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ADVANTAGES OF Ge(Li) AND PURE Ge DETECTORS IN GAMMA SPECTROMETRY MEASUREMENT OF U, Th, AND K

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Introduction

Direct gamma spectrometry provides a practical method of analysis of natural samples for U, Th and K, and has been used for many decades now in geochemical investigations. The high resolution semiconductor (Ge(Li) or pure Ge) detectors in use in the last 15 years or so have made this method of analysis more precise and less cumbersome than NaI(Tl) spectrometry. Smith and Wollenberg (1973) discuss in detail the U and Th estimation in geochemical samples using Ge(Li) spectrometry. The gamma spectrometric method using NaI(Tl) detectors has also been recently employed in TL applications (Meakins, et al., 1979; Proszynska, et al., 1982).

Advantages of Ge(Li) or pure Ge spectrometry

Compared to NaI(Tl) spectrometry the semiconductor detectors have the following advantages: (i) Due to the high resolution the specificity is excellent. To illustrate, an energy window for U measurement by NaI(Tl) of 1.62 to 1.9 MeV includes 8 gamma lines due to Th-232 (daughters) with an absolute intensity of 5.9% as against the 35.9% intensity for the 2.61 MeV gamma-ray. The K-40 energy window, 1.35 to 1.55 MeV, contains 7 lines (12.2% absolute intensity) due to U-238 and 5 lines (3.8% absolute intensity) due to Th-232. Single peaks specific to either element are easily evaluated by Ge(Li) spectrometry by simple addition of peak channel contents followed by a linear background subtraction. To obtain meaningful peak counts in the NaI(Tl) spectrum one must perform a least squares analysis using the information content of all the channels naturally requiring a computer. (ii) Samples with high Th/U or U/Th cannot be assayed for the lower concentration element (U or Th, respectively) by NaI(Tl) spectrometry. For example a thorium ore sample with Th/U of 30 was easily analysed for the U content by Ge(Li) spectrometry (Smith and Wollenberg, 1973), whereas this is altogether not possible with a NaI(Tl) detector. (iii) The simultaneous estimation of U or Th, in the case of Ge(Li) (or Ge) spectrometry, through photopeaks due to different daughter products provides an internal check as well as information on any disequilibrium in the series. Various gamma energies useful for this purpose are listed in Table 1 along with the nuclide names. It is seen that these spectrometers make possible direct estimation of U-238. Coles, et al. (1975) could detect 0.2 ppm of U-238 by direct estimation using a Compton-suppressed Ge(Li) spectrometer. It is also seen from Table 1 that it is sufficient to calibrate and measure only up to about 1.6 MeV. The lower energy lines from Tl-208 and Bi-214 could be used for Th and U estimation instead of 2.61 MeV and 1.76 MeV. This is advantageous since the detector efficiencies at the lower energies are appreciably higher.

Our system description and detection limits - In our laboratory off-shore core samples were measured using a Ge(Li) detector having a 16.5% relative efficiency and a resolution of 2.2 keV for the 1332 keV gamma of Co-60, coupled to a 1024 channel analyser. TL dating on these samples was done and is reported elsewhere (Sadasivan, et al., 1981). The detector had a lead shield of 7.5 cm thickness on the sides and 3 cm at the bottom. Just above the detector and covering half the top area (48 x 48 cm) there was 10 cm of lead while the remaining area was covered by a 1.2 cm thick steel plate. Typical background counts in relevant peaks are listed in Table 2. The gamma spectrum of a core sample is shown in Figure 1.

The peaks used for analysis are shown underlined in the figure. The detection limits for U, Th and K estimation in this system are given in Table 3 along with those obtained in our earlier system consisting of a 12.4 x 10.0 cm NaI(Tl) detector. The minimum detectable level is taken as three times the standard deviation of the background under the peak, accumulated for the same duration as the sample counting time. For the Ge(Li) system, the backgrounds under U or Th peaks have been taken as that which are obtained in a spectrum of Th standard containing 10 ppm of Th and in a spectrum of U standard having 5 ppm of U, respectively. The sample weights in the Ge(Li) system were about 300g while they were about 2 kg in the NaI(Tl) system. The detection sensitivity in Ge(Li) system is more than adequate for geological and environmental sample analysis. It must be remembered that with high U or Th the quoted detection limit for Th or U has no relevance in the case of NaI(Tl) detector.

It is possible to lower the detection limits for Ge(Li) detector since these are now available with very much higher active volumes (efficiencies) and also by effecting further reduction in background by better shielding. Thus samples of even less than 100g could be conveniently measured for the U, Th and K contents by direct spectrometry. Even with the set-up described above we could measure K in some archaeological specimens of total weight less than 10 grams (Nambi, et al., 1979).

In conclusion, direct spectrometry using semiconductor rather than NaI(Tl) detectors are more suited for U, Th and K estimation especially in TL dating applications where the available sample volumes are small. If gross alpha measurements are inadequate then the Ge(Li) or Ge detectors should be used.

Table 1

Series	Gamma Energy (keV)	Nuclide	Series	Gamma Energy (keV)	Nuclide
U	46.5	Pb-210	U	1001.1	Pa-234
	63.3	Th-234		1764.7	Bi-214
	186.0	Ra-226	Th	583.2	Tl-208
		U-235		3911.2	Ac-228
	352.0	Pb-214		968.9	Ac-228
	609.4	Bi-214		2614.5	Tl-208

Table 2

Peak Energy (keV)	Bkg/50000 Sec.
186.0	220
238.6	985
352.0	212
583.2	350
609.4	229
911.2	112
1120.4	374
1459.1	585

Table 3

Detector:	12.5 x 10.0 cm NaI(Tl)	16.5% rel. eff. Ge(Li)
Sample weight:	2000 gram	300 gram
Element	**Detection limit**	
U	25.0 µg	60 µg
Th	35.1 µg	270 µg
K	98.6 mg	200 mg

REFERENCES

Coles, D. G., Meadows, J. W. T. and Lindeken, C. L. (1975) The direct measurement of ppm levels of uranium in soils using high resolution Ge(Li) gamma-ray spectroscopy, Rept. Lawrence Livermore Laboratory, UCRL-76747.

Meakins, R. L., Dickson, B. L. and Kelly, J. C. (1979) Gamma-ray analysis of K, U and Th for dose-rate estimation in thermoluminescent dating. Archeometry, 21, 279-86.

Nambi, K. S. V., Sasidharan, R. and Soman, S. D. (1979) Thermoluminescence dating of potteries excavated at Bhagwanpura and Mathra, Rept. Bhabha Atomic Research Centre, Bombay, BARC-1013.

Proszynzka, H., Miller, M. A. and Wintle, A. G. (1982) Interlaboratory study of potassium contents using gamma spectrometric and atomic absorption analyses and comparison with grain size, Ancient TL, 18.

Sadasivan, S., Nambi, K. S. V. and Murali, A. V. (1981) Geochemical and thermoluminescence studies of the shales from the off-shore drill core, West coast of India. Modern Geology, 8, 13-22.

Smith, A. R. and Wollenberg, H. A. (1973) High resolution gamma ray spectrometry for laboratory analysis of the uranium and thorium decay series. Proc. Natural Radiation Environment, Conf. 720805, USERDA 1972.

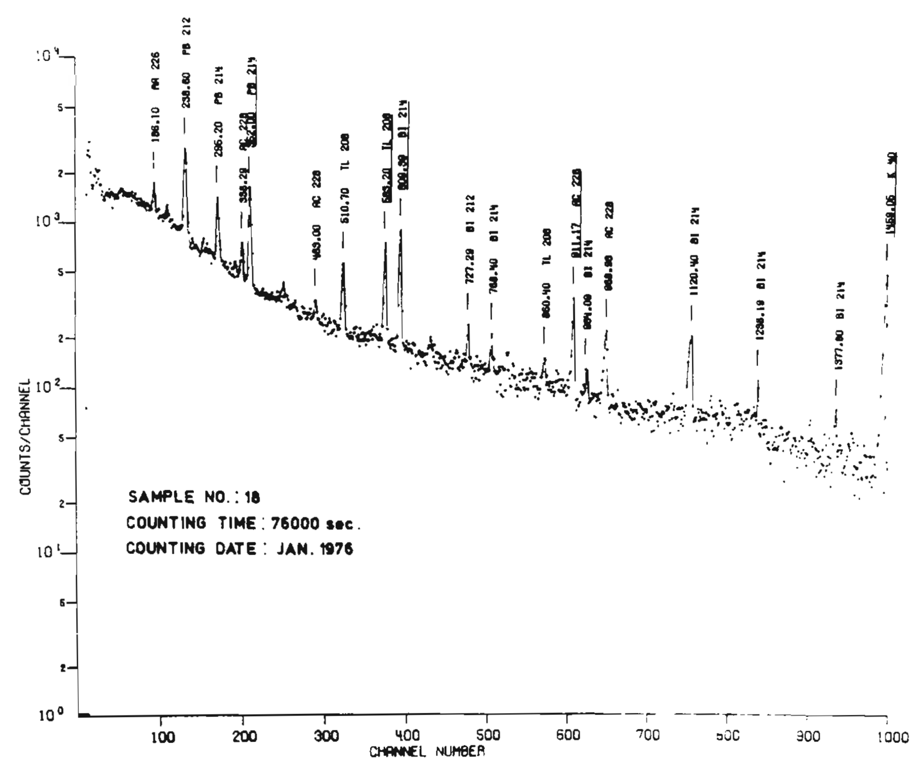

FIGURE:1. Ge(Li) SPECTRUM OF A DEEP CORE SAMPLE. ENERGY MARKINGS ARE IN KeV

(Compare this spectrum with the NaI(Tl) spectrum in Meakins et al.,1979)