Employment of portable gamma-ray spectrometer in survey and mapping of intrusive complexes: a case study from the Buddusò pluton (Sardinia)

ANTONIO PUCCINI (*), STEFANO CUCCURU (*), DANIELE SECHI (*), GIACOMO OGGIANO (*),
FABIO MANTOVANI (°), GERTI XHIXHA (°) & SARA MARIANI (**)

Key words: *Buddusò pluton, portable gamma-ray spectrometer, radioactivity, Sardinia-Corsica Batholith.*

This work illustrates the preliminary data concerning the employment of a portable gamma-ray spectrometer in survey and mapping of intrusive complexes.

To discriminate among different intrusions, which are generated from different magmatic pulse in composite batholiths made up of coalescent plutons, is not an easy task, particularly if different intrusions with similar petrofacies come into contact.

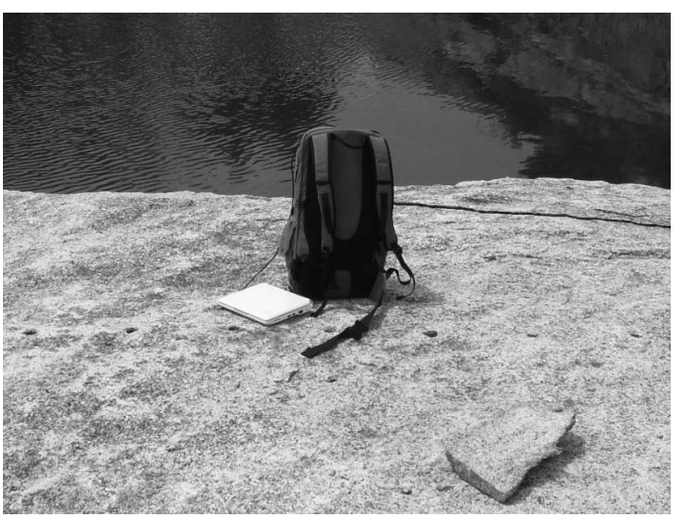

Fig. 1 – Portable gamma-ray spectrometer.

However, if textural and modal features are indistinguishable, the only effective way able to discriminate such intrusions is the chemical analysis of trace element, the cost of which is rarely sustainable when the aim of the survey is the production of a geological or thematic (dimension stone) map.

For this purpose a portable gamma-ray spectrometer at the National Lab of Legnaro (INFN) was developed. The equipment consists of one liter thallium-activated sodium iodide scintillator [NaI(Tl)], digiBASE by ORTEC and a netbook which manages also humidity and temperature sensors. By using the Jradview software is possible to process the data in real time and to determine uranium and thorium (in ppm), expressed as equivalent units, and potassium concentration (in %) as well as total activity expressed in Bq kg^{-1}. Following the IAEA guidelines (IAEA-TECDOC-1363 (2003)), the gamma-ray spectroscopic analysis is performed by monitoring three spectral windows: 1.37-1.57 MeV for ^{40}K , 1.66-1.86 MeV for ^{214}Bi and 2.41-2.81 MeV for ^{208}Tl.

The concentrations of U/Th are estimated by $^{214}Bi/^{208}Tl$ decays, under the assumption that the U and Th decay series are in secular equilibrium. This occurs when the parent half life is much longer than the daughter half life and then the number of atoms of a daughter isotope essentially becomes constant after some time. Two conditions are necessary for secular equilibrium. First, the parent radionuclide ($^{238}U/^{232}Th$) must have a half-life much longer than that of any other radionuclide in the series. Second, a sufficiently long period of time must have elapsed, to allow for ingrowth of the decay products. The state of secular equilibrium in natural uranium and thorium ores is significantly altered when they are processed to extract specific radionuclides, in particular Ra and Rn.

Assuming secular equilibrium we aimed to test the usefulness of this tool in geological mapping and in the identification of coalescent plutons which form the batholiths. The handiness of the instrument, the possibility of in situ measurement and, above all, the immediacy of the results in the outcrop, may be of considerable advantage in the expeditious survey of intrusive complexes.

Sardinia is an ideal testing area because a large portion of the Sardinia-Corsica Batholith is well exposed, consisting of several coalescent intrusions which often are very similar from textural and compositional point of view.

A campaign of measures on different intrusions and on their internal facies was therefore carried out. The acquired data highlighted that similar petrological facies of different plutons showed substantially different values of the considered nuclides. At the same time measurements made on slightly different facies belonging the same pluton showed comparable values.

We decided to focuse the tests on the Buddusò pluton and its host intrusions. The Buddusò pluton (BRUNETON & ORSINI, 1977;

(*) Dipartimento di Scienze Botaniche, Ecologiche e Geologiche – Università di Sassari, scuccuru@uniss.it

(°) Dipartimento di Fisica – Università di Ferrara

(**) Centro di Geotecnologie – Università di Siena

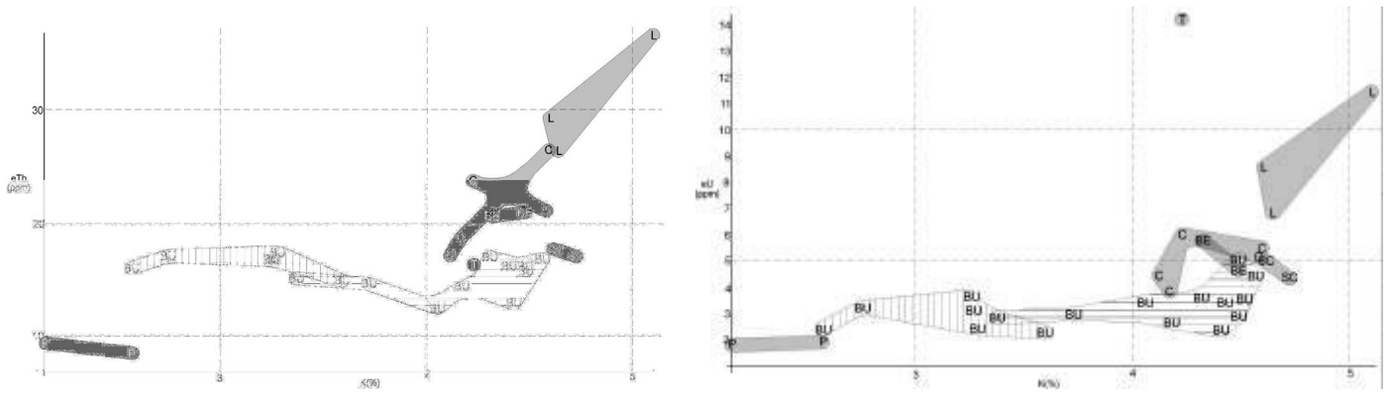

Fig. 2 – K-eTh and K-eU graphs. P: Pattada Pluton; C: Concas Pluton; BE: Benetutti pluton; L: M.te Lerno Pluton; SC: Sos Canales Pluton; T: Alà dei Sardi-Tepilora Pluton; BU: Buddusò Pluton (vertical lines: tonalites-granodiorites; horizontal lines: monzogranites – leucomonzogranites).

ORSINI & FERNANDEZ, 1987; BARBEY *et alii,* 2008) is a relatively small intrusion (about 70 km^2), with an internal structure of concentric shells which shows a normal magmatic differentiation from tonalitic-granodioritic facies in the external shell to monzogranitic and leucomonzogranitic facies in the core. This pluton is surrounded by the Concas, Sos Canales, Benetutti, Monte Lerno, Pattada and Alà dei Sardi-Tepilora plutons which range from the tonalities-granodiorites to leucomonzogranites.

All the acquired measurements were plotted on K-eTh and K-eU graphs which showed that the data arrange themselves forming populations corresponding to the different plutons (Fig. 2).

Taking into account only the Buddusò values, we noted that:

- an internal subdivision is present which corresponds to the different petrological terms that constitute the intrusion (tonalites-granodiorites and monzogranites-leucomonzogranites);

- there is a direct correlation from tonalites to leucomonzogranites and K and eU abundance. Instead the abundance of eTh appears less correlated;

- measurements made close to the contacts between different facies of the intrusion show transitional values between those of tonalitic-granodioritic and monzogranitic facies, whereas an appreciable differences rise between monzogranitic and leucomonzogranitic terms.

Conversely the granodiorites and tonalites of the Pattada intrusive unit, which are similar and seems continuous with the Buddusò intrusion, show meaningful difference in K/U and, particularly in K/Th ratios. As for the monzogranites and leucomonzogranites striking differences rise between the similar terms of Buddusò and P.ta Tepilora, M.te Lerno, Concas and Benetutti granites which as supposed belong to different intrusive pulses.

This first experimental test seems to encourage the employment of portable gamma-ray spectrometer as an aid in the expeditious survey of intrusive complexes. In fact our data show that K, eU and eTh concentrations of cogenetic facies (belonging the same pluton) are similar. Conversely, granitoids showing similar petrofacies but belonging to different intrusive units, show different concentration of the three considered nuclides.

REFERENCES

BARBEY P., GASQUET D., PIN C. & BOURGEIX A.L. (2008) - *Igneous banding, schlieren and mafic enclaves in calc-alkaline granites: the Budduso pluton (Sardinia)*. Lithos, **104**, 145-163.

BRUNETON P. & ORSINI J.B. (1977) - *Le massif granitique de Budduso: une seule intrusion de type zoné concentrique.* Compt. Rend. Acad. Sci. Paris, **284**, 151-154.

ORSINI J.B. & FERNANDEZ A. (1987) - *Signification de la discordance structurale entre fluidalité magmatique et zonalité pétrographique dans les intrusions de granitoides: l'exemple de l'intrusion de Budduso*. Compt. Rend. Acad. Sci. Paris, **304**, 993-996.

IAEA-TECDOC-1363 (2003) - *Guidelines for radioelement mapping using gamma ray spectrometry data*.