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THE SEIS LAGOS CARBONATITE COMPLEX

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ABSTRACT

This paper describes the Seis Lagos Carbonatite Complex located about 840 km from Manaus, on the northwestern part of the Estado do Amazonas, Brazil.* Geological reconnaissance mapping by Radam Project/DNPM, of the southwestern portion of the Guianês Cráton, determined three circular features arranged in a north-south trend and outcroping as thick lateritic radioactive hills surrounded by gneisses and migmatites of the peneplained Guianense Complex.

The complex was submited to deep weathering under lateritic conditions, having been completely covered by a residual capping, where iron and manganese ores, associated with limonitic ochres and pisolithic laterites, are conspicuously present.

The surface mantle of laterite, capping the iron carbonate and alkalic rocks underneath, shows radioactive anomalies of 3.000 to 15.000 cps. Chemical analyses of samples of these laterites, showed 1.3 to 3.4% Nb_2O_5 and 1.0 to 2.1% Ce.

Four holes were drilled to evaluate the economic potential for the unweathered carbonates beneath the lateritic mantle. The chemical data of certain intervals of the lithologic profiles showed significant anomalies in zinc, copper, niobium and cerium. Petrographic studies of core samples, and other analytical methods, revealed the presence of siderite, goethite, pyrite, phosphate of the gorceixite (?) group, and rutile (niobiferous ?).

Results of core drilling samples analysis of the Seis Lagos Carbonatite Complex are compared with some igneous rocks and limestones of the world on the basis of abundance of their minor and trace elements.

Log-log variation diagram of strontium and barium in carbonatite and limestone, exemplifield by South Africa and Angola carbonatites, are compared with the Seis Lagos Carbonatite Complex.

The Seis Lagos Carbonatite Complex belongs to the siderite-sövite type. (E.G).

INTRODUCTION

The Seis Lagos Carbonatite Complex is located in the northwestern portion of the State of Amazonas, Sheet NA.19-Z-D, Pico da Neblina. (Figures 1 and 2). It is composed by three circular structures with approximate diameters of 5.5, 0.75 and 0.50 kilometers arranged in a north-south trend, and emerging as thick lateritic radioactive hills on the left margin of the Iazinho creek.

The largest structure extends for 5.5 kilometers and has a width of 4.5 kilometers, being located at 00°17'10"N latitude and 66°40'51"WGr, longitude, 64 kilometers from the village of São Gabriel da Cachoeira (Uaupés).

Geomorphically it forms an anomalous elevation circular in shape. The country rock consists of gneisses and migmatites of the peneplained Guianense Complex. The

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thick mantle of lateritic capping, with altitudes ranging from 300 to 400 meters , constitutes the positive relief and reveals radioactive anomalies of 3.000 to 15.000 cps, whilst gammaspectrometer data indicate U/Th relations in the order of 1:2 to 1:4.

The lateritic capping which covers the plug possesses a series of lakes,namely, Corredor, Jussara, Dragão, Pata, Malaquita I and Malaquita II, as well as dryness sinkings, at different levels, with underground colapses.

An unusual feature of the Seis Lagos a Carbonatite Complex is the thermal spring with water temperature of 41°C and an out-flow of 1657 liters/hour located 1.270 meters westward from the Dragão Lake.

The Seis Lagos Carbonatite Complex was recognized, in 1975, by geologists of the Radam Project/DNPM through reconnaissance mapping of the area in the northwestern portion of the Guianês Craton. Issler (1975, internal report) named the Uaupés radioactive hills of Uaupés Carbonatite. Later, NUCLEBRÁS geologists (Hassano, Biondi and Javaroni, 1975), presented a series of suggestions and recomendations , and Moraes (1975), visiting the carbonatitic diatreme of Seis Lagos, reported it to be the radioactivity product of a thorium anomaly. Saad (1975) also visited the area and his observations are contained in an internal report of Montreal Engenharia. Issler (1975), at the X Inter-Guyana Geological Conference, presented a brief report on the Seis Lagos Carbonatite.

LATERITES

Similar to other carbonatitic complexes of the world described by Heinrich (1966), Tuttle and Gittins (1966) and Verwoerd (1966), the Seis Lagos Carbonatite underwent deep weathering under lateritical conditions, having been completely covered by a residual capping where manganesiferous and limonitic ochres and pisolitic laterites are conspicuously present. The depth of the alteration is of aproximately 230 meters, but the contact between laterite and carbonate at subsurface must have a very irregular pattern.

Chemical analysis of samples of surface laterites and manganese ore are shown in Table I, whereas the analysis of trace elements are in Table II.

RADIOACTIVITY

Preliminary traverses taken from the heliport, on the western margin of the Dragão Lake, presented pisolitic and breccia-like laterites with significant radioactive anomalies of 3.000 to 15.000 cps, while the gamaspectrometer showed U/Th ratios varyng between 1:2 and 1:4.

Adopting Verwoerd's (1966) criteria, scintilometric and altimetric profiles were constructed, using traverses performed by the Radam Project/DNPM geologists , as shown in Figure 3.

DRILLINGS

During 1975, using the basic geological data from the Radam Project/DNPM, the Departamento Nacional da Produção Mineral, through the Divisão de Geologia e Mineralogia (DGM) elaborated the Seis Lagos Project which included the drilling of 1.000 meters of drill-holes with the objective of evaluating the economic potential of the unweathered carbonates beneath the lateritic mantle. This drilling program was carried out by Companhia de Pesquisa de Recursos Minerais (CPRM).

Four drill-holes were drilled, for a total of 1.083 meters:1-SG-01-AM(255m) , 1-SG-02-AM (231m), 1-SG-03-AM (110m) and 1-SG-04-AM (493m).

The lithologic profiles of the four drill-holes are much complicated due to the diversity of the rock matter contained in the lateritic mantle and of the sedimentary-like rocks,as well as the felsic rocks (fenites ?); iron carbonate and barite were also found.

Geochemical analysis of samples from certain intervals of the four holes showed anomalies in zinc, copper,niobium and cerium. Radiometric data, although scanty, show that certain intervals of the lithologic profiles are more radioactive than others.

PETROGRAPHY

Core samples AM-04 (238.90-242m), AM-05 (238.90-242m) and AM-06 (292.00-295m) from drill-hole 1-SG-04-AM were submitted to petrographic studies and other more sophisticated analytical methods at the Seção de Análise da Divisão de Geologia (DIGEO), Projeto Radam, Belém, and Laboratório Central de Análises Minerais (LAMIN), Companhia de Pesquisa de Recursos Minerais (CPRM), Rio de Janeiro. The results are shown in Table III.

DISCUSSION OF THE RESULTS

All of the five mineral species identified in core samples of the Seis Lagos Carbonatite Complex are common in other carbonatite occurrences of the world, as follows:

- Siderite: according to Heinrich (1966), ..."siderite has been reported in about half a dozen carbonatites (e.g., at Mountain Pass, Mbeya, Kalkfeld); it probably existed at one time in others but was destroyed during the deuteric stage of the carbonatite consolidation. In the Mbeya, Tanganyika carbonatite, large metacrystals of siderite that replaced sövite were converted to aggregates of hematite and quartz (James and McKie, 1958). Several of the African carbonatites contain local coarse phases of a dark-brown to black, microscopically dark or opaque, carbonate usually identified megascopicaly as siderite. Analyses, however, usually show this material to be mainly a manganiferous ankerite that has been secondarilly enriched in Fe and Mn oxides. In some carbonatites, calcite choked with minute hematite inclusions also give rise, upon weathering, to rocks of "sideritic" aspects".

Verwoerd (1966) says that ..."carbonatite of the siderite-magnesite series has not yet been found, but Garson and Smith (1958) and Garson (1962) describe carbonatite rich in siderite as sideritic carbonatite and as siderite-sövite".

- Goethite: this mineral has undoubtedly a supergene origin in carbonatites. Heinrich (1966) describes primary goethite in one of the Fen sövite bodies as clusters of small needles perched on the walls of vugs developed in very coarse-grained calcite.

- Pyrite: Heinrich (1966) comments that ..."pyrite is the most widely distributed sulphide (actually the only common one), and in some carbonatites it is unusually abundant. Von Eckermann (1948 A) describes a pyritic sövite with 37.9 per cent pyrite, 46.1 per cent calcite, and 16 per cent augite. Pyrite commonly forms disseminated euhedra but may also be included in mafic silicate species, such as diopside (Oka, Quebec). At Fen, Norway, some pyrite is rimmed by magnetite".

- Gorceixite: Heinrich (1966) relates that ..."gorceixite found at Mrima Hill, Kenya, is regarded as hypogene by McKie (1962) and as supergene by Coetzee and Edwards (1959)".

- Rutile: Heinrich (1966) says that ..."most, if not all, carbonatitic rutiles are niobian (ilmenorutile): Idaho, 13 per cent Nb (Heinrich et al., 1958); Magnet Cove, 1.3 to 2.2 per cent Nb (Ericksen and Blade, 1963)"

GEOCHEMICAL ASPECTS

The analytical results of drill core samples (AM-04, AM-05), AM-06), from drill-hole 1-SG-04-AM, are compared, using minor and trace element abundances (ppm) in carbonatites, with those in igneous rocks and limestones (after Pecora, 1956; Gold, 1963; and Heinrich, 1966; Stanton, 1972). Table IV.

LOG-LOG VARIATION DIAGRAM OF BARIUM VERSUS STRONTIUM

Both barium and strontium occur abundantly and variously in carbonatites and their associated rocks (i.e. Von Eckermann, 1952; Higazy, 1954; Pecora, 1956; Gold, 1963; and Bowden, 1962).

Verwoerd (1966), studying the trace elements in South African carbonatites, constructed a log-log variation diagram of Ba versus Sr. From his work it is noted that the carbonatites may be divided into:

a) high Sr group (Ondurakorume, Kalfeld, Okorusu, Goudini);
b) low Sr group (Tweerivier, Nooitgedacht, Derdepoort, Glenover, Spitskop, Loolekop, Chilwa, Shawa, Dorowa), with the dividing line at about 5.000 ppm of Sr.

This division probably has genetic significance because the high Sr group belongs to a single petrogenetic province (except Goudini) of which the unusually high Sr content is also reflected by corresponding metacarbonatites.

By calculating the averagesof the available analyses (Ba shows a general increase in the some direction), the group of Transvaal carbonatite can be arranged in the following series, with Sr contents in ascending order:

Tweerivier	Derdepoort	Nooitgedacht	Spitskop	Glenover	Loolekop	Goudini
620	850	1540	1600	2492	3722	9975ppm

According to Verwoerd (op.cit.) the metacarbonatites also fail into two groups:

a) those with Sr contents higher than 1000 ppm, which are fairly definitely related to carbonatite (Goudini, Kruidfonteir), and
b) those with Sr lower than 1.000ppm, whose relationship with carbonatites is doubtful (Kobe,Premier Mime, Garub).

In the modified Verwoerd's log-log variation diagram of Ba versus Sr (Figure 4), the Ba and Sr data of Angola carbonatites (cf.Lapido-Loureiro, 1973) was plotted, falling in the low Sr group of Verwoerd (op.cit).

The Seis Lagos Carbonatite Complex presents some problems, as follows:

a) The Sr contents is lower than 1.000ppm; therefore, its relationship with carbonatites is doubtful;
b) the Ba contents shows a general increase, as it should be in true carbonatites:
c) the Nb and Ce contents is compatible with carbonatites.

THERMAL SPRING

A thermal spring with water temperature of 41°C and an out-flow of 1657 liters/hour was found by Radam Project/DNPM geologists during a geological traverse 1210 meters westward from Dragão Lake.

One liter of the water collected at the spring was submitted to chemical analysis at Laboratório do Instituto de Desenvolvimento Econômico-Social do Pará (IDESP), with the following results:

Chlorides	3.75ppm
Iron	0.46ppm
Aluminium	not detected
Barium	not detected
Sodium	0.23ppm
Potassium	0.39ppm
Magnesium	1.96ppm
Manganese	0.008ppm
pH	5.0

TECTONIC FRAMEWORK

Although the tectonic data of the Sheet NA.19/Pico da Neblina is scarce in the area of the Seis Lagos Carbonatite Complex, two systems of faults, trending NW-SE and NE-SW, were detected by field observations. It is possible that the emplacement of the Seis Lagos Carbonatite Complex occurred in a geologic environment in which the differential vertical movements between distinguished geologic provinces were still active. Thus, the Seis Lagos Carbonatite Complex is conditioned by deep faults capable of permitting the diffentiation of the magma of mantle source ascending to shallow levels of the crust, or even to the surface diatreme. In this manner, the carbonatite and allied alkaline or ultrabasic intrusions occur outside of the Amazonas Syneclise, inside the Guianês Craton, in belts which, at that time, were tectonically active. Such provinces were divided into faulted anteclises, dome shaped elevations, elongated warpings, rift zones or great fault systems for distances of more than 150 kilometers of the present limits of the Amazonas Syneclise. Although not detected in the Seis Lagos Carbonatite Complex area, kimberlites may be present and must be searched for in the proximity of the Seis Lagos hills, in zones of deep and elongated disjunction fractures.

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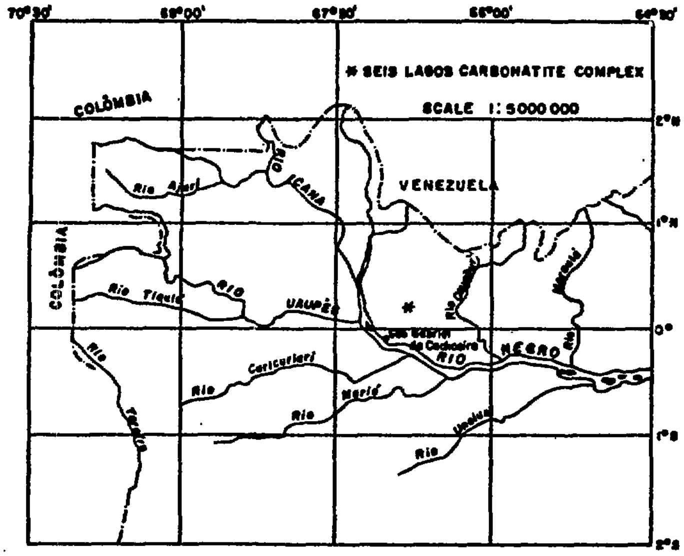

Figure 1. The localization of the Seis Lagos Carbonatite Complex.

Figure 2. Radar imagery of the Seis Lagos Carbonatite Complex.

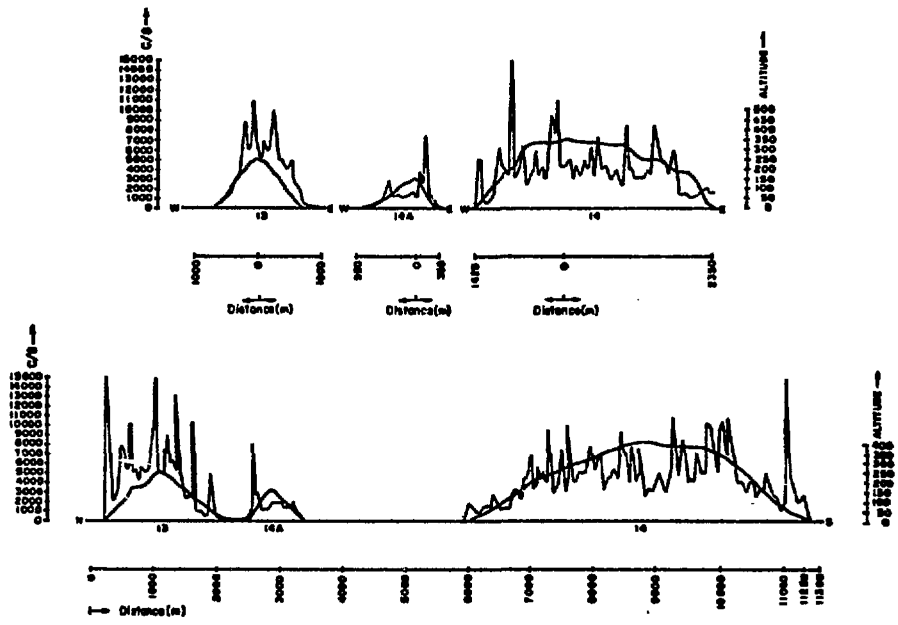

Figure 3. Scintillometric and altimetric profiles in the Seis Lagos Carbonatite Complex

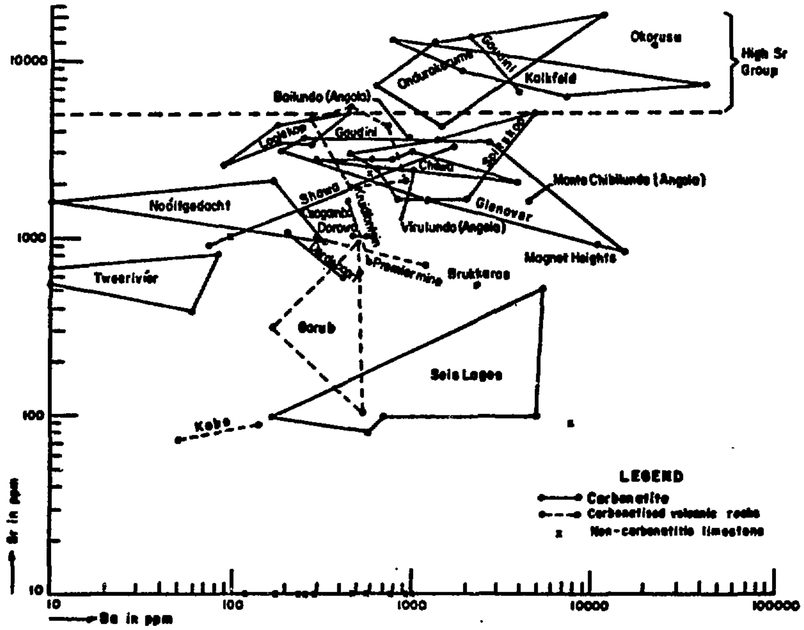

Figure 4. Log-log variation of Strontium and Barium in Carbonatite and Limestone modified from Verwoerd, 1966)

TABLE I

OXIDES \ SAMPLES	14 - 1	14 - 2	14 - 5	14 - 8	UF *	UM **
SiO_2 %	0,20	0,10	0,10	0,10	0,19	0,36
Al_2O_3 %	3,8	5,6	3,5	5,8	1,34	nil
Fe_2O_3 %	74,31	68,57	74,93	64,95	84,29	3,32
FeO %	0,18	0,22	0,15	0,22	nil	nil
MnO %	0,04	0,05	0,04	0,04	nil	61,60
TiO_2 %	-	-	-	-	0,80	0,81
CaO %	-	-	-	-	nil	nil
BaO %	-	-	-	-	nil	14,74
MgO %	-	-	-	-	0,26	1,08
K_2O %	< 0,01	0,01	0,01	< 0,01	0,08	0,02
Na_2O %	0,02	0,02	0,04	0,02	0,13	0,07
P_2O_5 %	1,6	2,2	1,7	2,1	0,34	0,11
U_3O_8 ppm	< 30	< 30	< 30	30	-	-
ThO_2 %	0,20	0,38	0,28	0,45	-	-
Nb_2O_5 %	1,3	2,5	1,8	3,4	-	-
H_2O^- %	-	-	-	-	0,98	0,84
P.F. %	-	-	-	-	10,87	10,92

GEOLOGIA E SONDAGENS LTDA. (GEOSOL). Dosage of FeO, Fe_2O_3, Al_2O_3, SiO_2, K_2O, Na_2O, MnO. FeO and Fe_2O_3 by humid analysis method. K_2O and Na_2O by Flame Photometry. Al_2O_3 and SiO_2 of fused samples by X Ray Fluorescence. MnO by Atomic Absortion. Bol. nº 12.132 B. Dosages of Nb_2O_5, P_2O_5, ThO_2, U_3O_8 by X Ray Fluorescence. Bol. nº 12.132 A. * Laterite ** Mn ore. Dosages of SiO_2, Al_2O_3, Fe_2O_3, FeO, MnO, TiO_2, CaO, BaO, MgO, K_2O, Na_2O, P_2O_5, H_2O^-, and P.F. (at 1000°C) performed in the Laboratório de Análises de Rochas e Minerais do Instituto de Geociências da U.F.R.G.S.

TABLE II

ELEMENTS \ SAMPLES	14 - 1	14 - 2	14 - 5	14 - 8
Sn ppm	140	260	180	300
Au ppm	< 0,05	< 0,05	< 0,05	< 0,05
Ag ppm	< 1	< 1	< 1	< 1
Ba ppm	< 10	< 10	< 10	< 10
Be ppm	< 5	< 5	< 5	< 5
Ta ppm	< 200	< 200	< 200	< 200
La %	1,4	0,52	0,51	0,54
Ce %	2,1	1,3	1,0	1,3
Y %	0,018	0,028	0,020	0,026

GEOLOGIA E SONDAGENS LTDA. (GEOSOL). Dosages of Sn, Ag, Ba, Be, Ta, La, Ce, Y, by Optic Spectrography; the method used reports the total concentration of the element. Bol. nº 12.132. Au by Atomic Absortion in 40g of the sample. Bol. nº 12.132A.

TABLE III

SAMPLE NUMBER	CLASSIFICATION	MINERALOGICAL COMPOSITION
AM-04	Ferruginous carbonatic breccia	Siderite, goethite, pyrite, phosphate of the gorceixite(?) group, rutile (niobiferous?)
AM-05	Ferruginous carbonatic breccia	Siderite, goethite, pyrite, phosphate of the gorceixite(?) group, rutile (niobiferous?)
AM-06	Ferruginous carbonatic breccia	Siderite, goethite, pyrite, phosphate of the gorceixite(?) group, rutile (niobiferous?)

OBS. Siderite and pyrite identified by X Ray Diffraction, Gorceixite identified by X Ray Diffraction and Semi-quantitative Emission Spectroscopy, Rutile recognized by his petrographic properties as: brown colour, high relief and green pleocroism, confirmed by X Ray Diffraction that show the rutile line. Date from: Bel. 603/LAMIN/75 and Bel. 607/LAMIN/75.

TABLE IV

	All igneous rocks	Gabbros	Ultramafic to felsic alkaline rocks	Limestones	Carbonatites	Seis-Lagos Carbonatite AM-04	AM-05	AM-06
RE_2O_3 (tot.)	50	5	100-500		200-n x 100.000	2400	2900	24000
BaO	300	200	1000-10.000		5000-100.000			
SrO	300	200	1000-10.000		5000-20.000			
Nb_2O_5	5	20	10-30		10-5000			
Ta_2O_5	2	1	1-10		0.1			
ZrO_2	300	100	400-2000		10			
TiO_2	6000	15.000	5000-20.000		1000-30.000			
Sc	13			1	10	>100	70	>100
Co	18			0.1	17	100	20	50
Ni	100			20.0	8	< 5	< 5	< 5
Cu	70			4	2.5	< 5	< 5	20
Ca	26			4	1	–	–	–
Y	20			30	96	500	70	70
Zr	170			19	1120	< 100	< 100	< 100
Nb	20			0.3	1961	300	150	2000
Mo	1.7			0.4	42	-	-	-
Sn	32			1	4	20[i]	10[i]	10[i]
Cr	117			11	49	< 10	< 10	< 10
La	40			1	516	150	80	> 1000
Ce	40			11.5	1506	3000	< 500	10.000
P_2O_5	3000	3000	2000-20.000		1000-n x 10.000			
F	500	300	100-2000		200-24.000	250	200	1100
S	500	2000	1000-3000		10.000-100.000	1300	1500	24300

OBS. RE_2O_3 was determined by humid analysis method, the other determinations were obtained by Semi-quantitative Emission Spectroscopy, i Interference. Date from: Bel. 03/LAMIN/76, 056/LAMIN/76, 031/LAMIN/76 (CPRM).