The presence of uranium in the meteorite should result in the production of the 2·33-day neptunium-239 activity and of the fission product 12·8-day barium-140 upon exposure to neutrons. By comparison with the production of these nuclides in the spiked 'mock meteorite', the uranium content of the meteorite can be determined.

At least three irradiations on each meteorite were carried out, with the results indicated in Table 1. Although some 10–20 c./min. of radioactivity were usually found in the isolated barium, this did not decay with the characteristics of the 12·8-day barium-140 – 40-hr. lanthanum-140 chain. Thus from the barium analyses we can only set upper limits to the uranium content of the meteorites.

Table 1. Activation Analysis for Uranium in Iron Meteorites

Irradiation number	Uranium (gm.)/meteorite (gm.) ($\times 10^{10}$)			
	Tamarugal*		Thunda†	
	Barium-140	Neptunium-239	Barium-140	Neptunium-239
I	< 3·5‡	—	—	—
II	<14	< 2·1§	—	—
III	< 3·5	< 1·7	< 3·4	< 1·0§
IV	< 7	<45	<11	<20
V	< 1·4	< 4·4	< 1·8	Lost

* Dalton, Paneth, Reasbeck, Thomson and Mayne (see ref. 2) quote: 30–34 $\times 10^{-10}$ gm. uranium/gm. in Tamarugal.

† Dalton and co-workers (see ref. 1) quote: 55 $\times 10^{-10}$ gm. uranium/gm. for Thunda.

‡ The limit in irradiation I was calculated from the flux as determined by the production of cobalt-60 and iron-59, and checked by gold and bismuth monitors. No mock meteorite sample was run in this irradiation.

§ These samples were dissolved under oxidizing conditions (see text); all others were dissolved under conditions designed to keep the neptunium in a state of oxidation capable of being carried by fluoride.

Small amounts of β-activity came through the neptunium chemistry also. Although it often decayed with approximately the correct half-life, we are not sure that it necessarily was neptunium-239. The limits for the uranium content calculated from this apparent neptunium-239 activity were consistent with those from the barium analyses.

On the basis of these experiments we do not feel that we have detected any uranium in iron meteorites. Because of varying conditions, the limits set in the different experiments show some scatter; more than half are lower than 5×10^{-10} gm./gm.

The comparison with the 'mock meteorite' should obviate most of the usual corrections in this type of analysis[4]. In addition, consistent limits were calculated from the approximately known flux at the irradiation positions. Since the production of cobalt-60 and iron-59 in irradiations I, II and III agreed with this flux and the accepted iron and cobalt contents of iron meteorites, there could not have been any significant self-shadowing in the sample.

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[1] Dalton, Golden, Martin, Mercer and Thomson, *Geochim. et Cosmochim. Acta*, **3**, 272 (1953).

[2] Dalton, Paneth, Reasbeck, Thomson and Mayne, *Nature*, **172**, 1168 (1953).

[3] Urey, H. C., *Nature*, **175**, 321 (1955).

[4] For a general description of the activation method of analysis, see, for example, Meinke, W. W., *Science*, **121**, 177 (1955).

Magnitude and Energy of Earthquakes

In a paper presented at a meeting of the Seismological Society of America on April 29, 1955[1], we have revised previous work[2] on the relation of earthquake magnitude M to energy E (in ergs). Methods formerly used to extend the magnitude scale for local earthquakes to teleseisms lead to inconsistencies, so that in effect three different magnitude scales are in use: (1) M_L, the magnitude originally defined by Richter[3] for local earthquakes in California as recorded on standard torsion seismometers. (2) M_S, that based on calculated ground amplitudes for surface waves of periods of about 20 sec. in shallow teleseisms. (3) M_B, that based on the amplitude/period ratio in body waves for both shallow and deep earthquakes.

Using new data, the following partly empirical equations have been set up:

$$\log E = 9 \cdot 4 + 2 \cdot 14\, M_L - 0 \cdot 054\, M_L^2$$
$$M_S - M_B = A\,(M_S - B),$$

where, originally[1], $A = 0 \cdot 4$, $B = 7$; further investigation suggests slight numerical revision.

Data are scarcely sufficient to establish a relation between M_B and M_L. Tentative correlations are as follows:

M_L	3	5	7	9
M_B	4·0	5·5	6·8	8·1
M_S	(2·4)	4·7	6·9	8·7±
$\log E$	15·4	18·9	22·1	25·2

For a given observed shock E is much lower than previously estimated. One main source for this decrease is the great difference in amplitudes recorded for similar earthquakes at different sites. In 1942 accelerograph data obtained by the U.S. Coast and Geodetic Survey at metropolitan locations (mostly on sedimentary rocks or alluvium) were correlated directly with seismograms at stations of the Pasadena group (mostly on basement rock). Closer study and experimentation now establish a mean amplitude ratio of about $2\frac{1}{2}:1$ between the two groups of installations, with extreme values of about 10 : 1.

For further research on magnitude and energy we are now using M_B as a general standard, reducing M_S and M_L to that basis so far as practicable. Tentatively,

$$\log E = 5 \cdot 8 + 2 \cdot 4\, M_B.$$

We recommend that, in publication, any systematic change in numerical magnitudes, or in routine methods for determining them, be deferred pending further study of the relation of M_L to the other quantities.

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[1] Gutenberg, B., and Richter, C. F., submitted to *Bull. Seismol. Soc. Amer.*

[2] Gutenberg, B., and Richter, C. F., *Bull. Seismol. Soc. Amer.*, **32**, 163 (1942).

[3] Richter, C. F., *Bull. Seismol. Soc. Amer.*, **25**, 1 (1935).