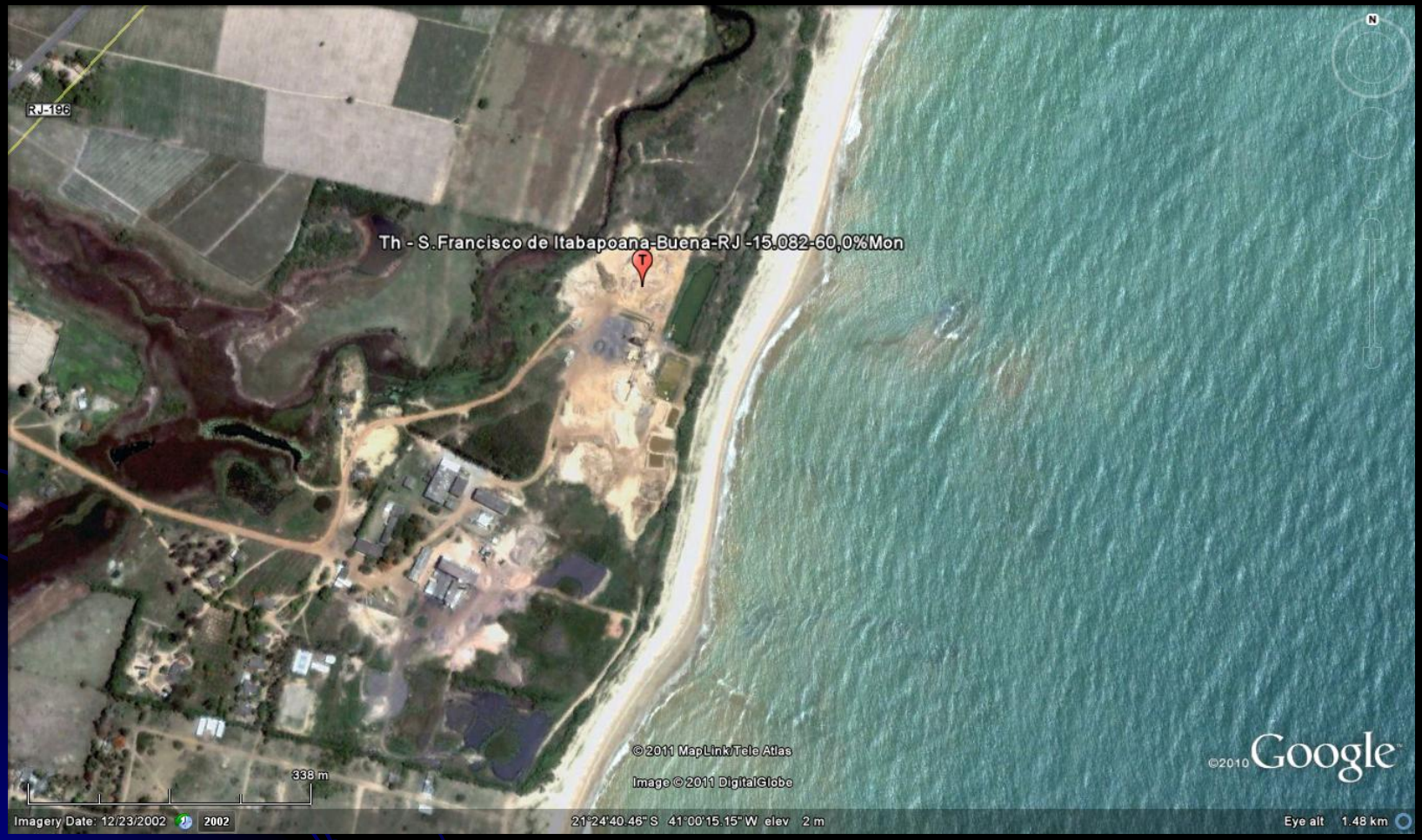
THORIUM , UNFC (3,3,3) IN BRASIL

URAM - 2014 – VIENNA - IAEA

ROBERTO C. VILLAS-BÔAS

CETEM - Center for Minerals Technology

CYTED – Iberoamerican Programme for Science, Technology & Development



ALL (3,3,3) and some (2,1,1) Thorium in Brasil LISTED at

IAEA/INFCIS/ThDEPO

WORLD THORIUM DEPOSITS AND RESOURCES

HTTPS://INFCIS.IAEA.ORG/THDEPO/DEPOSITDETAILS/299?

TO UNDERSTAND BRAZILIAN MINERAL RESOURCES : GENERALITIES

URAM 2014 – VIENNA

Roberto C. Villas-Bôas

- Size : 8.5 million square km
- Geographical location : South America
- Infrastructure: roads, education, research
- Population : 195 million inhabitants
- GDP : US$ 2,090,314 million
- GDP – minerals : US$ 40 billion
- Investments in Mining :US$ 62 billion(2010-2014)

GDP : source **2010** **International Monetary Fund**

GDP minerals and investments : source 2011 **IBRAM**

BRASIL : MINING POLICIES (TAXES)

KORES – SEOUL 2011

Roberto C. Villas-Bôas

source : PwC Global Mining Group , Dec. 2010

- CORPORATE TAX : 15% + 10%1 Social Contribution of 9% based on net profit (worldwide income regime)
- REMITTANCE TAX : 0% on dividends;15% on royalties and technical service;25% on others ;25% on services with no transfer of technology;
- SPECIFIC MINING TAX : The rate varies according to the type of mineral, from 0.2% to 3%6 ;
- FISCAL STABILITY REGIMES AND FISCAL INCENTIVES : Fiscal Stability Regime: not applicable ; Depreciation: the general rule is straight line basis ;Specific depreciation rules for mining ;
- TAX LOSS CARRYFORWARD : No limitations
- **ALSO : Deduction of interest from equity and Brazilian tax laws allow an interesting tax planning tool in which interest paid to shareholders in the company as a return on invested capital (equity) can be deducted from income tax purposes.**

BRASIL : MINING GENERALITIES

VIENNA – URAM 2014

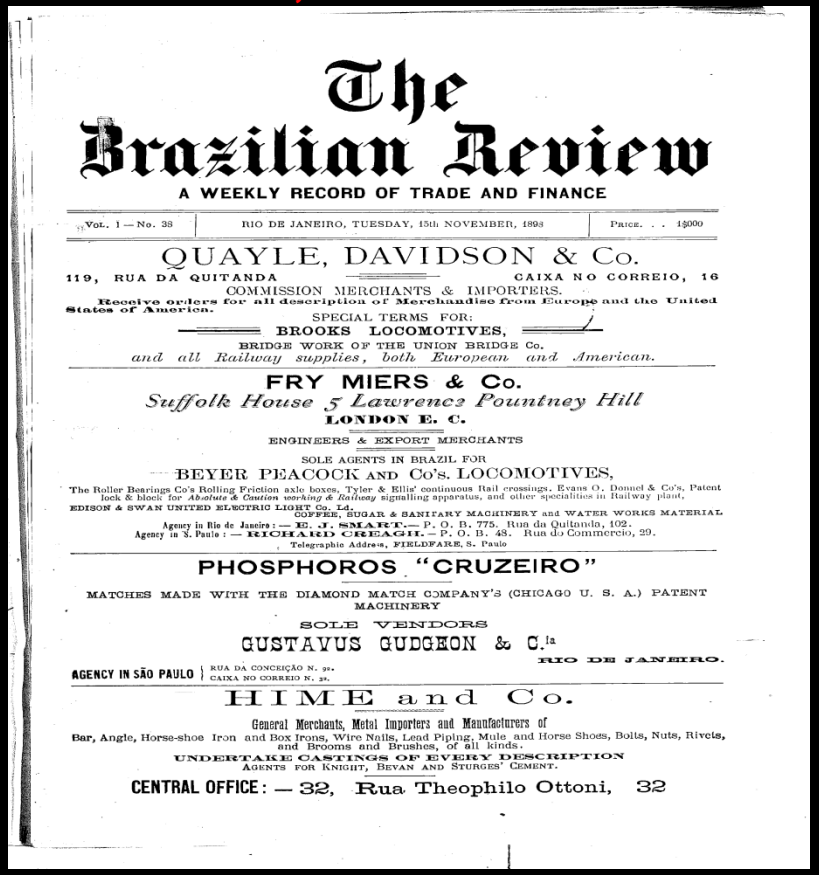
Villas-Bôas

MAJOR PLAYER IN

- Niobium (1º)
- Iron Ore (1º)
- Manganese (2º)
- Tantalite (2º)
- Bauxite (2º)
- Graphite (3º)
- Ornamental Stones (4º)

FORMERLY A MAJOR PLAYER IN : THORIUM !

1885 to 1914 , then second to INDIA



The Brazilian Review

A WEEKLY RECORD OF TRADE AND FINANCE

Vol. 1 — No. 38 | RIO DE JANEIRO, TUESDAY, 15th NOVEMBER, 1898 | Price. . . 1$000

QUAYLE, DAVIDSON & Co.

119, RUA DA QUITANDA — CAIXA NO CORREIO, 16

COMMISSION MERCHANTS & IMPORTERS.

Receive orders for all description of Merchandise from Europe and the United States of America.

SPECIAL TERMS FOR:

BROOKS LOCOMOTIVES,

BRIDGE WORK OF THE UNION BRIDGE Co.

and all Railway supplies, both European and American.

FRY MIERS & Co.

Suffolk House 5 Lawrence Pountney Hill

LONDON E. C.

ENGINEERS & EXPORT MERCHANTS

SOLE AGENTS IN BRAZIL FOR

BEYER PEACOCK AND Co's. LOCOMOTIVES,

The Roller Bearings Co's Rolling Friction axle boxes, Tyler & Ellis' continuous Rail crossings, Evans O. Donnel & Co's, Patent lock & block for *Absolute & Caution working & Railway* signalling apparatus, and other specialities in Railway plant,

EDISON & SWAN UNITED ELECTRIC LIGHT Co. Ld.

COFFEE, SUGAR & SANITARY MACHINERY and WATER WORKS MATERIAL

Agency in Rio de Janeiro: — E. J. SMART.— P. O. B. 775. Rua da Quitanda, 102.

Agency in S. Paulo: — RICHARD CREAGH.— P. O. B. 43. Rua do Commercio, 29.

Telegraphic Address, FIELDFARE, S. Paulo

PHOSPHOROS "CRUZEIRO"

MATCHES MADE WITH THE DIAMOND MATCH COMPANY'S (CHICAGO U. S. A.) PATENT MACHINERY

SOLE VENDORS

GUSTAVUS GUDGEON & C.ia

RIO DE JANEIRO.

AGENCY IN SÃO PAULO | RUA DA CONCEIÇÃO N. 32. CAIXA NO CORREIO N. 32.

HIME and Co.

General Merchants, Metal Importers and Manufacturers of

Bar, Angle, Horse-shoe Iron and Box Irons, Wire Nails, Lead Piping, Mule and Horse Shoes, Bolts, Nuts, Rivets, and Brooms and Brushes, of all kinds.

UNDERTAKE CASTINGS OF EVERY DESCRIPTION

AGENTS FOR KNIGHT, BEVAN AND STURGES' CEMENT.

CENTRAL OFFICE: — 32, Rua Theophilo Ottoni, 32

Analysis of Prado Beach Sands (1887)

Analysis of the Prado Sands shows them to contain the following metals in different combinations:

Thorium	1.5% to 3.5%
Ytrium	1.0% to 3.0%
Cerium	62.0% to 70.0%
Aluminium	3.0%
Iron	2.5%
Lithanium	2.5%

The Monazite comprising the Prado Sands is a phosphate of serium, lithanium and didyium with 2 to 20% of oxide of thorium, and are derived from the decomposition of the country gneiss. Their market value is said to be 7 francs per 1,000 grammes of thorium contained. A good deal of discussion has been going on in regard to the proprietary rights to these valuable deposits. It appears that Mr. Gordon acquired by purchase what is

URAM – 2014- Vienna - IAEA
Roberto C. Villas-Bôas

Selected Brazilian main mining areas and HDI SUSTAINABILITY

Human Development Indicator

BRAZIL overall:

0.748 (Firjan)

Eastern Europe and Central Asia overall:

0.771

WORLD overall ;

0.624

- Municipality = M
- State = S
- Numbers = HDI – M

CENTRAL BRAZIL

- Itabira - MG Fe (S= 0.766 M= 0.798)
- Araxá - MG Nb (S=0.766 M=0.799)
- Nova Lima - MG Au (S= 0.766 M=0.821)
- Catalão - GO P_2O_5 (S= 0.773 M=0.818)

THE AMAZON

- Parauapebas - PA Fe(S= 0.720 M=0.740)
- Barcarena - PA Al_2O_3 (S=0.720 M= 0.769)
- P.Figueiredo - AM Sn (S=0.713 M=0.742)

Types of thorium UNFC (3,3,3) in Brasil

URAM -2014 Villas-Bôas

- Placer, shoreline
- Placer, alluvial
- Carbonatite with residual enrichment (Barreiro,Catalao)
- Carbonatite (Salitre,MG)
- Pitinga granites (AM)
- Alkalic Igneous

What we are talking about ?

URAM - 2014

Roberto C. Villas-Bôas

Rare Metals

Beryllium
Cesium
Gallium
Germanium
Hafnium
Indium
Lithium
Niobium
Rubidium
Tantalum
Thorium
Tin
Zirconium

BRASIL: important reserves and production
BRASIL : good possibilities
BRASIL : important resources

Rare Earths Elements

Dysprosium
Erbium
Europium
Gadolinium
Holmium
Lanthanum
Lutetium
Neodymium
Praseodymium
Promethium
Samarium
Scandium
Terbium
Thulium
Ytterbium
Yttrium

Brasil´s Rare Metals

URAM-2014

Roberto C. Villas-Bôas

Nb : largest world producer

Barreiro Alkaline Complex

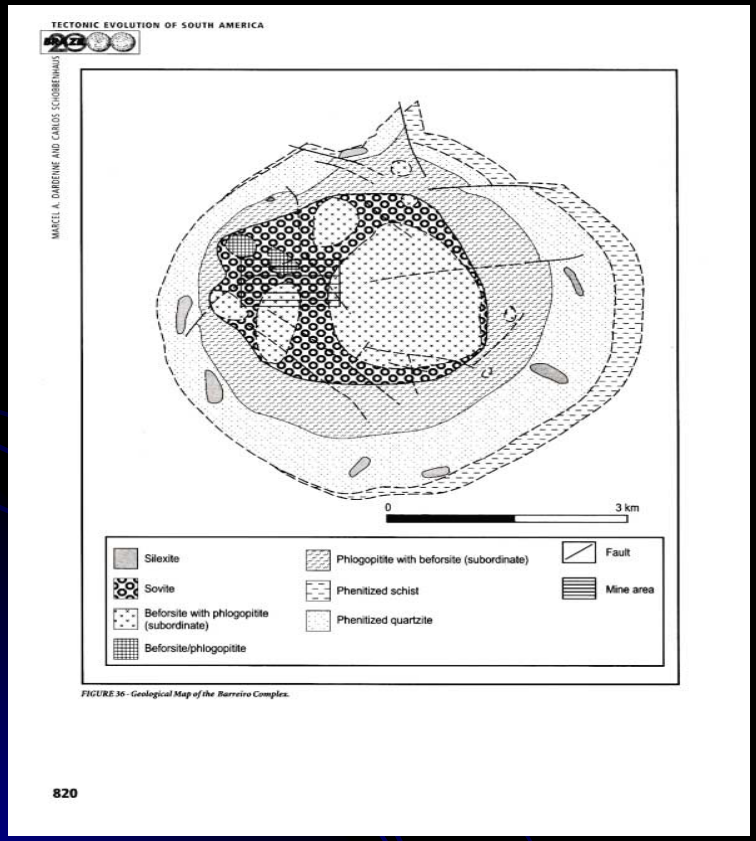


FIGURE 36 - Geological Map of the Barreiro Complex.

Niobium

PRODUCTS

- STANDARD FERRONIOBIUM
- HIGH PURITY FERRONIOBIUM
- NICKEL NIOBIUM
- HIGH PURITY NIOBIUM OXIDE
- OPTICAL GRADE NIOBIUM OXIDE

NIOBIUM METAL

- - COMMERCIAL GRADE
- - REACTOR GRADE

NIOBIUM 1% zr

- - COMMERCIAL GRADE
- - REACTOR GRADE

HDI (Araxá) = 0,7799

Brasil´s Rare Metals

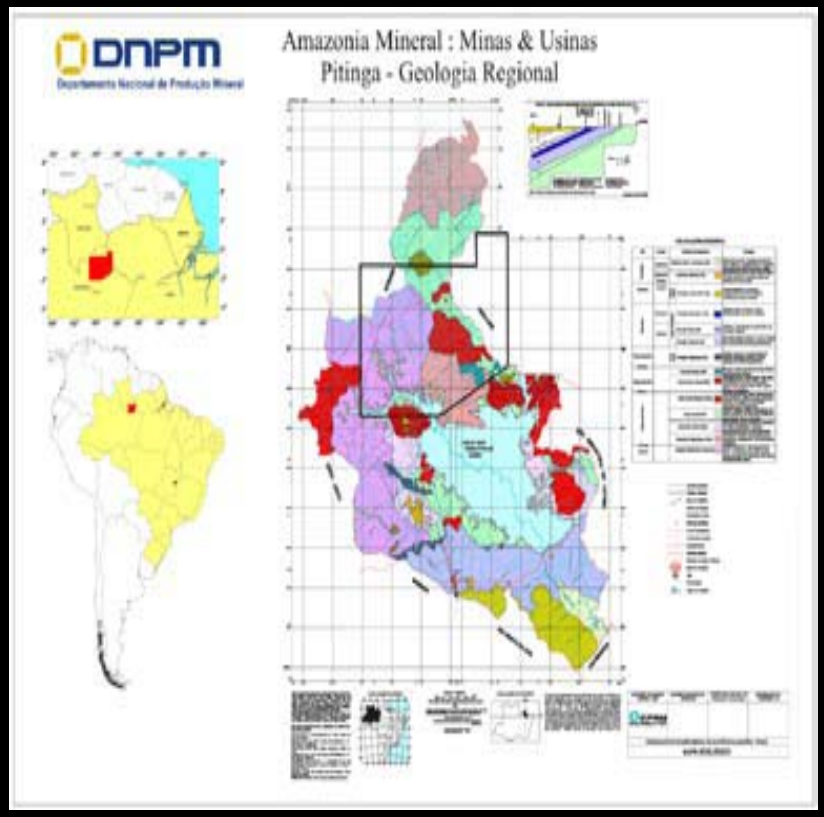
URAM - 2014

Roberto C. Villas-Bôas

Sn: 4th world´s reserves (9.4%)

Sn – Pitinga Mine – AM

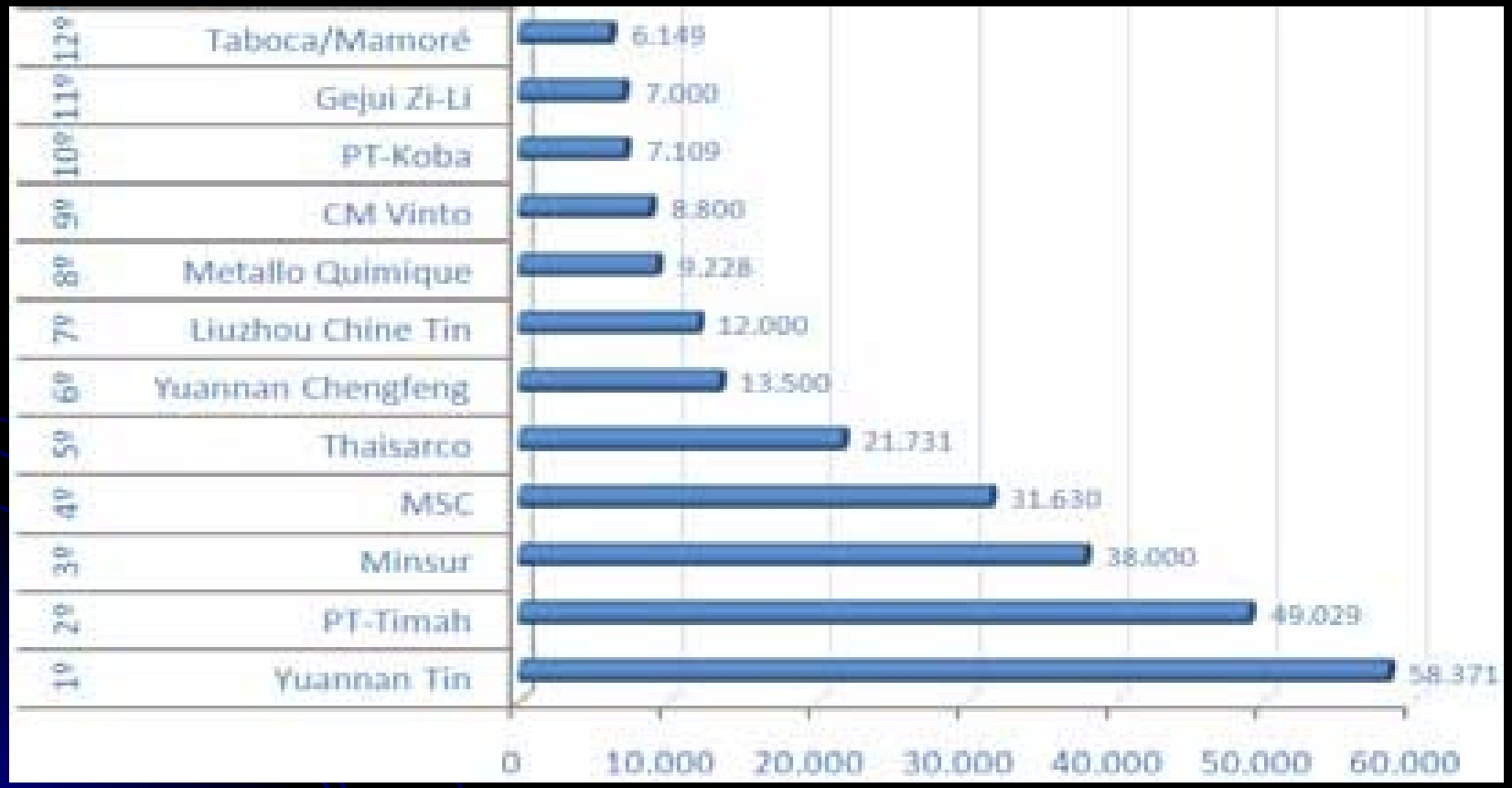
HDI = 0,6166



Brasil´s Rare Metals
ranking of world´s metallic Sn plants

URAM -2014

Roberto C. Villas-Bôas



Brasil´s Rare Metals
ranking of world´s metallic Ta plants

URAM -2014

Roberto C. Villas-Bôas

TANTALUM (2008)

Reserves (103t Ta2O5)		WP (%)
Brasil	**79.200**	**40,98**
Austrália	69.000	35,70
Egipt	14.014	7,25
China	8.370	4,33
Tailând	7.700	3,98
Nigéria	7.000	3,62
Moçambique	6.032	3,12
Canadá	5.000	2,59
Congo RD	1.500	0,78
Ruanda	1.500	0,78
WORLD	**193.284**	**100,00**

Ta_2O_5

Mina Pitinga (*Sn, Ta, Nb, Pb) 150-200.000*

lbs/ano Mineração Taboca S.A. (Grupo MINSUR - Peru) Município de Presidente Figueiredo – **AM** **HDI = 0,6166**

Mina Mibra (Ta, Nb, Sn) 100 t/ano

Cia. Estanho Minas Brasil - MIBRA (Metallurg Group) Município de São João Del Rey – MG **HDI= 0,6902**

Mina Cacheirinha (Sn, Nb-Ta) nd ... COOGER - Coop. Garimpeiros do Estado de Rondônia Município de Itapuã d´Oeste – RO **0,5427**

Mina Massangana (Nb-Ta) nd METALMIG Município de Ariquemes – RO **0,6625**

What about Rare – Earths ?

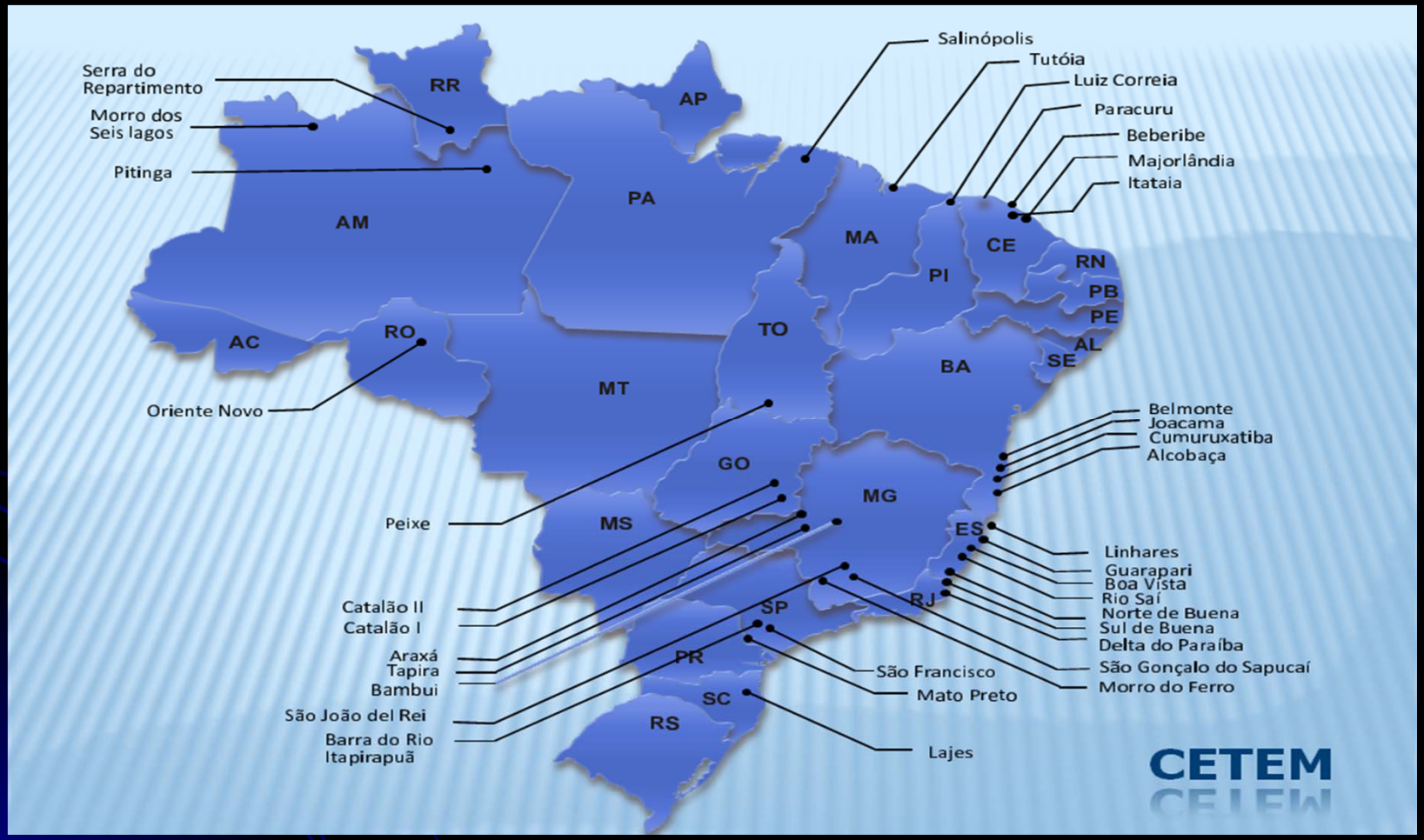
- Because rare earth elements are often associated with the radioactive elements uranium and thorium, many rare earth deposits are discovered during exploration for these elements.
- Most production of rare earth elements is from the processing of monazite and bastnäsite, the REO compounds recovered by S-X.

Rare – Earths in Brazil

URAM - 2014

source : Lapido & Santos ,CETEM, 2011

Roberto C. Villas-Bôas



What about Rare – Earths ?

URAM - 2014

Roberto C. Villas-Bôas

IMPORTER ?

- Brazilian RE reported reserves (DNPM/MME) 44,000 t measured and indicated
- Reported domestic production in 2005 and 2006 = 958 t/y
- World´s participation in 2006 = 0,8%
- THEN : CHINA !

A BIT OF...HISTORY

- In 1942 it was introduced the chemical processing of monazites to extract rare earths in Brazil in the ORQUIMA S.A. plant located in São Paulo City
- Monazite sands were mined and beneficiated at the SUPRA / SULBA plant in Buena, up to 1960
- NORM wastes bearing mesothorium (228 Ra) started to be generated in Brazil ever since (PASCHOA, 1993).

However, just in CATALÃO , Goiás, Central Brazil

Type Ore	Main Mineralogy	Reserves (a) (ton)	REO (%)
Carbonatite	Magnetite, dolomite, monazite, stroncianite, pyrite, other minors (b)	15.903.072	6,64
Saprolitic or Laterite	Quartz, apatite, magnetite, almenite, hematite, ghoetite, monazite, other minors	54.504.757	8,39
Altered / silicate (c)	Quartz, monazite, hematite, barite, cerianite, apatite, other minors	8.254.383	10,5
	Cut off: 5% REO	78.664.212	
	T O T A L (a)	119.723.180	

(a) Measured + indicates + inferred

(b) Criptocristaline mainly

(c) Results from weathering of carbonatite ore

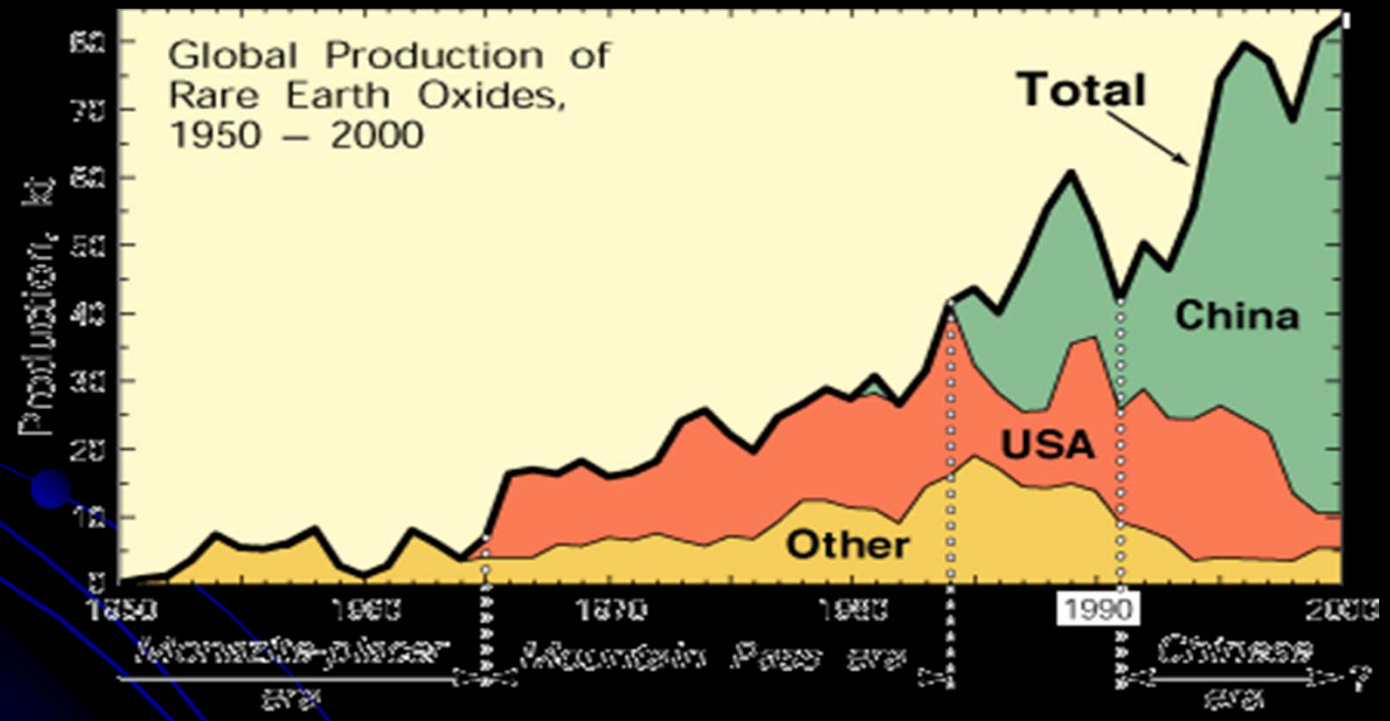
Source: Ribeiro, 2008; Newmann, 1999

But, then CHINA !

KURAM - 2014

Villas-Bôas

source : USGS



What about Thorium and Rare – Earths processing ?

URAM – 2014 – Vienna - IAEA

Roberto C. Villas-Bôas

The Buena Mine : as a case study

- The Buena monazite mine is located in the municipality of São Francisco de Itabapoana, (21 º 24´36” S and 41º00´18”W), northern part of the State of Rio de Janeiro, and it is well served by several interstate roads. According to the AMB – 2004, the Brazilian Mineral Yearbook, in Buena alone there are 1.292.282 metric tons of ROM monazite ore.
- Typical composition might be as follows:

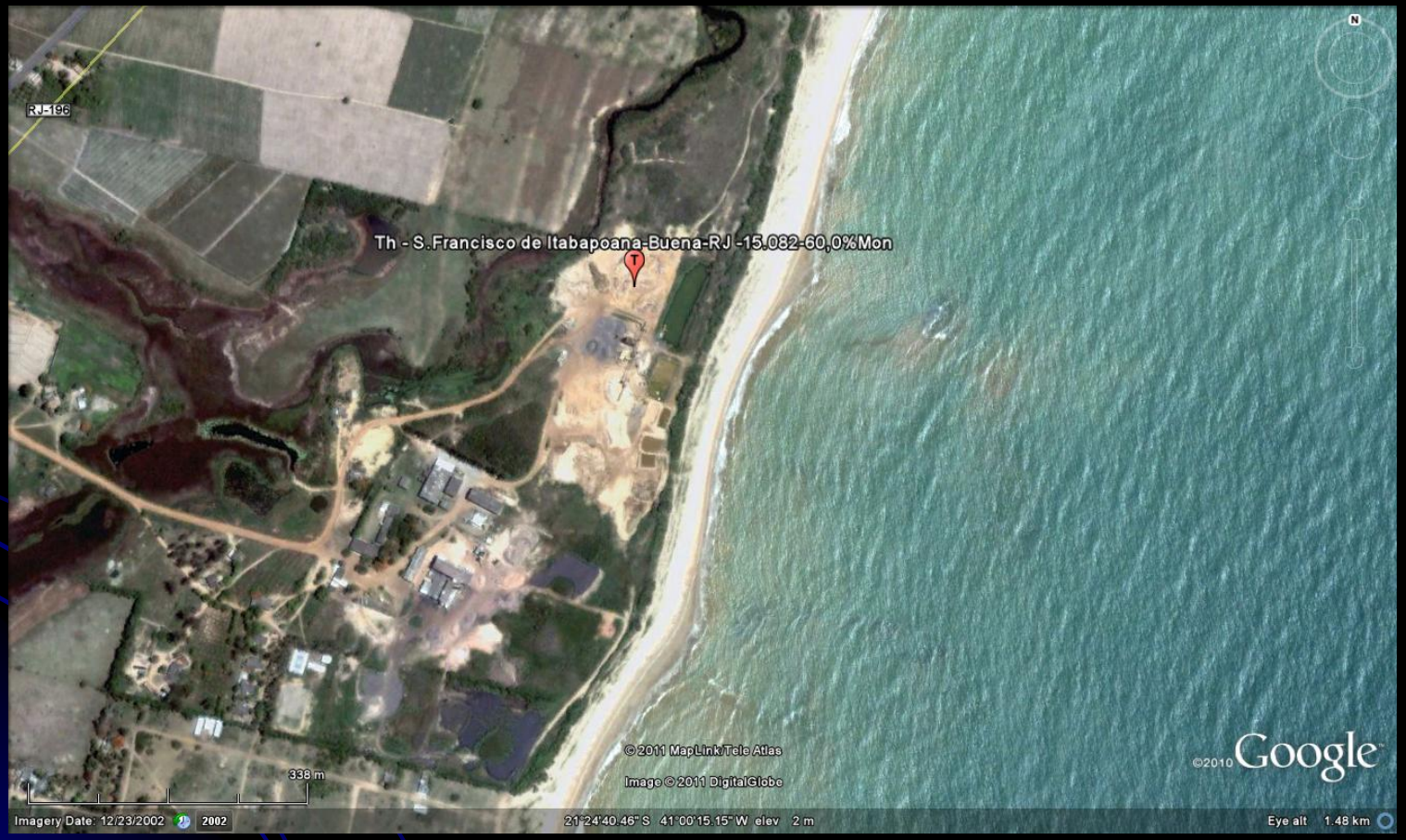
Oxide	%
ThO2	6.5
U3O2	0.17
(RE)2O3	59.2 (includes Ce2O3)
Ce2O8	26.8
P2O5	26.0
Fe2O3	0.51
TiO2	1.75
SiO2	2.2

The Buena Mine : as a case study HDI = 0,6995

21 º 24´36” S 41º00´18”W

URAM – 2014 – Vienna -IAEA

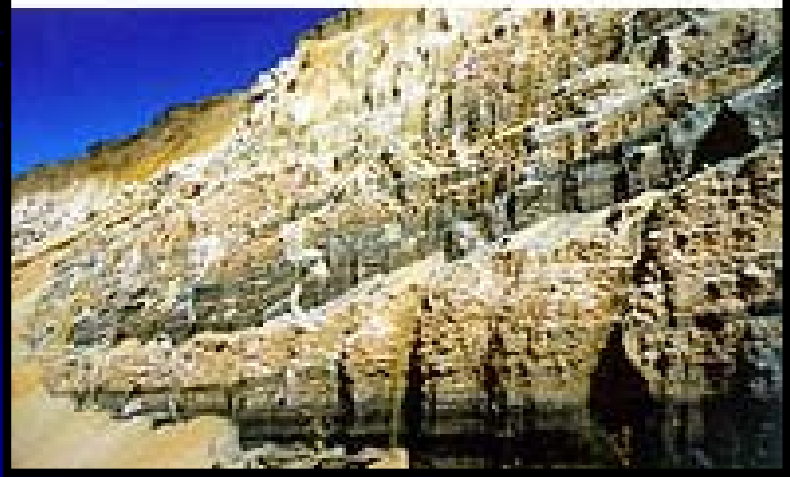
Roberto C. Villas-Bôas



The Buena Mine : as a case study

URAM - 2014

Roberto C. Villas-Bôas



- INB – Industrias Nucleares Brasileiras –, state monopoly created in 1988 ,in 1994 ,succeeding NUCLEMON, 1976, that succeeded NUCLEBRAS,1974,that succeeded CBTN,1972, that succeeded CNEN,1960, all state monopoly, that succeeded ORQUIMA,1940,private company,.
- It holds the prospection, exploration, mining, industrialization and commercialization rights of the monazite sands derived from the paleoshore deposits in the region.
- The mine has been in standstill since the Chinese boom on rare earths.

The Buena Mine : as a case study

URAM - 2014

Roberto C. Villas-Bôas

Mining in Buena is conducted in a very simple, logical and rational way:

1. soil rich in organic matter is removed and stored for reclaiming purposes ;
2. overburden is them shoveled of ;
3. shoveling continues and extracts the monazite rich ore mineral;
4. trucks transport it to the physical beneficiation plant nearby located;
5. concentrates and wastes are produced;
6. reclaiming of the mined area is performed;

A two step physical beneficiation process is then performed:

1. Humphrey´s spirals concentrate the “heavy minerals” part of the “monazite sands”, consisting of monazite, ilmenite, zirconite and rutile. Waste product from this operation, paleo sea shore sand, is returned for the concomitant reclaiming operations.
2. the concentrates from step one are subjected to electromagnetic, electrostatic and further gravimetric operations to produce cleaner concentrates.
3. The overall ore recovery is of 85%.
4. As mentioned, reclaiming is performed concomitantly, transporting the wasted materials from the concentrations steps, one and two, to the mining trenches and covering up with the separated and stored upper soil from operation 1.

The Buena Mine : as a case study

S-X semi-commercial plant 1992/1993

La,Ce,E,Pr,Nd,Sm,Eu,Gd,Tb,Dy,Ho,Er,Yb,Y

URAM - 2014

Roberto C. Villas-Bôas

VISTA EXTERNA DA UDES

VISTA INTERNA DA UDES

The Buena Mine : as a case study

Radioactive wastes : MESOTHORIUM

URAM - 2014

Roberto C. Villas-Bôas

RADIONUCLIDE	Activity	Concen	tration	(kBq/kg)	
	EAC	Oil	Mon	Pyr	Apatite
Ra-226	10	30	0.06 - 6.7	0.2-100	3
Ra-228	10	30	0.3-33	0.5-300	3

Exempt activity concentrations (EAC) for radionuclides and AC in selected NORM wastes in Brazil. After PASCHOA , 1994.

As it is well known, the potential risks of radioactive mining wastes in which natural long lived decay products are mobilized in the case of monazite mining are 20 to 50 orders of magnitude smaller than in uranium mining.

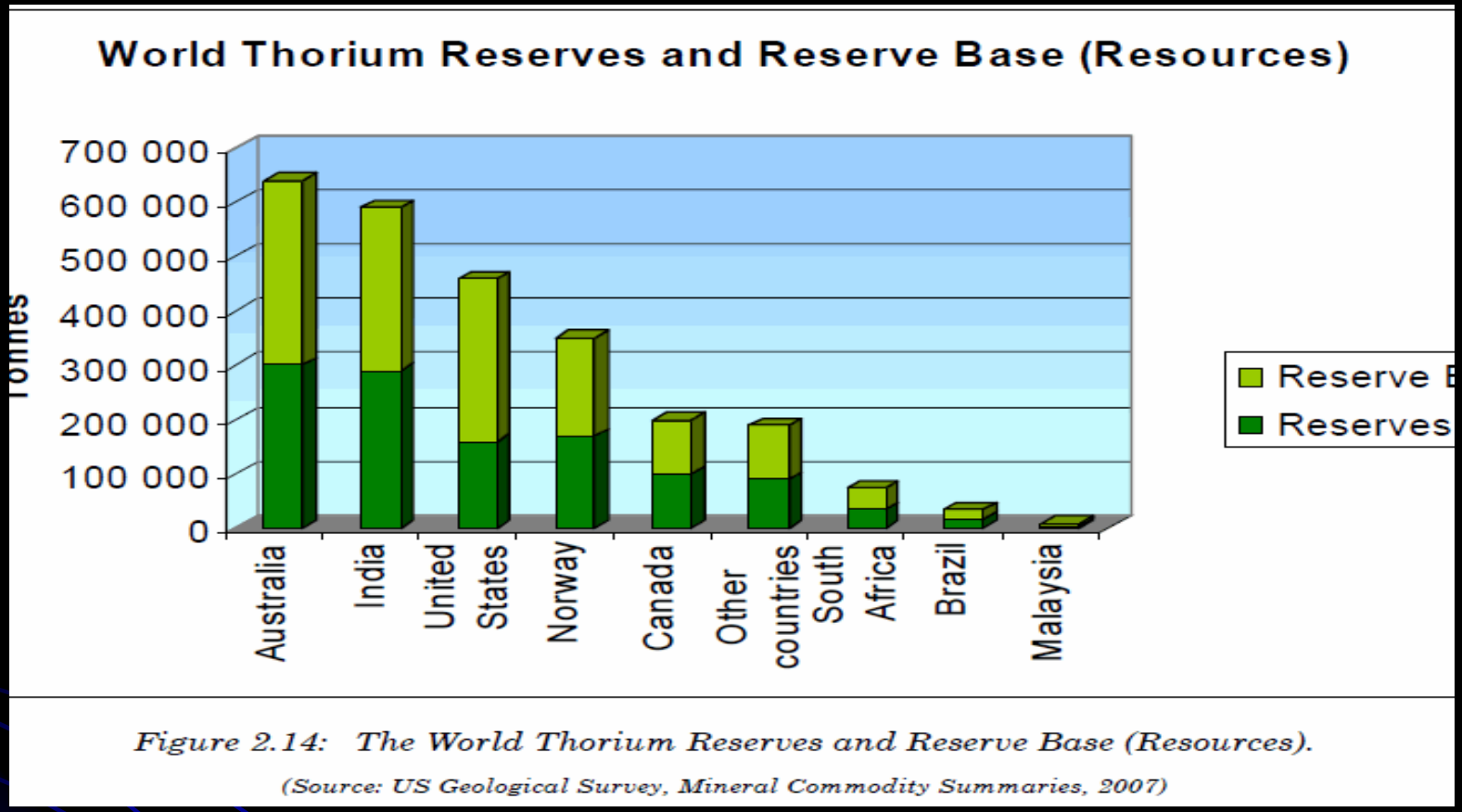


Figure 2.14: The World Thorium Reserves and Reserve Base (Resources).

(Source: US Geological Survey, Mineral Commodity Summaries, 2007)

World Th RESOURCES

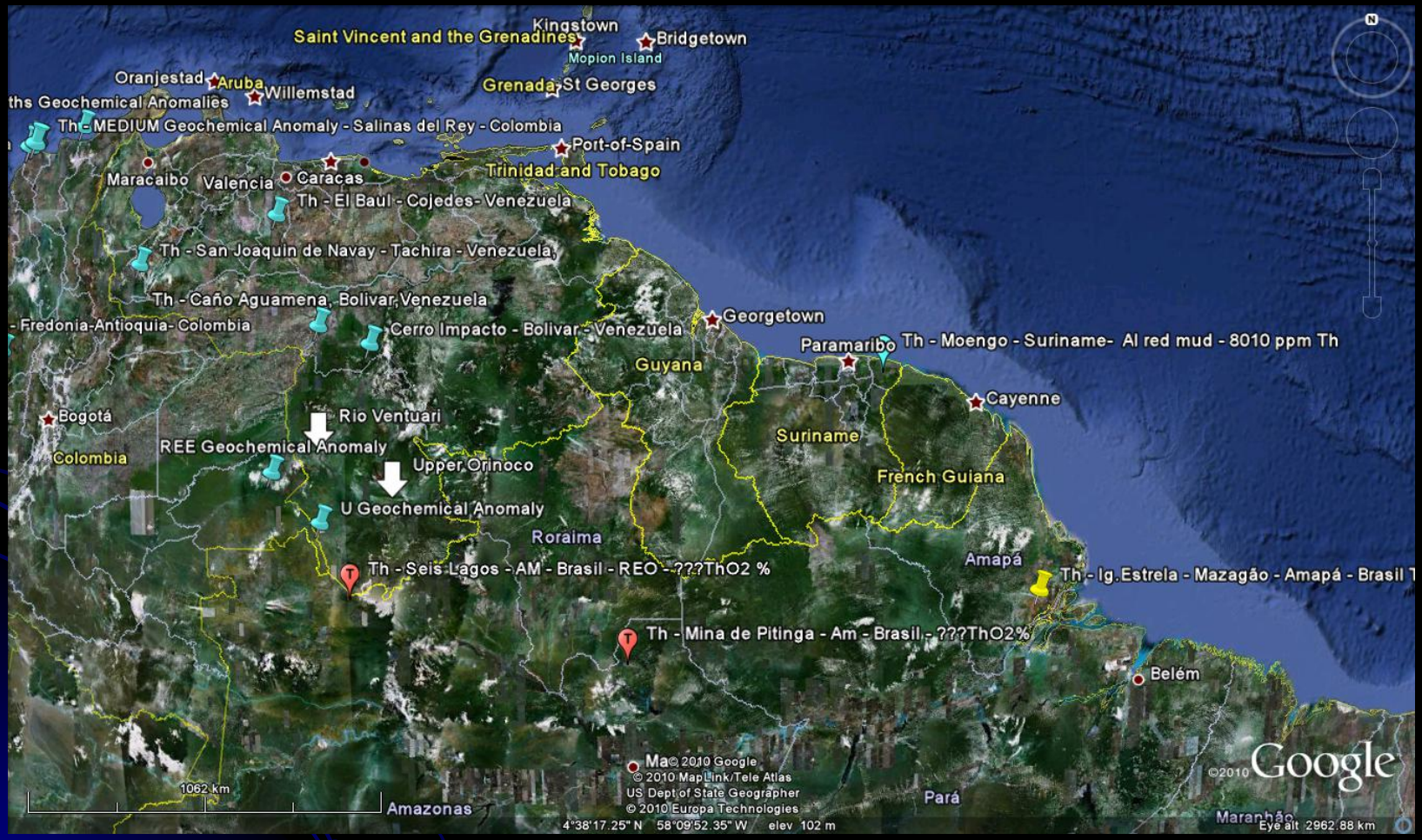
RESERVES OR RESOURCES ?

Roberto C. Villas-Bôas

Brazil, Venezuela, Colombia, Guiana's

URAM – 2014 – Vienna - IAEA

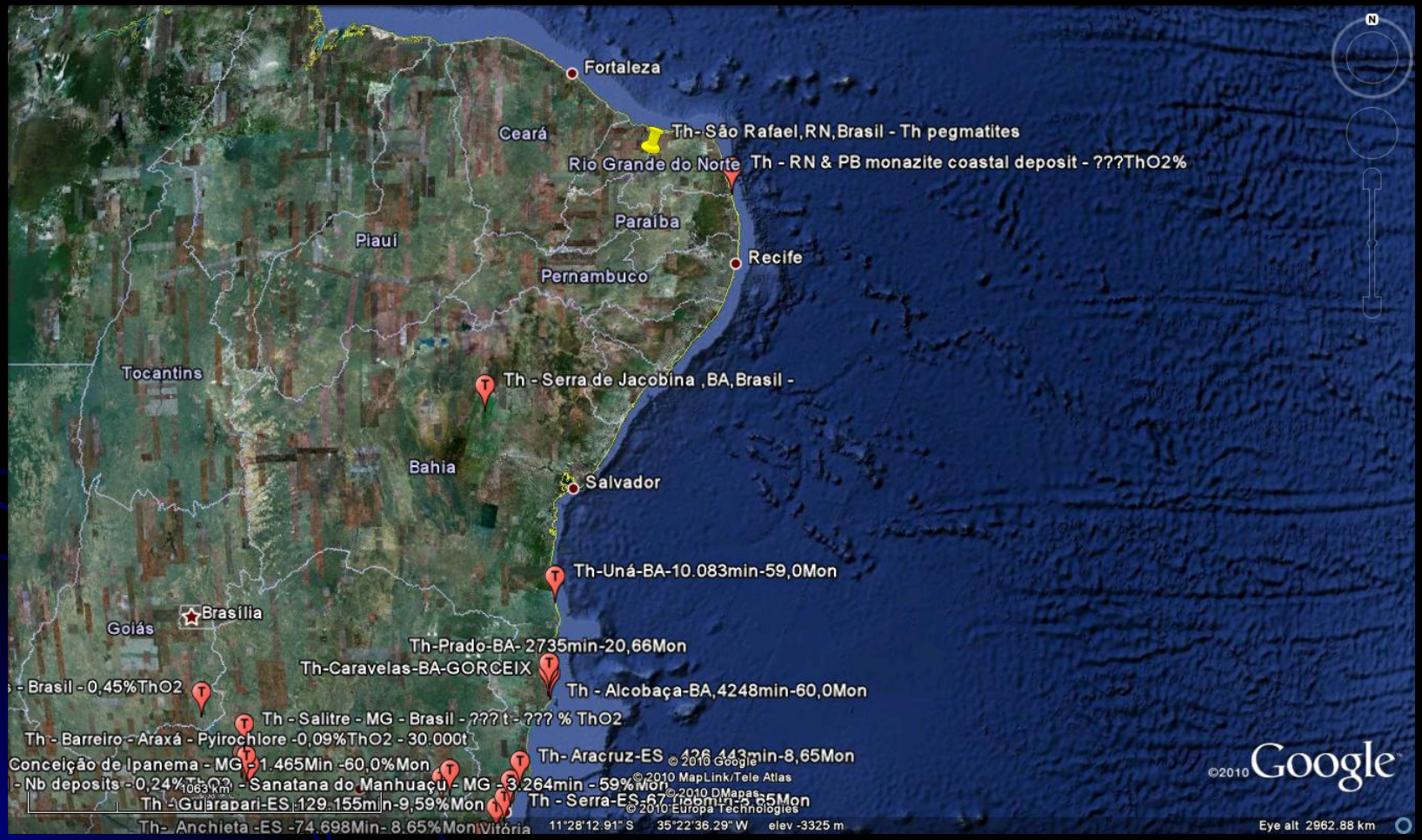
Roberto C. Villas-Bôas



Brazil, NE coast & interior

URAM - 2014

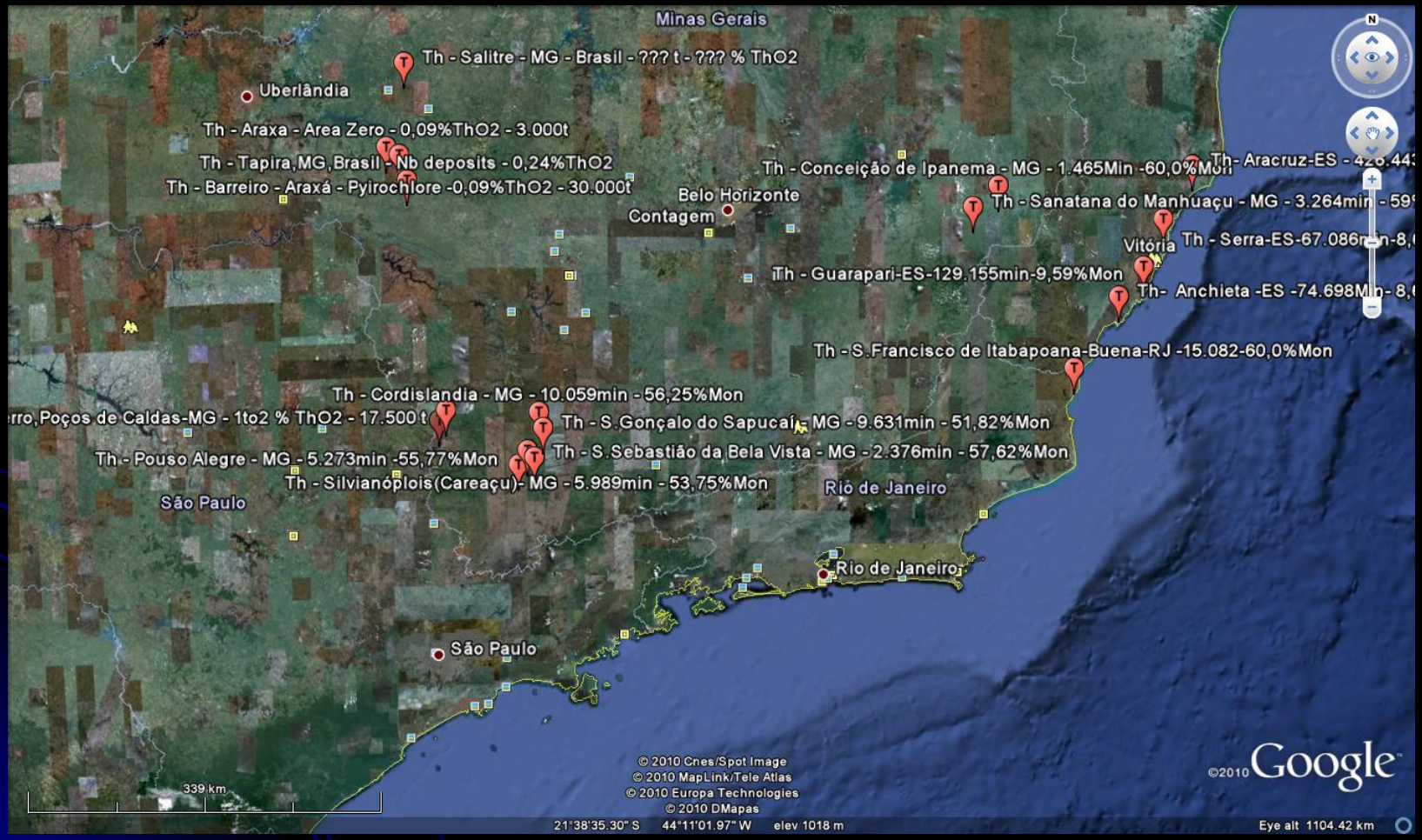
Roberto C. Villas-Bôas



Brasil, SE coast & interior

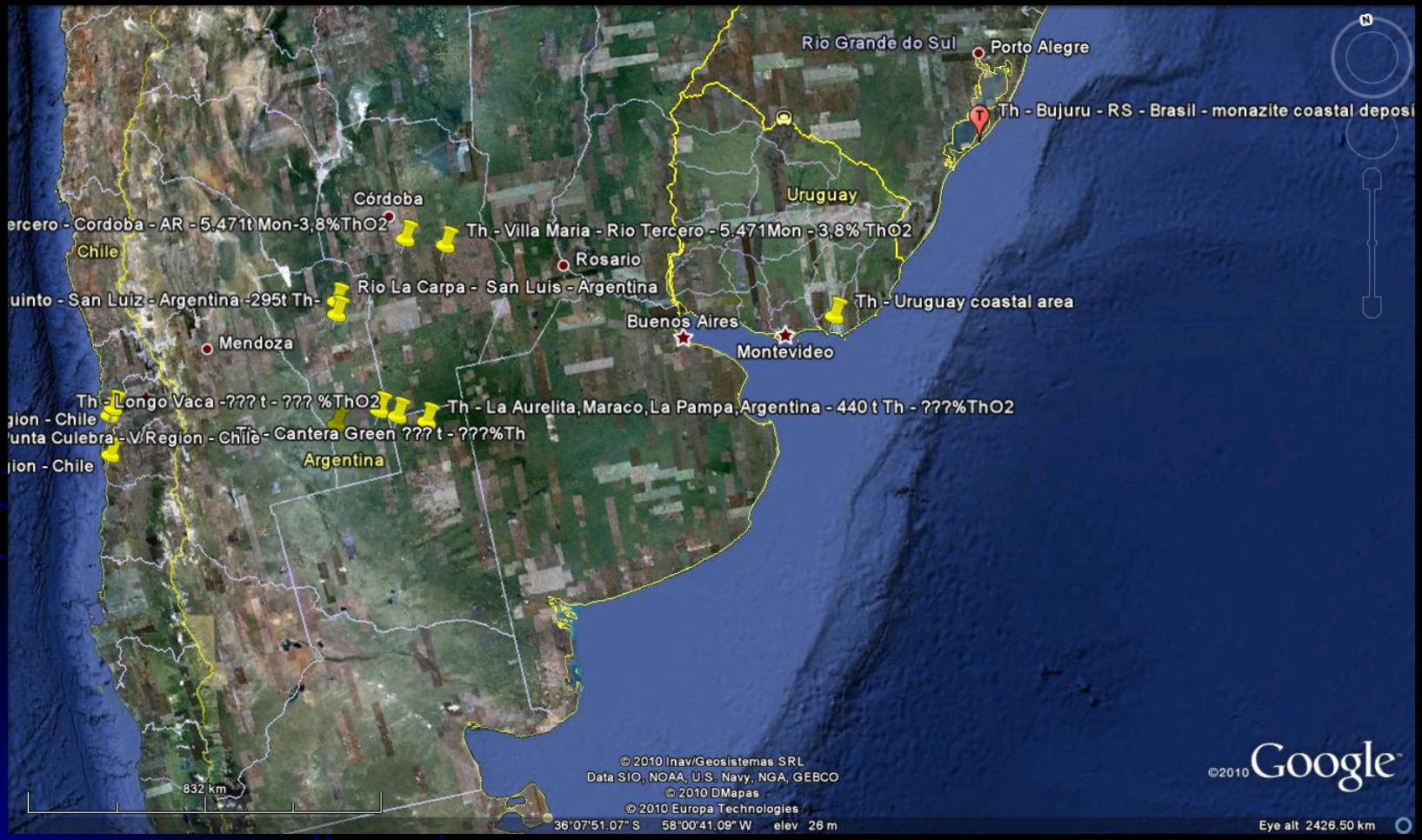
URAM – 2014 – Vienna - IAEA

Roberto C. Villas-Bôas



Brazil (S),Uruguay, Argentina & Chile

URAM – 2014 – Vienna - IAEA Villas-Bôas



Brazil´s rare earths occurrences and deposits, other than monazite

URAM – 2014 – Vienna - IAEA Roberto C. Villas-Boas

CARBONATITE

Barra do Itapirapua : 24 - 41´S / 49 - 13´W ; 6% REE in hematite mine. REE probably from hydrothermal solutions. **0,6204**

Itanhaem : 24 0 08´S / 46-48´W ; REE found in biotite tinguaite dikes.. **0,7517**

Mato Preto : 24-45S / 49-12W ; F mine closed in 1999.

Salitre I and II : 19-02S / 46-47W ; High REE. **0,6394**

CARBONATITE WITH RESIDUAL ENRICHMENT

Angico dos Dias : Bahia

Anitápolis : 27-48S / 49-05W ; P producer; REE occurrence **0,6499**

Araxa (Barreiro) : 19-38S / 46-56W ; 450 Mt Nb ore @ 2.5% Nb2O5, 4.4% REO + 0.8 Mt

- laterite ore @ 13.5% REO, 2% Nb2O5, 0.05% U3O8 (1984); 0.546 Mt @ 10- 11% REO (1982); 462 Mt @ 0.033% REO . Nb-P producer; REE-Ba occurrence ; Weathered carbonatite with 3 separate deposits. Barreiro Complex is circular and about 4.5 km in diameter. World's largest Nb mine and deposit . **0,7799**

Caiapo : 16-00S / 51-45W ; Anomalous Sr, Ba, REE in the lateritic cover .

Brazil´s rare earths occurrences and deposits, other than monazite

URAM – 2014 – Vienna - IAEA

Roberto C. Villas--Bôas

CARBONATITE WITH RESIDUAL ENRICHMENT

Catalão I : 18-15S / 47-47W ; Nb-P producer; minor by producer of REE (Ce); Ti **0,8301**

Catalão II : 18-02S / 47-52W ; Nb resource ; REE phosphates **0,8301**

Maicuru : 00-28S / 54-13W; laterite contains 17% REE .

Maraconai : 00-32S / 53-24W ;

Matum (Marum, Mutum) : 01-53S / 57-25W ; Most of intrusion lies in Guyana.

Morro Dos Seis Lagos(São Gabriel da Cachoeira) : 00-38N / 66-24W ; 0.13 Mt REE; 1.50% REO in laterite cover . 3 carbonatitic alkaline pipes that form laterite-covered hills. Laterites average 230 m in depth. 3 bill.t ore 2.8% Nb_2O_5 **0,4526**

Serra Negra : 18-55S / 46-50W ; 200 Mt @ 27.7% Ti2– Ti concentrates contain 3%REE; Hi LREE/HREE ratio. **0,6855**

Tapira : 19-54S / 46-52W ; 150 Mt @ 0.03% REO; 166 @ 0.03% REO ; phosphate mine. **0,6834**

Brazil´s rare earths occurrences and deposits, other than monazite

URAM – 2014 – Vienna - IAEA Roberto C. Villas-Bôas

ALKALIC IGNEOUS

Arenopolis (Areianopolis) : **0,5933**

16-22S / 51-32W ; Rare earths concentrated in dikes within the syenite.

Jacupiranga :

24-42S / 48-08W ; P-Lime producer; REE, Ni Occurrence . **0,6594**

Mutum :

01-53N / 57-25W ; **0,6375**

Poços de Caldas (Morro do Ferro): **0,8045**

21-55S / 46-34W ; >1.0 Mt @ 4% REO, 1%

ThO2; 1.5 Mt bas or 0.050 t REO (1990); 6 Mt @ 3% REO. Past producer U,Zr, Bauxite. Eudialyte contents range from 0 to 11% in the relatively small host bodies. Was once one of world's biggest baddeleyite deposits, but now nearly depleted. Weathered magnetite stockwork in alkaline rocks.

Sucunduri : 8-32S / 59-28W ;

Brazil´s rare earths occurrences and deposits, other than monazite

URAM – 2014 - Vienna -IAEA

Roberto C. Villas-Bôas

OTHER IGNEOUS-AFFILIATED (INCLUDING PEGMATITES AND VEINS)

Pitinga : 00-45S / 60-07W ; Potential byproduct . Greisenization of biotite granite produced primary mineralization. Also weathered zone with assoc. placers **0,6166**

PLACER, Shoreline and Alluvial

already mentioned monazites

OTHER - Uranium Deposits

Carajas (Igarape Bahia) : 7 to 8 degrees S and 49 to 51 W ; Archean “Olympic Dam type” deposit ; Cu-Fe-Au-U-REE

WHY Th REACTORS ?

GO TO :

URAM – 2014 - Vienna -IAEA

Roberto C. Villas-Bôas

Government of India : “Thorium as a Safe and Clean Energy Source”.

Thorium Fight @ ThEC13