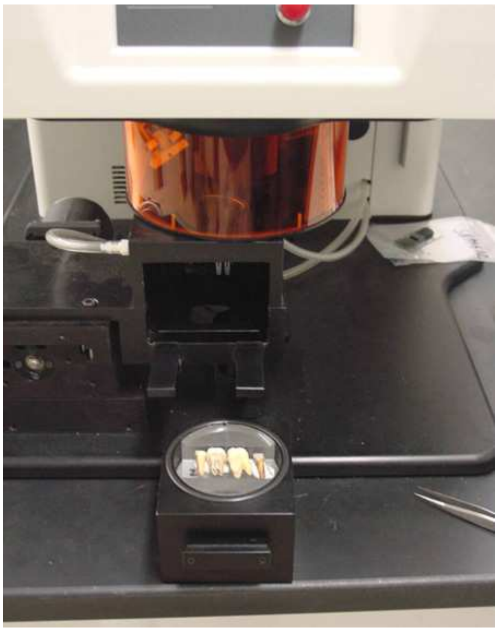
Detecting Foreigners in Archaeological Human Dental Enamel in Yucatán, México.



Research Year: 2006
Culture: Maya
Chronology: Classic and Colonial
Location: Yucatán and Campeche, México
Sites: Xcambó, Calakmul, and Campeche

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Abstract

Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) has been applied to the enamel of the first permanent molar of subadult and adult human teeth from three archaeological Maya sites from northern Yucatán in order to detect regional variation in trace element composition. The scope of the analysis was to characterize the elemental composition in the three areas (corresponding to Xcambó, Campeche and Calakmul), resting upon the pattern obtained from the subadults, and from that be able to assess the presence of adult individuals whose elemental composition does not correspond to that of the subadults. After ruling out diagenesis, those individuals should represent foreigners who migrated into the area at some point in their life. Two individuals at Calakmul and two more at Xcambó have been detected to show clear differences in the trace elements composition of their teeth. None of them overlaps with the ranges of variability that characterize the three sites, which indicates that they might have originated from some different area in the Maya region.

Resumen

El presente estudio aplica la ablación láser acoplada a la espectrometría de masa LA-ICP-MS a los dientes humanos de adultos y subadultos procedentes de los sitios maya de Xcambó, Calakmul y Campeche, en el norte de Yucatán, para poder determinar la variabilidad en la composición en elementos traza a nivel regional. La investigación mira a establecer la composición química en las tres áreas, a partir de la información recabada por los individuos subadultos, y de allá inferir sobre la presencia de adultos cuya composición no corresponde a la que caracteriza el sitio. Una vez descartada la posibilidad de diagénesis, esta diferencia debería atestiguar que los individuos eran foráneos que migraron al sitio en cualquier momento de su vida. Se han detectado dos individuos en Calakmul y dos más en Xcambó que aparentemente no pertenecen al sitio. Sin embargo, ninguno de los cuatro cae en el rango de variabilidad de los otros sitios, lo que indica que podrían haber llegado desde áreas en la región que no han sido investigadas por este análisis.

Introduction

The present research project aimed at applying the use of trace elements from human dental enamel in order to assess skeletal chemical variability as well as detect the presence of foreign individuals within archaeological samples, by mean of (LA-ICP-MS laser-ablation inductively-coupled-plasma mass-spectrometry). This research rests upon the assumption that the trace elements that are incorporated into the enamel are indicative of the environmental water chemical composition (the hydro-geological environment) (Molleson, 1988; White et al., 2002; Burton et al. 2003), in a similar manner to the strontium isotope dynamic (Price et al., 1994a, b; 1998; 2000). The decision to use LA-ICP-MS was dictated by the fact that laser ablation is very little destructive, can be employed on small fragments of dental tissue to the extreme that it may not require the cutting or breaking of the archaeological specimen (Cucina et al., 2007).

Although diagenetic changes are known to have profound effects on the elemental composition of bone (Sandford and Weaver, 2000), dental enamel is a highly mineralized tissue that is much less prone to undergo diagenetic modifications (Martin et al., 1998; Burton and Price, 2000).

In order to confirm this hypothesis, the present research project focused on the first permanent molar from the skeletal remains of young subadults and adults from three Classic and colonial sites in Yucatán; Xcambó, Calakmul (both dated to the Classic period) and Campeche (the colonial cemetery encountered around the basement of the ancient church in the town's Plaza) (Figure 1). The chemical composition encountered in the subadult individuals is supposed to represented the sites' local signature, to be compared to the adults' ones from the same site (Cucina and Neff, 2006).

Figure 1. Map of Yucatán showing the location of the three archaeological sites (circled in black). (After FAMSI map.)

Materials and Methods

Enamel composition was analyzed by LA-ICP-MS at the Department of Anthropology, California State University in Long Beach. The equipment is a New Wave UP213 laser that produces a laser light with a 213nm wave-length. The laser was coupled with a GBC Optimass "time of flight" (TOF) ICP-MS-TOF (Figure 2). The TOF mass spectrometer counts the time every element requires to "fly" into the collector, which depends on the element's atomic weight, so that it can simultaneously collect all the elements whose atomic weight is between 23 (Na) and 238 (U). It produces 30,000 pulses per second and acquires 30,000 sets of information on every element produced per second.

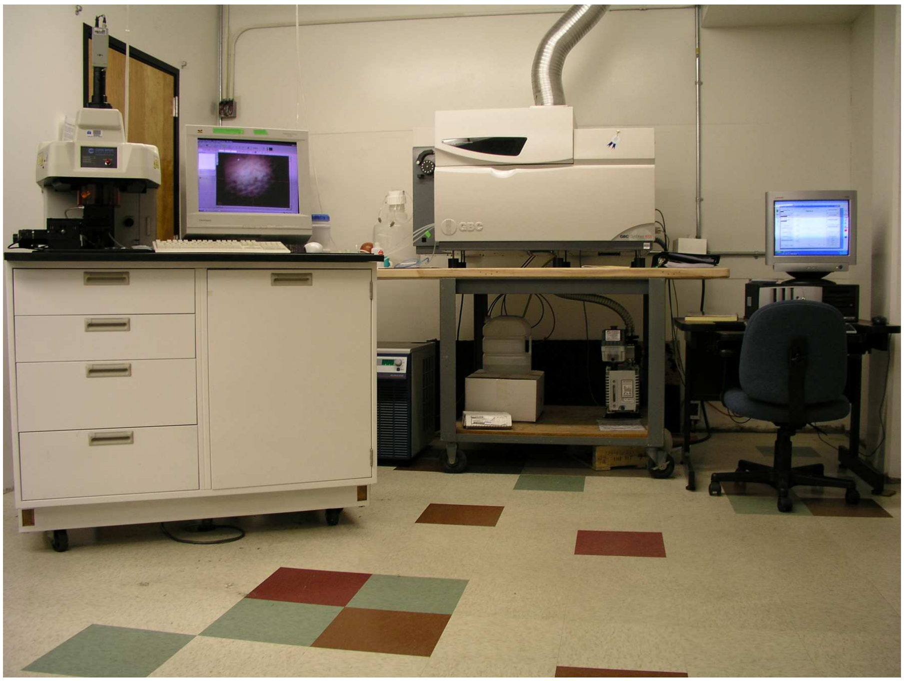

Figure 2. Laser Ablation Inductively Coupled Plasma Mass Spectrometer (photo by J. Dudgeon).

The laser was set up to read a linear raster in the so called “hidden enamel” (Hillson, 1996) right below the top of the molars’ cusps or, in case of occlusal wear, in an area close to the occlusal surface approximately in between the enamel’s external layers and the dentino-enamel junction. Every raster was initially pre-ablated at 100% intensity with a laser expansion of 200 microns without connecting the mass spectrometer, in order to remove any potential contaminant that could enter the plasma. On average, four to five dental fragments can be housed in the laser chamber (Figure 3), along with the glass butte standards. All the fragments and the standards were simultaneously pre-ablated. After this process was concluded, the laser was connected to the mass spectrometer and the actual reading started. For data-collection, the laser beam was set to 100microns at 100% intensity, which usually produces a 5microns deep groove.

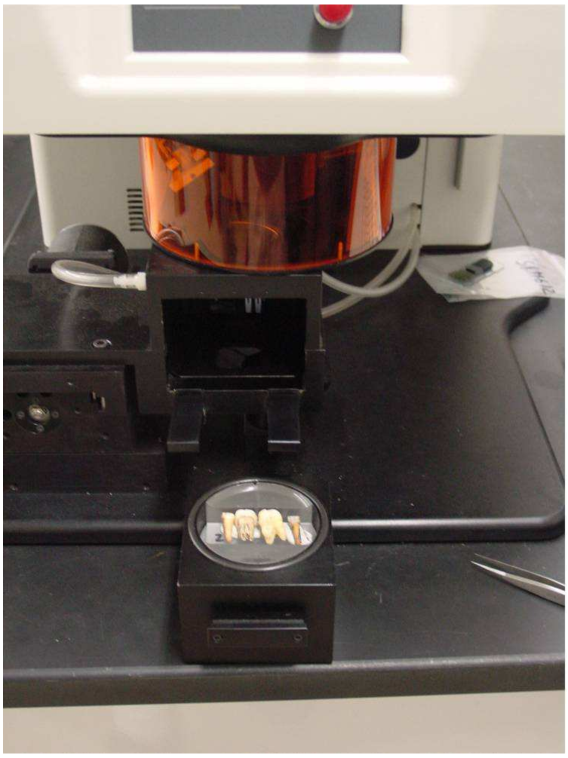

Figure 3. Some dental specimens ready to be analyzed in the laser chamber (photo by J. Dudgeon).

Since enamel elemental composition is not known, the equipment used to be calibrated using the glass butte standards SRM610, SRM612 and SRM614 at the same time. These standards are of known elemental composition, which permits to calibrate their signal intensity and correlate to it to that produced by the teeth. Calibration is a fairly common problem, in particular for the LA-ICP-MS that fluctuates during the day. The lack of a standard that reflects the hydroxyapatite chemical composition bounds to use glass buttes that are not optimized for a mineralized organic material (Cox et al., 1996; Budd et al., 1998; Lee et al., 1999; Kang et al., 2004). Nonetheless, it must be said that it is indeed not necessary to know the actual ppm value of every element, rather its internal normalization to the amount of Calcium (Ca) that is used as inner standard material. For this reason, as Table 1 will show, elemental composition is standardized on a constant amount of Ca (Budd et al., 1998; Kang et al., 2004).

Table 1. Absolute concentration of fifteen elements from Calakmul, Xcambó and Campeche

Individual	Na	Mg25	Al	Si	P	Cl	K	Ti	Ni	Zn66	Br	Se	Sr88	I	Ba
CLK-001	1033.80	747.20	5.23	102.17	194123.57	37.18	59.00	21.43	4.07	9.96	34.01	2.52	261.00	59.18	8.67
CLK-002	919.06	680.93	14.63	205.11	190947.30	36.34	62.20	18.59	4.12	13.78	32.23	1.97	189.20	53.58	17.53
CLK-003	831.00	598.37	13.08	146.36	191255.29	38.58	61.21	15.82	4.30	17.81	60.63	2.22	221.07	53.00	9.22
CLK-004	1106.21	770.09	15.22	129.77	187680.59	21.84	100.35	14.30	2.07	7.92	18.85	2.51	276.11	54.13	6.47
CLK-005	1036.57	548.82	5.75	67.65	184290.90	29.52	39.84	12.61	1.76	14.75	22.11	2.17	261.84	52.92	10.02
CLK-006	854.94	566.31	0.37	36.54	186761.00	31.08	44.30	13.63	0.33	7.13	31.50	1.55	130.74	52.26	5.18
Mean	**963.60**	**651.95**	**9.04**	**114.60**	**189176.44**	**32.42**	**61.15**	**16.06**	**2.77**	**11.89**	**33.22**	**2.16**	**223.33**	**54.18**	**9.52**
S.D.	**111.32**	**94.56**	**6.10**	**59.81**	**3574.13**	**6.30**	**21.36**	**3.35**	**1.63**	**4.22**	**14.74**	**0.36**	**55.55**	**2.53**	**4.32**
CLKA-001	1405.50	789.40	11.54	132.20	180301.59	38.06	143.04	15.31	3.57	14.12	34.02	1.63	201.34	54.14	4.71
CLKA-003	1256.05	707.40	2.75	34.74	182251.50	40.11	105.23	16.05	1.69	9.73	29.62	1.48	297.62	47.53	2.37
CLKA-004	1147.10	821.79	0.35	33.07	178611.50	26.79	86.79	13.07	0.98	5.23	47.01	1.67	317.23	42.59	8.79
CLKA-005	1138.03	994.47	0.13	25.84	182467.87	48.07	107.75	15.46	0.43	19.95	39.08	1.64	175.20	32.03	1.97
CLKA-006	1388.05	1329.19	5.76	77.05	191668.27	58.23	180.88	22.21	1.53	13.58	30.28	0.85	103.59	33.14	8.94
CLKA-007	1351.81	1382.08	0.24	23.95	190275.04	35.93	155.06	17.23	0.35	5.55	23.75	1.52	39.35	33.82	6.11
CLKA-008	2101.47	1011.26	0.78	34.48	177716.10	43.62	139.40	16.80	0.78	3.96	18.80	1.21	148.43	47.70	2.00
CLKA-009	1848.98	833.19	3.31	68.43	183064.91	48.77	175.95	13.72	1.17	4.05	27.96	1.47	360.17	51.12	1.28
CLKA-010	1848.20	1285.17	3.32	52.70	183125.27	42.33	142.10	13.84	0.93	4.92	20.92	1.15	81.11	51.47	1.70
CLKA-011	1500.49	1284.99	8.27	81.91	167099.38	50.84	271.90	13.68	1.12	22.04	34.37	1.33	2000.15	48.50	42.76
CLKA-012	1507.07	1650.54	28.77	491.64	187121.73	25.48	159.81	13.57	2.11	7.84	33.36	1.68	128.34	56.31	39.75
CLKA-013	1907.52	1091.38	2.95	44.31	182519.46	33.34	93.96	12.17	1.20	3.30	39.64	1.88	59.02	52.45	12.79
Mean	**1533.35**	**1098.40**	**5.68**	**91.69**	**182185.22**	**40.96**	**146.82**	**15.26**	**1.32**	**9.52**	**31.57**	**1.46**	**325.96**	**45.90**	**11.10**
S.D.	**318.53**	**289.50**	**8.06**	**129.72**	**6363.76**	**9.77**	**50.12**	**2.68**	**0.86**	**6.47**	**8.16**	**0.28**	**537.38**	**8.54**	**14.55**
PPP-001	70.26	417.71	2.79	30.10	209723.00	59.13	2.29	15.84	0.82	2.45	43.23	0.59	80.04	45.39	0.39
PPP-002	71.41	654.90	4.49	40.79	201920.17	34.88	1.81	18.21	0.37	1.87	20.22	0.72	61.48	45.17	0.28
PPP-003	76.48	762.04	1.32	60.16	193655.23	15.74	1.51	15.19	0.22	2.83	29.72	0.72	53.07	44.42	0.46
PPP-004	63.34	677.72	0.40	16.18	194651.50	51.95	1.27	14.92	0.06	1.11	41.72	0.78	51.11	41.15	0.09
PPP-005	66.45	807.53	4.59	30.11	190872.26	28.05	1.42	15.15	0.10	1.36	19.13	0.32	62.79	37.13	0.17
PPP-006	287.42	691.09	4.01	17.19	215358.57	46.91	16.76	14.67	0.69	1.48	35.07	0.83	44.35	52.85	0.16
PPP-007	337.21	751.26	4.83	15.22	220470.79	16.25	17.01	12.07	1.06	1.72	21.77	1.32	62.14	75.64	0.50
PPP-008	282.87	460.24	16.28	91.63	211787.61	43.20	22.23	12.57	4.07	4.19	38.34	1.09	57.75	72.99	0.80
PPP-009	295.01	651.74	28.64	57.10	207443.50	23.94	19.42	12.17	1.45	2.80	38.13	1.44	81.09	87.91	0.66
PPP-010	284.17	562.01	1.05	11.32	206613.60	48.57	19.96	12.52	1.16	1.18	30.61	1.18	53.33	44.20	0.21
PPP-011	662.57	507.14	0.57	6.53	257016.72	58.25	32.97	16.54	3.21	2.22	34.50	1.62	15.59	60.00	0.39
PPP-012	660.78	580.17	18.91	66.65	240149.92	56.93	39.57	17.79	5.20	1.98	35.50	1.40	18.50	51.51	0.25
PPP-013	706.97	753.69	8.72	40.79	235511.09	43.40	40.00	16.25	3.57	2.52	45.46	1.36	13.88	48.61	0.19
PPP-014	607.88	419.93	9.89	30.93	204522.45	51.58	28.50	14.56	2.78	2.72	34.86	1.52	83.29	63.99	0.45
PPP-015	563.31	600.47	4.17	18.24	191983.40	67.05	26.11	17.72	2.00	6.09	34.93	1.27	169.32	47.55	5.25
Mean	**335.74**	**619.84**	**7.38**	**35.53**	**212111.99**	**43.06**	**18.06**	**15.08**	**1.78**	**2.44**	**33.55**	**1.08**	**60.51**	**54.57**	**0.68**
S.D.	**244.93**	**126.94**	**8.06**	**24.16**	**19182.60**	**15.98**	**13.92**	**2.05**	**1.62**	**1.29**	**8.04**	**0.39**	**37.41**	**14.58**	**1.28**
XC-001	341.24	968.74	11.25	20.47	212045.92	37.66	0.33	10.07	23.19	1.82	37.54	3.60	214.49	9.70	0.46
XC-002	362.62	1157.36	1.04	7.93	213346.88	17.29	0.22	7.43	17.49	1.44	49.77	2.52	145.74	25.36	0.13
XC-003	227.22	864.10	2.16	2.83	245260.42	41.61	0.03	5.30	0.66	5.75	36.60	2.25	110.94	18.25	0.10
XC-004	263.10	987.63	6.64	3.11	222682.35	33.66	0.13	6.11	31.29	2.26	35.19	2.15	177.05	25.21	0.29
XC-005	235.27	834.66	0.59	0.87	218853.51	63.54	0.19	4.99	2.53	2.44	25.23	1.24	207.61	50.80	0.10
XC-006	267.77	1157.09	1.19	0.67	227231.06	45.49	0.18	4.55	2.31	1.02	25.12	1.38	136.85	69.28	0.08
XC-007	302.90	798.09	11.13	5.27	326348.62	61.50	0.28	11.17	13.32	5.88	58.72	5.16	132.29	160.62	0.48
XC-008	289.42	891.42	0.86	0.99	276069.15	74.81	0.40	9.13	7.05	2.41	31.75	2.00	93.09	137.45	0.11
XC-009	292.93	1138.09	20.30	7.44	233629.49	68.64	0.65	10.03	81.98	6.56	24.29	1.59	162.84	152.40	0.77
XC-010	281.11	1004.61	5.36	2.65	233725.36	58.63	0.34	5.72	19.39	1.92	16.70	1.13	99.89	104.00	0.13
XC-011	261.34	811.07	15.59	3.69	277222.37	35.68	0.36	4.51	21.80	2.65	23.81	2.27	244.26	206.62	0.95
XC-013	862.92	1370.63	40.63	292.20	211242.13	57.13	12.06	26.25	21.88	5.51	16.92	0.45	272.95	90.08	1.35
XC-014	846.98	1077.55	10.14	83.70	250126.73	32.01	7.40	14.49	9.50	2.56	29.43	1.38	228.90	82.38	0.40
XC-015	873.77	1007.32	1.77	13.12	248189.98	38.73	6.49	10.64	8.99	2.26	23.37	1.34	167.91	80.58	0.03
XC-016	741.32	1037.26	5.17	33.68	234877.59	50.29	8.80	10.51	6.22	1.97	8.97	1.22	266.81	98.35	0.63

Individual	Na	Mg25	Al	Si	P	Cl	K	Ti	Ni	Zn66	Br	Se	Sr88	I	Ba
XC-017	748.93	879.10	3.97	26.19	212088.79	51.12	7.67	11.44	5.13	1.75	26.47	1.19	247.77	74.82	0.33
XC-018	838.61	1430.82	8.37	62.23	265577.89	37.06	10.30	15.16	11.70	4.23	12.34	2.08	315.67	99.97	1.05
XC-019	914.43	961.93	1.50	17.50	242389.21	49.36	13.14	17.80	9.37	2.72	32.10	1.69	200.67	102.08	0.48
XC-020	877.57	1074.17	5.57	23.76	204414.52	78.06	10.19	16.22	7.44	2.66	25.40	1.05	206.91	79.13	0.61
XC-021	846.44	1097.18	1.56	15.60	205431.52	67.61	12.09	18.45	8.36	2.30	30.19	1.77	200.89	84.46	0.50
XC-022	756.06	1001.61	0.78	13.70	206254.45	100.13	10.08	14.53	8.54	1.84	43.35	2.35	149.67	87.57	0.16
XC-023	752.44	735.93	2.01	21.37	238626.62	71.77	11.38	14.15	10.98	2.57	49.62	2.35	278.29	105.21	0.50
XC-024	1098.14	1542.96	2.19	16.72	249059.61	52.51	15.95	17.54	12.48	4.22	48.68	1.81	204.73	130.12	0.10
Mean	**577.50**	**1036.06**	**6.95**	**29.38**	**237160.62**	**53.23**	**5.59**	**11.57**	**14.85**	**2.99**	**30.94**	**1.91**	**194.18**	**90.19**	**0.42**
S.D.	**296.91**	**202.24**	**9.02**	**60.69**	**29086.54**	**18.66**	**5.54**	**5.52**	**16.48**	**1.56**	**12.68**	**0.97**	**60.42**	**47.46**	**0.35**
XCA-001	1392.63	877.32	0.10	19.32	180606.52	40.95	35.27	12.93	1.57	1.16	41.66	0.75	133.27	81.33	0.04
XCA-002	948.64	505.70	11.22	71.28	188023.25	131.61	45.51	11.70	1.62	8.68	49.19	0.82	172.87	71.32	0.37
XCA-003	1363.32	835.52	0.89	12.69	186933.44	82.81	36.90	13.73	1.50	1.49	54.03	0.67	189.15	62.99	0.07
XCA-004	1429.29	756.46	2.95	11.89	192172.83	51.63	37.84	11.33	1.37	2.07	57.21	0.81	147.68	62.20	0.15
XCA-005	1182.95	744.03	19.61	74.44	188119.65	103.76	42.45	12.04	1.51	3.25	53.19	0.41	157.29	59.83	0.37
XCA-006	1230.94	567.84	2.00	6.76	187891.96	123.28	31.75	11.04	1.46	4.16	49.52	0.33	163.79	70.58	0.07
XCA-007	1078.62	1011.12	16.16	98.80	178821.74	35.00	52.40	21.65	15.33	1.42	15.19	0.99	175.09	12.84	0.40
XCA-008	1017.18	1255.24	12.89	61.37	183932.57	26.64	40.65	16.54	10.36	1.73	37.80	0.67	207.97	25.69	0.42
XCA-009	910.18	846.08	0.91	39.17	190521.73	33.91	23.02	12.95	7.64	1.57	33.89	0.89	129.37	41.13	0.10
XCA-010	1129.10	1221.09	6.87	17.90	189203.95	30.78	30.37	12.08	6.61	2.04	27.53	0.55	208.25	34.37	0.29
XCA-011	1035.04	1031.87	3.46	11.85	206712.51	26.71	40.38	8.33	4.74	1.76	50.94	0.44	76.31	52.71	0.15
XCA-012	639.41	852.21	2.09	105.70	202981.65	151.35	42.05	17.98	8.05	3.10	31.77	1.05	96.26	55.01	0.08
XCA-013	909.36	1226.85	0.95	68.08	204289.32	67.82	79.70	17.19	7.38	1.09	33.82	0.75	154.53	50.63	0.09
XCA-014	847.25	1063.88	1.66	33.03	199390.03	113.81	38.20	15.54	6.74	2.06	46.71	1.06	251.06	51.89	0.15
XCA-015	796.06	931.60	0.15	21.21	204038.43	116.10	27.93	13.88	5.91	1.74	27.92	0.89	112.75	57.44	0.12
XCA-016	839.40	1024.76	1.02	10.31	202327.99	90.17	36.41	12.31	5.78	1.17	29.16	0.85	192.68	46.05	0.15
XCA-017	310.87	764.58	0.81	52.57	191462.83	92.84	19.99	13.33	0.88	5.07	32.30	1.28	118.21	71.35	0.15
XCA-018	314.88	653.73	0.56	40.64	194529.97	110.24	22.52	13.74	1.01	2.46	34.61	1.07	192.81	116.99	0.13
XCA-019	308.72	797.14	1.00	33.15	189320.29	94.84	23.00	12.31	1.11	0.75	33.64	0.91	196.11	110.71	0.15
XCA-020	337.46	882.87	1.29	29.40	189564.18	94.98	35.09	12.37	0.94	1.05	27.66	0.69	192.81	68.46	0.11
XCA-021	1002.00	910.20	0.25	15.19	198182.68	90.94	27.55	14.41	1.38	1.07	32.94	0.91	70.93	60.00	0.05
XCA-022	873.22	716.61	1.78	24.58	204365.19	101.43	20.89	11.54	1.68	1.10	34.45	1.08	98.34	113.82	0.41
XCA-023	972.55	816.78	1.03	5.16	188251.59	102.91	23.37	11.54	1.29	1.72	25.17	0.51	22.43	32.66	0.10
XCA-024	862.90	633.57	0.51	6.21	202540.78	71.62	17.33	11.51	1.46	0.79	23.05	0.44	147.64	36.53	0.08
XCA-025	66.27	664.36	0.44	34.74	201975.36	41.62	5.19	6.06	13.75	11.61	38.36	1.14	111.01	51.83	0.08
XCA-026	62.42	947.13	1.74	87.06	201658.41	22.05	5.23	8.81	14.33	6.21	45.13	1.95	65.50	61.21	0.35
XCA-027	57.78	1018.59	0.93	27.97	199070.56	33.54	3.76	11.18	10.35	5.14	28.36	1.37	123.18	37.14	0.19
XCA-028	56.99	1096.91	12.78	757.15	219088.71	55.83	5.90	20.06	18.20	24.15	62.26	3.12	119.52	217.98	0.48
XCA-029	41.94	988.09	1.09	33.11	207837.83	21.40	4.51	9.93	14.47	5.71	28.71	2.17	133.52	49.63	0.40
XCA-030	53.12	1028.66	2.31	28.46	208744.03	25.47	4.05	10.27	13.18	6.09	40.87	2.63	81.04	49.52	0.25
XCA-031	50.12	950.23	4.70	68.76	205464.16	41.07	3.78	15.90	13.84	11.44	46.01	2.45	177.49	80.07	0.26
XCA-032	53.29	711.18	0.44	26.43	199683.13	33.89	3.23	8.51	10.33	7.80	20.32	1.80	120.66	42.07	0.17
XCA-033	49.34	845.47	4.46	51.02	198484.33	46.43	3.27	7.49	9.60	6.34	28.74	1.78	216.92	51.78	0.94
XCA-034	39.06	786.72	1.60	26.95	197492.44	43.63	2.35	8.88	6.73	10.53	19.27	1.56	129.45	42.59	0.50
XCA-035	216.70	1263.10	1.35	26.23	218958.25	37.20	12.80	15.69	15.10	5.48	54.55	4.97	101.08	86.26	0.30
XCA-036	220.87	1786.98	1.25	24.17	210625.88	37.32	12.24	16.45	9.64	3.85	39.01	2.84	347.49	61.77	1.03
XCA-037	229.53	725.70	14.61	95.56	196587.60	42.87	9.06	10.45	13.01	7.43	30.95	1.43	117.14	62.64	0.29
XCA-038	244.65	718.65	2.16	18.35	210857.91	41.56	11.28	12.98	13.49	9.13	51.40	3.85	240.85	60.36	0.33
XCA-039	239.25	1469.45	3.58	18.42	213747.33	51.21	7.57	11.04	6.03	7.79	30.47	2.74	336.30	54.35	1.73
XCA-040	220.92	963.46	1.98	26.23	197979.12	43.63	4.97	9.56	6.00	6.26	34.74	2.18	29.57	66.72	1.17
XCA-041	349.35	1136.90	1.63	25.22	197833.42	34.40	5.53	11.89	1.91	3.33	21.92	0.80	53.80	46.82	0.18
XCA-042	930.06	1093.88	0.27	68.04	190650.46	63.80	27.59	19.62	4.49	2.48	41.26	1.98	288.61	55.55	0.17
XCA-043	793.65	1143.09	1.58	37.18	195442.65	101.44	21.45	16.42	3.56	4.69	42.54	1.87	121.17	42.52	0.18
XCA-044	938.17	989.63	0.95	24.47	194728.34	74.31	22.68	12.98	2.53	2.76	30.48	1.44	124.34	36.15	0.09
XCA-045	895.02	1281.02	0.14	13.57	198313.11	76.29	18.13	12.79	2.36	1.35	30.16	1.38	161.82	32.71	0.12
XCA-046	972.91	1654.68	0.20	11.18	198001.72	54.98	24.55	10.83	1.93	1.92	35.90	1.55	226.72	31.44	0.04
XCA-047	991.18	1230.88	0.15	7.51	203815.31	60.05	22.91	11.51	2.05	2.73	34.14	0.87	293.90	28.29	0.32
XCA-048	2584.55	2470.87	0.91	68.27	198693.86	85.72	84.43	24.22	2.08	6.99	28.54	0.91	267.04	41.91	0.86
XCA-049	2134.85	1166.84	0.44	46.70	197964.65	81.05	59.61	19.42	2.32	1.86	44.80	1.60	254.05	44.91	0.34

Individual	Na	Mg25	Al	Si	P	Cl	K	Ti	Ni	Zn66	Br	Se	Sr88	I	Ba
XCA-050	1967.68	893.34	1.87	53.09	194611.13	103.95	79.26	17.03	2.14	10.23	43.98	2.54	143.04	41.50	0.22
XCA-051	2072.91	1014.68	0.43	36.73	193158.37	65.47	52.81	15.02	1.90	2.51	53.62	1.55	91.38	34.90	0.06
XCA-052	1949.16	1094.24	0.91	30.38	188846.67	86.44	46.78	15.82	1.89	5.97	45.85	1.37	202.97	36.43	0.16
XCA-053	2747.86	1241.55	1.38	33.47	198104.71	69.32	71.26	19.09	2.89	2.29	55.91	3.84	144.73	48.96	0.10
XCA-054	2532.44	990.36	0.64	20.60	191196.25	78.05	66.71	15.78	2.66	1.18	20.32	3.58	140.31	54.57	0.12
XCA-056	2966.81	1034.60	0.19	8.53	196652.03	77.47	71.23	17.07	2.39	3.99	41.33	2.10	162.60	39.25	0.07
XCA-057	3007.89	1126.58	0.39	10.90	198017.34	67.69	77.19	15.43	2.14	2.17	31.40	2.68	123.88	40.36	0.07
XCA-058	2929.43	1071.88	0.34	6.86	187862.20	46.74	89.44	13.95	2.06	1.41	59.15	1.57	144.96	38.60	0.05
XCA-059	2703.10	1076.73	0.61	10.85	192153.97	75.07	71.05	14.35	2.27	1.66	46.05	2.07	18.50	46.88	0.87
XCA-060	2550.55	942.88	2.36	21.86	190295.56	87.30	72.81	14.37	2.42	2.84	54.38	2.11	192.91	41.59	0.17
XCA-061	638.19	790.30	0.13	6.57	176657.44	46.06	21.99	16.49	3.74	1.12	24.12	0.79	145.71	10.04	0.03
XCA-062	612.45	611.24	0.43	2.94	180375.46	39.29	22.05	9.52	2.58	1.17	30.29	0.61	117.31	24.90	0.18
XCA-063	655.62	1235.38	0.14	1.31	184403.67	17.34	21.42	8.81	2.26	1.24	22.33	0.37	240.16	35.70	0.04
XCA-064	472.35	666.14	1.50	0.63	185697.87	73.29	14.85	7.56	2.04	5.08	22.70	0.31	22.95	52.76	0.20
XCA-065	583.61	901.34	0.30	0.30	187850.22	43.73	34.50	6.87	2.30	1.72	12.41	0.18	147.87	62.26	0.15
XCA-066	616.11	889.61	0.52	0.14	192126.41	50.68	30.24	7.58	1.91	2.00	18.99	0.51	211.47	50.04	0.23
XCA-067	1274.72	595.29	0.07	40.41	194033.18	110.73	23.68	15.68	1.68	1.60	44.61	0.68	238.54	65.32	0.05
XCA-068	1194.93	704.96	0.25	26.86	187392.61	91.34	26.63	13.11	1.61	3.95	27.66	0.67	137.97	70.68	0.04
XCA-106	106.84	765.71	0.68	18.68	214788.65	52.75	5.54	7.96	8.72	1.98	59.20	1.78	59.01	73.35	0.02
XCA-107	96.51	765.01	1.21	20.42	208817.64	43.96	4.35	7.00	5.17	1.03	38.50	1.05	79.16	71.28	0.06
XCA-108	150.08	960.54	0.35	20.87	220683.04	44.94	6.45	9.80	5.72	1.40	46.17	1.49	6.86	53.47	0.07
XCA-109	143.83	761.95	1.32	31.72	225701.77	66.88	6.76	11.91	6.75	4.72	71.47	1.83	141.92	78.74	0.09
XCA-110	128.04	4720.09	1.61	20.77	183497.28	39.52	2.49	7.99	0.64	4.69	6.53	0.15	3451.41	309.34	10.45
XCA-111	169.62	1098.50	0.25	17.01	215976.50	35.15	6.44	7.66	4.89	1.37	62.48	1.16	126.59	99.25	0.14
XCA-112	163.90	728.01	0.93	21.26	220223.86	58.54	7.07	10.19	7.15	2.08	43.43	1.94	133.01	99.95	0.06
XCA-113	287.25	847.59	19.96	66.29	247365.30	59.77	13.34	16.47	16.56	4.15	112.49	3.99	83.22	105.60	0.21
XCA-114	243.35	777.99	2.49	58.21	216156.36	73.84	8.66	11.31	7.24	2.27	96.52	2.16	106.99	82.01	0.12
XCA-115	240.42	979.13	1.96	16.11	211765.52	80.50	7.47	8.18	5.64	3.50	54.90	1.45	188.52	95.63	0.07
XCA-116	219.76	895.89	1.48	17.85	216715.67	82.84	6.99	11.03	4.83	2.75	37.69	1.34	104.10	75.15	0.08
XCA-117	205.52	691.22	0.98	13.01	213028.73	92.27	4.14	9.22	4.69	2.69	47.14	1.15	86.17	79.43	0.03
XCA-118	192.04	557.78	1.13	40.21	194907.02	99.09	31.80	14.78	1.28	136.87	25.97	2.35	152.43	45.16	0.29
XCA-119	368.88	1342.05	0.37	33.05	208944.13	20.37	43.32	15.86	0.70	2.63	25.60	2.67	24.83	32.05	0.12
XCA-120	269.04	813.49	2.74	48.99	214899.60	69.86	31.40	13.25	0.61	2.15	37.80	2.83	110.77	42.79	0.09
XCA-120	200.80	816.67	1.40	31.26	201115.97	74.69	36.31	14.92	0.89	2.41	37.78	3.49	176.01	42.99	0.07
XCA-121	244.47	1965.44	12.37	77.32	212236.16	36.16	55.41	15.33	0.67	1.93	29.18	2.73	218.30	37.76	0.75
XCA-122	219.92	783.05	1.66	31.15	214297.44	68.19	30.98	13.25	0.71	76.52	42.49	4.32	130.81	53.93	0.18
XCA-123	240.89	721.14	0.36	32.31	227344.62	57.39	33.16	13.35	0.95	2.47	44.77	4.53	112.11	54.96	0.04
XCA-124	289.63	1206.05	0.93	34.49	236419.37	21.34	38.32	11.47	0.46	1.30	42.82	3.95	80.85	63.26	0.05
XCA-125	307.95	748.63	0.74	44.47	214801.28	58.22	29.84	13.98	0.59	8.60	45.35	4.10	117.81	58.15	0.04
XCA-126	270.30	1037.81	0.49	30.84	206835.05	42.49	34.54	12.38	0.62	1.31	39.13	3.50	116.79	72.86	0.09
XCA-127	255.44	922.85	0.13	13.11	207706.48	48.22	36.80	11.60	0.71	1.09	41.79	3.32	85.42	65.42	0.05
XCA-128	494.87	938.95	0.34	9.62	199948.24	45.21	136.35	6.00	0.84	2.06	29.82	2.08	295.45	56.03	0.13
XCA-129	442.72	1052.44	3.02	26.45	204533.34	41.45	104.14	4.72	0.50	1.41	32.50	1.43	97.58	65.40	0.07
XCA-130	515.87	976.08	0.35	11.14	193144.48	87.43	133.41	5.50	0.38	1.52	31.68	2.05	139.12	49.97	0.06
XCA-131	506.65	969.27	0.38	13.48	193296.86	98.82	132.82	5.78	0.48	1.17	28.43	2.11	152.05	43.03	0.05
XCA-132	505.03	943.33	1.01	16.04	204746.26	87.66	162.54	5.22	0.81	1.51	33.17	2.31	151.51	59.06	0.15
XCA-133	395.54	1249.15	1.98	30.34	227323.52	59.92	99.29	4.75	0.69	2.40	43.17	1.72	301.72	56.24	0.91
XCA-134	427.47	869.78	0.50	21.02	218119.58	62.09	92.81	4.68	0.73	2.99	34.85	2.20	7.42	41.10	0.17
XCA-135	381.31	685.49	1.03	95.76	217645.20	80.37	131.92	4.79	0.98	3.07	37.05	2.44	151.86	52.77	0.08
Mean	**759.02**	**1005.43**	**2.33**	**38.77**	**201227.59**	**64.86**	**36.59**	**12.23**	**4.50**	**5.65**	**38.85**	**1.74**	**180.27**	**60.14**	**0.33**
S.D.	**765.31**	**478.45**	**4.04**	**77.07**	**12963.78**	**28.30**	**34.36**	**4.01**	**4.51**	**15.64**	**15.29**	**1.10**	**341.19**	**36.51**	**1.07**

The subadult samples consist of six individuals (first molars) from the site of Calakmul (CLK), 15 individuals from Campeche (PPP – Proyecto Parque Principal) and 24 individuals from Xcambó (XC). While the Classic period samples are also represented by adult individuals in order to detect the presence of potential foreigners, the Campeche sample was selected only for subadults. This was due to the fact that Campeche, during the early colonial times, was inhabited by a very dynamic, multiethnic population, which would have drastically increased the inner variability of the adult segment of the residents. As regards the two adult samples, 13 individuals came from Calakmul (CLKA where A stands for Adult) and 99 individuals from Xcambó (XCA) (Table 1).

Every tooth was vertically sectioned to expose the inner portion of the enamel cup. This way, the laser scanning could avoid the most external layers of the enamel that can, at least partially, be affected by diagenesis. Fifty-six elements have been recorded using LA-ICP-MS, starting from sodium (Na) up to Uranium (U). Lighter elements (whose atomic weight is less than 23) cannot be detected by the mass spectrometer.

The glass butte standards were ablated at the beginning and end of every batch of four to five teeth. Although time-consuming, this approach did permit to limit the error introduced by the equipment's normal fluctuations during the day and therefore calculate intensities (and from there concentrations) that were as close as possible to reality.

Results

Individual concentrations are listed in Table 1. All data are normalized to 398,936 ppm that represents the Calcium content (Calcium not shown in Table 1). In the case of the adult individual n. 2 from Calakmul, and n 55 from Xcambó, as well as subadult 12 from Xcambó, almost all the trace elements values fell outside the range of variability encountered at the site, as well as at the other sites analyzed from the region. Even though it could be indicative that these specific individuals were foreigners coming from some unscanned, undetected area, I rather believe that the chemical evidence is more likely suggesting diagenetic changes that occurred to the elemental composition. Therefore, these individuals were removed from the analyses.

The majority of the elements is below detection level or is present with less than 1 ppm. This reduces to 15 the actual number of elements that could be used in this analysis. Also Iron (Fe) was removed from the pool of analyzable elements because we noted that its output was quite unstable through time. As we can appreciate from Table 1, Barium (Ba) was not removed because it shows high values in the Calakmul sample, in contrast to the others for which it does not reach the unit, meaning that it can be discriminative of the Calakmul area. Table 1 also shows the averages and standard deviations of the absolute values for each of the 15 elements divided by site and sorted according to subadult or adult age.

An initial Principal Component Analysis was run on the subadults sample only. Table 2 lists the eigenvalues and the variance explained by the non-rotated and rotated components. According to the sedimentation graphic (not shown), the three first components are those that better explain the distribution of the samples. The three components explain the 60.7% of the variance (56.7% for the rotated components).

Table 2. Eigenvalues, Principal Component Analysis, infant sample

Component	Initial eigenvalues			Eigenvalues from the rotated matrix		
	Total	% variance	% combined variance	Total	% variance	% combined variance
1	4.339	28.928	28.928	3.836	25.576	25.576
2	2.912	19.411	48.339	2.729	18.194	43.770
3	1.855	12.368	60.707	1.945	12.967	56.737
4	1.305	8.699	69.406	1.823	12.153	68.890
5	1.300	8.667	78.074	1.378	9.184	78.074
6	.809	5.390	83.464			
7	.761	5.071	88.535			
8	.437	2.913	91.448			
9	.382	2.548	93.996			
10	.270	1.803	95.799			
11	.251	1.670	97.469			
12	.157	1.047	98.516			
13	.096	.637	99.154			
14	.080	.535	99.688			
15	.047	.312	100.000			

The elements' contribution for each component is listed in Table 3. Barium (Ba), Zinc (Zn) and Potassium (K) are the elements that weight most in the first component (values are in bold), that explain the 28.9% (25.5 rotated) of the total variance. The second component (19.4% - 18.2% rotated) is characterized mainly by Selenium (Se) and Iodine (I) (bold values), while the third component's weight is mainly due to Manganese (Mg) and Bromine (Br). The plot from the first and second components (Figure 4 and Figure 5) discriminates Calakmul' subadults (at the right end of the positive axis) from the other two samples that, on the contrary, show the same level of variability along the first component. This is due to the higher concentration of Ba, Zn and K in Calakmul. In turn, the second component (Figure 4 and Figure 6) tends to discriminate Xcambó, whose individuals are spread mainly along the positive, upper side of the axis, against Campeche and Calakmul, both along the negative side of the component. In this case, Se and I are responsible for such distribution. Finally, the third component (vertical –Y- axis in Figure 5 and Figure 6) discriminates Xcambó (positive side) from Campeche and Calakmul (negative side).

Table 3. Matrix of rotated components, Varimax rotation, infant samples

	Components				
	1	2	3	4	5
Na	.703	.014	.402	-.053	.456
Mg25	-.152	.356	**.753**	.030	.131
Al	.158	.158	.040	.921	-.027
Si	.560	-.246	.119	.688	.120
P	-.294	.773	.018	-.078	.106
Cl	-.219	.300	-.026	-.114	.729
K	**.813**	-.265	-.161	.126	.072
Ti	.334	-.386	-.038	.373	.654
Ni	-.161	.588	.278	.381	-.124
Zn66	**.878**	.053	-.086	.193	-.110
Br	.188	.332	**-.717**	-.170	.213
Se	.426	**.741**	-.164	-.244	-.126
Sr88	.513	.290	.697	-.027	.045
I	-.122	**.703**	.240	.192	.235
Ba	**.885**	-.156	-.048	.122	-.123

As Figure 6 shows, there is some overlapping in the distribution of every sample along both components, tough Calakmul and Campeche are more evenly overlapping than Xcambó that tends to gather away.

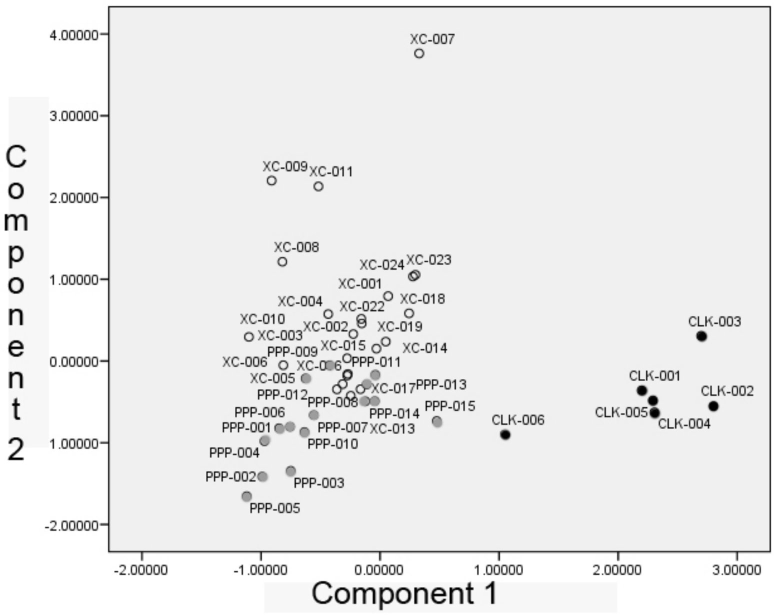

Figure 4. Principal Component Analysis: plot of the first and second components for the subadult samples only.

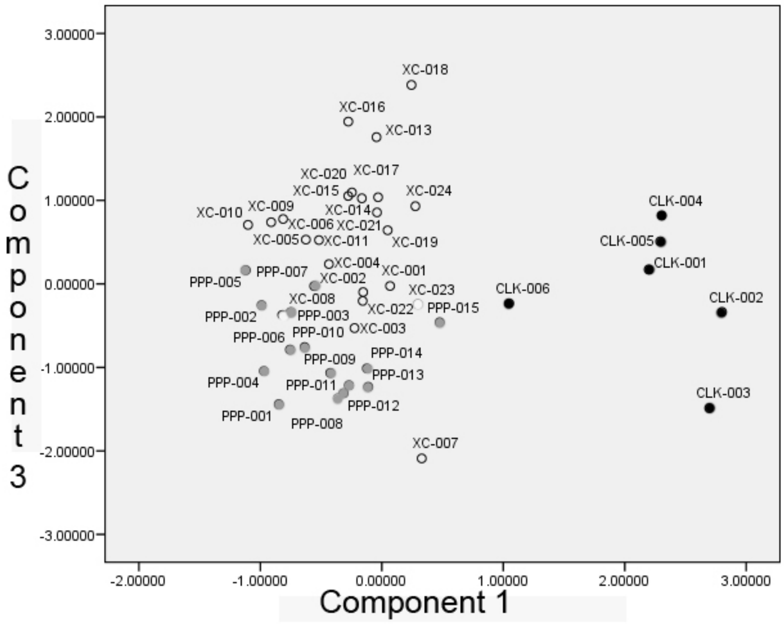

Figure 5. Principal Component Analysis: plot of the first and third components for the subadult samples only.

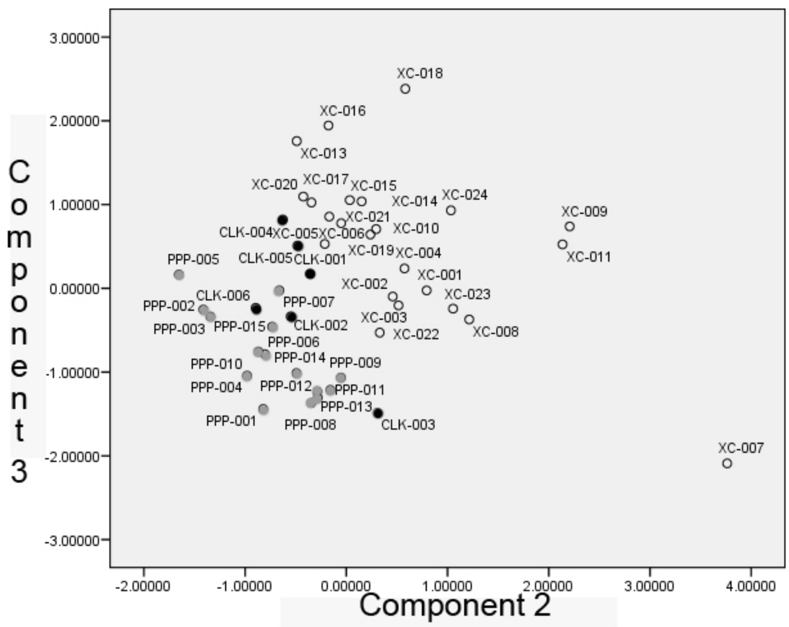

Figure 6. Principal Component Analysis: plot of the second and third components for the subadult samples only.

As regards the adult segment of the populations, the analysis has been addressed to the individuals from Xcambó and Calakmul. The two Calakmul sub-samples (subadults and adults) show a pattern of distribution, along the first component of the PCA plot, in which only one adult (CLKA-012) clearly separates from the rest of the population (Figure 7). This individual is characterized by a higher level of Al, Si and Ba, which discriminate the first component (Table 4). The adult individual labeled CLKA-011 has the highest values of Ba, way much higher than the subadults and much higher than individual 012. While the former is not discriminated and falls together with all the other individuals in the plot formed by the first and second component, he stands out of the group in the first and third component plot (Figure 8). This specimen is actually discriminated by his high concentration of Sr that characterizes the third component (as also visible in Figure 8 and Figure 9).

Table 4. Matrix of rotated components, Varimax rotation, Calakmul samples

	Components				
	1	2	3	4	5
Na	.003	-.349	.243	-.805	-.065
Mg25	.504	**-.749**	.098	-.310	.034
Al	**.931**	.237	-.011	.085	.025
Si	**.960**	.097	-.114	.033	-.022
P	.171	.180	**-.823**	.168	.386
Cl	-.284	-.440	.415	-.067	.671
K	.249	-.565	.630	-.326	.187
Ti	-.005	-.060	-.268	.070	.902
Ni	.392	.675	-.089	.278	.459
Zn66	.098	.033	.493	.686	.355
Br	.094	.029	.043	.741	-.047
Se	.158	.752	-.242	.336	-.161
Sr88	.093	-.010	**.937**	.145	-.006
I	.375	**.830**	.083	-.238	-.165
Ba	**.762**	-.111	.502	.169	-.123

Furthermore, what calls the attention in the distribution of the Calakmul sample in the plot is that, despite the individuals are fairly homogeneous along the first and third components, that explains respectively the 29.9% and 15.1% of variance (20.9% and 18.9% rotated respectively) (Table 5), the subadults are somehow separated from the adults along the second component (22.3% variance, 20.1% rotated) (Figure 7 and Figure 8). The elements that discriminate this component (Table 4) are Mg and I (Iodine). The first element is present in higher concentration in the adults while Iodine is higher in the subadults.

Table 5. Eigenvalues, Principal Component Analysis, Calakmul sample

Component	Initial eigenvalues			Eigenvalues from the rotated matrix		
	Total	% variance	% combined variance	Total	% variance	% combined variance
1	4.484	29.895	29.895	3.140	20.935	20.935
2	3.354	22.357	52.252	3.023	20.153	41.088
3	2.274	15.162	67.415	2.847	18.979	60.067
4	1.965	13.102	80.517	2.212	14.746	74.813
5	1.006	6.709	87.226	1.862	12.413	87.226
6	.746	4.977	92.202			
7	.414	2.759	94.962			
8	.274	1.830	96.791			
9	.179	1.193	97.984			
10	.155	1.032	99.017			
11	.075	.501	99.518			
12	.041	.276	99.794			
13	.020	.131	99.925			
14	.009	.063	99.988			
15	.002	.012	100.000			

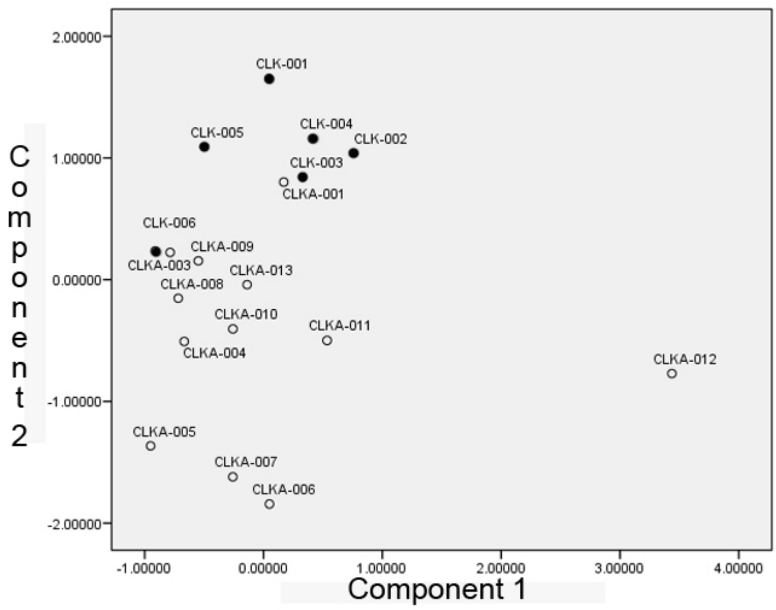

Figure 7. Principal Component Analysis: plot of the first and second components for the Calakmul samples (adults and subadults).

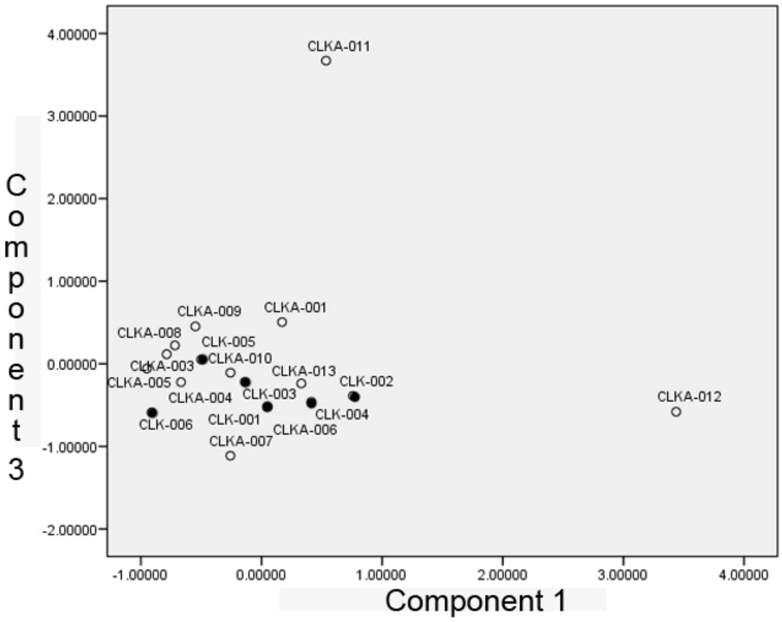

Figure 8. Principal Component Analysis: plot of the first and third components for the Calakmul samples (adults and subadults).

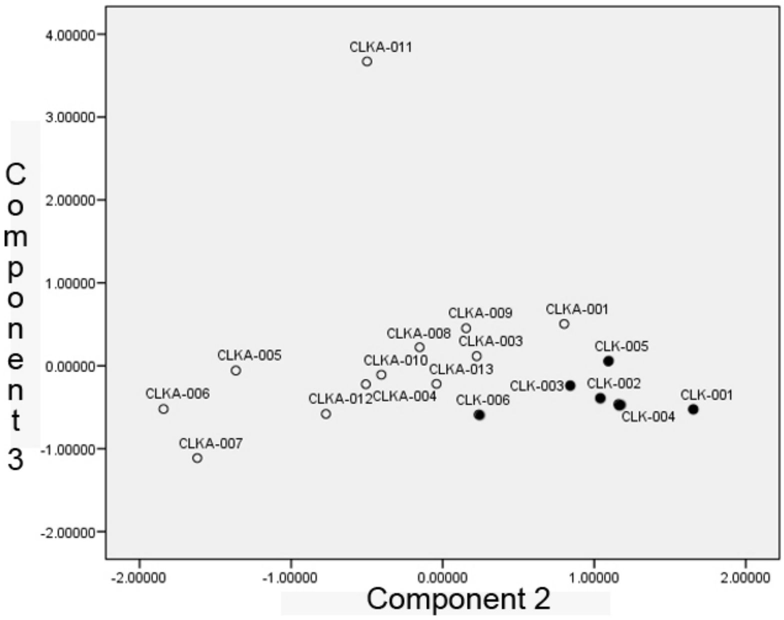

Figure 9. Principal Component Analysis: plot of the second and third components for the Calakmul samples (adults and subadults).

The Xcambó sample shows similar results as Calakmul. The principal component analysis indicates that the first six components are the most explicative of the individuals' distribution (Table 6).

Table 6. Matrix of rotated components, Varimax rotation, Xcambó samples

	Components					
	1	2	3	4	5	6
Na	-.015	**.827**	.022	-.041	.126	-.222
Mg25	**.887**	.190	.048	-.059	-.248	-.058
Al	.042	-.099	**.832**	.004	-.067	-.081
Si	.067	.083	.670	.105	.162	.311
P	.032	-.488	.174	.635	-.107	-.167
Cl	-.106	.236	-.056	-.062	.866	.074
K	-.040	.617	-.322	.054	.093	-.001
Ti	.032	.629	.551	.067	.082	.169
Ni	-.027	-.385	.636	.070	-.225	-.192
Zn66	-.025	-.092	.037	.029	.049	.911
Br	-.191	.125	.055	.692	.282	-.070
Se	-.056	.040	-.010	.828	-.313	.268
Sr88	**.961**	-.039	-.056	-.127	.022	.014
I	.643	-.416	.297	.275	.332	-.068
Ba	**.961**	-.085	.041	-.109	-.032	.031

In particular, the first three ones explain overall the 52.5% (49.0% rotated) of the total variability. The elements that discriminate the first component are Mg, Sr and Ba, the second component is mainly represented by Na and the third by Al (Table 7). The bidimensional plot distribution along the first and second components (Figure 10) shows one adult individual (labeled XCA-110) that clearly diverges from all the others along the first component. The individual elemental concentration is in fact particularly high in Barium, Strontium and Manganese. The remaining elements are not separating him from the rest of the sample (as the distribution along the second and third components indicates – see Figure 11 and Figure 12). If it were not for this individual, the first component shows a relatively narrow range of variability.

Table 7. Matrix of rotated components, Varimax rotation, all the samples

	Components					
	1	2	3	4	5	6
Na	**.700**	.055	.127	.067	.348	-.357
Mg25	.090	**.845**	.013	-.048	-.048	-.178
Al	-.160	.005	**.845**	-.037	-.177	-.035
Si	.073	.072	**.797**	.064	-.014	.216
P	-.647	.051	.012	.495	-.113	-.108
Cl	.024	-.014	-.128	-.004	.854	.131
K	**.814**	.126	.106	.061	-.118	.062
Ti	.330	-.057	.551	.066	.411	-.125
Ni	-.570	.061	.381	.100	-.112	-.161
Zn66	.061	-.025	.104	.085	.101	.878
Br	-.019	-.136	.053	.710	.256	-.037
Se	-.033	-.008	.004	.864	-.194	.158
Sr88	.116	**.906**	-.023	-.149	-.059	.123
I	-.534	.658	.195	.142	.156	.056
Ba	.500	.354	.412	-.034	-.356	.233

The second component, instead, shows a wide range of variability, even though the distribution is homogeneous and no specific individual sets aside (Figure 10 and Figure 12). Finally, the third component reveals that three (or four) individuals separate from the rest of the sample because of their higher concentration of Al. Nonetheless, two of them are subadults (XC-013 and XC-009. They concentration of Al (and Si for individual XC-013) is significantly higher than in the others, which may indicate either that they were not born at Xcambó but likely migrated in when still young.

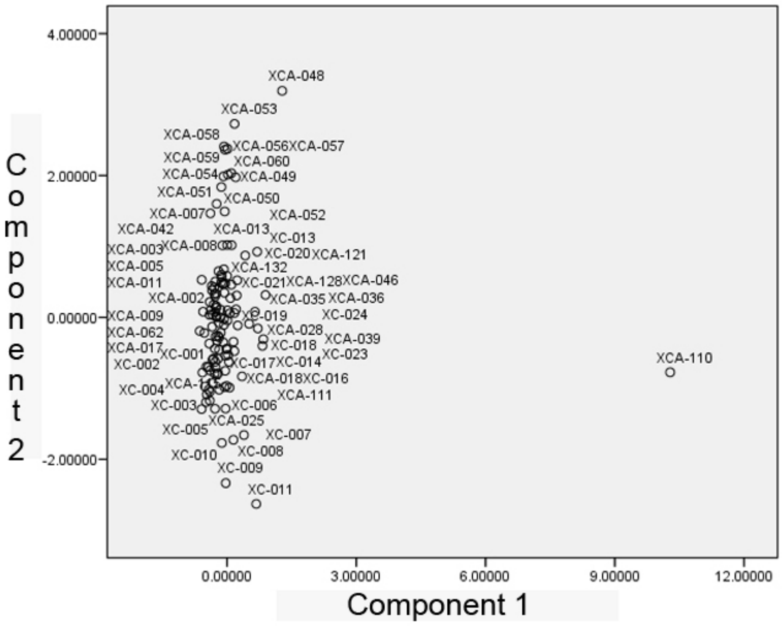

Figure 10. Principal Component Analysis: plot of the first and second components for the Xcambó samples (adults and subadults).

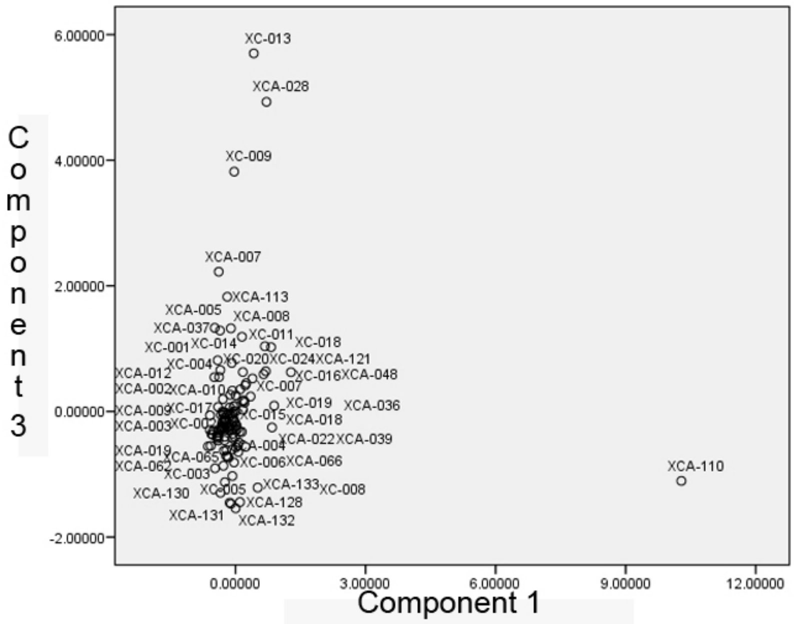

Figure 11. Principal Component Analysis: plot of the first and third components for the Xcambó samples (adults and subadults).

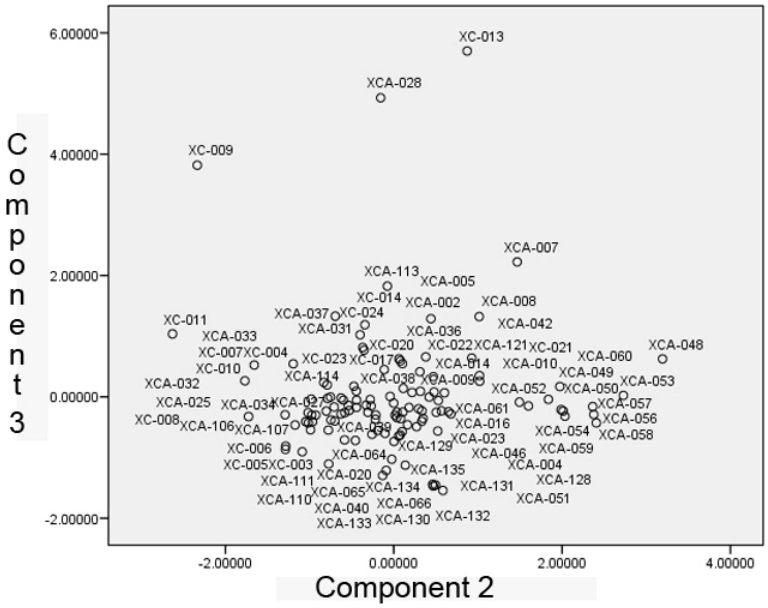

Figure 12. Principal Component Analysis: plot of the second and third components for the Xcambó samples (adults and subadults).

We can exclude that their high values are just reflecting a wide range of variability (see Table 1) because in particular XC-013 is a clear outlier for these two elements. This implies that also adult individual XCA-028 is very likely from another area, not because of his concentration of Al, rather for his outlying value of Si (Table 1).

When we compute all the samples together along the first and second components (Figure 13 and Figure 15), we can appreciate a very wide variability along the first component, in which Calakmul occupies the right, positive end, while Xcambó and Campeche tend to overlap, even though Campeche is set on the negative side of the second component. What stands out is the fact that the adult individual CLKA-011 from Calakmul and the adult individual XCA-110 from Xcambó separate along the second component, which is characterized mainly by Strontium and Manganese (Table 7). Interestingly, none of them tends to get closer to any of their non-original samples (as for example Campeche), which indicates that they might have immigrated from some other area that has not been screened in this analysis. The third component (Figure 14 and Figure 15) shows that adult individual CLKA-012, adult XCA-028 and subadult XC-013 are all characterized by high values of Al and Si (in particular Si) that weight most in the third component (Table 7).

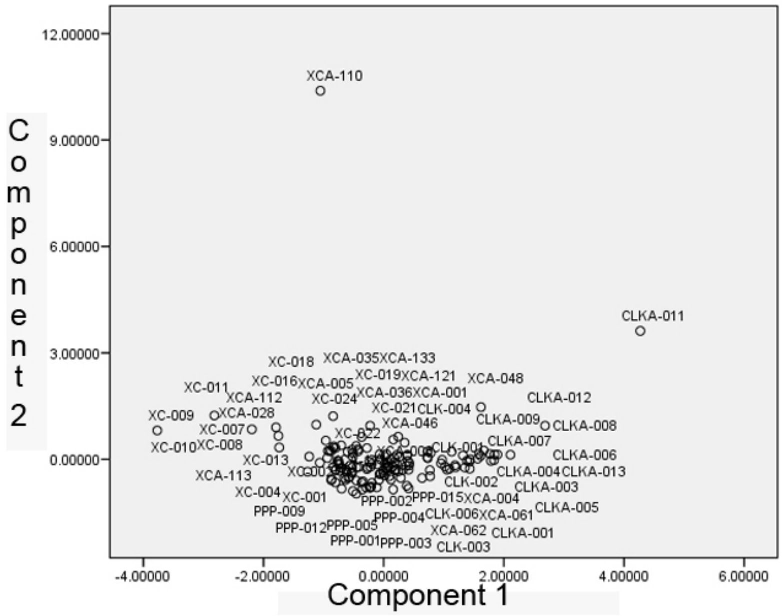

Figure 13. Principal Component Analysis: plot of the first and second components for all the samples together (adults and subadults).

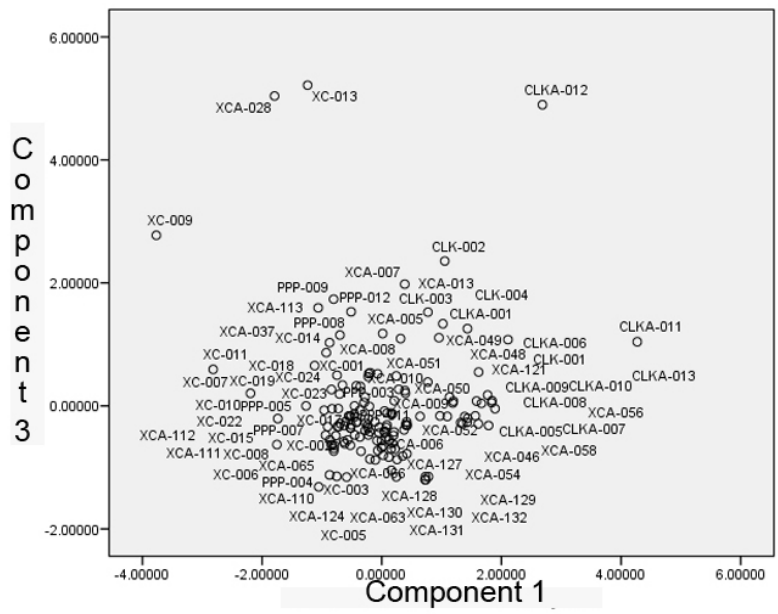

Figure 14. Principal Component Analysis: plot of the first and third components for all the samples together (adults and subadults).

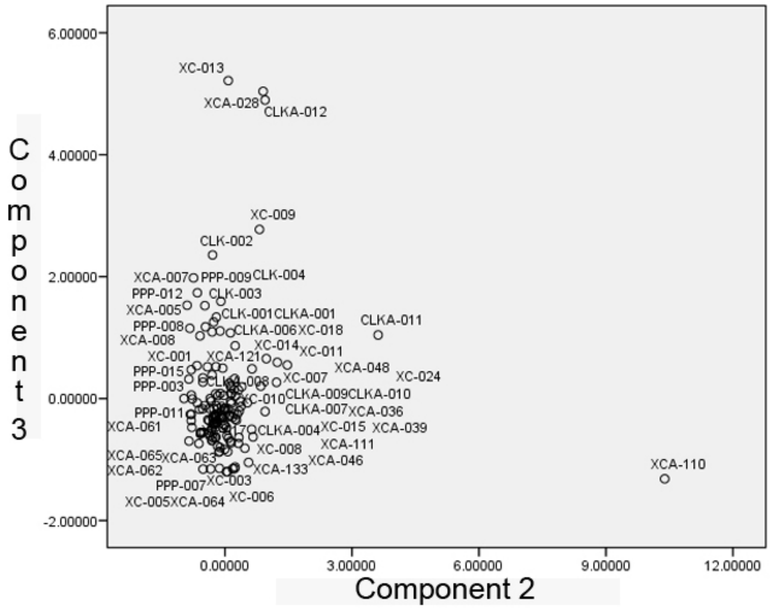

Figure 15. Principal Component Analysis: plot of the second and third components for all the samples together (adults and subadults).

Discussion

Laser ablation-inductively coupled plasma – mass spectrometry (LA-ICP-MS) is a very useful analytical technique in the analysis of trace element composition in archaeological materials. During the last decade of the 20th century, it reached prominent position in the field of research in material science (Speakman and Neff 2005:1). The technique has the ability to target very small specific areas, a useful tool in the analysis of temporal variation in the elemental composition of human teeth (Cox et al. 1996; Budd et al. 1998; Lee et al. 1999; Lochner et al. 1999; Dolphin et al. 2005). Kang et al. (2004) report the different level of intensity of metal trace element throughout the enamel and dentine surface of vertically sectioned teeth. They found high levels of lead in the dentine and pulp areas, but very low in the enamel area. This is consistent with the results obtained in the present analysis; due to the fact that this analysis targeted the hidden enamel (Hillson, 1996) lead was not detected at high concentrations and therefore is not part of the fifteen elements analyzed.

The elemental patterns encountered in this analysis permit to discriminate only few individuals that tend to set away from the rest of their group. Interestingly, none of them falls within the range of variability of the three sites, which may indicate that they migrated from other regions in the Maya realm. At Calakmul, for example, the two adult individuals (011 and 012) come from structure II, (e2c-2c; e2-1). While individual 012 does not show any particular evidence that might be informative of his local or foreign origin, individual 011 comes from a problematical, sacrificial context. The provenance of sacrificial victims is very variable, but as Cucina and Tiesler (2007) mention, they might come from other parts of the region either as captives or individuals kidnapped during raids.

On the other hand, like for individual e2-1 from Calakmul, also Xcambó individuals 028 and 110 do not present particular evidence that permits to infer on their local or foreign origin, like for example the association with foreign, imported ceramics. In fact Sierra (1999) detected and reported the presence of ceramic artifacts that came from areas as far as Veracruz and Belize, none of which has been monitored in this analysis. Sr isotope analyses performed on some individuals at the site (028 and 110 were not among them) revealed the presence of foreign individuals (unfortunately, Sr isotope analysis is destructive) (Tiesler, personal communication 2007). Even though the two individuals do not associate with non-local elements, we cannot exclude that they might have migrated into the site some time during their life.

Among the fifteen elements used in this analysis, Barium, Potassium and Zinc seem to represent the ones that mostly discriminate Calakmul infants from the subadult of the other samples. Interestingly, only some of the fifteen elements analyzed discriminated individuals or groups (as for example Ba, Zn, Mg, I, Sr). Strontium and Barium have been used as potential indicators of geographical origins (Burton et al. 2003); the authors argument that, depending upon the kind of hydrogeological environment, geographical differences between or among areas can overcome intra-site local variability. In our cases, Xcambó and Campeche are coastal populations from northern Yucatán, while Calakmul is an inland site in the southern Mexican Petén close to the Guatemala border, and this could explain the fact that Barium discriminates (along with Potassium and Zinc) the latter site from the two others.

Even though almost all these elements are linked to dietary intake (Gilbert, 1985; Mertz, 1985; Molleson, 1988; Ezzo, 1994; Ezzo et al., 1995; Sandford and Weaver, 2000), I feel confident that in the case of subadults they are more likely reflecting the environment rather than diet. In fact, Goodman and colleagues (2004) reported that they could distinguish, within the New York African Burial Ground cemetery in New York, those individuals who were born in the African from those born locally.

Variation of one single element is not strong enough to permit assess the local versus foreign origin of individuals. Those adults or subadults that stood out of the group are distinguished by two or more elements, contrary to stable isotope analyses. In some context one specific element may discriminate (see Barium in the case of Calakmul), nonetheless every group is defined by its whole set of elemental concentrations.

It must be underlined, for the sake of truth, that trace elements are under the influence of a set of variables that may have little to do with the place of origin (diet, diagenesis, individual biopurification), which makes them at present less reliable than stable isotopes. Nonetheless, the fact that trace elements can be analyzed using a non-destructive (LA-ICP-MS) technique permits to repeat the analysis limitlessly on the same sample, which can be a benefit in case of future technological improvements of laser ablation techniques.

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