Distribution of Natural Radionuclides (K, Th and U) in Aplite Dyke from the Beira Uraniferous Province (Fornos de Algodres, Portugal)

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Introduction / Objectives

Focus of the study: **U-rich aplite dyke** sited in the Beira uraniferous province, in Fornos de Algodres area (Northern Portugal). The dyke intruded in Hercynian granitic rocks shows **spheroidal weathering**, consisting mainly of yellowish residual clay with boulders of less altered aplite.

Main objectives: study of trace element distributions, especially U, in the aplite. A vertical profile, different size fractions, and various concentrically weathered shells of rock, were examined. The goal is to better understand the geochemical behavior and redistribution of U during weathering of these rocks.

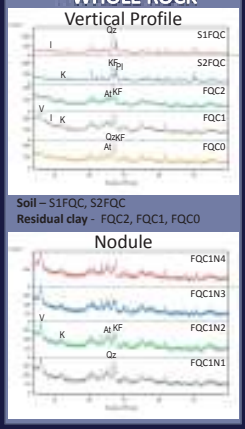
Materials / Methods

Chemical and mineralogical composition was obtained for **whole rock** (<2 mm) of 9 samples and for various **grain-size fractions** (>63 µm, 20-63 µm, 2-20 µm and <2 µm) of 4 samples from a vertical profile (residual clay-2 and soil-2).

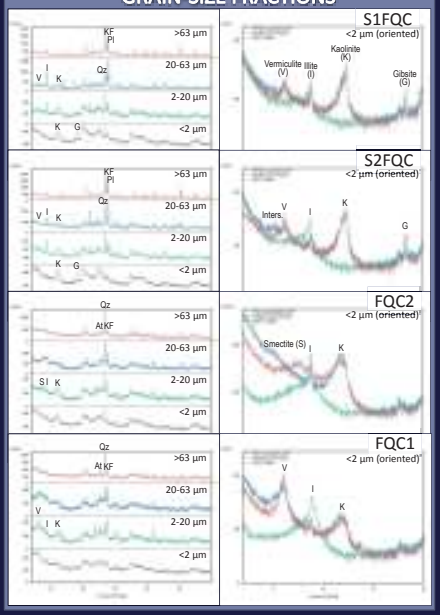
The **mineralogy** was studied by **XRD** and **chemical analysis** was made by **INAA**, using the Portuguese Research Reactor at ITN. **Field gamma spectrometry (FGS)**, using a NaI 3"x3" probe, and **high resolution gamma spectrometry (HRGS)** in the lab, were performed for sample FQC1, in order to determine the concentrations of natural radionuclides (K, Th, U) that are responsible for terrestrial gamma radiation.

FQC1N1 – external shell; FQC1N2 – middle shell; FQC1N3 – inner shell; FQC1N4 – core

Whole Rock

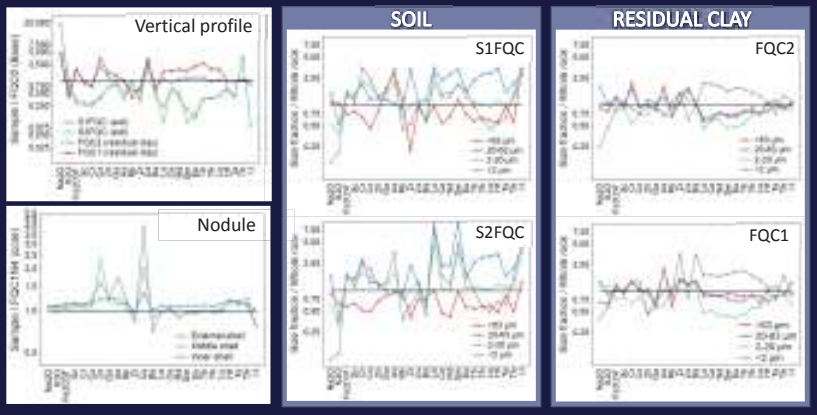


Grain-size fractions



Legend:

At – anatase
G – gibbsite
KF – K feldspar
Pl – plagioclase
Qz – quartz
Inters. – interstratificates
I – illite
K – kaolinite
S – smectite
V – vermiculite



Mineralogy

The samples have similar mineralogical composition, but the proportions vary. They consist of quartz and K-feldspar and minor plagioclase and anatase. The clay minerals are vermiculite, kaolinite, illite and rarely smectite and gibbsite.

Vertical profile – **a) soils** are richer in quartz and contain plagioclase; their clay minerals are kaolinite, illite, vermiculite and gibbsite; **b) residual clays** commonly contain anatase and are richer in clay minerals (kaolinite, illite, vermiculite and rarely smectite), especially towards the top.

Nodule – The proportions of quartz and clay minerals, as well as the kaolinite/vermiculite ratio, increase towards the external shell of the nodule.

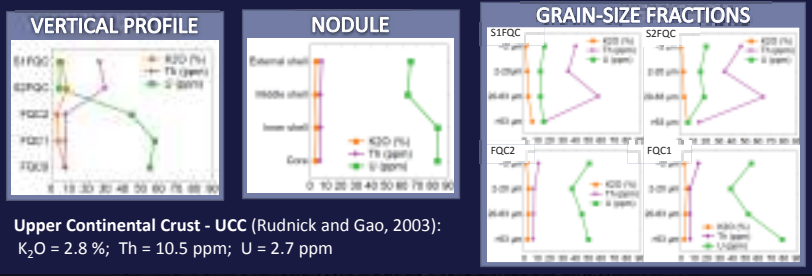
Grain-size fractions – the proportions of quartz and feldspars tend to diminish with decreasing grain-size, whereas that of clay minerals increases. Gibbsite occurs only in the finer fractions of the soils, especially in the <2 µm fraction.

Geochemistry

Vertical profile – **Residual clays** have similar composition, with REE, Na, Co, Fe and Cs contents increasing towards the top. **Soils** composition is quite different from clays, having lower amounts of Sc, Cr, Co, Fe, REE and U, and higher Na, Cs and Th contents, suggesting that abundant detrital components of soils were tranported from a different weathered source area, in accordance with the mineralogy.

Nodule – The more external/altered shells are clearly enriched in Cs, Zn and As, and have lower U, Ba and Zr concentrations than the core. The inner shell is also slightly enriched in REE.

Grain-size fractions – **a)** The finer fractions of **soils** have lower contents of alkalis, and higher contents of Cr, Co, As, light REE and U. The 20-63 µm fraction is especially enriched in Zr, Hf, and REE, including the heavy REE. The sand fraction has lower concentrations of most elements; **b)** In **residual clays** the clay fraction is depleted in alkalis, mainly Na and K, and it is enriched in REE and Th. Lower contents of REE occur in the 2-20 µm silty fraction.



Upper Continental Crust - UCC (Rudnick and Gao, 2003):
K_2O = 2.8 %; Th = 10.5 ppm; U = 2.7 ppm

FQC1 sample (clay-rich sediment)			INAA	FGS	HRGS
	K	%	3.1	2.1	3.0
	Th	ppm	7.9	7.1	8.1
^{238}U	**U** (parent)	ppm	57.8	-	-
U (^{234}Th; ^{226}Ra + ^{235}U)	**U** (pre-Rn)	ppm	-	-	37.5
U (^{214}Pb; ^{214}Bi)	**U** (post-Rn)	ppm	-	12.1	19.0
	U (^{210}Pb)	ppm	-	-	17.9

INAA - instrumental neutron activation analysis; **FGS** - field gamma spectrometry; **HRGS** - high resolution gamma spectrometry (lab measurements, unsealed)

Geochemistry: K_2O, Th and U Distribution

a) **Vertical profile** – The high amounts of Th and K_2O in soils are probably related to the high amounts of feldspars. The U content is about 20 times UCC in residual clays.

b) **Nodule** – Similar Th and K_2O values were found through the nodule. The nodule is even more enriched in U than the residual clays, especially in its core and inner shell (U is 31 times UCC).

c) **Grain-size fractions** – The K_2O concentration decreases slightly for smaller grain-sizes; Th tends to increase slightly for smaller grain-sizes but shows strong enrichment, out of trend, in the 20-63 µm fraction of soils. Uranium content tends to be higher in clay and sand fractions of residual clays.

K, Th, U Concentrations – Methods Comparison

K and Th concentrations obtained by INAA, FGS and HRGS are similar. Slightly lower values from the field measurements are related to in situ water.

Differences between parent concentration of U (INAA) and equivalent parent concentration based on pre-radon daughters (HRGS) , may indicate systematic effects on U determination at these high concentrations.

The much lower equivalent parent concentrations obtained from post-Rn isotopes, measured unsealed in lab and field, indicate the escape of radon gas (Rn loss = 49 %). This is supported by the similar value for ^{210}Pb, indicating radon release during recent decades.

Final Remarks

Strong variations in natural radionuclide concentrations relate to differences in source material.

Higher U contents in clay fraction suggest the U is mainly adsorbed on clay minerals. This is consistent with limited U losses from the zone of the dyke during chemical weathering, and also with observations of significant Rn escape.

The general high concentration of U in the aplite vein is a potential source of radon emission to the atmosphere that may have harmful environmental impact.

This work was conducted as part of the FCT funded postdoctoral program of M.J. Trindade (SFRH/BPD/41047/2007) and was supported by the FCT funded project PTDC/AAC-AMB/121375/201