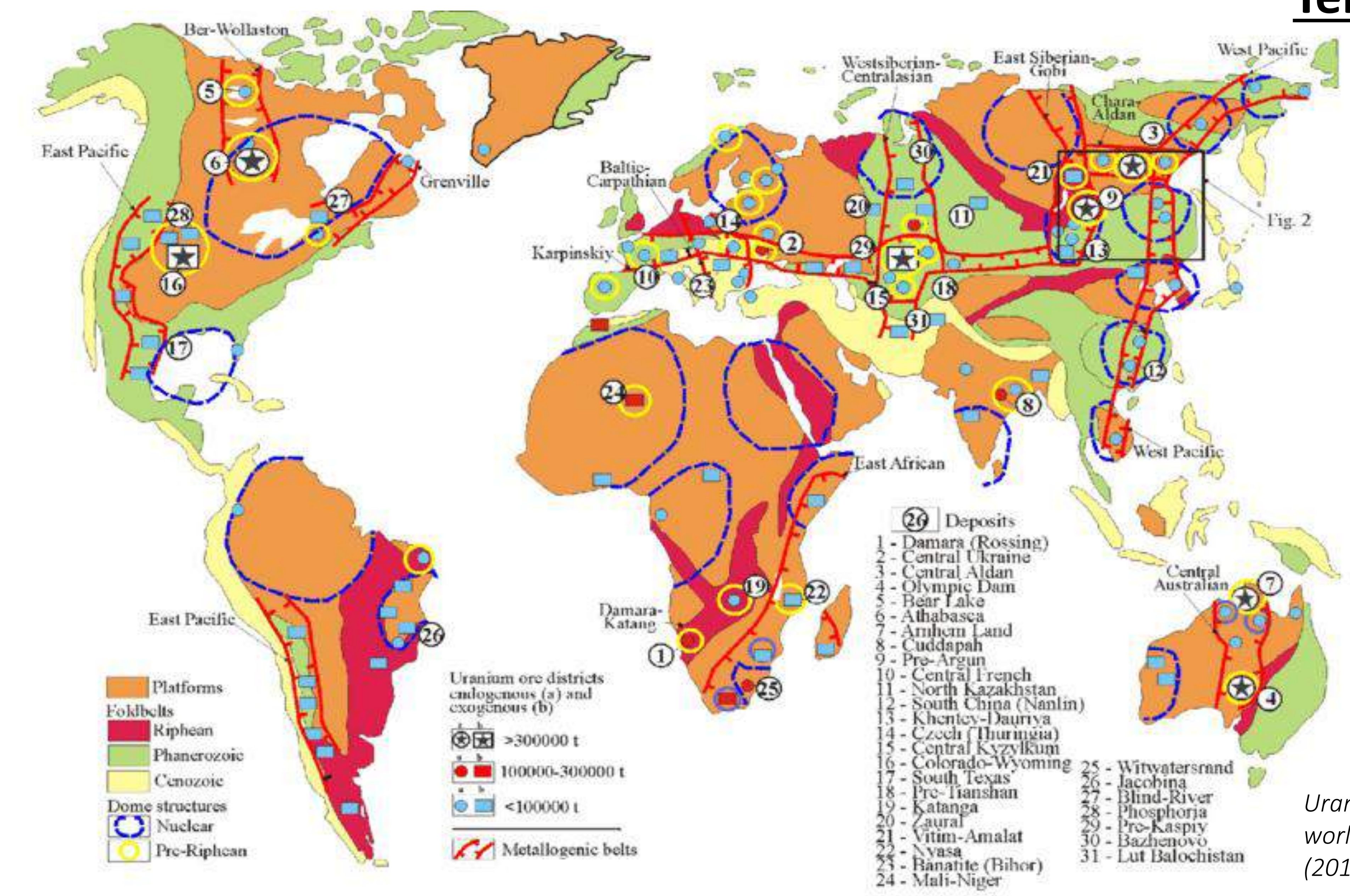
ENEA
Italian National Agency for New Technologies, Energy and Sustainable Economic Development

Nuclear Forensic of Uranium Ore Materials out of Regulatory Control: Galaxy Serpent exercise v3

EGU General Assembly 2024
EGU24-1715
16 aprile 2024

Telloli Chiara*, Ottaviano G, Rocchi F, Padoani F, Rizzo
ENEA, Nuclear Department
Methods and Techniques for Nuclear Security, Monitoring and Traceability Laboratory
*chiara.telloli@enea.it



Uranium provinces of the world. Afanasiev et al. (2014), Dahlkamp, 2009.

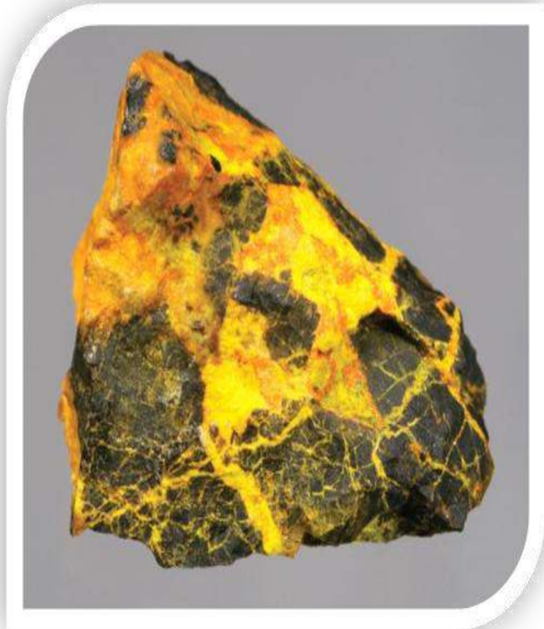
NUCLEAR FORENSICS is one of the pillars of **NUCLEAR SECURITY** as a response to criminal acts and illicit trafficking involving nuclear materials or other radioactive materials out of regulatory control (MORC). ENEA has been participating in a series of international virtual web-based exercises "GALAXY SERPENT" with the aim of developing national competences and National Nuclear Forensics Libraries (NNFLs) as a valuable support in nuclear forensic investigations. The last exercise, GS v3, fit in the field of safety and mitigation of CBRNe risks.

EXERCISE SCENARIO

1) 1st scenario describes the trafficking of Uranium ore concentrate (Uoc). The Government requires the organization of Uoc information in a NNFL, to support forensic investigations.

2) 2nd scenario describes, following an anonymous tip, the interception of a vehicle leaving the country with illicit load. Three sealed containers, marked only with radioactivity warning symbols, are identified on board. The inspections reveal the presence of geological sources in each container and subsequent isotopic investigations specify the presence of Uoc. The government requires the use of the NNFL previously created, to verify the consistency between the samples intercepted and the samples in the NNFL itself.

Phase 1: creation of the **NNFL** listing the sample **FORENSIC SIGNATURES** according to the **four affinity classes** of basalt (IAB, MORB, OIB, ZCRFB) from which Uoc was extracted. The investigation field was narrowed according to:

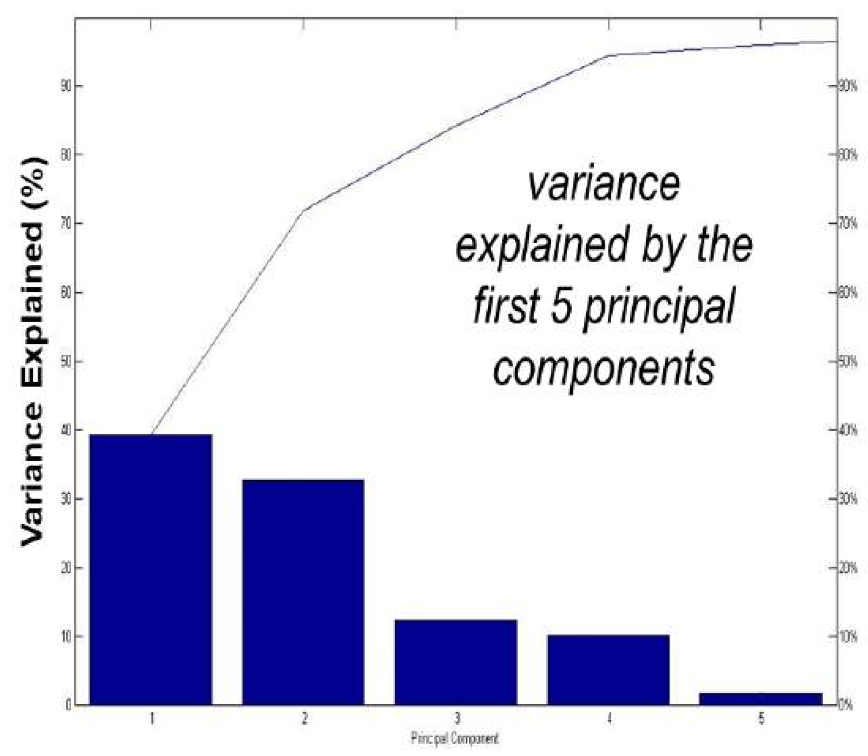


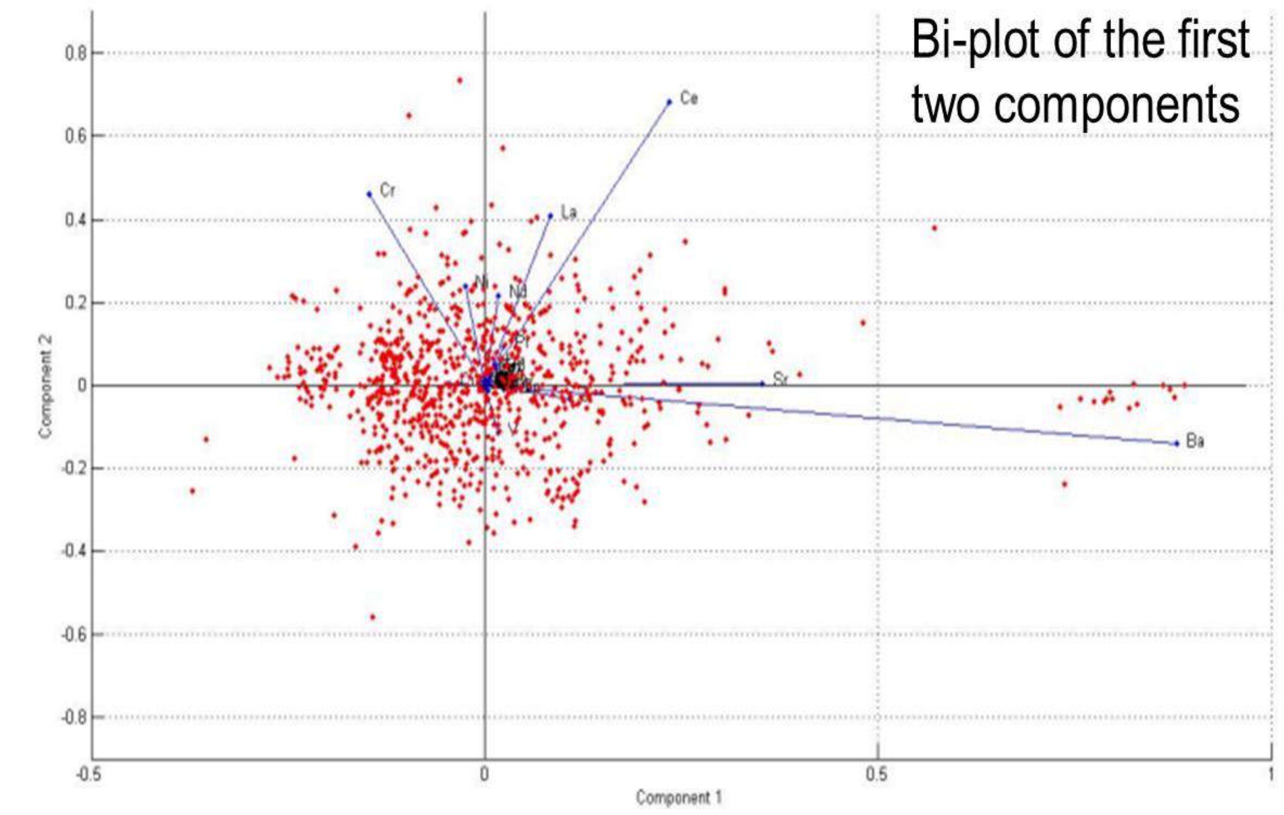
Basalt from uranium core

- PCA analysis: biased result;
- The sample has the lower variability respect to the remaining signatures;
- It is not a "trace element" and so it was not so useful for traceability investigation.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	AFFINITY	SAMPLE_ID	U	Ti	Al	Fe	Ca	Mg	Mn	K	Na	P	La	Ce
2	IAB	58685	788000	0,11	11,94	9,2	11,44	10,39	0,18	1,52	2,81	0,4	39,3	44,2
3	IAB	20972-FIL_93	809000	0,42	19,4	8,5	10,7	5,5	0,16	1,3	2,3	0,21	46,5	86,4
4	IAB	29358-P.1147.3	796000	0,30	19,6	8,17	12,22	7,4	0,14	0,38	2,04	0,08	27,4	96,7
5	IAB	12990-AB953-1	815000	0,41	18,39		10,25	4,83	0,18	1,15	2,47	0,19	24,5	69,2
6	IAB	14662-WA48	820000	0,27	16,66		8,89	9,12	0,12	0,41	3,84	0,04	45,7	98,5
7	IAB	49090	798300	0,42	17,59		12,07	6,2	0,19	0,56	2,24	0,1	54,4	122
8	IAB	61883	795600	0,50	19,49		11,22	5,5	0,15	0,24	2,19	0,12	88,9	150
9	IAB	170120	815000	0,50	19,8		10,02	5,54	0,19	0,68	2,9	0,17	131	230
10	IAB	8399-24	769500	0,50	17,6	8,74	10,28	11,59	0,21	0,59	2,22	0,14	147	241
11	IAB	10199-T072	818400	0,19	16,79		12,16	6,79	0,18	0,16	1,19	0,02	28,6	80
12	IAB	90543	771000	0,50	19,2	9,99	7,54	6,01	0,2	0,89	3,44	0,08	103	143
13	IAB	43502	816300	0,43	19,63	9,13	10,01	5,56	0,16	0,21	2,12	0,08	204	300
14	IAB	137268	803900	0,50	18,44	10,88	10,05	6,07	0,19	0,22	2,11	0,06	243	271
15	IAB	51014	816200	0,26	16,65		9,93	3,63	0,2	0,4	2,27	0,156	104	168
16	IAB	142652	812700	0,50	17,45	7,86	10,42	7,8	0,17	0,61	2,89	0,11	295	368
17	IAB	8801-SST.6.3	813700	0,41	16,15		11,47	6,19	0,22	0,29	2,19	0,05	126	196
18	IAB	8197-SSM_5.4	786600	0,28	18,58		12,89	8,24	0,18	0,1	1,3	0,35	138	228
19	IAB	8790-SSC.35.1	803700	0,41	18,65		11,65	5,78	0,18	0,055	1,82	0,02	176	306
20	IAB	14182-SSS_10.1	803400	0,50	16,83	9,71	11,31	7,45	0,17	0,35	2	0,09	241	394
21	IAB	41026	798200	0,31	19,86		12,38	6,59	0,18	0,09	1,71	0,03	231	469
22	IAB	40947	799200	0,34	16,53		12,58	8,27	0,18	0,12	1,6	0,02		

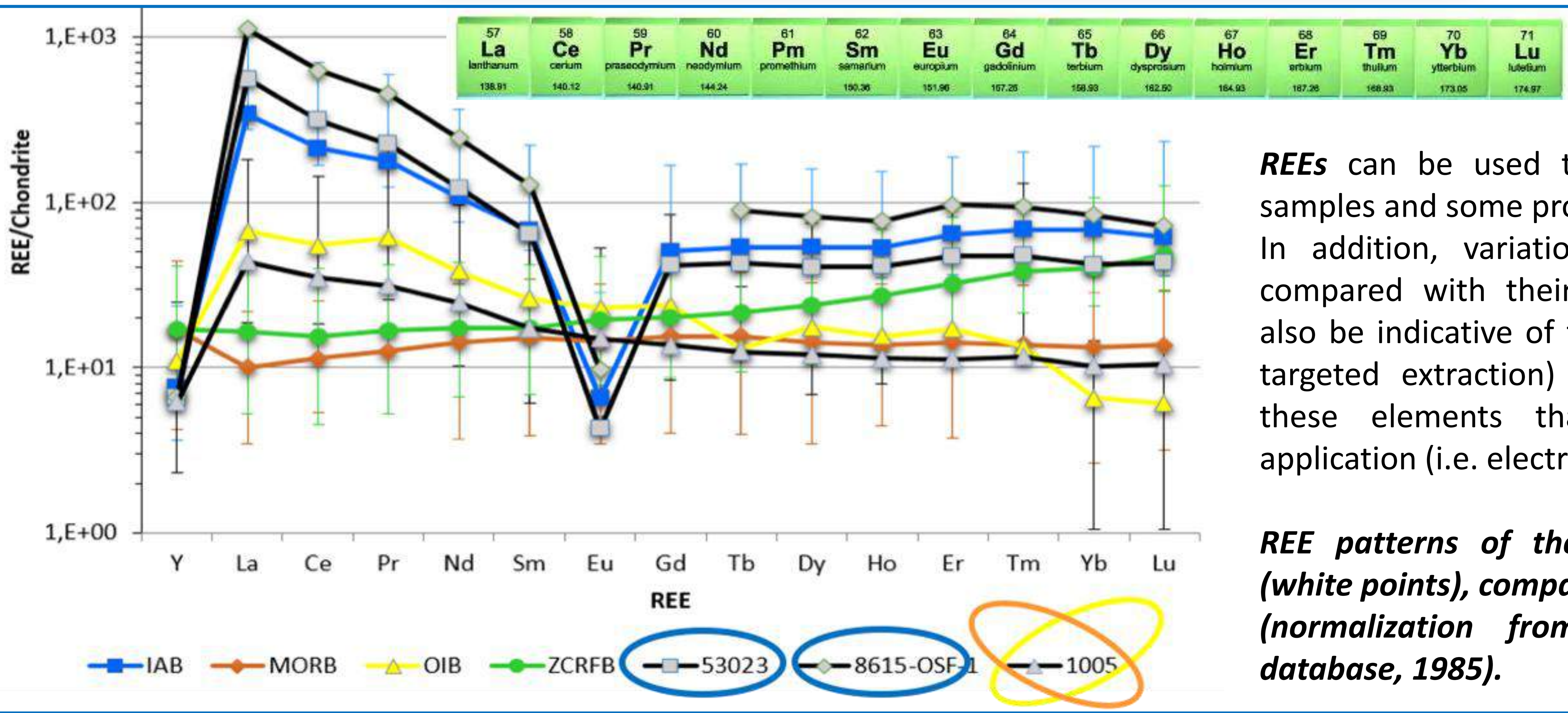
The **Principal Component Analysis** (***PCA***) was applied to the NNFL matrix to narrow the investigation field by selecting the most significant parameters (keeping the variability of the whole database).





PCA: 95% of the variance is explained by the first five components; the first three components explain more than two thirds (85%) of the variance (Fig. left).

Phase 2: the assessments of the consistency among the three unknown samples and between of each of them with the NNFL has been carried out using REE patterns as main fingerprint of the affinity classes.



REEs can be used to verify the origin of the samples and some process they have experienced. In addition, variations in their concentration, compared with their natural abundance, could also be indicative of technological processes (like targeted extraction) aimed at the recovery of these elements that have high technology application (i.e. electronics).

REE patterns of the three unknown samples (white points), compared to REE patterns of NNFL (normalization from "Taylor & McLennan" database, 1985).

CONCLUSIONS:

First unknown sample 53023	**→ IAB**
Second unknown sample 8615	**→ IAB**
Third unknown samples 1005	**→ IOB or MORB**

The enrichment in light REE compared to MORB pattern should be investigated as it can be clue of a different rocks genesis and we cannot establish its origin. The inconsistency among the three unknown samples make the illicit trafficking scenario more complex, suggesting a multiple breach of the control chain of the materials. The exercise showed that the availability of a geochemical dataset of REEs and trace elements of Uoc, combined with the application of specific tools, can usefully support nuclear forensic investigations on materials transportation control.