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U–PB DATING OF ZIRCON FROM SEGUELA GRANITE TO 2094± 2.2 MARELATED TO CRETACEOUS KIMBERLITE IN IVORY COAST (WEST AFRICA). PALEOPROTEROZOIC-AGE COMPONENTS WITHIN ARCHEAN AND BIRIMIAN OROGENESIS

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ABSTRACT

U-Pb dating of zircon from Seguela granite pluton and kimberlite in Côte d'Ivoire showedexclusivily paleo- proterozoic age components. The zircon fractions from the Seguela granite and the zircon rims from Toubabouko kimberlite gave closely similar ages corresponding to upper intercepts at 2093±1,5 Ma and 2094±2.2 Ma, respectively.This age of ca 2094 Ma, has been interpreted as a marker of the major tectonomagmatic episode in this part of the West African Craton. The new zircon ages, reflecting the magmatic and tectonothermal events in the Seguela area was highly correlated with various magmatic and metamorphic events elsewhere in West Africa. In addition, the regional metamorphism associated with the Eburnean tectono-thermal event affected the Birimian formations in the time span between 2102+1 Ma and 2092+2 Ma. The stage, ca 2094 Ma, corresponding to the emplacements of intrusions of large complexes of peraluminous granitoids and batholiths of potassic calc-alkaline granitoids in a transcurrent tectonic context, implied on the one hand, an infracrustal melting of both lower crust (metabasic rocks) and upper crust and, on the other hand, a partial melting of a crustal metaigneous protoliths heated by underplating magmas.

Keywords: U–Pb; Geochronology; Zircon ; Granite; Paleoproterozoic, Birimian; Seguela, Ivory Coast, West Africa.

Introduction

The West African Craton (Fig. 1) and its extension were recognised asa zone of crustal growth during the Palaeoproterozoic ([1]; [2]; [3]; [4]; [5]; [6] Man shield a part of this crust consists of an association sedimentary basins, plutono-volcanic belts and granitoid batholiths resembling Archaean granite–greenstone formations. [1] and [2]showed that the main Palaeoproterozoic crustal growth event, in the West African Craton, derived from the formation in which we are Archaean crustal component.

The juvenile character was confirmed by further studies ([5]; [7]), with the exception of the area close to the older Archaean Man nucleus ([8] ;[9]), where there is clear evidence of recycling of Archaean material. The available geochronological data cluster into two apparent age groups, though there seems to be no gap in the magmatic activity from 2200 to 2070 Ma (Fig. 2).

These two groups have been considered to reflect the existence of two successive periods of crust formation in 130 Ma: the Birimian sensu stricto at ca. 2185–2100 Ma, ([10];[11]; [2]; [12]; [13] ;[14]; [15]). Slightly younger ages (2090–2070 Ma) were reported for granitoids from Guinea ([16]) and Sénégal ([15]).

Seguela granite zone are intermediate within Archean granito-gneissic rocks and paleoproterozoic (Eburnean or Birimian) formations. For This granitoids transitional zone,the U-Pb isotopic datation realized by Kouamelan ([8] ;[9]) showed younger ages around (2100 Ma). The aim of this paper is to justify through U-Pb isotopic dating method the Paleoproterozoic age of Seguela granite pluton proposed by Kouamelan ([8] ;[9]).

1. Geological setting

West Africa Paleoproterozoic domain is located in the eastern part of Sassandra Fault in Ivory Coast (Fig.1). Rocks are dated between 2.2 and 2.0 Ga (e.g. [8] ;[9] ; [7]; [17]; [18]; [15[19]; [13]; [20]; [21]; [22]). Seguela diamond-bearing kimbelite field is located in the central-western part of IvoryCoast, 30 km North of Seguela city (Fig. 2). In this region diamonds are found disseminated into eluvia, colluvia and alluvia with an average of 0.3 ct; and the source for these diamonds ares considered to be the two main kimberlitic dykes of Bobi and Toubabouko. Two companies (Waston & SODEMI) have been active in mining activities in the places with higher diamond concentration in the filed from Bobi to Toubabouko. In the present days, there is no more industrial activity and only individual diggers are working in the area. The dykes, trending N170°E, crosscut the granitic plutons and amphibolites of the Palaeoproterozoic Birimian formations of the West-African Craton. The Seguela granite is dated at 2091 Ma ([23]; [24]).

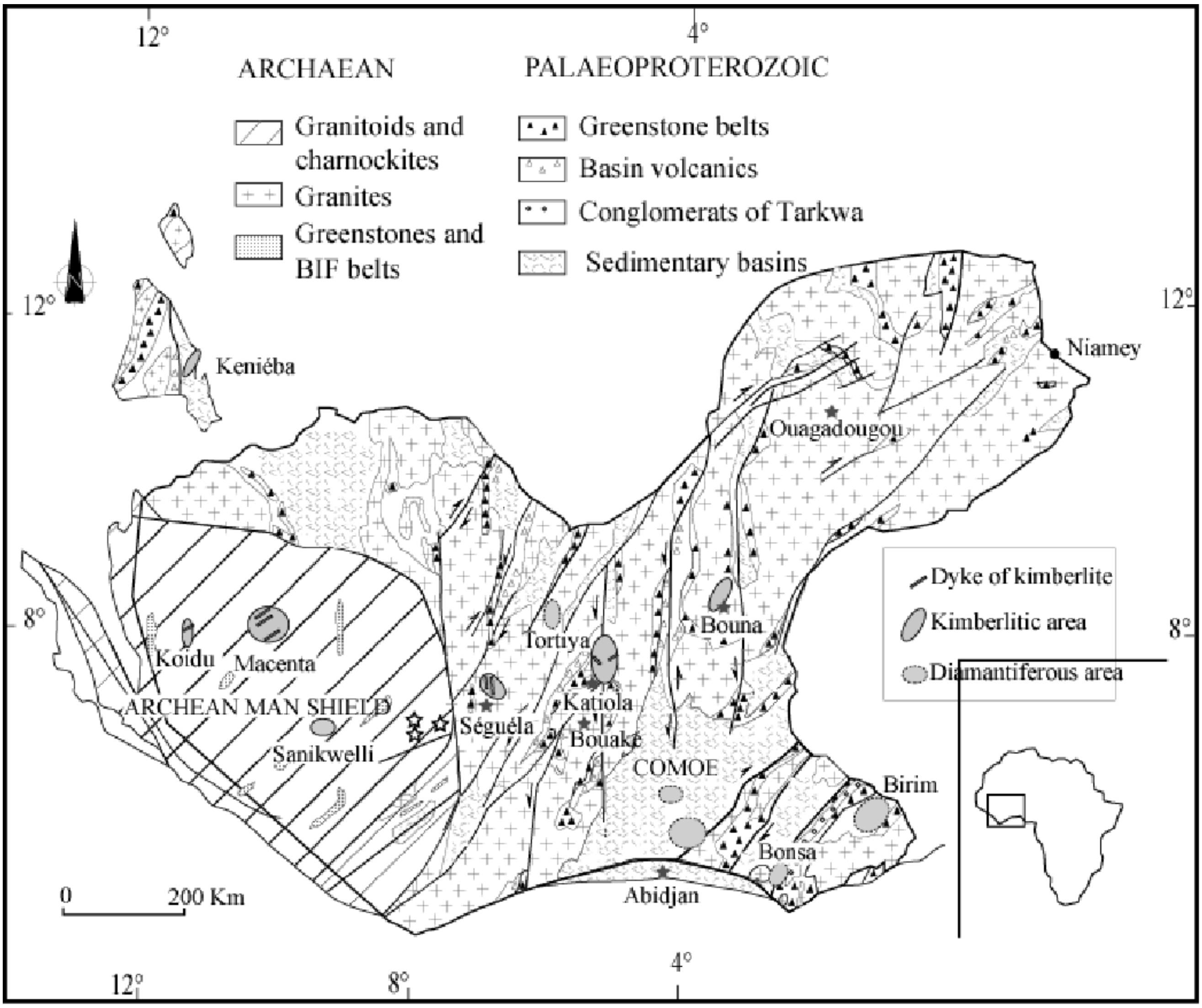

Figure 1. Simplified geological map showing tectono-stratigraphic provinces of archeans and paleoproterozoic formations of the Man Shield (West Africa craton). Modified from [11].

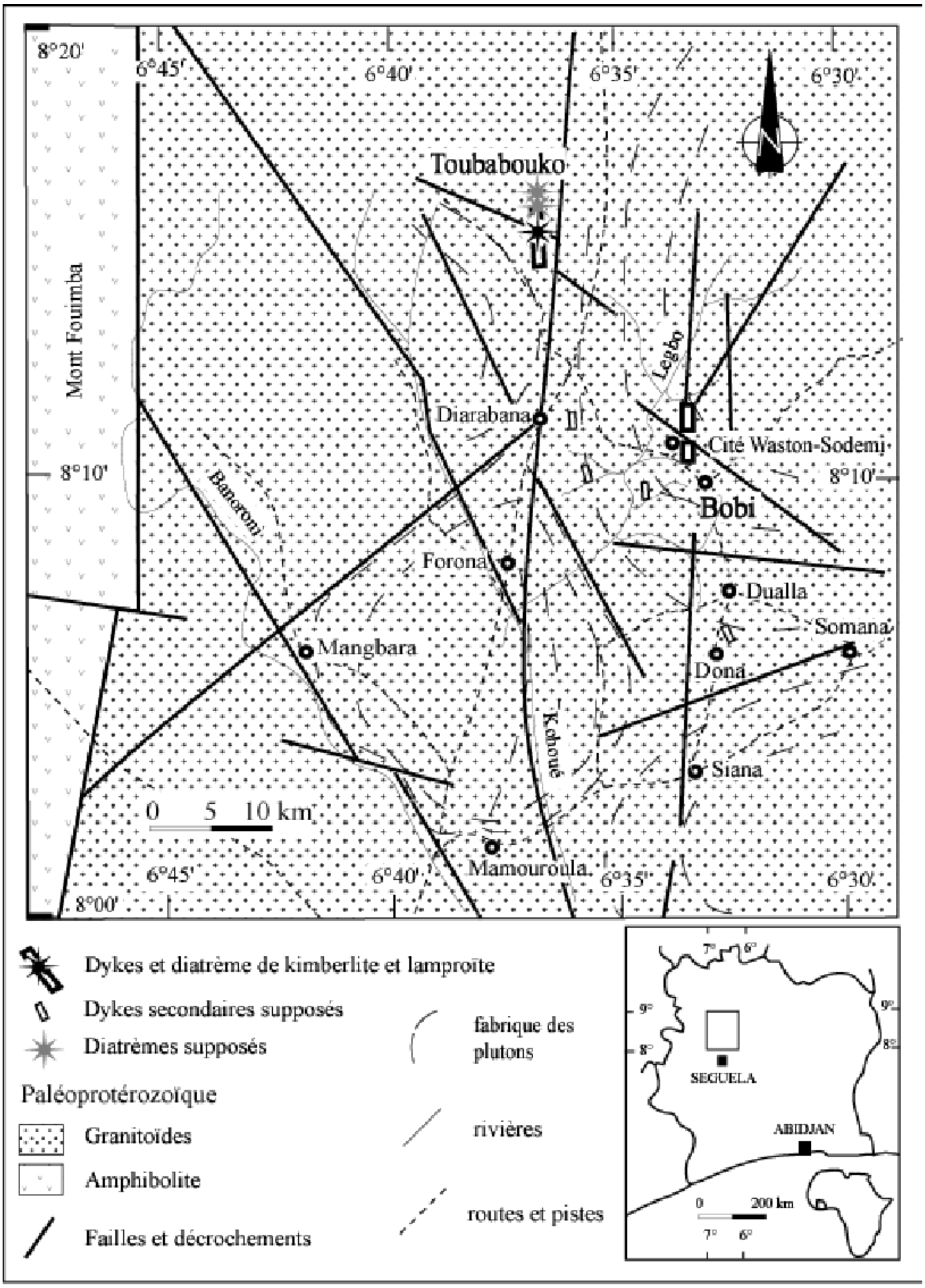

Figure 2. Geological map of Seguela area in Côte d'Ivoire [25].

2. METHODOLOGY

2.1.Major and REE elements analysis

The geochemical data were realized within the analytical laboratory of the CRPG (Nancy, France). Major oxide analyses were obtained using emission spectroscopy on ICP-AES whereas trace-element geochemistry were determined by mass spectroscopy on ICP-MS. Results for both major and trace elements are given in Table 1.

Samples were chipped and cleaned in acid before being crushed and powdered. Powders were mixed by coning several times to ensure homogeneity. 300 mg of the powdered sample were considered for determination of loss on ignition by living the samples in a muffle furnace at 1000°C for 12 hours. For preparation of glass fusion discs, sample was mixed with lithium tetraborate (LiBO3) and the mixture was heated in a furnace to 1050°C and cast in carbon dies to form the discs.

Major elements, together with V, Cr, Ni, Zn, Ga, Rb, Sr, Y, Zr, Nb, Ba, La, Ce, Pb, and Th were analysed on the prepared discs by X-Ray fluorescence (XFR) spectrometer at the Centre de Recherche Pétrographique et Géochimique de Nancy (France) using spectrometer ICP-AES Jobin Yvon JY70 for major elements (Si, Al, Fe total, Mn, Mg, Ca, Na, K, P, Ti).

2.2.U-Pb Isotopic analysis

Extraction of zircon for U–Pb analyses followed standard procedures described in [26] ; [27] and [28].). Imaging of polished zircon grains was carried out using a Nanolab 7 scanning electron microscope equipped with electron backscatter (BSE) and energy dispersive (EDS) detectors. U–Pb isotopic results are presented in Table 1 and Fig. 2 (errorsand error ellipses given at 2σ). Errors for calculated ages in the text and figures were quoted at 95% confidence levels. Zircon normally incorporates negligible amounts of common Pb when it crystallizes. Common Pb in zircon was corrected using the isotopic composition of laboratory blank (see footnotes to Table 2).

3. RESULTS

Petrological and geochemical data are presented in this part of the article. Macroscopic and microscopic mineralogy associated to major REE patterns and U-Pb isotopic data are given in the following part.

3.1.PETROLOGY

Sample MA-12 is characterized by aphanitic texture and essentially composed by felsic minerals as: quartz (30%),orthoclase (32.47%), albite (26.04%)and anorthite (6.71%). In addition Seguela granite is peraluminous silica oversaturated. Secondary minerals are biotite, zircon, magnetite and ilmenite.

3.2. GEOCHEMISTRY

3.2.1. Major and REE elementsgeo chemistry

Seguela granite is represented by sample MA-12. Granite MA-12 is more silicious (75%) than potasic ratio (K_2O/Na_2O = 1.79). Granite normalized patterns are enriched in LILE relative to HFSE and show weak negative Nb-Ta anomalies (La_n/Yb_n= 218.29). Th/Yb(43.29) and Ta/Yb (0.64)ratios show contiental active margine signature. In addition Rb(165 ppm) , Th(14ppm) and Hf(5.38 ppm) contents show Archean and volcanic arc signature (Table 1).

3.2.2. Geochronological and U-Pb iotopic data

The results of the isotope measurements are given in Table 2 and plotted in Fig.5 and Fig.6. The errors in Table 2 are quoted at 1 σ. The age errors are quoted at the 99% confidence level. Error ellipses in the figures are given at the 2 σ level.

3.2.2.1. Zircons fractions from Seguela granite (First generation)

First generation is characterized by 4 series of zircons grains represented in first line of concordia. Serie 1zircons (30 grains) ages vary from 2060 Ma to 2094.4 Ma. Serie 2 zircons (9 grains) 2060 Ma to 2100 Ma. Discordia line showed two series, 3 and 4. Between these series therewere Itemediat serie and isodat 1. Serie 3(22 grains) values varied from 2065 to 2070. Serie 4(20 grains) varied from 2085 to 2095.

3.2.2.2. Zircons fractions from Seguela Kimberlite (Second generation)

The Seguela granite (sample MA-12) maximum age recorded was 2094±1.5 Ma. As this granite is not affected by any later event. It interpreted as the magmatic emplacement age of granite from seguela. The second generation of zircon from Seguela kimberlite (sample K012) analysis provided a restricted age to 2093±2.2 Ma which is also the age defined for the first generation of granite. We can also conclude that second generation are considered as inherited zircons grains found in the seguela granite.this is possible then kimberlite magma were contaminated by crustal composition during the progress of magma towards the earth crustTable 1. Chemical analysis of Seguela samples

SEGUELA											
se sur roche totale											
	Lamproite à olivine de Bobi	Kimberlite d Toubabouko	Kimberlite noduleuse Toubabouko	,amproites à olivine de Toubabouko		Enclaves de pyroxénites à cumulat d'olivine			Dolérite de Toubabouko	Granite	Argile du Maar Toubabouko
	K-11	k-12	K-3B2	K-2A1	MA-6	MA-6B	T-25	T- S4	MA-9	MA-12	MA-7
SiO2	36,95	49,75	55,60	50,76	52,33	49,76	42,30	41,84	48,50	72,55	47,01
Al2O3	7,11	4,35	1,61	4,85	4,36	3,45	4,59	4,62	14,63	14,22	24,91
Fe2O3	10,25	6,84	6,12	11,76	8,27	8,33	14,90	15,04	12,66	1,96	9,36
MnO	0,14	0,11	0,05	0,13	0,10	0,08	0,20	0,19	0,18	0,00	0,05
MgO	20,27	21,28	26,43	10,84	11,74	21,25	29,52	31,22	7,29	0,46	1,46
CaO	8,10	5,48	1,31	3,75	4,93	2,98	3,65	3,73	12,77	1,47	0,57
Na2O	0,72	0,24	0,10	3,80	3,50	0,14	0,54	0,72	1,49	3,08	0,52
K2O	1,11	0,20	0,73	5,96	6,29	0,47	1,13	0,48	0,10	5,50	1,34
TiO2	3,98	2,61	1,52	1,96	3,72	3,65	0,32	0,33	0,91	0,25	1,12
P2O5	1,36	1,16	0,64	1,85	0,78	1,60	0,09	0,09	0,11	0,09	0,12
Pf	9,45	8,05	6,00	4,21	3,63	8,51	2,78	1,91	1,29	0,36	13,37
Total	99,46	99,93	100,02	99,87	99,63	100,22	100,02	100,17	99,83	99,94	99,86
Mg#	66,42	75,68	81,20	47,96	58,67	71,84	66,46	67,49	36,54	19,01	13,49
CI	1,99	2,51	2,05	2,61	2,47	2,40	1,49	1,47	8,63	7,84	17,50
ilmI	0,63	0,44	0,27	0,60	0,49	0,54	0,48	0,48	1,81	0,19	2,53
FeOt/MgO	0,51	0,34	0,30	0,58	0,41	0,41	0,74	0,74	0,62	0,10	0,46
K2O/Na2O	1,54	0,83	7,30	1,57	1,80	3,36	2,09	0,67	0,07	1,79	2,58
MgO/CaO	2,50	3,88	20,18	2,89	2,38	7,13	8,09	8,37	0,57	0,31	2,56
CaO/MgO	0,40	0,26	0,05	0,35	0,42	0,14	0,12	0,12	1,75	3,20	0,39
SIO2/Al2O3	5,20	11,44	34,53	10,47	12,00	14,42	9,22	9,06	3,32	5,10	1,89
ce de Contamination											
MgO/(MgO+Fe2O3)											
Indice d'ilménite											

Table 2 :Isotopic analysis of Seguela granite zircons fractions.

SEGUELA/GRANITE/GRAINS	Measured isotopic ratios					
SERIE 1	207Pb / 235U	207Pb/235U-error	206Pb / 238U	206Pb/238U-error	Rho-XY	Ages (Ma)
1	6.6000	0,496	0.3763	0,495	0,99	2059
2	6.6108	0,226	0.3766	0,224	0,98	2060
3	6.6216	0,496	0.3769	0,495	0,99	2062
4	6.6324	0,226	0.3773	0,224	0,98	2064
5	6.6433	0,496	0.3776	0,495	0,99	2065
6	6.6542	0,226	0.3779	0,224	0,98	2066
7	6.6651	0,496	0.3782	0,495	0,99	2068
8	6.6760	0,226	0.3785	0,224	0,98	2070
9	6.6869	0,496	0.3788	0,495	0,99	2071
10	6.6979	0,496	0.3791	0,495	0,99	2072
11	6.7088	0,226	0.3794	0,224	0,98	2073
12	6.7198	0,496	0.3797	0,495	0,99	2075
13	6.7308	0,226	0.3800	0,224	0,98	2076

14	6.7418	0,496	0.3803	0,495	0,99	2078
15	6.7528	0,226	0.3807	0,224	0,98	2080
16	6.7638	0,496	0.3810	0,495	0,99	2081
17	6.7749	0,226	0.3813	0,224	0,98	2082
18	6.7859	0,496	0.3816	0,495	0,99	2083
19	6.7970	0,496	0.3819	0,495	0,99	2085
20	6.8081	0,226	0.3822	0,224	0,98	2086
21	6.8192	0,496	0.3825	0,495	0,99	2088
22	6.8304	0,226	0.3828	0,224	0,98	2090
23	6.8415	0,496	0.3831	0,495	0,99	2091
24	6.8527	0,226	0.3834	0,224	0,98	2092
25	6.8638	0,496	0.3838	0,495	0,99	2093
26	6.8750	0,226	0.3841	0,224	0,98	2095
27	6.8862	0,496	0.3844	0,495	0,99	2096
28	6.8975	0,496	0.3847	0,495	0,99	2098
29	6.9087	0,226	0.3850	0,224	0,98	2099
30	6.9200	0,496	0.3853	0,495	0,99	2100
SERIE 2						
1	6.6048	0,496	0.3765	0,495	0,99	2060
2	6.6424	0,226	0.3775	0,224	0,98	2065
3	6.6801	0,496	0.3786	0,495	0,99	2070
4	6.7180	0,226	0.3797	0,224	0,98	2075
5	6.7561	0,496	0.3807	0,495	0,99	2080
6	6.7944	0,226	0.3818	0,224	0,98	2085
7	6.8329	0,496	0.3829	0,495	0,99	2090
8	6.8664	0,226	0.3838	0,224	0,98	2095
9	6.9104	0,496	0.3850	0,495	0,99	2100
SERIE isodat1						
1	6.6702	0,496	0.3726	0,495	0,99	2070
2	6.8340	0,226	0.3820	0,224	0,98	2090
SERIE 3						

1	6.6000	0,496	0.3686	0,495	0,99	2060
2	6.8664	0,226	0.3838	0,224	0,98	2094
SERIE 5						
1	6.7925	0,496	0.3797	0,495	0,99	2085
2	6.7942	0,226	0.3797	0,224	0,98	2085
3	6.7942	0,496	0.3799	0,495	0,99	2085
4	6.7991	0,226	0.3799	0,224	0,97	2085
5	6.7991	0,496	0.3802	0,495	0,99	2086
6	6.8068	0,226	0.3802	0,224	0,99	2086
7	6.8068	0,496	0.3807	0,495	0,98	2086
8	6.8168	0,226	0.3807	0,224	0,99	2088
9	6.8168	0,496	0.3813	0,495	0,99	2088
10	6.8281	0,226	0.3813	0,224	0,99	2088
11	6.8281	0,496	0.3820	0,495	0,99	2090
12	6.8399	0,226	0.3820	0,224	0,96	2090
13	6.8399	0,496	0.3826	0,495	0,99	2090
14	6.8512	0,226	0.3826	0,224	0,99	2090
15	6.8512	0,496	0.3832	0,495	0,98	2092
16	6.8612	0,226	0.3832	0,224	0,99	2093
17	6.8612	0,496	0.3837	0,495	0,99	2093
18	6.8689	0,226	0.3837	0,224	0,99	2093
19	6.8689	0,496	0.3841	0,495	0,97	2095
20	6.8738	0,226	0.3841	0,224	0,99	2095
21	6.8738	0,496	0.3843	0,496	0,99	2095
22	6.8755	0,226	0.3843	0,224	0,97	2095
SERIE 6						
1	6.6525	0,496	0.3716	0,495	0,99	2064
2	6.6525	0,226	0.3717	0,224	0,99	2064
3	6.6547	0,496	0.3717	0,495	0,99	2064
4	6.6547	0,226	0.3718	0,224	0,99	2065
5	6.6581	0,496	0.3718	0,495	0,99	2064
6	6.6581	0,226	0.3721	0,224	0,99	2065
7	6.6625	0,496	0.3721	0,495	0,99	2065
8	6.6625	0,226	0.3723	0,224	0,99	2065
9	6.6676	0,496	0.3723	0,495	0,99	2065
10	6.6676	0,226	0.3726	0,224	0,99	2066
11	6.6702	0,496	0.3726	0,495	0,99	2066
13	6.6778	0,496	0.3729	0,495	0,99	2066
14	6.6778	0,226	0.3732	0,224	0,99	2068
15	6.6823	0,496	0.3732	0,495	0,99	2068
16	6.6823	0,226	0.3734	0,224	0,99	2068
17	6.6857	0,496	0.3734	0,495	0,99	2070
18	6.6857	0,226	0.3735	0,224	0,99	2070
19	6.6879	0,496	0.3735	0,495	0,99	2070
20	6.6879	0,226	0.3736	0,224	0,99	2070
21	6.6886	0,496	0.3736	0,496	0,99	2071

SEGUELA/KIMBERLITE/GRAINS	Measured isotopic ratios					
SERIE 1	**207Pb / 235U**	**207Pb/235U-error**	**206Pb / 238U**	**206Pb/238U-error**	**Rho-XY**	**Ages (Ma)**
1	6.18	0,496	0.3639	0,495	0,99	2000
2	6.22	0,226	0.3660	0,224	0,98	2010
3	6.32	0,496	0.3680	0,495	0,99	2020
4	6.39	0,226	0.3700	0,224	0,98	2030
5	6.47	0,496	0.3723	0,495	0,99	2040
6	6.53	0,226	0.3742	0,224	0,98	2050

7	6.61	0,496	0.3763	0,495	0,99	2060
8	6.69	0,226	0.3784	0,224	0,98	2070
9	6.75	0,496	0.3810	0,495	0,99	2080
10	6.84	0,496	0.3830	0,495	0,99	2090

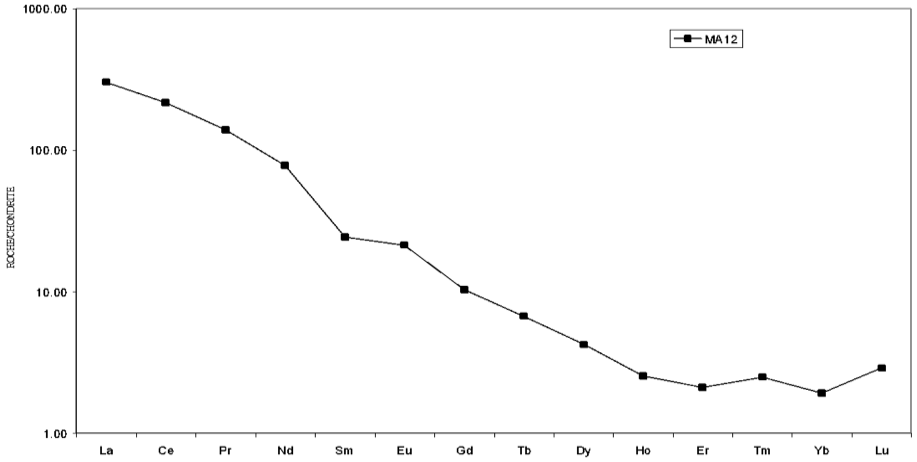

Figure 4. Rare earth elements spectrum of Seguela granit normalized to chondrite [29].

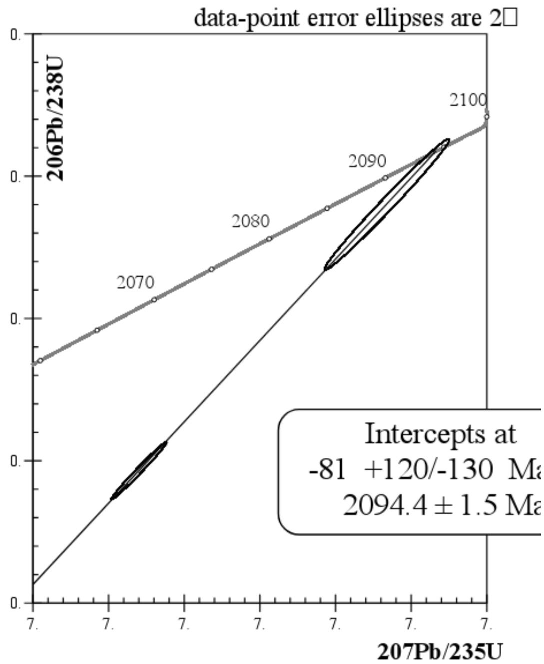

Figure 5. Multi element diagram of Seguela Granit normaized using primitive mantle [29].

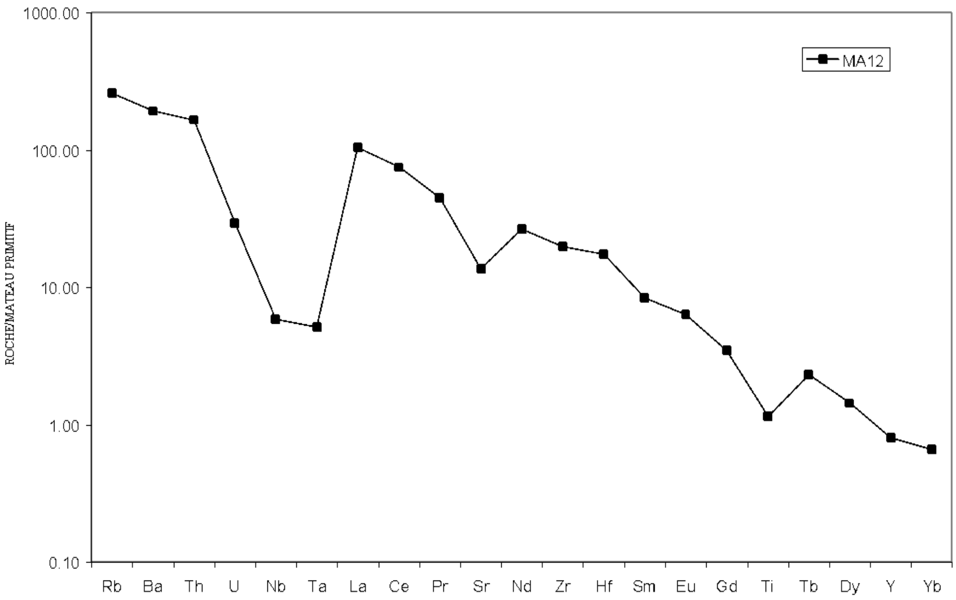

Figure 6: Concordia diagram corresponding to analysed zircons fractions from Seguela granite

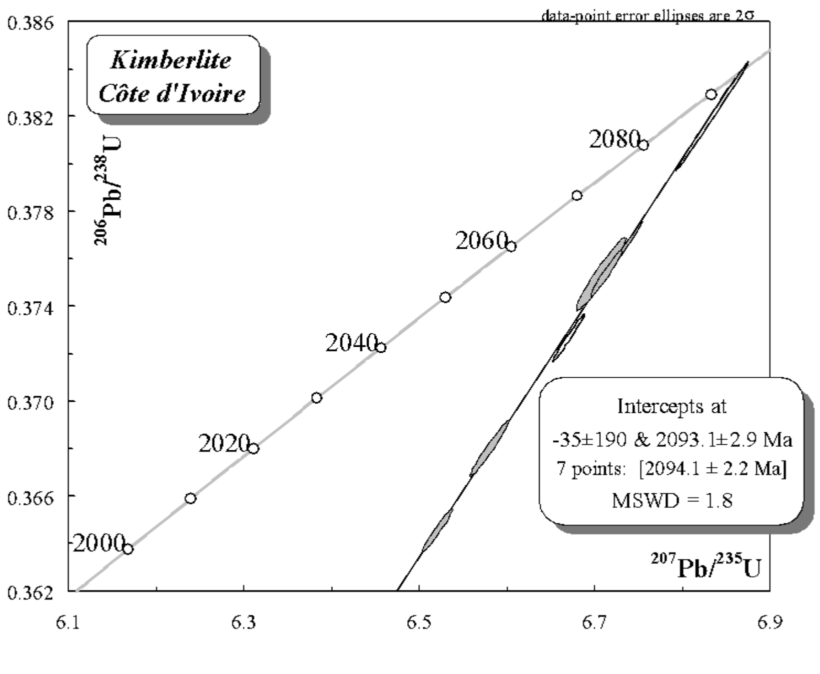

Figure 7: Concordia diagram corresponding to analysed zircons fractions from Seguela Kimberlite.

1. Discussion

This study showed that the Seguela area does not differ significantly from the other Birimian domains in the Man shield with respect to the nature and age of emplacement of granitoids. Geochronological data clearly showed that the Seguela granitoids pluton emplaced in transcurrent tectonic regime. The age range of all the granitoids studied fall within the age range previously defined from general and local studies [2]; [12]; [14]; [15]. The Seguela granitic pluton U-Pb isotopic data correspond the general scheme now well-established for the whole Palaeoproterozoic domain in West Africa.

Two generations of granitoids, or whether they correspond to two different provinces (see [12]). Although older ages seem to be found in Ghana [12] and younger ones in Guinea and Sénégal ([16]; [15]), the pattern of age distribution is probably much more complex because of the presence of zircon U–Pb ages at 2096 Ma (Seguela) and 2147 to 2135 Ma in the SASCA area in southwestern Côte d'Ivoire [23], and in the Kedougou-Kéniéba inlier of ages at 2155 ±34 Ma and 2165 ±1Ma ([15]), and as old as 2194 Ma ([2]).

It is important to notice that kimberlite zircons in Seguela area are inherited from granite. This event derived from magma kimberlitic ascent through upper mantle and stay in earth crust. The characteristic incompatible element ratios reflect both the characteristics of the metasomatised source region and fractionation effects arising from the presence of residual phases during partial melting [30].

Conclusion

Petrogaphic characteristics of Seguela granite pluton suggest it was crystallised from melts. The extreme enrichment in incompatible elements fractionated REE patterns and high volatile content of the Seguela granite pointed toward a crustal source.Granite have on average higher abundances of LILE and LREE.Geochemical signatures are characterized by La_n/Yb_n, Th/Yb, and Ta/Yb ratios which are similary to other Ivory Coast, Ghana, Senegal, Burkina Faso andMali Granitoids. These ratios reflects continental active margine calcalkaline and arc volcanic signatures. In comparison to other West African granitoids Seguela granitic pluton U-Pb isotopic data 2094±2.2 Ma correspond to the general scheme now well-established for the whole Palaeoproterozoic domain in West Africa.

Acknowledgments

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