

RADIOACTIVITY ANALYSES OF OIL WELL SAMPLES*

BRUNO PONTECORVO†

ABSTRACT

A laboratory method of analyzing the radioactivity of rock samples is described in which the laboratory tests are designed to simulate the conditions which prevail when radioactivity logs of wells are made. Thus the radioactivity of samples may be correlated with the results of such well logs and their interpretation improved thereby.

The radioactivity of rock samples has been studied considerably since the discovery was made that very small amounts of radioactive elements are always present in matter. Recent accurate measurements on sedimentary rocks have been performed using the "emanation method." A critical and complete discussion of the subject matter, including an extensive bibliography may be found in a recent paper of Evans and Goodman.¹ Radioactivity logging of oil wells² gives a curve of the total gamma activity of the rocks in a well versus depth. The present paper describes a method of analyzing the radioactivity of samples which was developed in our laboratory *with the purpose of obtaining information useful for the interpretation of radioactivity well logs*. Of course, it is also quite desirable to have the means for predicting the type of radioactivity logs in a given area from a study of the sample radioactivity of this area.

In order to develop a method of correlating radioactivity logs with the radioactivity of samples, it must be remembered that:

First, the radioactivity well-logging instrument is affected only by gamma rays emitted from formations, and not by alpha and beta radiations. On the contrary, in the laboratory we may measure gamma, beta, and alpha rays from samples.

Second, the only radioelements which in practice contribute to radioactivity logs are: the uranium family, the thorium family, and potassium. Uranium and thorium are assumed to be in equilibrium with all their products.

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† Well Surveys, Inc., Tulsa, Oklahoma.

¹ R. D. Evans and C. Goodman, Bulletin of the Geological Society of America, vol. 52, No. 4, p. 459 (1941).

² G. H. Westby and S. A. Scherbatskoy, *Oil and Gas Journal*, February 22, 1940, p. 62. W. G. Green and R. E. Fearon, *GEOPHYSICS*, vol. 5, No. 3, p. 272 (1940). W. L. Russell, *The Oil Weekly*, November 11, 1940.

Third, the quantity of rock affecting the survey instrument is exceedingly large. On the contrary, for obvious practical reasons, this is not true in the case of samples. The fact that the size of the sample is inherently small, and the quantity of rock represented by well logging exceedingly large is the most serious source of difficulty in correlating sample measurements with radioactivity well logs.

Difficulties occur not only because the intensity of the gamma radiations from a small sample is very weak, but because the gamma radiation emitted by rocks has a very complicated spectrum caused by different components of the uranium family, the thorium family, and potassium.

Every component of the radiation has a different weighting factor for its effect on any gamma ray detector, which depends upon the thickness of the detecting instrument walls, and possible filters, such as casing, and also upon the geometrical conditions and the amount of rock present.

In general, in a well, the complex gamma radiation will be in equilibrium with its secondary Compton gamma radiation. This will not be the case for all the components if we measure the activity of a small rock sample.

It can be said that the well logging instrument has a greater weighting factor than a sample instrument for radioelements emitting gamma rays of high quantum energy. This assertion is not in conflict with the fact that, because of the degradate radiations, gamma rays which are actually recorded in the sub-surface instrument are on the average softer than those recorded by a sample instrument.

In order to correlate the measurements in a well and the measurements on samples, we first make a sample measurement exactly comparable with a well measurement by reproducing the well conditions in an "artificial well" (Fig. 1) in the laboratory, using very large amounts of rock. We prepare very large samples containing only the uranium family, only the thorium family, and only potassium, and then determine in a calibration measurement the ionization produced in the logging instrument by the separate components.

The correlation of sample radioactivity measurements with radioactivity well logs then becomes essentially the problem of measuring in any sample the separate amounts of uranium family, thorium family, and potassium. This has been done by a method which is considerably less sensitive than the emanation methods, but which has the advantage of not destroying the samples. Furthermore, the emana-

tion method obviously cannot give the analyses of potassium which are of primary importance for our purpose. Because of the small sensitivity of the present method, we use it only for the strongly active samples (see below).

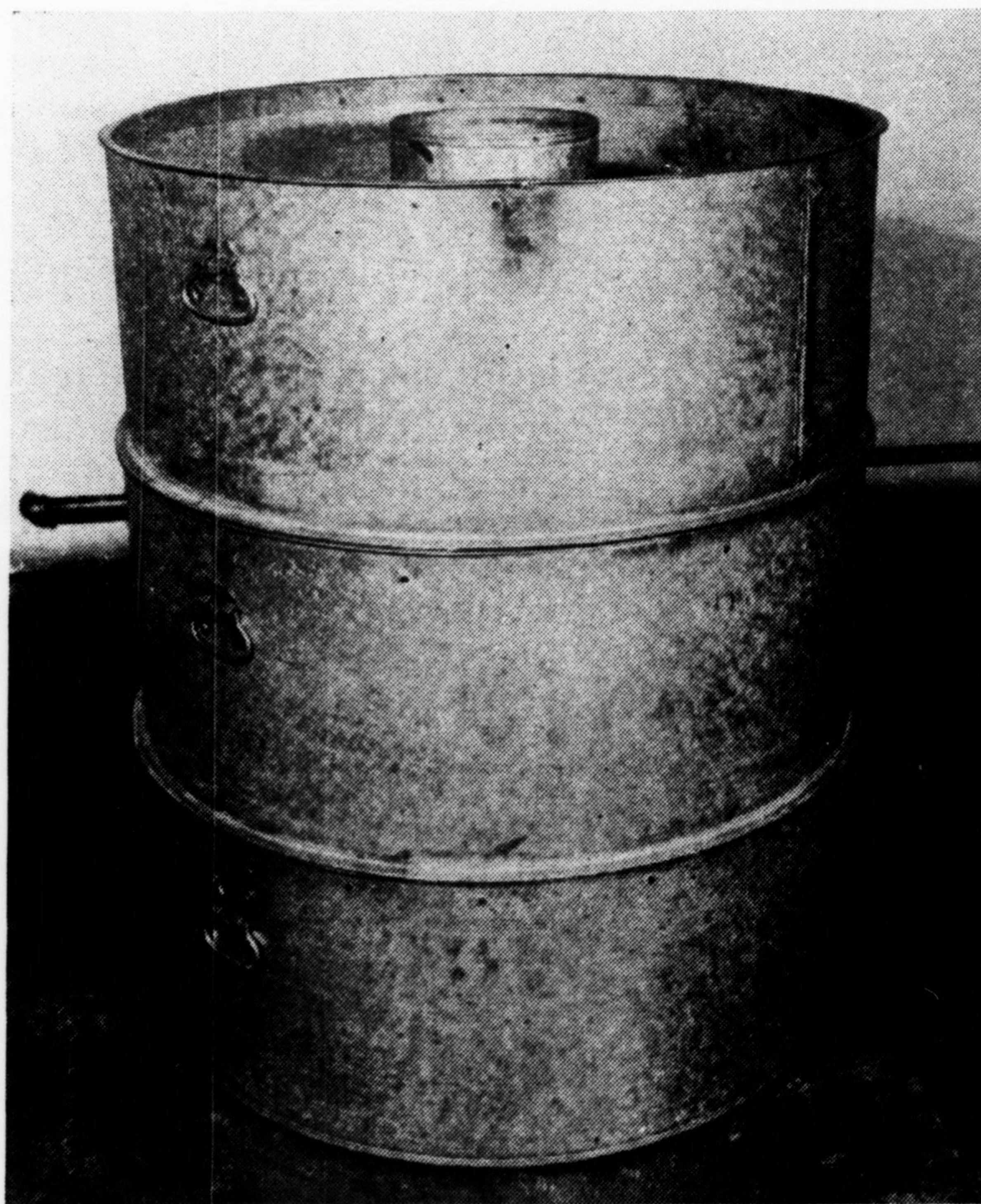


FIG. 1. Artificial well.

The present method consists in measuring the activity of a sample with three Geiger-Mueller counters, No. 1, No. 2, and No. 3 (Fig. 2). To every counter corresponds a standard sample container No. 1, No. 2, and No. 3. The container has an annular shape and is placed around the counter. The thicknesses of the inner wall of the containers (including the wall of the counter) are:

<i>Geiger Counter + Container</i>	<i>Wall Thickness in Aluminum Equivalent</i>	<i>Amount of Sample Used</i>	<i>Radiation Chiefly Detected</i>
No. 1	7 mm.	280 grams	Gamma
No. 2	0.6 mm.	70 grams	Beta + Gamma
No. 3	0.1 mm.	18 grams	Beta

It is clear that the counter No. 1 will record only gamma rays, counter No. 3 practically only beta rays, and counter No. 2 will record gamma and energetic beta rays together, with weighting factors for the thorium family, uranium family, and potassium which have to be determined only once.

These weighting factors are obtained in a calibration measurement, by determining the activity in each counter, of three artificial samples:



FIG. 2. Containers 1, 2, 3, and Geiger Counter shielded by lead.

the first containing quartz sand plus Carnotite, the second containing quartz sand plus Monazite, the third containing quartz sand plus potassium chloride.

Using the calibration data, the amount of thorium, uranium, and potassium in any sample can be obtained from the simple solution of a system of three linear equations with three unknowns. In fact, the ratio of the number of beta rays to the number of gamma rays is very different for potassium and the uranium and thorium families, and on

the other hand, the spectra of beta rays from various radioelements present considerable differences.³

Because of the small sensitivity of the present method, we can use it only for the "strongly active" samples, in which we are especially interested. We define conventionally "strongly active" samples as those which give > 2 impulses per minute above the background (20 impulses/minute) in our gamma counter: this figure would correspond, for a sample containing *only* the uranium family, to 5×10^{-12} gram of radium per gram of rock.

In conclusion the writer wishes to thank Mr. R. E. Fearon and Mr. T. H. Gilmartin for their collaboration in this work.

³ See, for instance, E. Rutherford, J. Chadwick, C. D. Ellis, *Radiations from Radioactive Substances*, Cambridge University Press, 1930, p. 408; and P. Curie, *Radioactivité*, Hermann Editeur, 1935, vol. I, p. 292.