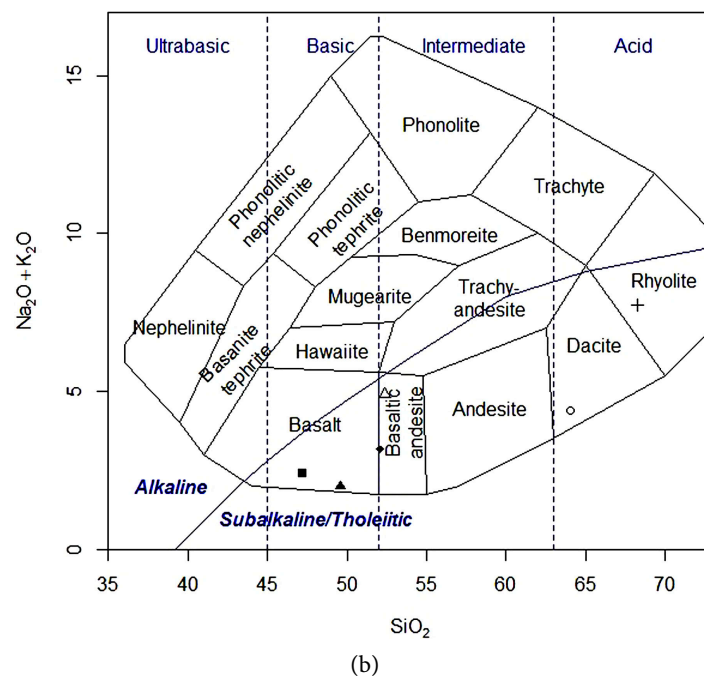
In sample NK222, laser-ablation analyses of zircon cores yielded mean ages of 2119 Ma based on the $^{207}\text{Pb}/^{235}\text{U}$ system and 2124 Ma based on the $^{206}\text{Pb}/^{238}\text{U}$ system. Analyses of the zircon rims yielded mean ages of 2114 Ma and 2104 Ma, respectively. In sample NK229, analyses of zircon cores produced mean ages of 2164 Ma ($^{207}\text{Pb}/^{235}\text{U}$) and 2169 Ma ($^{206}\text{Pb}/^{238}\text{U}$). Because concordant U-Pb ages provide the most reliable estimates of zircon crystallization, the concordant analyses were used for the geological interpretation [29].

The monzodiorite sample NK222 yielded a concordia age of 2120 ± 1.8 Ma (MSWD = 1.4; N = 25). The 5 - 20 Ma age difference between zircon cores and rims is interpreted to reflect a period of zircon overgrowth during the later stages of pluton development. The muscovite-granite sample NK229, collected from the central part of the KLB greenstone belt, yielded a concordia age of 2161 ± 2.4 Ma (Figure 7).

AFM plot (Irvine and Baragar 1971)



TAS (Cox et al. 1979)



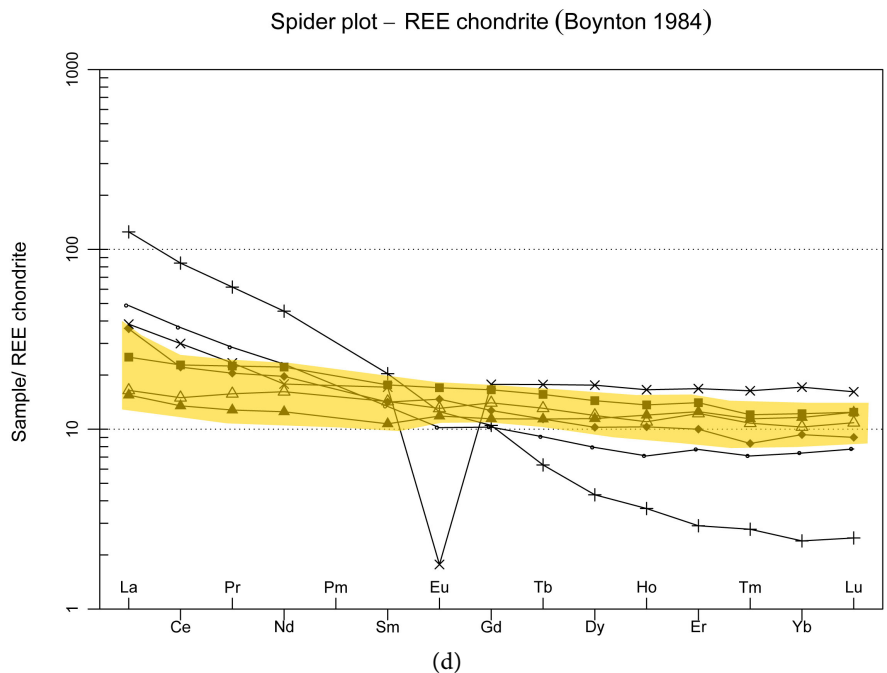
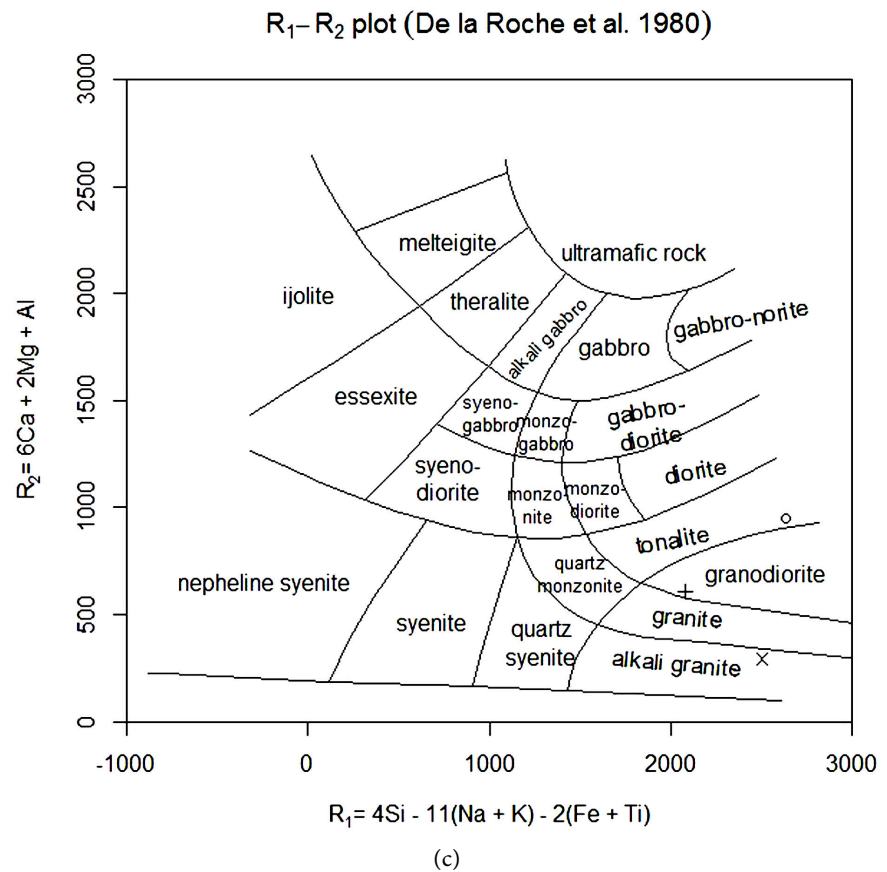


Figure 4. Classification diagrams using major and minor elements of the KLB suite. (a) AFM plot indicating the affinities of the studied rocks; (b) TAS diagram [33] discriminating volcanic rocks; (c) R_1 - R_2 diagram for plutonic rocks [34]; and (d) Chondrite-normalized REE diagram for studied rocks. The volcanic rock patterns are highlighted in orange (normalized to Boynton).

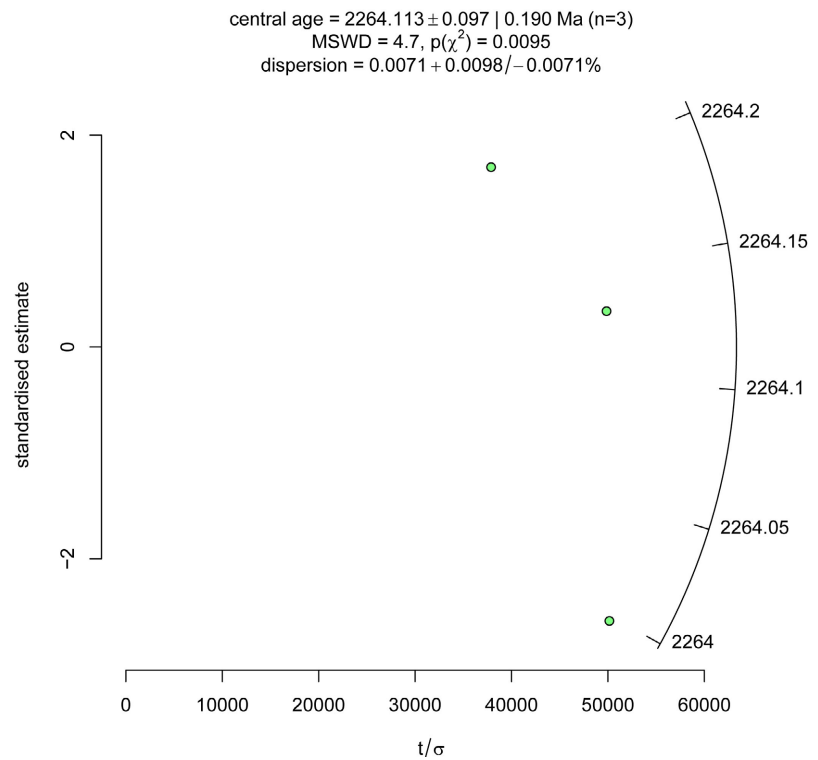


Figure 5. Mean age of the Sm-Nd isotopes of three tholeiitic KLB volcanics in the diagram [35].

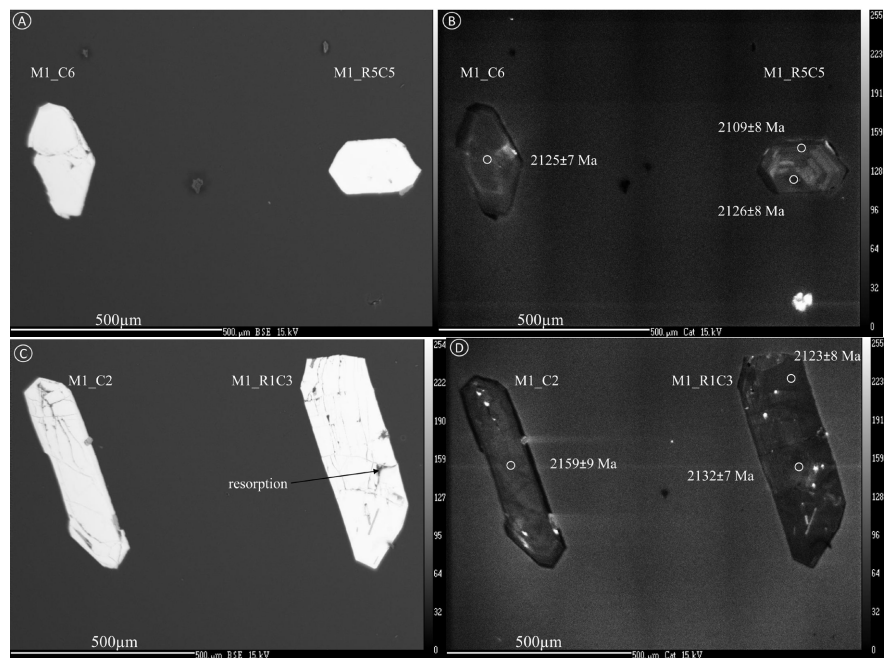


Figure 6. Zircon textures in the NK222 monzodiorite and NK229 muscovite granite plutons. (a) Bipyramidal zircon grain from NK222 with weak internal zoning and a xenocrystic core (M1C6). (b) Pyramidal NK222 zircon grain showing oscillatory zoning and a metamict core (M1R5C5). (c) Fractured, acicular to bipyramidal NK229 zircon grain with truncated zoning and a Zr-Th-enriched outer rim (M1C2). (d) Prismatic NK229 zircon grain exhibiting planar resorption surfaces (M1R1C3).

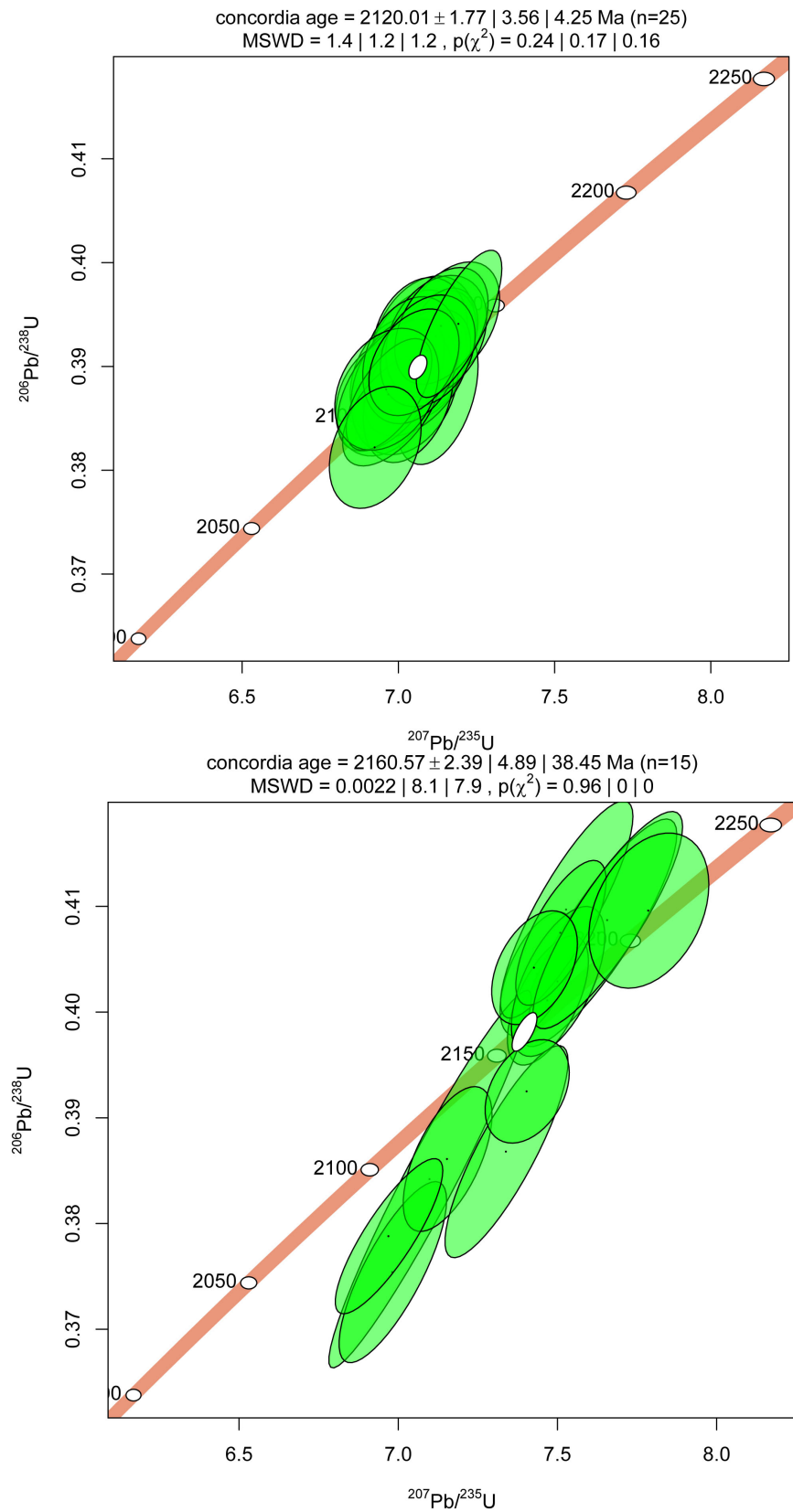


Figure 7. Wetherill diagrams showing uncorrected (common Pb) U-Pb isotope ratios of zircon and Concordia age from the tonalite and muscovite granite.

Table 1. Whole rock geochemical data of selected rocks on the KLB greenstone.

Sample	NK200	NK247	NK261	NK272	NK222	NK229	NK252
type	Basalt	Andesite porphyry	Amphibolite	Lapilli tuf	Monzodiorite	Muscovite granite	Trondhjemite
SiO ₂	52.08	52.4	49.58	47.24	68.22	75.41	64.06
Al ₂ O ₃	16.44	16.17	12.92	14.97	15.04	13.79	15.1
Fe ₂ O ₃	10.57	11.3	13.6	12.83	3.1	1.35	5.74
MgO	5.12	5.63	6.26	3.49	1.26	0.02	2.43
CaO	9.65	4.9	12.2	7.57	2.31	0.2	4.97
Na ₂ O	2.8	4.86	1.55	1.18	4.66	4.18	3.71
K ₂ O	0.36	0.05	0.43	1.23	3.08	4.27	0.69
TiO ₂	1.09	1.18	0.95	1.26	0.44	0.01	0.49
P ₂ O ₅	0.13	0.1	0.08	0.12	0.15	0.02	0.09
MnO	0.16	0.17	0.22	0.11	0.04	0.07	0.09
Cr ₂ O ₃	0.01	0.018	0.011	0.01	0.006	0.002	0.008
Ba	66	37	36	98	873	152	277
Ni	45	51	82	36	<20	<20	37
Sc	27	29	44	26	5	2	11
LOI	1.4	3	2	9.8	1.5	0.6	2.5
Total	99.8	99.82	99.78	99.84	99.85	99.96	99.88
Be	3	<1	<1	<1	<1	<1	2
Co	32.9	41.2	54.9	58.1	7.6	0.6	15.7
Cs	0.2	<0.1	0.5	0.5	1.3	1.6	0.4
Ga	16.9	10.7	14.4	18.1	21.2	18.6	15.3
Hf	2.1	2.1	1.6	2.9	4.7	3.5	3.5
Nb	3.3	3.5	3.9	4.5	6.1	12.4	5.7
Rb	10	0.3	10.7	30.2	83.8	161.9	24.2
Sn	2	<1	<1	1	1	4	<1
Sr	236.9	120.7	221.1	166.6	599.1	15	268.9
Ta	0.2	0.3	0.3	0.3	0.3	2	0.5
Th	0.4	0.3	0.4	0.6	7.8	6.3	2.3
U	<0.1	0.1	<0.1	0.2	1.9	2.6	1.6
V	242	190	277	219	41	<8	86
W	2.1	<0.5	1.8	1.9	<0.5	5.2	<0.5
Zr	79.7	75.6	56.7	105.7	185.4	60.2	121.5
Y	19.5	21.3	21	25.4	9.3	36.2	14.7
La	11.2	5.1	4.8	7.8	38.8	11.9	15.1
Ce	17.9	12.1	10.9	18.4	67.8	24.2	29.7
Pr	2.5	1.92	1.56	2.74	7.53	2.85	3.48

Continued

Nd	11.8	9.7	7.5	13.3	27.2	10.7	13.8
Sm	2.76	2.78	2.09	3.44	3.97	3.34	2.61
Eu	1.08	0.96	0.87	1.25	0.92	0.13	0.75
Gd	3.29	3.63	2.96	4.29	2.72	4.6	2.66
Tb	0.54	0.62	0.54	0.74	0.3	0.84	0.43
Dy	3.3	3.84	3.69	4.64	1.39	5.66	2.55
Ho	0.74	0.79	0.86	0.98	0.26	1.19	0.51
Er	2.1	2.57	2.63	2.95	0.61	3.53	1.62
Tm	0.27	0.35	0.37	0.39	0.09	0.53	0.23
Yb	1.95	2.15	2.43	2.55	0.5	3.58	1.54
Lu	0.29	0.35	0.4	0.4	0.08	0.52	0.25

Table 2. Whole-rock Sm-Nd isotopic data calculated from the selected volcanic suite.

Samples	NK200	NK261	NK272
Nd (ppm)	11.57	7.862	12.18
Sm (ppm)	3.219	2.45	3.663
$^{143}\text{Nd}/^{144}\text{Nd}$	0.512181	0.512502	0.512354
$\pm(2s) \times 10^{-6}$	11	14	11
$^{147}\text{Sm}/^{144}\text{Nd}$	0.16813	0.18833	0.18175
$\pm(2s) \times 10^{-5}$	4	5	5
TCHUR (Ga)	2.43	2.47	2.88
TDM (Ga)	3.22	3.86	3.76
ϵNd (t)	-0.61	-0.22	-1.20
$\pm(2s)$	0.22	0.29	0.22

Table 3. U-Pb isotope data for zircons from the KLB granitoids.

Sample	Concentration (ppm)			Isotopic ratios				Ages (Ma)			
	Pb	U	Th	$^{207}\text{Pb}/^{235}\text{U}$	$\pm 2s$	$^{206}\text{Pb}/^{238}\text{U}$	$\pm 2s$	$^{207}\text{Pb}/^{235}\text{U}$	$\pm 2s$	$^{206}\text{Pb}/^{238}\text{U}$	$\pm 2s$
NK222_c-10	593.5	75.7	60.7	7.165	0.065	0.3942	0.0024	2132.16	8.08	2142.3	11.1
NK222_c-12	570	72.2	60.6	7.036	0.058	0.3894	0.0023	2115.99	7.33	2120.0	10.7
NK222_c-15	559.3	71.4	59.81	7.046	0.060	0.3915	0.0024	2117.25	7.57	2129.8	11.1
NK222_c-2	638.7	93.9	65.5	7.123	0.054	0.3874	0.0028	2126.92	6.75	2110.8	13.0
NK222_c-3	547.2	68.5	56.2	6.995	0.061	0.3889	0.0024	2110.79	7.75	2117.7	11.1
NK222_c-5	363.3	52.2	37.52	7.082	0.067	0.3926	0.0025	2121.78	8.42	2134.9	11.6
NK222_c-6	489	67.5	50.0	7.103	0.060	0.3912	0.0025	2124.42	7.52	2128.4	11.6
NK222_c-11	384.3	61.2	40.2	7.069	0.062	0.3927	0.0024	2120.15	7.80	2135.3	11.1
NK222_c-14	399	78.4	41.27	7.085	0.055	0.3903	0.0022	2122.16	6.91	2124.2	10.2

Continued

NK222_c-15	1033	161	108.8	7.144	0.045	0.3929	0.0019	2129.54	5.61	2136.26	8.79
NK222_c-16	456.1	66.4	49.34	6.954	0.063	0.3870	0.0023	2105.57	8.04	2108.9	10.7
NK222_c-2	303	52.2	32.6	7.020	0.070	0.3881	0.0027	2113.96	8.86	2114.0	12.5
NK222_c-20	237.6	54.9	24.94	7.060	0.070	0.3894	0.0025	2119.02	8.82	2120.0	11.6
NK222_c-22	632	83.4	65.8	7.032	0.059	0.3871	0.0026	2115.48	7.46	2109.4	12.1
NK222_c-23	445.6	63.40	47.34	6.976	0.070	0.3882	0.0026	2108.38	8.91	2114.5	12.1
NK222_c-24	574	77.8	60.9	6.978	0.064	0.3858	0.0022	2108.63	8.15	2103.3	10.2
NK222_c-31	394.6	61.91	40.38	7.121	0.066	0.3929	0.0024	2126.67	8.25	2136.3	11.1
NK222_c-35	294.6	56.47	30.61	7.040	0.063	0.3906	0.0025	2116.49	7.96	2125.6	11.6
NK222_c-4	610	80.7	61.4	7.138	0.061	0.3939	0.0023	2128.80	7.61	2140.9	10.6
NK222_c-44	559	79.8	57.8	7.094	0.062	0.3915	0.0022	2123.29	7.78	2129.8	10.2
NK222_r-1	483	150	85.9	4.85	0.19	0.245	0.012	1793.6	33.0	1412.6	62.1
NK222_r-3	416.7	79.9	42.84	6.970	0.056	0.3873	0.0022	2107.61	7.13	2110.3	10.2
NK222_r-5	255.4	51.03	26.74	6.963	0.068	0.3878	0.0024	2106.72	8.67	2112.6	11.1
NK222_r-7	548.8	320	51.3	7.194	0.056	0.3941	0.0029	2135.76	6.94	2141.8	13.4
NK222_r-1	475.6	63.72	51.47	6.926	0.060	0.3822	0.0024	2101.99	7.69	2086.6	11.2
NK229_c-1	1500	233.3	141.7	7.63	0.10	0.4075	0.0044	2185	12	2202	20
NK229_c-12	1235	180.2	122.2	7.437	0.048	0.4036	0.0024	2165.0	5.8	2185	11
NK229_c-13	742	184.5	68.8	7.470	0.052	0.4011	0.0025	2168.8	6.4	2174	11
NK229_c-2	557	145.2	57.0	7.529	0.085	0.4097	0.0042	2175	10	2212	19
NK229_c-22	1287	145.9	122.7	7.502	0.060	0.4029	0.0029	2172.4	7.3	2183	13
NK229_c-23	628.1	152.7	58.74	7.511	0.058	0.4075	0.0028	2173.7	7.0	2203	13
NK229_c-3	849	142.2	92.2	7.155	0.057	0.3861	0.0028	2129.5	7.1	2104	13
NK229_c-27	1956	238.8	180.7	7.340	0.079	0.3868	0.0041	2150.9	9.9	2106	19
NK229_c-37	554.8	126.8	49.58	7.405	0.054	0.3925	0.0020	2160.3	6.6	2134.0	9.2
NK229_c-38	427	118.2	42.4	7.428	0.055	0.4042	0.0022	2163.1	6.6	2188	10

5. Discussion

5.1. Magma Source and Geodynamic Evolution

The mafic rocks exhibiting tholeiitic affinity in the KLB of various units (basalt, pyroclastic, andesite, and associated gabbro) have nearly flat rare-earth spectra ($\Sigma\text{TR} = 17.6 - 54.55$ ppm and $(\text{La}/\text{Yb})\text{N} = 1.5$), resembling N-MORB island arc signatures. Comparable birimian mafic suites show tholeiitic compositions together with LILE and LREE enrichment, HFSE depletion, and negative Nb-Ta anomalies, features widely interpreted as evidence for subduction-modified mantle and arc magmatism [18]. The $^{143}\text{Nd}/^{144}\text{Nd}$ isotope ratios of these rocks (0.51218

to 0.51250) indicate a common magmatic source, but the negative ϵNd (2.2 Ga) values (-1.2 to -0.22) show that the rocks were slightly less radiogenic than CHUR at the time of crystallization. This is consistent with the primary magma being extracted from a metasomatized mantle source during the Archean period, subsequently enriched through interaction with crustal materials, similar to modern subduction settings. This contradicts the hypothesis of a juvenile source for the sWAC magma [4] [12] [13] [19] [36] [37].

The granitoids in the belt exhibit a diverse composition, including calc-alkaline and adakitic types, with both igneous ($A/\text{CNK} = 0.95 - 1.03$) and sedimentary ($A/\text{CNK} = 1.16 - 1.45$) protoliths showing meta-aluminous to peraluminous characteristics. Normalized rare earth ratios $(\text{La}/\text{Yb})_N = 2.2 - 52.3$ combined with trace elements discrimination ($\text{Rb} < 170$ and $\text{Y} + \text{Nb} < 50$) are compatible with a volcanic-arc granite field. These data support generation from more than one parental reservoir rather than a single homogeneous magma source. Regional studies of birimian granitoids have addressed calc-alkaline I-type and TTG-like compositions, enrichment in Ba and Th, and depletion in Nb, Ta, Zr, Hf and Ti [9] [10] [12] [13].

Combined geological and geochemical features are consistent with modern subduction-related plutonism and support a model of magma generation through partial melting of the metasomatized mantle wedge, fractional crystallization and magma mixing along with crustal assimilation during ascent, similar to contemporary oceanic arc systems [18].

5.2. Geochronology of the Belt

The Sm-Nd model ages for the lower stratigraphy sequence (tholeiitic suites) yield an average age of 2264 ± 0.1 Ma ($Nd_i = 0.50967$), overlain by calc-alkaline units comprising andesite, dacite, and rhyodacite with associated plutonic rocks. This bimodal volcanism pattern, with a tholeiitic lower sequence succeeded by calc-alkaline upper stratigraphy, is well documented across birimian greenstone belts of the sWAC [38] is recognized broadly as a signature of subduction initiation during early paleoproterozoic plate tectonics and arc growth. Down south in Côte d'Ivoire, calc-alkaline rhyodacite yields 2104 ± 2 Ma, contemporaneous to the plutonic rocks [19]. [9] previously dated a rhyolite tuff from the Goren belt in the Kaya region to 2238 ± 5 Ma by Pb/Pb in zircon, which was considered the oldest age in Burkina Faso. The KLB granitoids yield two distinct ages (2161 ± 2.4 Ma and 2120 ± 1 Ma) align to the first generation of Eburnean plutonism with geochemical similarities to the calc-alkaline rocks of recent subduction zones [1] [9]. The paleoproterozoic crust of Kampti may have originated from a depleted ancient mantle that was enriched by contamination or reworking of a subducted pre-birimian crust. The second hypothesis is more plausible, as suggested by [32] and [18] on the Dabakala and Winneba terrains in Ghana. The geological, petrological, geochemical, and isotopic data support the model of arc magmatism generated in an oceanic subduction environment (Figure 8).

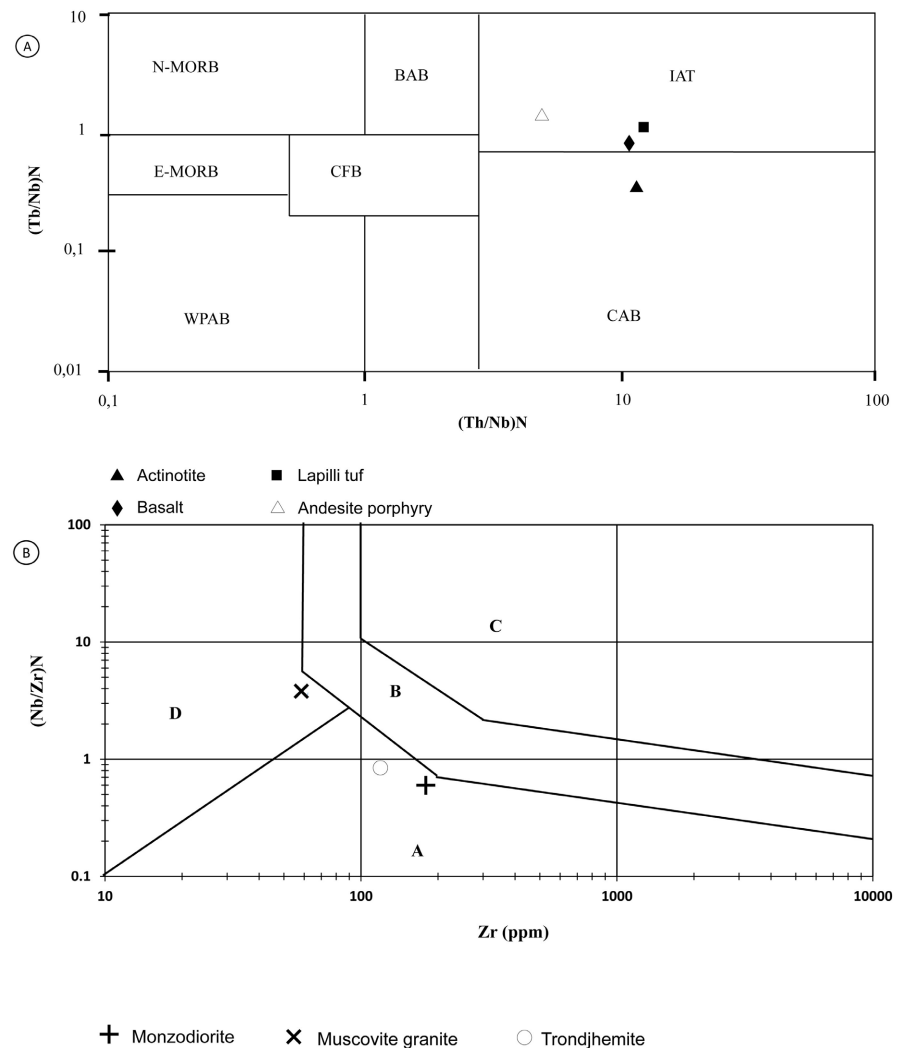


Figure 8. (a) Diagram $(Th/Nb)_N$ vs $(Tb/Nb)_N$ of characterization of geotectonic sites of volcanic rocks (modified from [39]). N-MORB—depleted type mid-oceanic ridge basalts (N-type MORB); E-MORB—enriched type mid-oceanic ridge basalt (E-type MORB); WPAB—intraplate alkaline basalts; CFB—continental tholeiite; BAB—tholeiite of back-arc basin; IAT— island arc tholeiite; CAB—calc-alkaline basalts of active margin. (b) Diagram Zr versus $(Nb/Zr)_N$ [39] [40] for the granitoids with distinction of the different geochemical groups. A—Mantle calc-alkaline magmatism (subduction zones); B—crustal calc-alkaline magmatism; C—intraplate alkaline magmatism; D—peraluminous leucogranites linked to collision zones.

6. Conclusion

The KLB displays a multi-phase magmatic evolution characterizing the early paleo-proterozoic subduction regime. The initial phase (ca. 2264 Ma) involved eruption of tholeiitic volcanism, including basaltic flows and pyroclastic deposits, along with associated mafic-ultramafic cumulate complexes at the base of the lower stratigraphy. The overlying upper sequence (2161 - 2120 Ma) is dominated by calc-alkaline plutonic rocks and subordinate andesitic volcanism, with locally preserved epiclastic and sedimentary deposits. The mafic rocks exhibit rare-earth spectra

($\Sigma\text{TR} = 17.6 - 54.55$ ppm, $(\text{La/Yb})_N = 1.5$) resembling the N-MORBs of island arcs. Contrastingly, the granitoids in the belt have a calc-alkaline composition and originate from both igneous and sedimentary sources. The isochron age of 2264 ± 0.1 Ma obtained on the tholeiitic volcanics represents one of the oldest precisely dated volcanic horizons in the birimian greenstone belts, providing a robust chronological anchor for early paleoproterozoic crustal growth. The Nd isotopic composition and model ages (3.2 - 4.9 Ga) indicate derivation from a metasomatized Archean mantle source, consistent with subduction-related enrichment. The two zircon U-Pb ages from granitic rocks [2161 ± 2.4 Ma (MSWD = 0, N = 15) and 2120 ± 1.8 Ma] define two generations of calc-alkaline plutonism during the Eburnean orogeny, correlating with documented crustal growth events throughout the Baoulé-Mossi shield and west African Craton.

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Author Contributions

Conceptualization: Mathieu Nanema and Urbain Wenmenga; methodology: Urbain Wenmenga; software: Yao Honoré Koffi; validation: Mathieu Nanema and Urbain Wenmenga; investigation: Mathieu Nanema and Wendkouni Pasedcé Pauline Zongo; resources: Mathieu. Nanem; data curation: Adama Ouédraogo Yaméogo; writing original draft preparation: Mathieu Nanema; writing—review and editing: Mathieu Nanema, Wendkouni Pasedcé Pauline Zongo and Adama Ouédraogo Yaméogo; visualization: Wendkouni Pasedcé Pauline Zongo; supervision: Urbain Wenmenga; project administration: Mathieu Nanema; funding acquisition: Mathieu Nanema and Urbain Wenmenga. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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