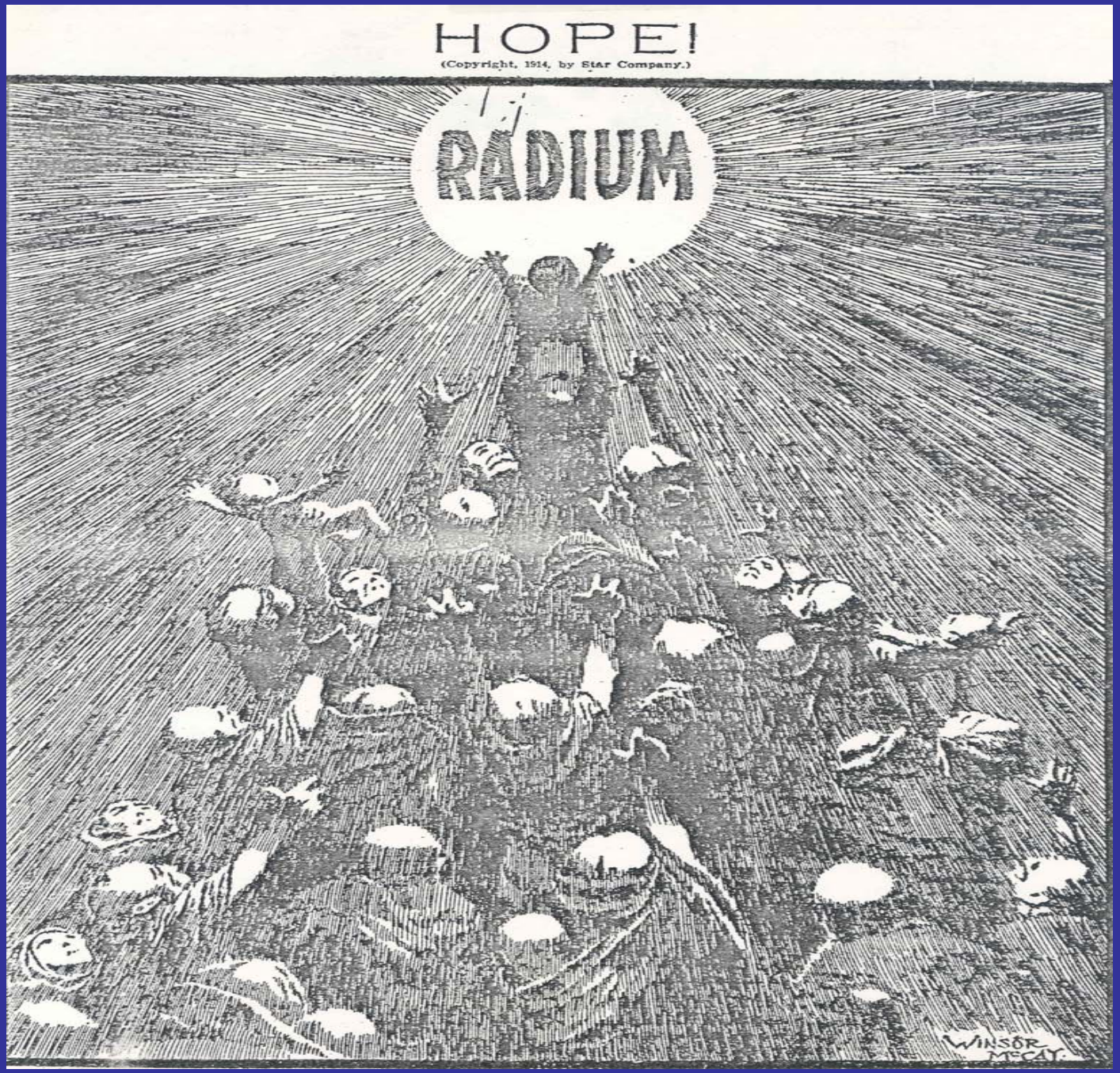
The Saga of the Radium Dial Painters

The first occupational internal dose study cohort

R. E. Toohey, Ph.D., CHP

Oak Ridge Associated Universities

HOPE!



1re ANNÉE. — N° 1 Le Numéro : 50 Centimes JANVIER 1899

LE RADIUM

PUBLICATION MENSUELLE

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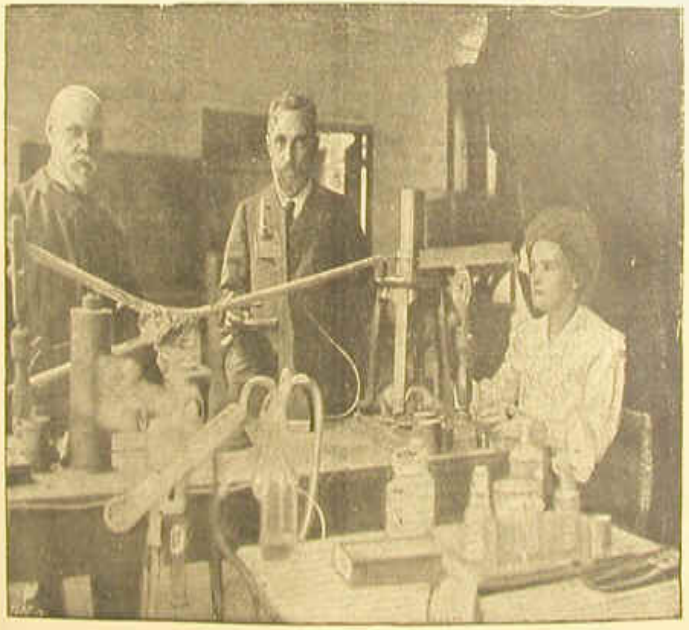
Henri FARJAS

ADMINISTRATION : 36, Rue de l'Arcade, PARIS
TÉLÉPHONE : 124-03
Abonnements : Un An, 5 fr. — Union Postale, 7 fr.

Le Laboratoire de la Rue Lhomond



M. & Mme CURIE

NOTA. — Les abonnements partent du mois de Janvier ; on ne donne pas d'abonnement de 6 mois. Le *Radium* est en vente chez les Libraires, Marchands de journaux et dans les Gares, on n'envoie pas de numéro spécimen.

RADIUM

A MONTHLY JOURNAL DEVOTED TO THE CHEMISTRY, PHYSICS AND THERAPEUTICS OF RADIUM AND RADIO-ACTIVE SUBSTANCES.

Edited and Published by Charles H. Viol, Ph. D. and William H. Cameron, M. D., with the assistance of collaborators working in the fields of Radiochemistry, Radioactivity and Radiumtherapy.

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Address all communications to the Editors, Forbes and Meyran Avenues, Pittsburgh, Pa.

VOL. III APRIL, 1914 No. 1

INFLUENCE OF INTRAVENOUS INJECTION OF SOLUBLE RADIUM SALTS IN HIGH BLOOD PRESSURE.

By FREDERICK PROESCHER, M. D.

FIGURE 1 The April 1914 issue of the journal *Radium* carried this title page.

THE COUNCIL ON PHARMACY AND CHEMISTRY OF THE AMERICAN MEDICAL ASSOCIATION HAS ACCEPTED FOR INCLUSION WITH NEW AND NON-OFFICIAL REMEDIES THE FOLLOWING PRODUCTS OF THE STANDARD CHEMICAL COMPANY OF PITTSBURGH, PENNSYLVANIA:

Radium Bromide
Radium Chloride
Radium Sulfate
Radium Carbonate

"Standard" Radium Solution for Drinking
"Standard" Radium Solution for Bathing
"Standard" Radium Compress
"Standard" Radium Earth

For Literature Address

RADIUM CHEMICAL COMPANY

Forbes and Meyran Avenues, Pittsburgh, Pa.

You are cordially invited to visit our exhibit at the annual meeting of the Illinois State Medical Society, Springfield, Illinois, May 18th, 19th and 20th, 1915, Masonic Temple. Booth Number 18.

FIGURE 3 This advertisement for radium preparations to be used


Jáchymov
Jáchymov
Trade RADIUMCHEMA mark
Radio-active compress
Radiumchema
Large size: 6/8 in.
The activity of this compress is constant.
Contents of Radium:
0·1 mg
Directions for use inside.
The genuineness and the contents of Radium are guaranteed only as long as the original seals remain intact.
Chemical Works Kolín-Jáchymov (Czechoslovakia).
Radiumchema Department.

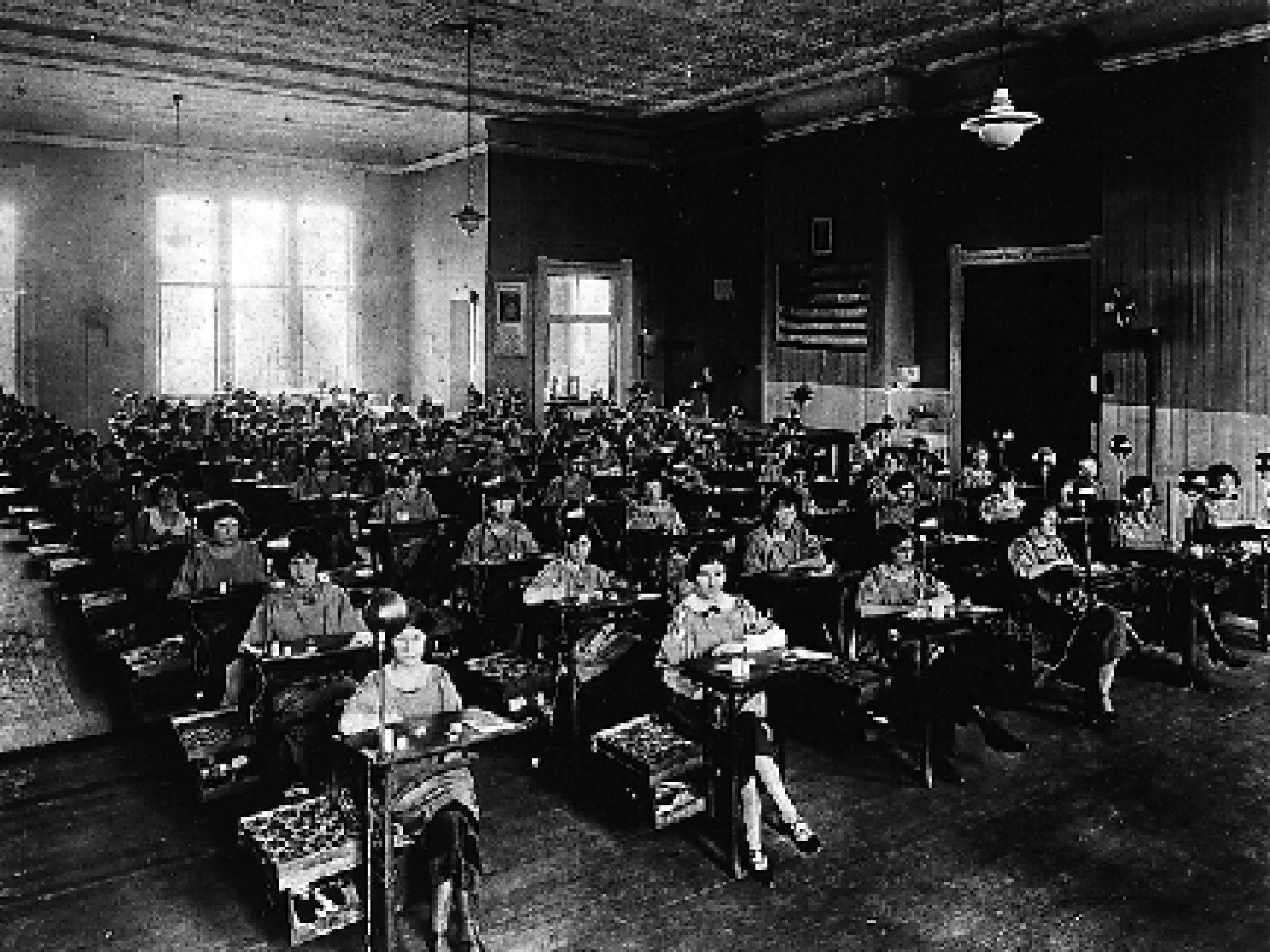

RADITHOR
REG. U. S. PAT. OFF.
CERTIFIED
Radioactive Water
Contains
Radium and Mesothorium
in Triple Distilled Water

Radium properties

- Ra-226: member of U-238 decay chain, physical half-life of 1620 years, alpha emitter, parent of Rn-222
- Ra-228: (also referred to as mesothorium), member of Th-232 decay chain, 5.8 –yr half-life, beta emitter, but with alpha-emitting progeny
- Both are bone-volume seekers
- Ra-228 deposits about 2.5 x as much alpha energy in bone as dose Ra-226
- Gastrointestinal absorption of each about 20%
- Gamma-ray dose rate from Ra-226 = 0.8 mR per hour per mCi at 1 meter

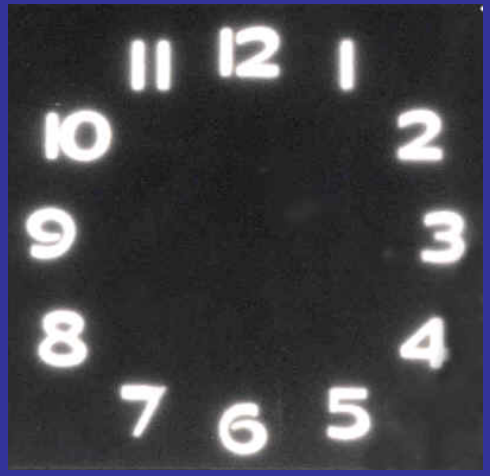
Dial-painting industry

- Waterbury, CT
  - Waterbury Clock Co.
  - Studied by Evans at MIT
- East Orange, NJ
  - Radium Dial, Inc.
  - Studied by NJ State Health Dept.
- Elgin, Ottawa, Peru, LaSalle, IL
  - Elgin Watch Co. and Radium Dial, Inc.
  - Elgin State Hospital: iatrogenic cases
  - Studied by ACRH and ANL-E

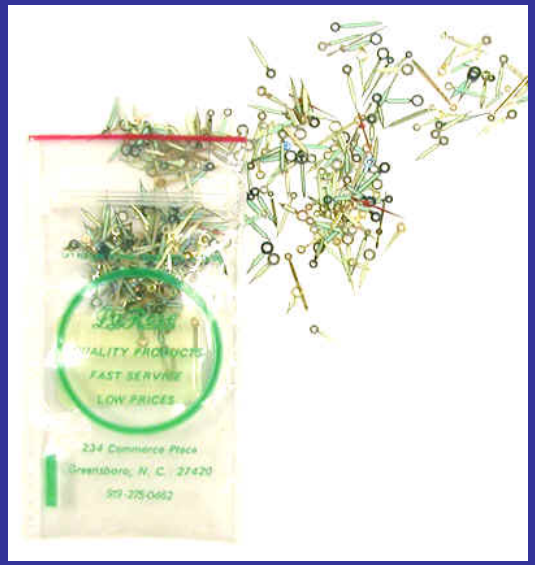



Bottle of glue
Radium powder
Dial being painted


11 12 1
10 2
9 3
8 4
7 6 5


11 12 1
10 2
9 3
8 4
7 6 5

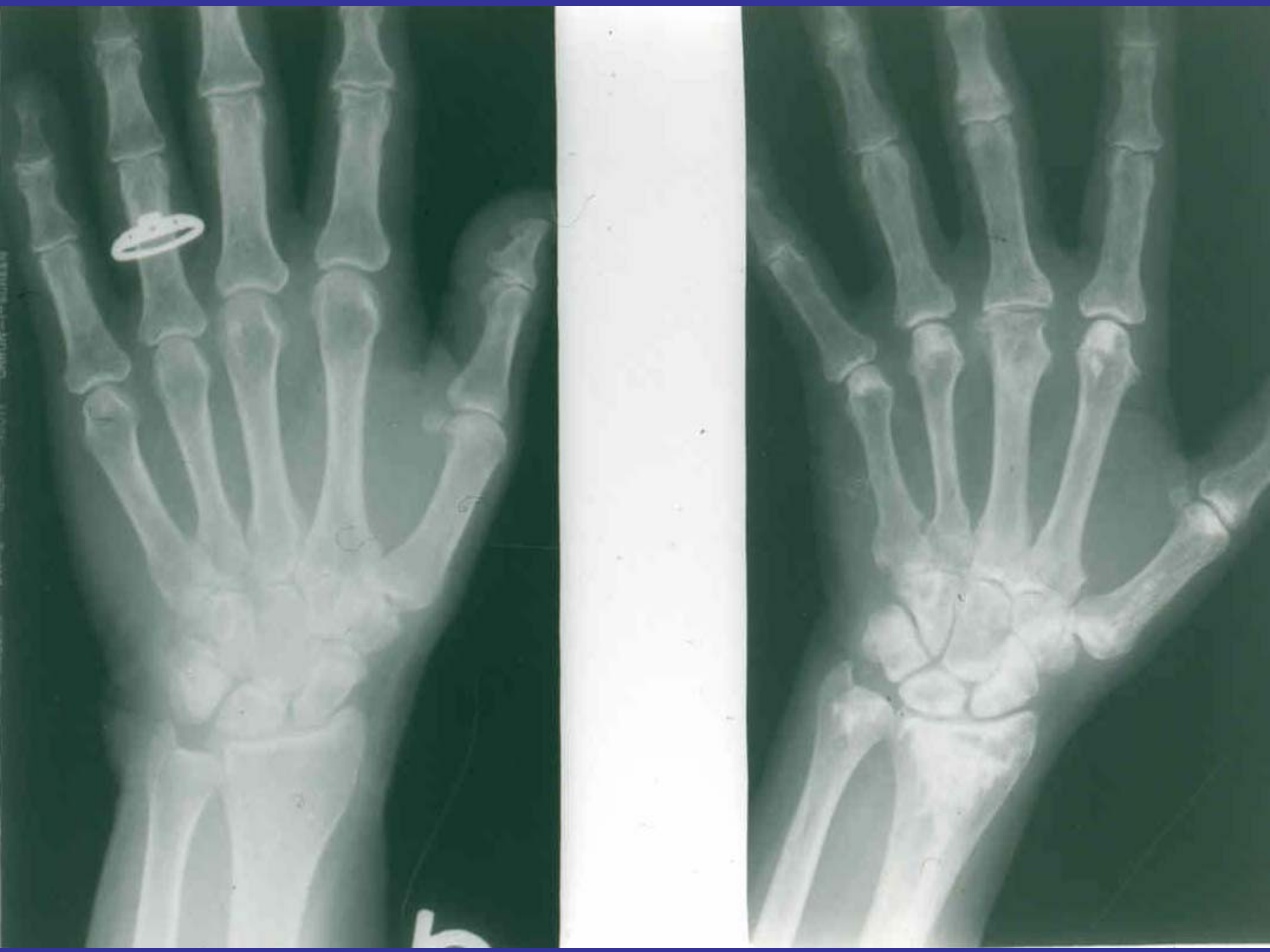

FIND IT in the DARK!
Radi-Glo
PATENT APPLIED FOR
GENUINE RADIUM RAY
"SPOTTER" BUTTON
NEED NEVER BE EXPOSED TO LIGHT FOR RECHARGE
INSTRUCTIONS: For example, on light switches, simply remove one plate screw, center one Radi-Glo button over opening (countersunk side toward you) and replace the screw. Radi-Glo buttons can be glued, sewn, stapled, screwed or attached to hundreds of objects and places for instant visibility in darkness. Scotch tape or other adhesive may be used.
LIFETIME USE • APPLY ANYWHERE
LIGHT SWITCHES • STAIRS • DARKROOM
(SEE OVER)


FAST SERVICE
LOW PRICES
234 Commerce Place
Greensboro, N. C. 27420

Radium health effects

- First noted by Dr. Theodore Blum, a NJ dentist in the early 1920's
- "Radium jaw" analogous to "phossy jaw"
- Quantified by Dr. Harrison Martland, pathologist in Orange NJ
- Numerous trials and stories on the "girls doomed to die" in the late 1920's


NO. CHR-
ANL. HE

Radium Workers at Deadly Task

A simple safety standard

- Don’t eat the paint
- Brush-tipping was forbidden as an unsafe labor practice by the U. S. Department of Labor in 1929
- No dial workers from the 1930’s on had significant intakes of radium, but were followed up because of external gamma exposure

Why study radium?

- Robley ratios:

Pu toxicity in man/Ra toxicity in man =

Pu toxicity in dog/Ra toxicity in dog

- Dog studies:
  - ANL-E, Utah, UC Davis, ITRI, Colorado State, Hanford
- Human study: consolidated at the ANL-E Center for Human Radiobiology (CHR) in 1969

The CHR Radium Project

- Total population (est.) 6,000
- Names 5,000
- Located 3,500
- Measured 2,500

  (includes some deceased cases)

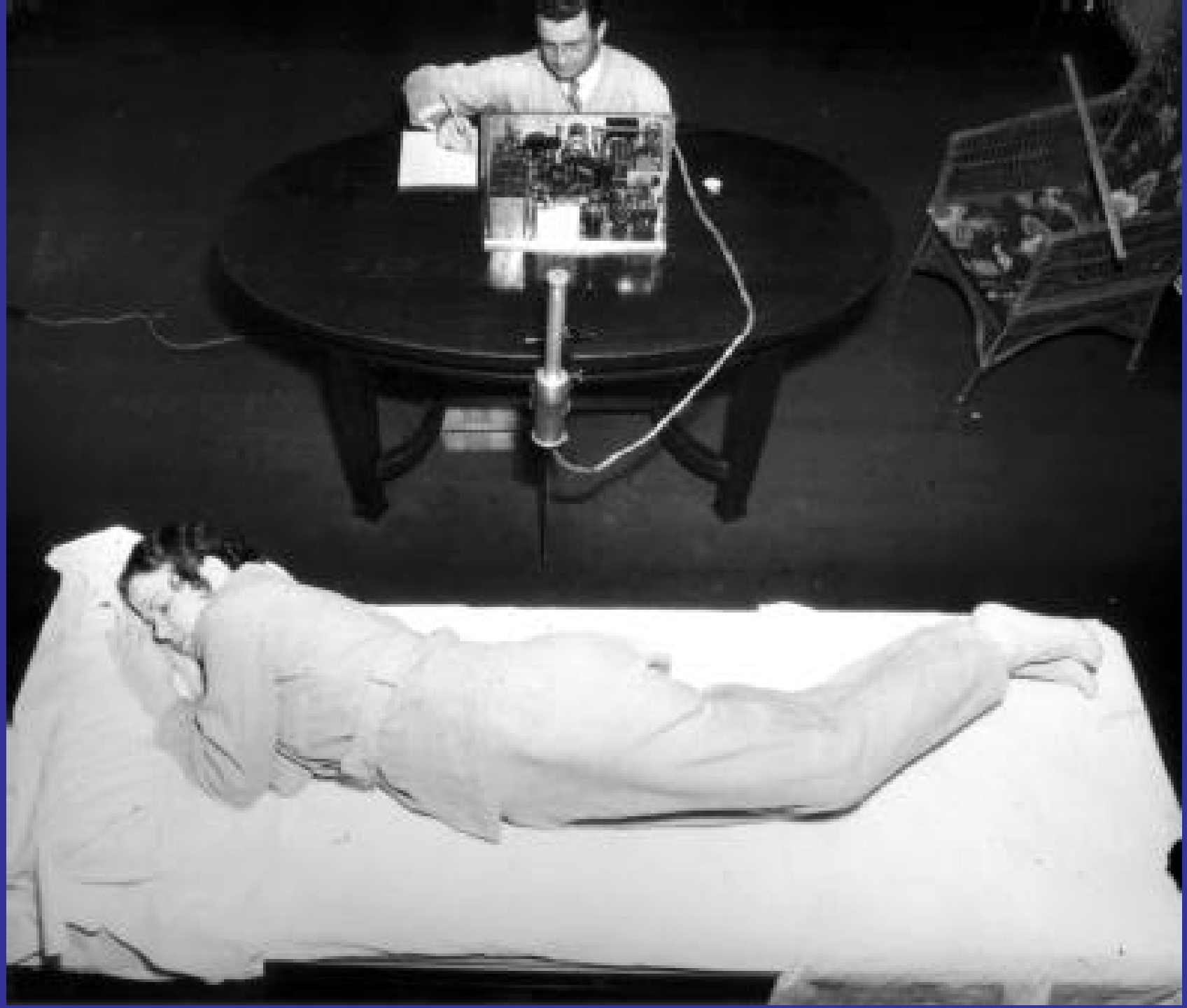
Measurement protocol

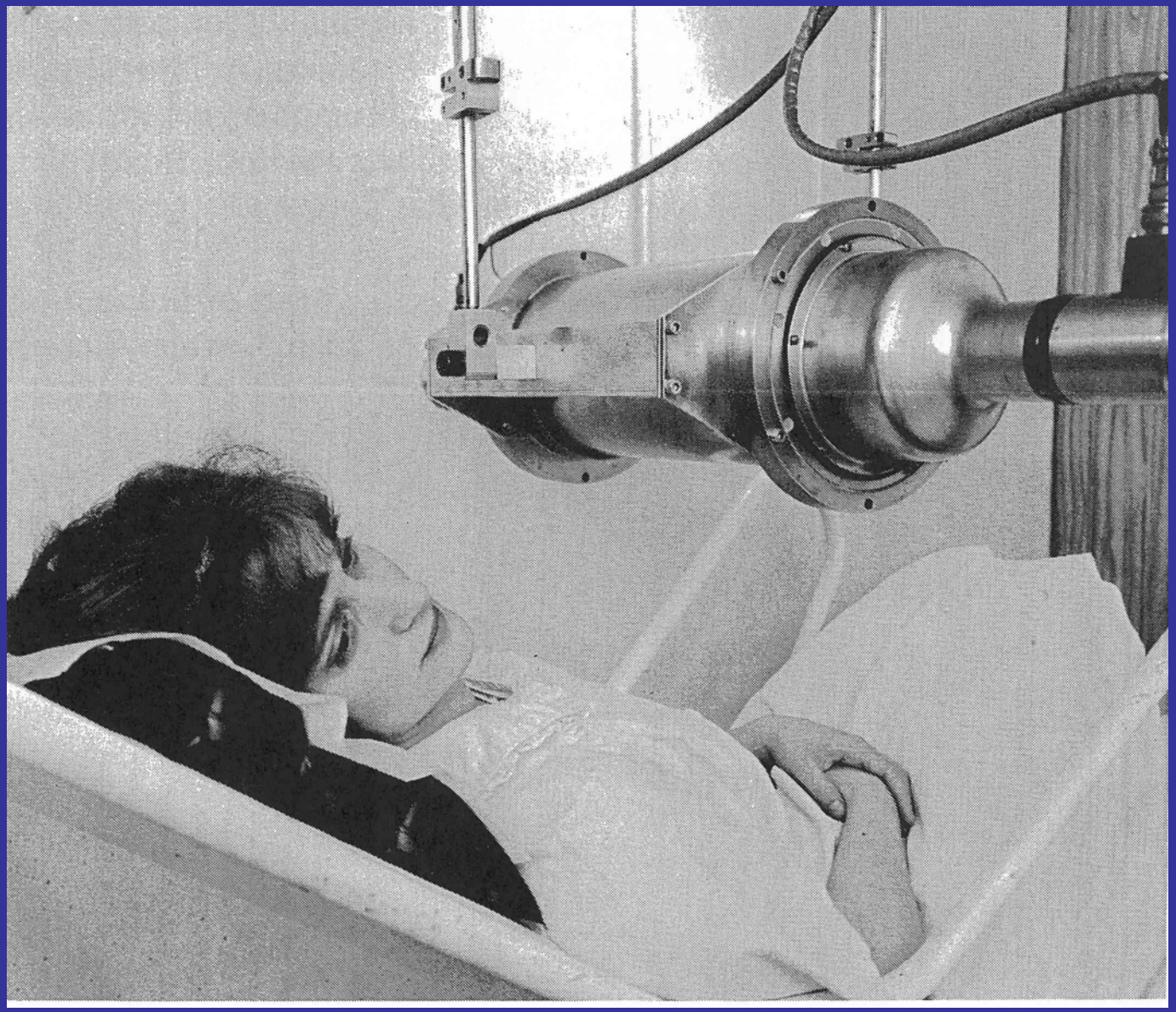
- Whole body count
  - may include 7-position scan
- Radon breath measurement
- Work history
- Medical exam and hx
- Skeletal x-ray survey

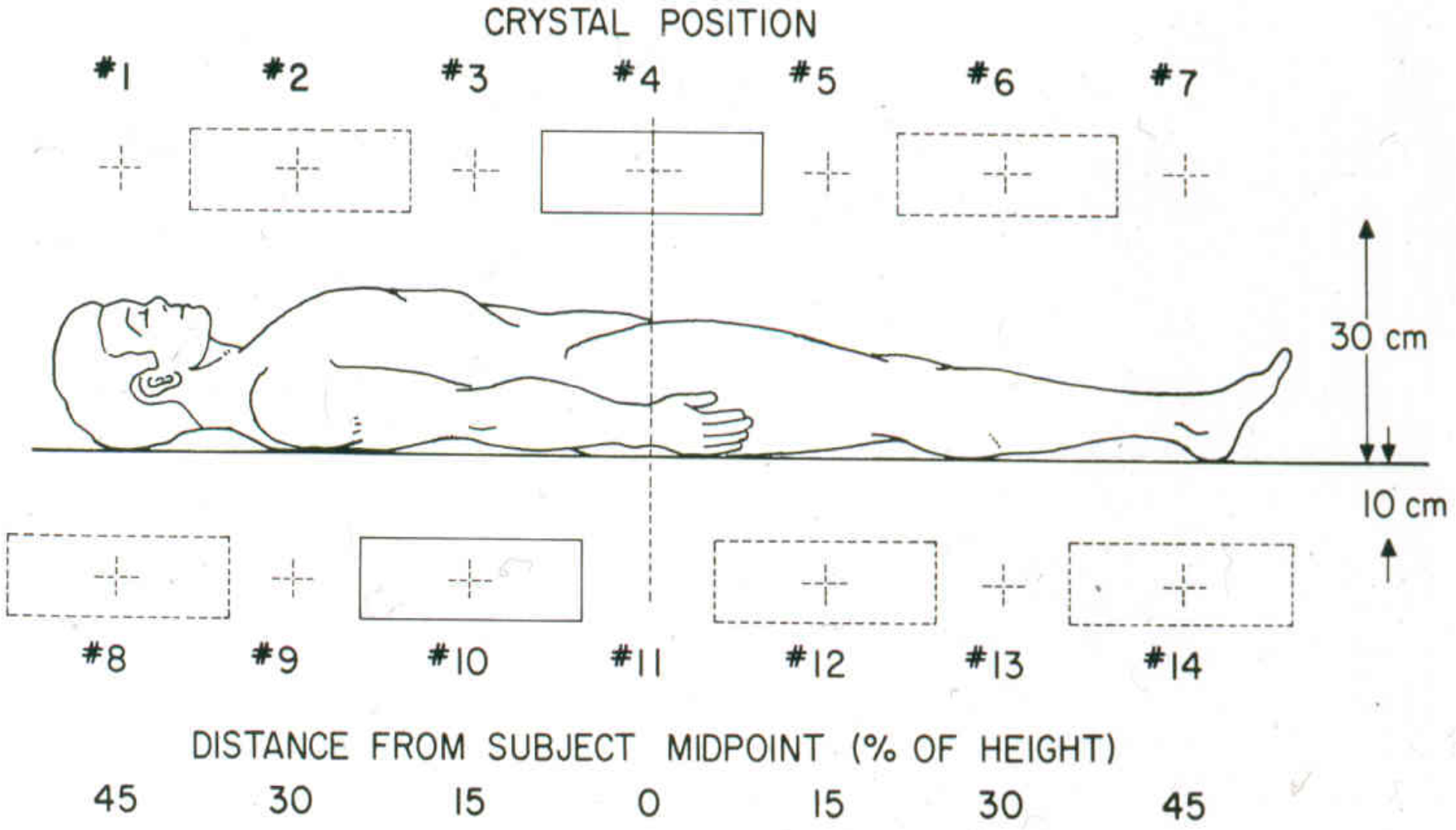
Human Studies Considerations

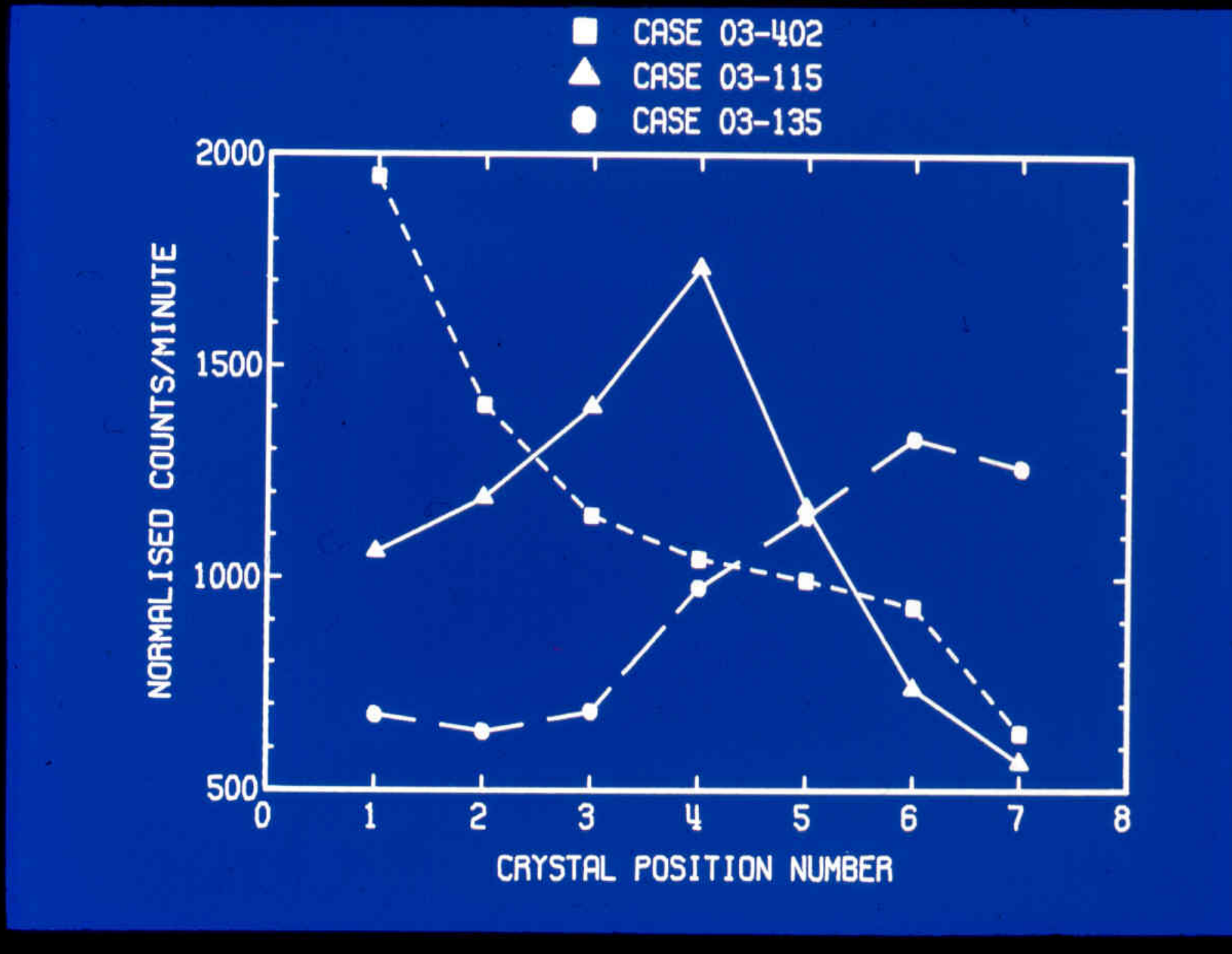
- Radium project under the oversight of ANL-E “Human Subjects Committee”
- Annual review by the Committee
- Annual report provided by the project
- Benefit of medical exam and small honorarium ($50) to subject
- Risks to subjects:
  - Claustrophobia from whole-body count
  - Discomfort from radon breath measurement
  - X-ray survey of skeleton

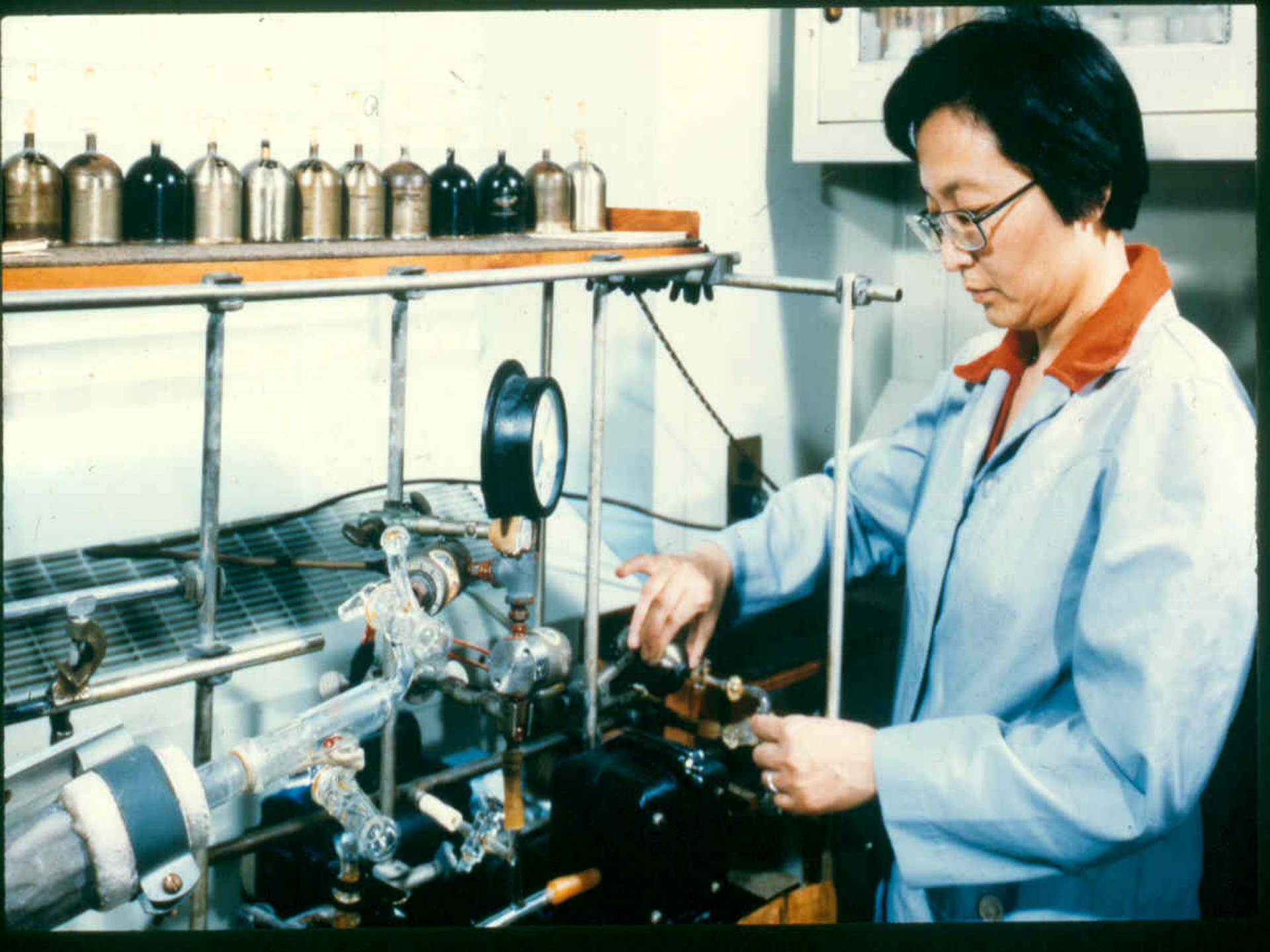
CHR Whole-Body Counter at ANL-E

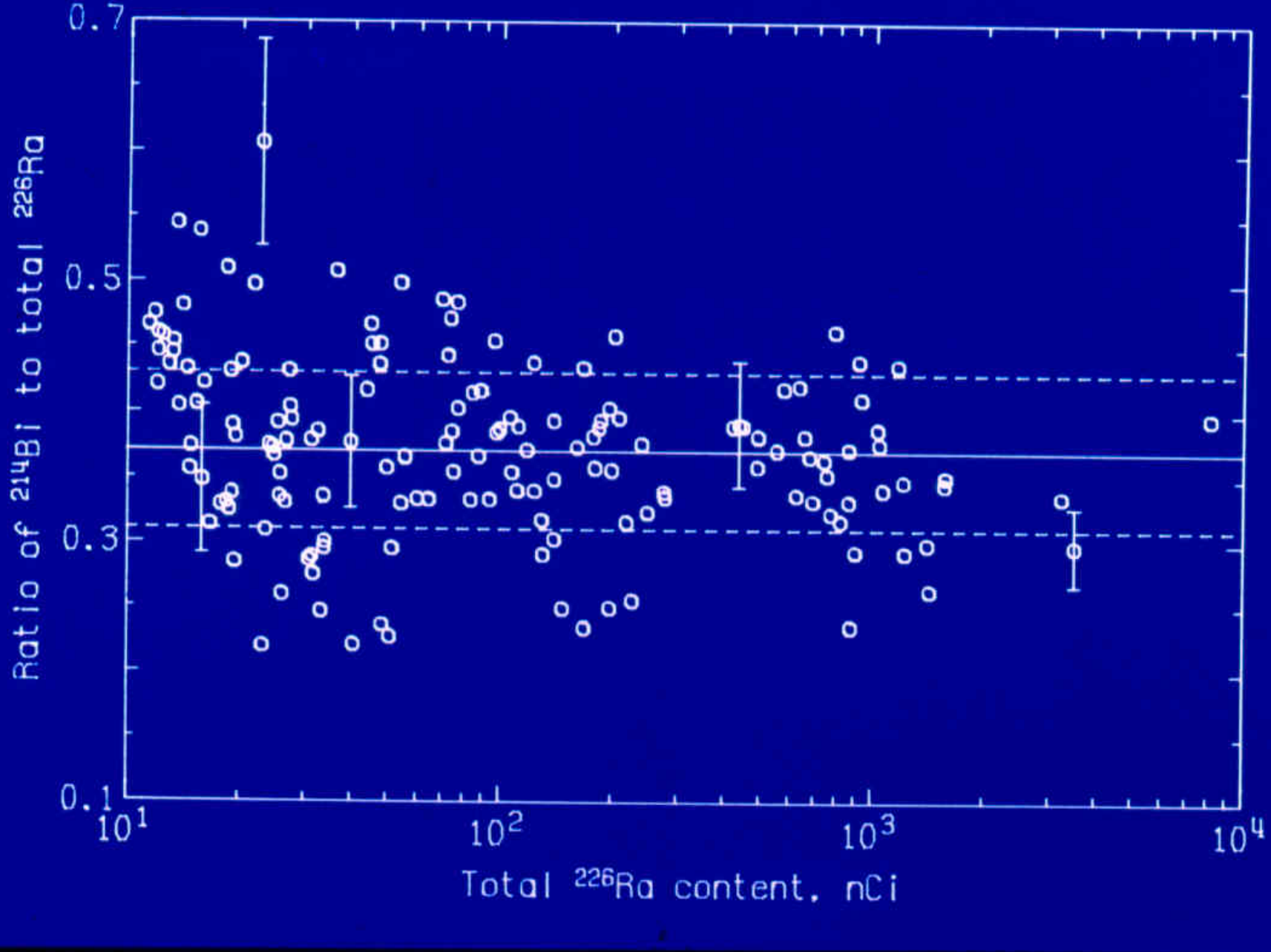





CRYSTAL POSITION
#1
#2
#3
#4
#5
#6
#7
30 cm
10 cm
#8
#9
#10
#11
#12
#13
#14
DISTANCE FROM SUBJECT MIDPOINT (% OF HEIGHT)
45
30
15
0
15
30
45


CASE 03-402
CASE 03-115
CASE 03-135
NORMALISED COUNTS/MINUTE
2000
1500
1000
500
0
1
2
3
4
5
6
7
8
CRYSTAL POSITION NUMBER




0.7
0.5
0.3
0.1
Ratio of ^{214}Bi to total ^{226}Ra
10^1
10^2
10^3
10^4
Total ^{226}Ra content, nCi

Retention of Radium

$R_t = R_0(0.54t^{-0.52})$

(Norris Function)

R_0 1000 nCi

R_{50y} 3.3 nCi

(1.2 nCi ^{214}Bi)

Entry at First Exposure

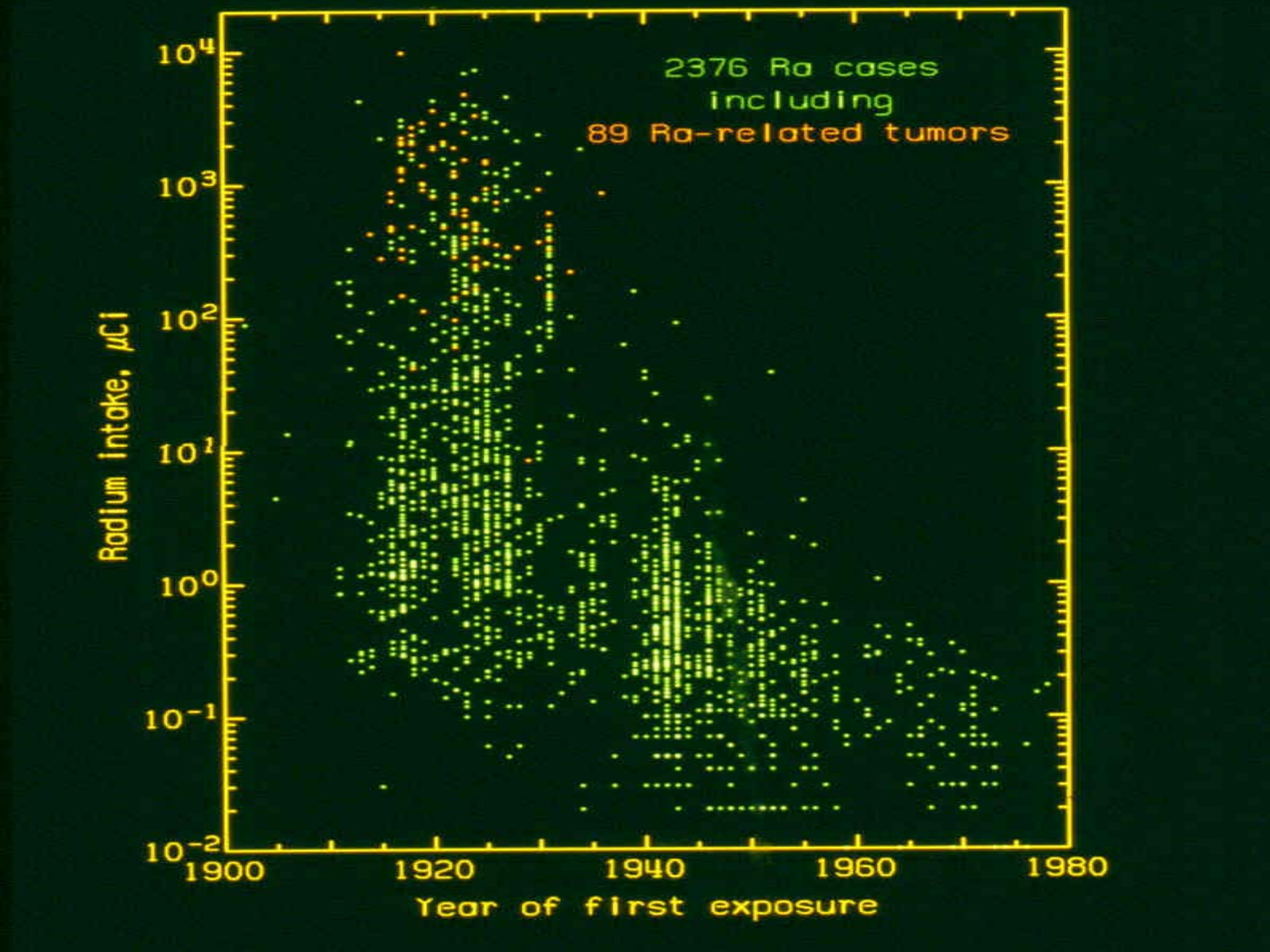
Radium measured	Yes	No
Number	759	476
Mean start date	1922.7	1922.1
Mean start age	19.0	21.5
Deaths:		
With Ra tumor	47	27
Other observed	188	267
Other expected	308	152
Obs./Exp.	0.61	1.76

TABLE 4 Growth in the Number of Measured Radium Cases

Year	Number of Measured Cases in the CHR Files at the End of the Year	Number of Malignancies in the Measured Cases	
		Sarcomas	Carcinomas
1969	777	51	20
1970	955	51	20
1971	1,032	51	20
1972	1,346	51	20
1973	1,568	54	27
1974	1,740	54	27
1975	1,832	55	27
1976	1,933	56	29
1977	2,072	58	29
1978	2,164	60	29
1979	2,223	60	29
1980	2,259	60	30
1981	2,282	60	31
1982	2,312	61	31
1983	2,400	61	32
1990	2,403	64	32

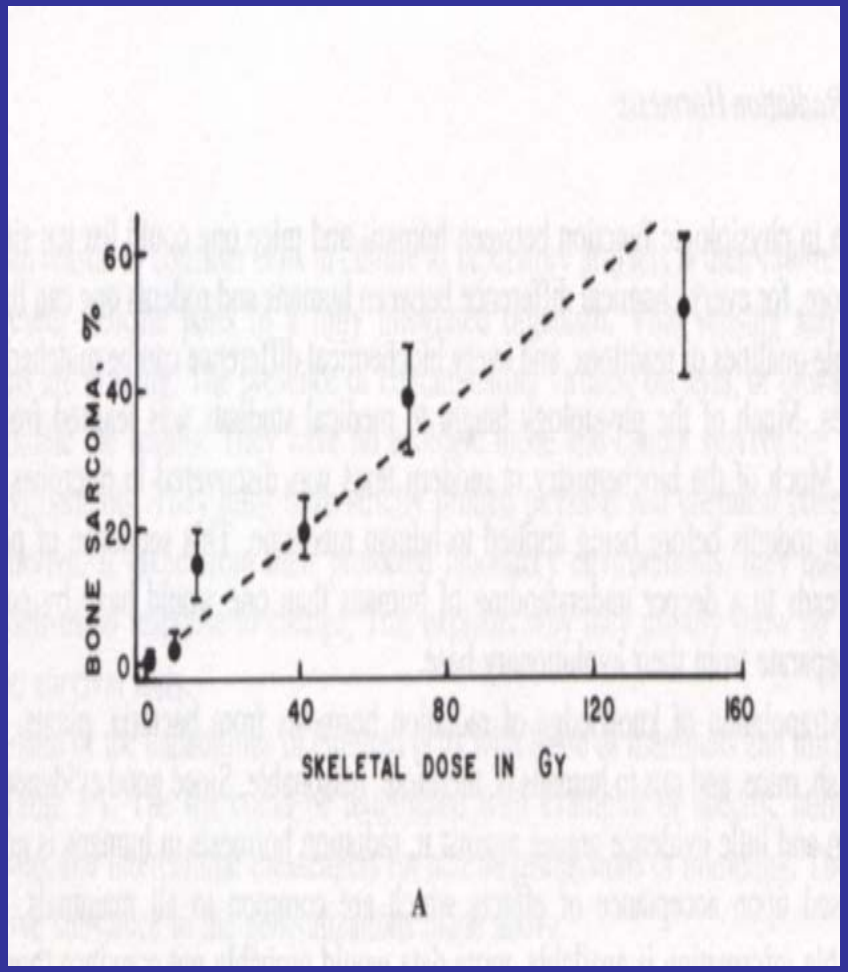
Malignancies observed

- Bone tumors:
  - Osteosarcomas
  - Chrodrosarcomas
  - Giant cell tumors
- Head Carcinomas:
  - Sinuses
  - Mastoids
- Nothing Else!
  - No excess leukemias
  - No other excess solid tumors

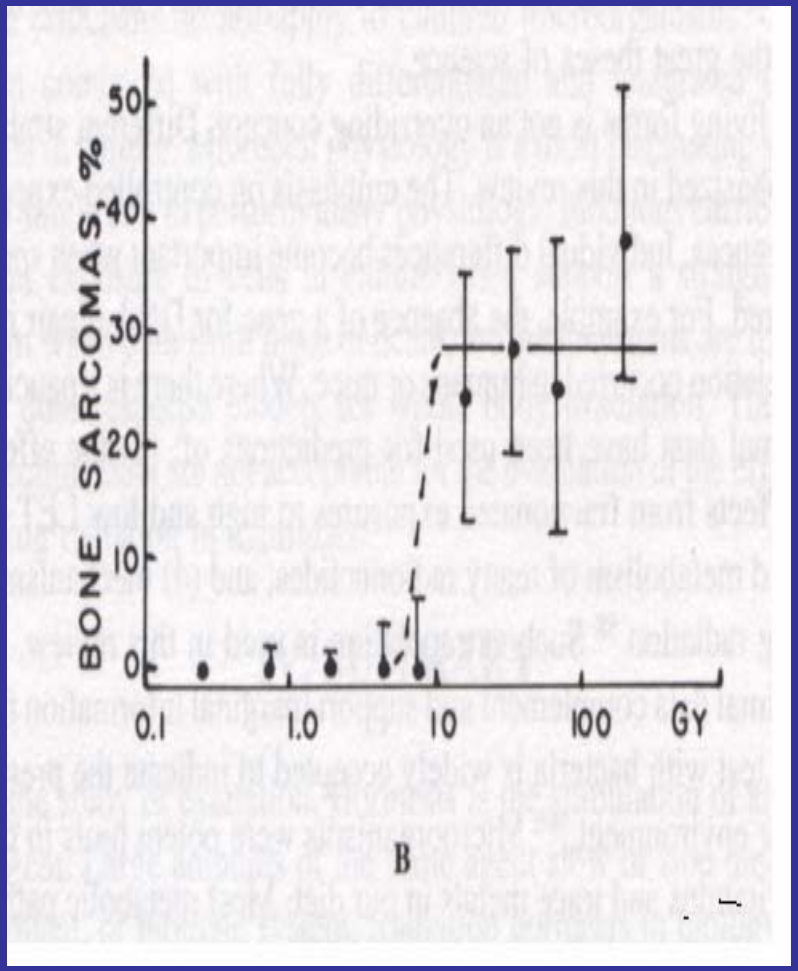

2376 Ra cases
including
89 Ra-related tumors
Radium intake, μCi
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
1900
1920
1940
1960
1980
Year of first exposure

Bone Tumor Incidence

Ra intake, μCi	Cases	Bone tumors
More than 2500	16	4
1000 -- 2499	22	15
500 -- 999	18	8
250 -- 499	32	9
100 -- 249	27	2
Less than 100	644	0

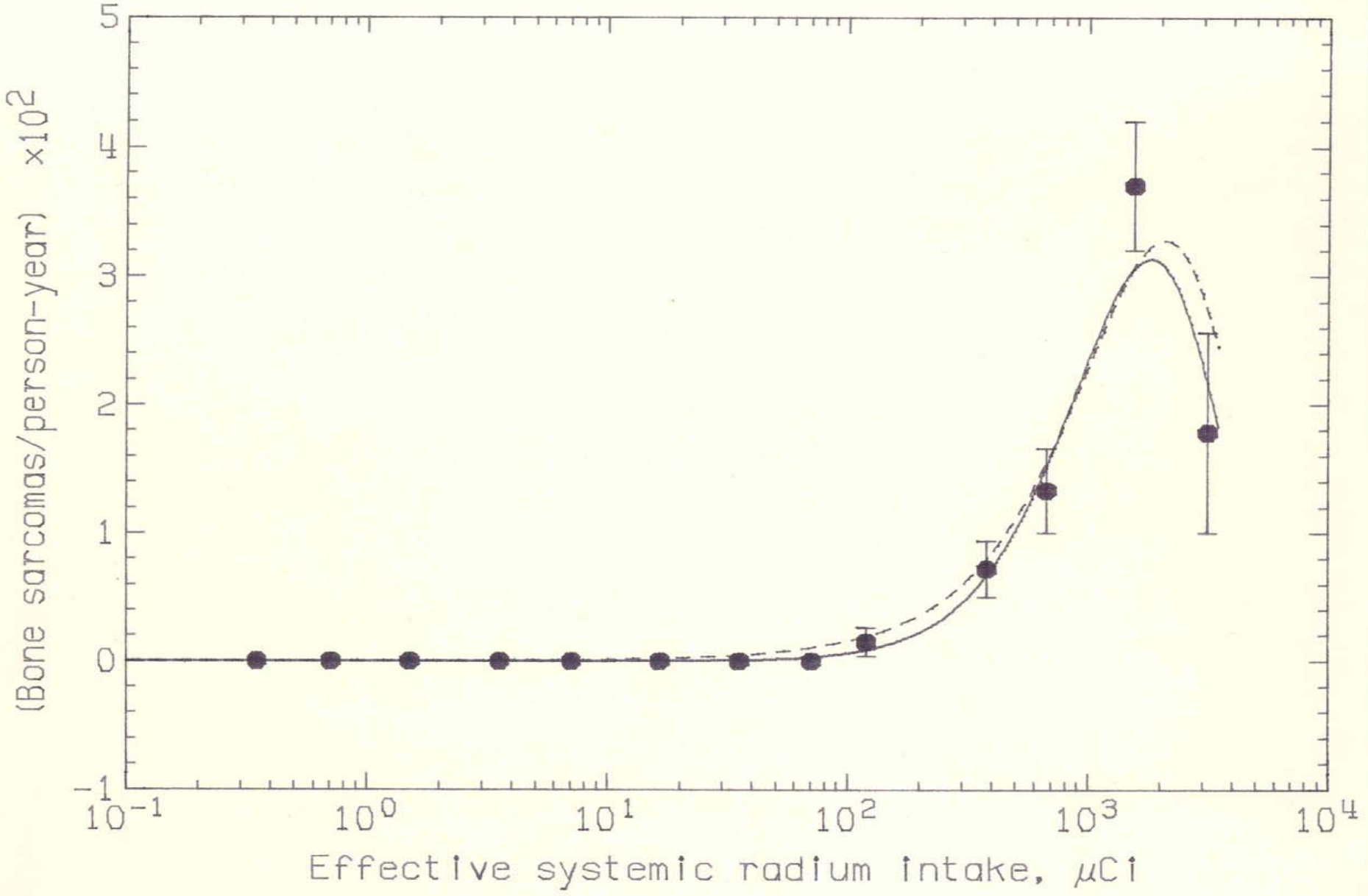


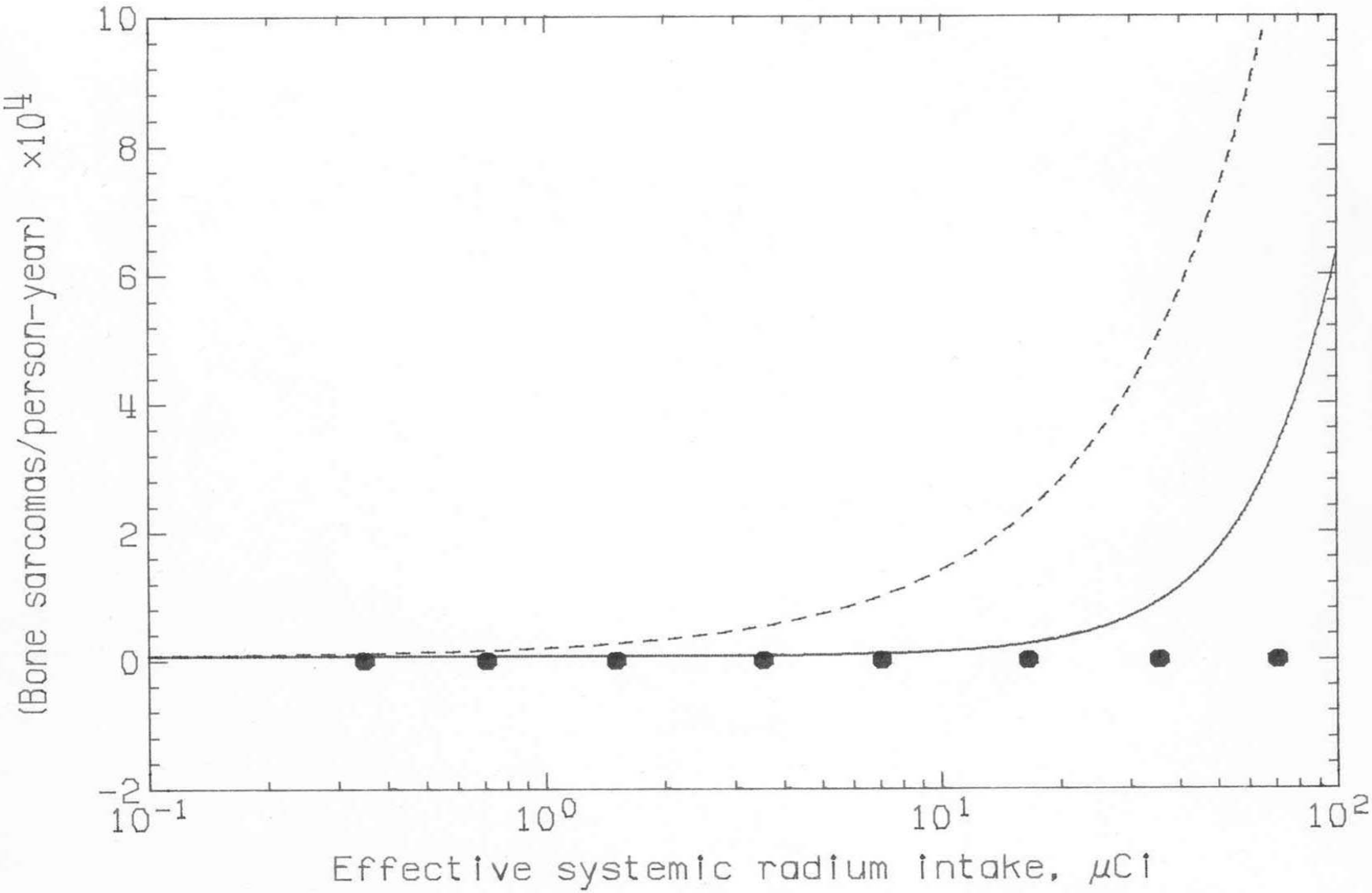
Linear scale



Log scale

Bone sarcoma in Radium dial painters


5
4
3
2
1
0
-1
(Bone sarcomas/person-year) x10^2
10^-1
10^0
10^1
10^2
10^3
10^4
Effective systemic radium intake, μCi


10
8
6
4
2
0
−2
(Bone sarcomas/person-year) ×10^4
10^−1
10^0
10^1
10^2
Effective systemic radium intake, μCi

Linear model predicts

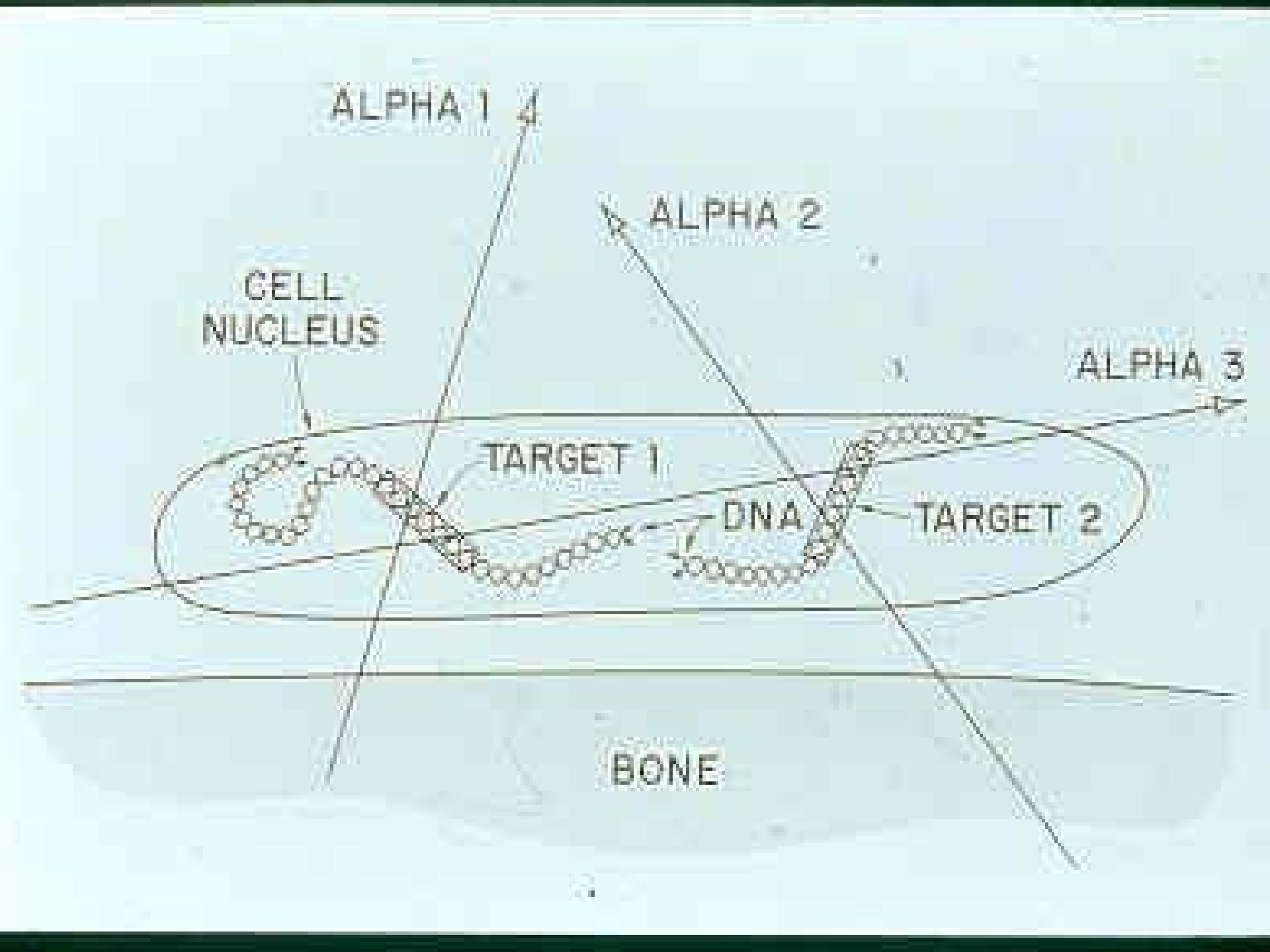
5 cancers below 9 μCi intake.

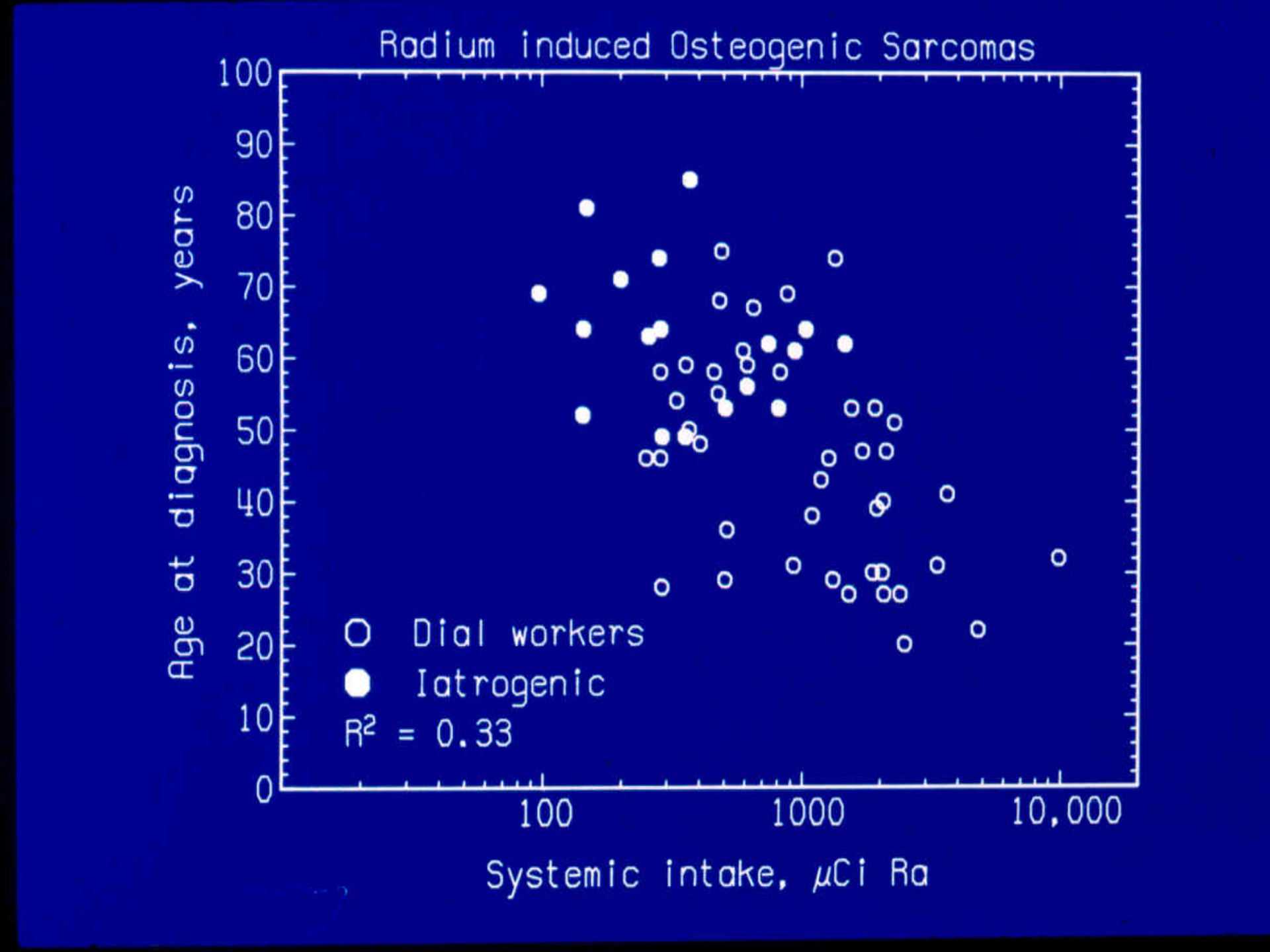
Observed = 0

p = 0.02

Quadratic model predicts

0.016 cancers.


ALPHA 1
ALPHA 2
CELL NUCLEUS
ALPHA 3
TARGET 1
DNA
TARGET 2
BONE


Radium induced Osteogenic Sarcomas
Age at diagnosis, years
100
90
80
70
60
50
40
30
20
10
0
100
1000
10,000
Systemic intake, μCi Ra
Dial workers
Iatrogenic
R² = 0.33

Radium standard

- No health effects noted in radium DPs with retained Ra-226 < 1.0 µCi
- Throw in a safety factor of 10
- MPBB for Ra-226 = 0.1 µCi

Plutonium standard

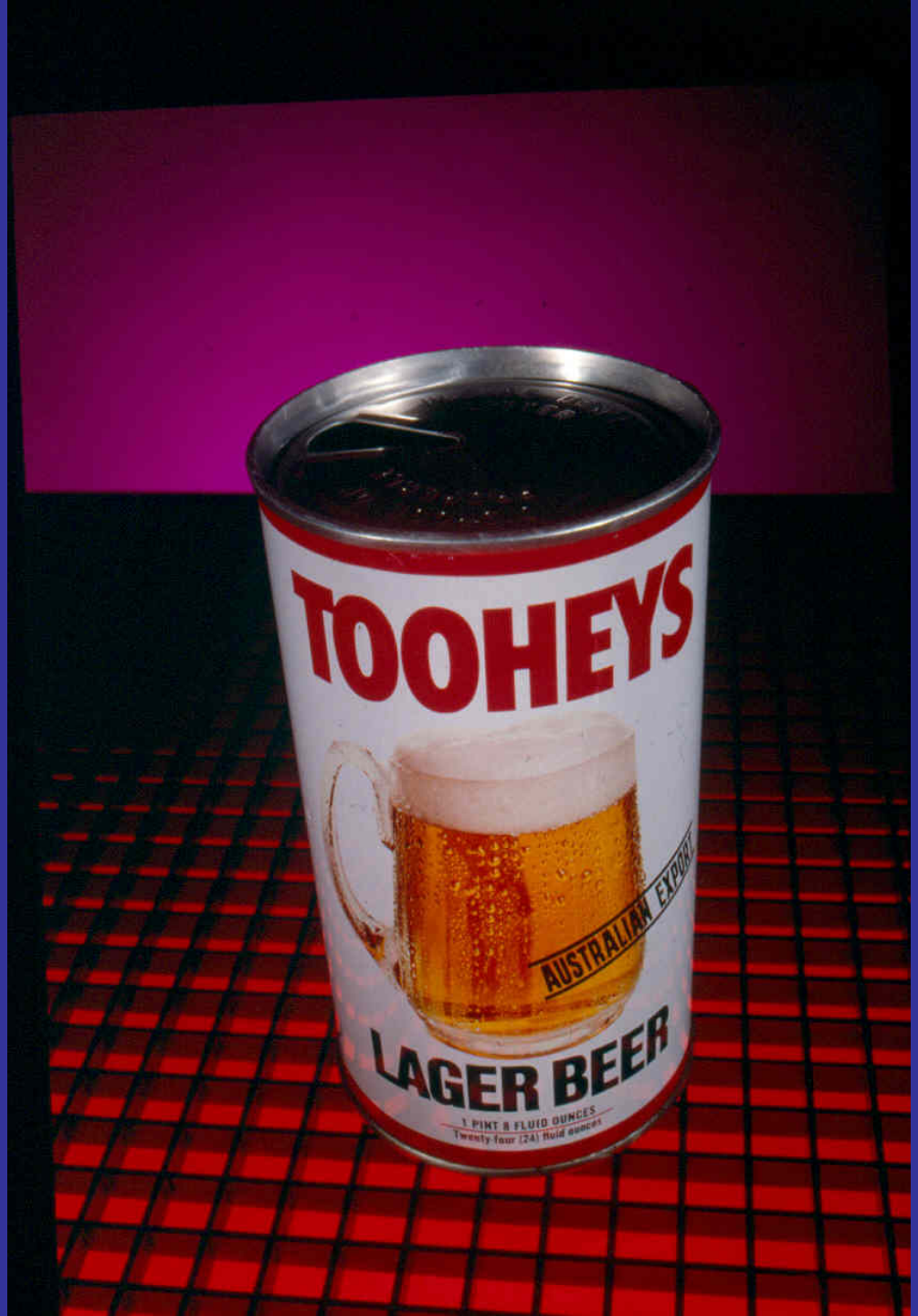
- Total alpha energy per decay of parent:
  - Ra-226 = 12 MeV
  - Pu-239 = 5 MeV about a factor of 2
- All Pu alpha energy deposited on bone surface, most Ra energy deposited in bone volume, about a factor of 5
- 100 nCi x 2/5 = 40 nCi

What about “deadly plutonium”

- In a follow-up of several dozen Los Alamos workers with plutonium intakes (mostly via contaminated wounds), one osteosarcoma of the pelvis was observed.
- However, if plutonium had been used instead of radium in the dial-painting industry, no cancers would have been observed, due to extremely low absorption (0.001%) from the gastrointestinal tract.

For more information

- http://www.orau.org/ptp/collection/radioluminescent/radioluminescent.htm
  - This site has photos of radioluminescent items in the PTP historical collection and some excellent articles on the paint and the painters
- http://www.rerowland.com/dial_painters.htm
- Radium in Humans: a Review of U.S. Studies. R. E. Rowland, ANL/ER-3, 1994
- “Deadly Glow” Ross Mullner, Univ. of Chicago Press


TOOHEYS
AUSTRALIAN EXPORT
LAGER BEER
1 PINT 8 FLUID OUNCES
Twenty four (24) fluid ounces