



Date: April 15, 1999

To: Dennis Chambers

CC: Ed Valdez, Ron Frerker, Greg Hempen, Rodney Alderson, David King, Robert Edwards,
Sherry Gibson,

From: Jim Moos

RE: Correlations of Isotopes in Soil Samples from the SLAPS 1998 Characterization

Thorium-230 is a contaminant of concern in soils at the St. Louis Airport Site (SLAPS) FUSRAP site but has a high detection limit (>2000 pCi/g) for field gamma screening using a "2x2" NaI detector. A co-occurring isotope that is more easily measured may be useful as a surrogate for Thorium-230 activity if the relationship between Thorium-230 and the other isotope is fairly constant.

Data

Four isotopes were examined as potential surrogates for Thorium-230 (Th-230): Actinium-227 (Ac-227), Protactinium-231 (Pa-231), Radium-226 (Ra-226), and Uranium-238 (U-238). Measurements from the 1998 SLAPS Characterization Study were used to examine these relationships. The dataset was limited to the activity range of interest for Th-230. Samples with Th-230 activity greater than 15 pCi/g, the proposed subsurface cleanup criteria, and less than 2000, the approximate detection limit of Th-230 by field gamma screening using a "2x2" NaI detector, were included in the analysis.

Approach

A regression approach was used to examine these relationships. The relationship between Th-230 and each surrogate was assumed to be linear. The increase in each isotope was assumed to be proportional above the background activity. The model was therefore fit by subtracting the average background activity from each sample measurement and fitting a linear regression with a zero intercept using the REG procedure in SAS software (SAS, 1989). The slope of the linear regression is a measure of the ratio of the isotopes when the intercept is zero. A regression approach also provides estimates of the significance and confidence limits of the slope estimate.

The mean of all background samples with results above the MDA and counting uncertainty (Table 1) was calculated for each isotope and subtracted from all site measurements. The results for each isotope were then plotted against Th-230 and regression statistics calculated.

Outliers

Results that are very different from the majority of the points (outliers) can have a large effect on the regression statistics. The SAS regression procedure calculates influence diagnostics that can be used to identify outliers. Results with a DFBETAS statistic greater than 2 were examined as potential outliers. DFBETAS is a measure of the change in the regression slope estimate caused by removing one observation. Sample SLA00630 was identified as an outlier in both the Ac-227 and U-238 regressions. Examination of the data package revealed that this sample had a high U-238 activity (1769 pCi/g) and that Th-230 could not be completely separated and should be considered estimated. All results from sample SLA00630 were removed from the analysis. Two samples were identified as outliers in the Th-230/Ra-226 regression. Samples SLA00463 and SLA00332 had high Ra-226 values but fell below the regression line. Although there was no other indications of problems with these samples they were removed from the analysis.

Regression Statistics

The regression statistics were recalculated after removing the three outliers from the data (Table 2). Th-230 was treated as the dependent variable and each of the other isotopes was used as independent variable. The statistics reported are the slope, standard error of the slope, probability of the slope estimate, upper and lower 95% confidence limits of the slope estimate, the number of data points used in the regression and the r^2 value.

The slope is a measure of the ratio of Th-230 to the independent variable. For example the slope of 65.047 for the Ac-227 regression with all data means that the Th-230 activity is generally 65 times the Ac-227 activity. The standard error is a measure of the uncertainty of the slope. It can be used to calculate confidence limits on the slope. For the Ac-227 regression with all data there is a 95% probability that the 'true' slope is between 60.310 and 69.784. Ninety-three sample results were used to fit this regression and the r^2 value is 0.89. This means that 89% of the variability in Th-230 can be accounted for by the variability of Ac-227. The probability estimate is the probability of estimating a slope that different from zero by chance alone. To have 95% confidence that the slope is different from zero, we consider results with a probability less than 0.05 as statistically significant.

Results

Regression slopes were calculated using all data together as well as the data for each investigation area (IA) separately. The number of points varied for each IA and isotope because only samples with Th-230 between 15 and 2000 pCi/g were used and for each isotope only detected results were used. IA-1,-7, and -10 did not have any samples with results in the activity range used.

The regression slopes using all data were statistically significant for all of the isotopes. Ac-227 and Pa-231 showed the strongest relationships with r^2 values of about 0.9. Ra-226 had an r^2 value of 0.81 while the relationship was weakest for U-238 with an r^2 value of 0.26.

Ac-227. The linear regression model fit well. The r^2 values were greater than 0.8 for all IAs except IA-3 and IA-13 with an overall r^2 value of 0.89 (Table 2). The relationship between Th-230 and Ac-227 was consistent across most of the IAs (Figure 1). Overlapping confidence limits on the slopes indicates that the slopes are not significantly different from IA to IA or from the regression model over all. The only limits that did not overlap were for IA-6 and IA-9 whose limits were below IA-5 (Table 2). The slopes that deviated the most from the overall slope also had large uncertainties and so were not significantly different from the other IAs. IA-3 had a slope of 120.5 but a large uncertainty because of a small data range. All Ac-227 results for IA-3 were less than 3 pCi/g (Attachment 1). Likewise IA-13 with only four points and a very small range (all results less than 0.1 pCi/g) had a negative slope that was not statistically different from zero (Table 2). Considering only the statistically significant slopes, the slopes for the IAs ranged from 43 to 120 compared to the slope on 65 over all of the data. Considering all of the data, the Th-230 activity was 60 to 70 times the Ac-227 activity.

Pa-231. The regression model fit well for Pa-231 (Figure 2) with r^2 values for all IAs at 0.78 or higher (Table 2). For Pa-231 all of the confidence limits for the slopes overlapped so there were no significant differences between IAs. The confidence limits on the overall slope ranged from 56 to 69. This was very similar to the range for Ac-227. Ac-227 is a decay product of Pa-231. The similar relationships between Ac-227 and Pa-231 with Th-230 would be expected if Ac-227 and Pa-231 were near equilibrium with each other. The Pa-231 regressions were based on fewer points than the Ac-227 regressions because Pa-231 was below the detection limit more often than Ac-227.

Ra-226. The regression models for Ra-226 had more variability in goodness of fit than Ac-227 and Pa-231. Ignoring IA-13, which did not have a statistically significant fit, the r^2 values for all IAs ranged from 0.67 to 1.0 (Table 2). The slopes for IA-8 and IA-9 were significantly higher than the other IAs (Figure 3). Ignoring IA-13, the slopes ranged from 36 to 72. The confidence limits on the overall slope ranged from 47 to 58. Ra-226 is a direct decay product of Th-230. The slope of approximately 50 indicates that these isotopes are not at equilibrium with each other.

U-238. The regressions between U-238 and Th-230 showed the most variability and the worst fits (Figure 4). The regressions for four IAs, IA-3, IA-4, IA-6, and IA-9, did not have statistically significant fits. The r^2 values for all IAs which did have statistically significant fits ranged from 0.62 to 0.96 (Table 2). The confidence limits on the overall slope ranged from 4.5 to 17.9. The slopes for IA-5 and IA-8 were significantly higher than IA-2. Th-230 is a decay product of U-238. The variability of the slopes indicates a disequilibrium between Th-230 and U-238. U-238 activity would not be a good predictor of Th-230 activity.

Conclusions.

Over all of the data, the regressions between Ac-227 and Pa-231 with Th-230 were very similar in slope (65 versus 62) and very similar in goodness of fit (0.89 versus 0.90). Considering that Ac-227 was above the detection limit more frequently than Pa-231, Ac-227 would make a better choice for predicting Th-230. Ra-226 is also a good predictor for most IAs except in IA-3 and IA-5 which showed significant scatter. U-238 showed high variability in slopes and poor fit and therefore would not be a good choice for estimating Th-230 activity.

References

SAS, 1989. SAS/STAT User's Guide, Version 6, Fourth Edition, Volume 2, Cary, NC: SAS Institute Inc., 1989. 846 pp.

Table 1. Mean Results for Background Samples

Isotope	Number of Samples	Mean Detect (pCi/g)	Maximum Detect (pCi/g)
Th-230	74	1.659	2.89
Ac-227	17	0.520	0.82
Pa-231	2	1.095	1.13
Ra-226	74	1.05	1.55
U-238	50	1.23	2.04

Table 2. Summary Statistics for Regression Models.

Area	Slope	Std Error of Slope	Probability of Slope Estimate	95% Lower Confidence Limit of Slope	95% Upper Confidence Limit of Slope	Number of Data Points	r ²
Ac-227 with Th-230							
All areas	65.047	2.385	0.000	60.310	69.784	93	0.89
IA-2	81.529	16.339	0.002	41.550	121.508	7	0.81
IA-3	120.547	28.124	0.001	59.269	181.824	13	0.60
IA-4	77.976	16.798	0.010	31.337	124.616	5	0.84
IA-5	82.210	6.731	0.000	68.347	96.073	26	0.86
IA-6	43.001	5.753	0.017	18.248	67.755	3	0.97
IA-8	66.299	1.318	0.000	63.559	69.040	22	0.99
IA-9	59.349	2.396	0.000	54.129	64.569	13	0.98
IA-13	-84.891	72.060	0.324	-314.219	144.437	4	0.32
Pa-231 with Th-230							
All areas	62.482	3.191	0.000	56.055	68.908	46	0.90
IA-2	77.096	20.577	0.020	19.966	134.226	5	0.78
IA-3	189.549	46.857	0.016	59.452	319.646	5	0.80
IA-4	80.915	23.486	0.041	6.170	155.659	4	0.80
IA-5	78.826	9.347	0.000	57.272	100.380	9	0.90
IA-6	42.020	6.919	0.026	12.249	71.791	3	0.95
IA-8	61.391	2.021	0.000	56.944	65.839	12	0.99
IA-9	57.662	3.358	0.000	49.445	65.879	7	0.98
IA-13	72.793 (Only 1 data point therefore no statistics)					1	
Ra-226 with Th-230							
All areas	52.432	2.556	0.000	47.358	57.506	97	0.81
IA-2	41.020	5.314	0.000	28.018	54.023	7	0.91
IA-3	36.004	5.431	0.000	24.271	47.738	14	0.77
IA-4	48.235	0.950	0.000	45.597	50.873	5	1.00
IA-5	42.676	5.909	0.000	30.531	54.822	27	0.67
IA-6	45.552	1.801	0.002	37.801	53.303	3	1.00
IA-8	71.603	3.530	0.000	64.261	78.944	22	0.95
IA-9	69.752	5.695	0.000	57.447	82.056	14	0.92
IA-13	-31.055	37.395	0.453	-134.881	72.771	5	0.15
U-238 with Th-230							
All areas	11.198	3.277	0.002	4.539	17.858	35	0.26
IA-2	5.232	1.679	0.021	1.124	9.341	7	0.62
IA-3	2.274	1.611	0.192	-1.370	5.918	4	0.12
IA-4	22.381	10.297	0.118	-10.390	55.151	10	0.18
IA-5	39.854	5.210	0.001	26.461	53.246	6	0.92
IA-6	21.110	7.311	0.102	-10.345	52.565	3	0.81
IA-8	110.461	16.944	0.023	37.556	183.366	3	0.96
IA-9	87.160	33.665	0.235	-340.595	514.916	2	0.87
IA-13	no data						

1998 SLAPS Soil Characterization Data
 Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
 Background Subtracted—Zero Intercept

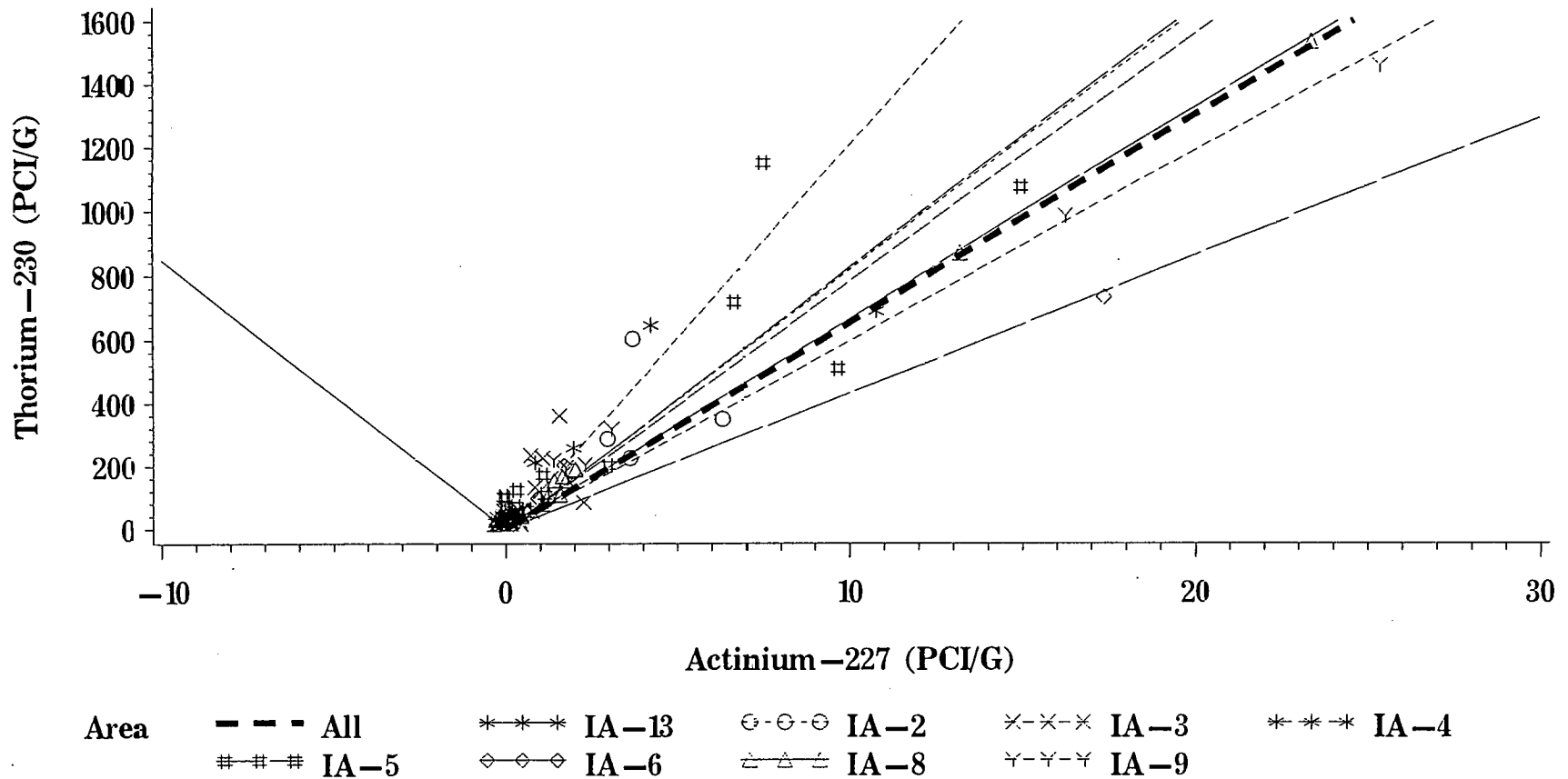


Figure 1. Relationship between Thorium-230 and Actinium-227.

1998 SLAPS Soil Characterization Data
 Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
 Background Subtracted—Zero Intercept

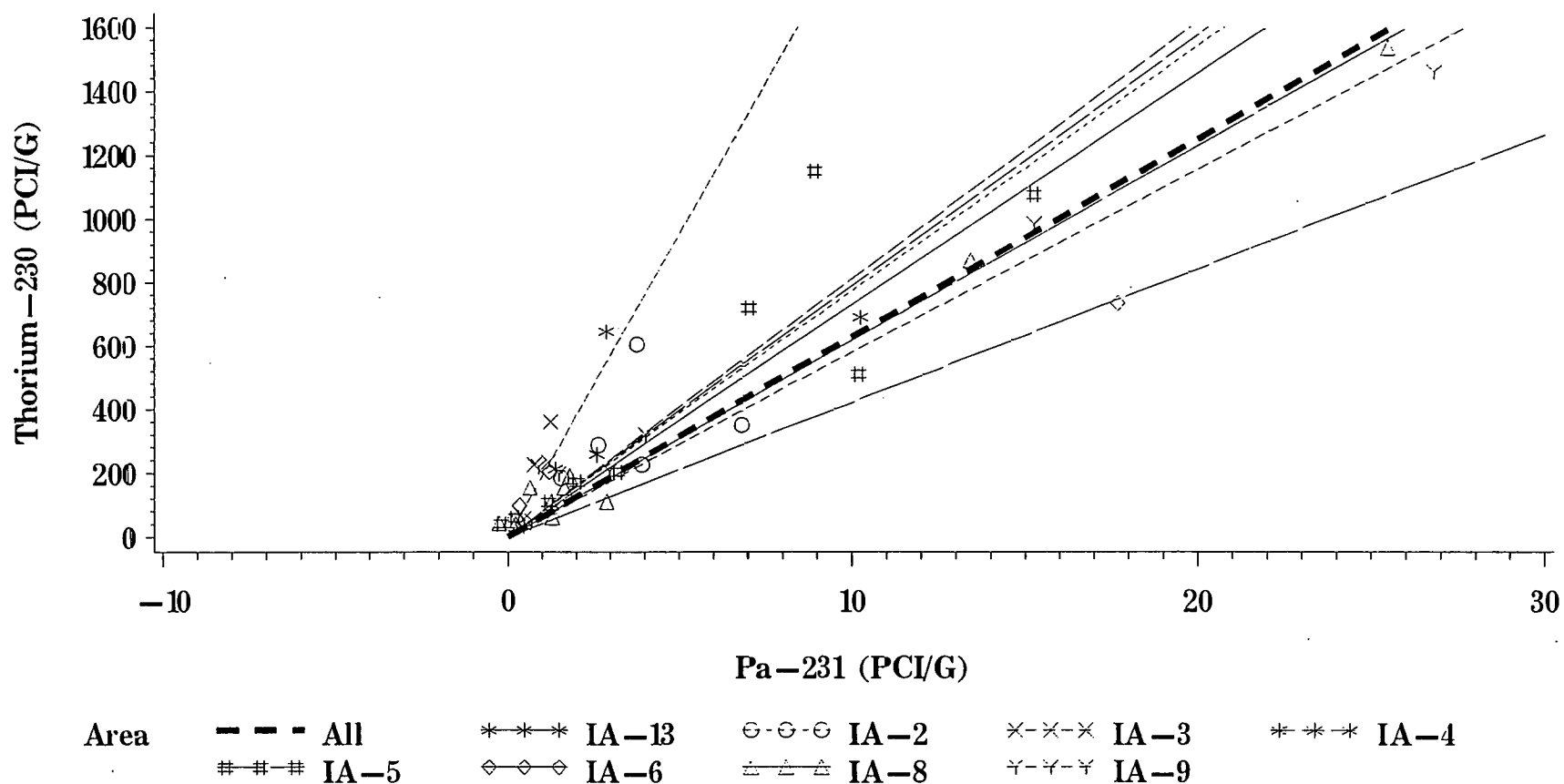


Figure 2. Relationship between Thorium-230 and Protactinium-231.

1998 SLAPS Soil Characterization Data
 Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
 Background Subtracted—Zero Intercept

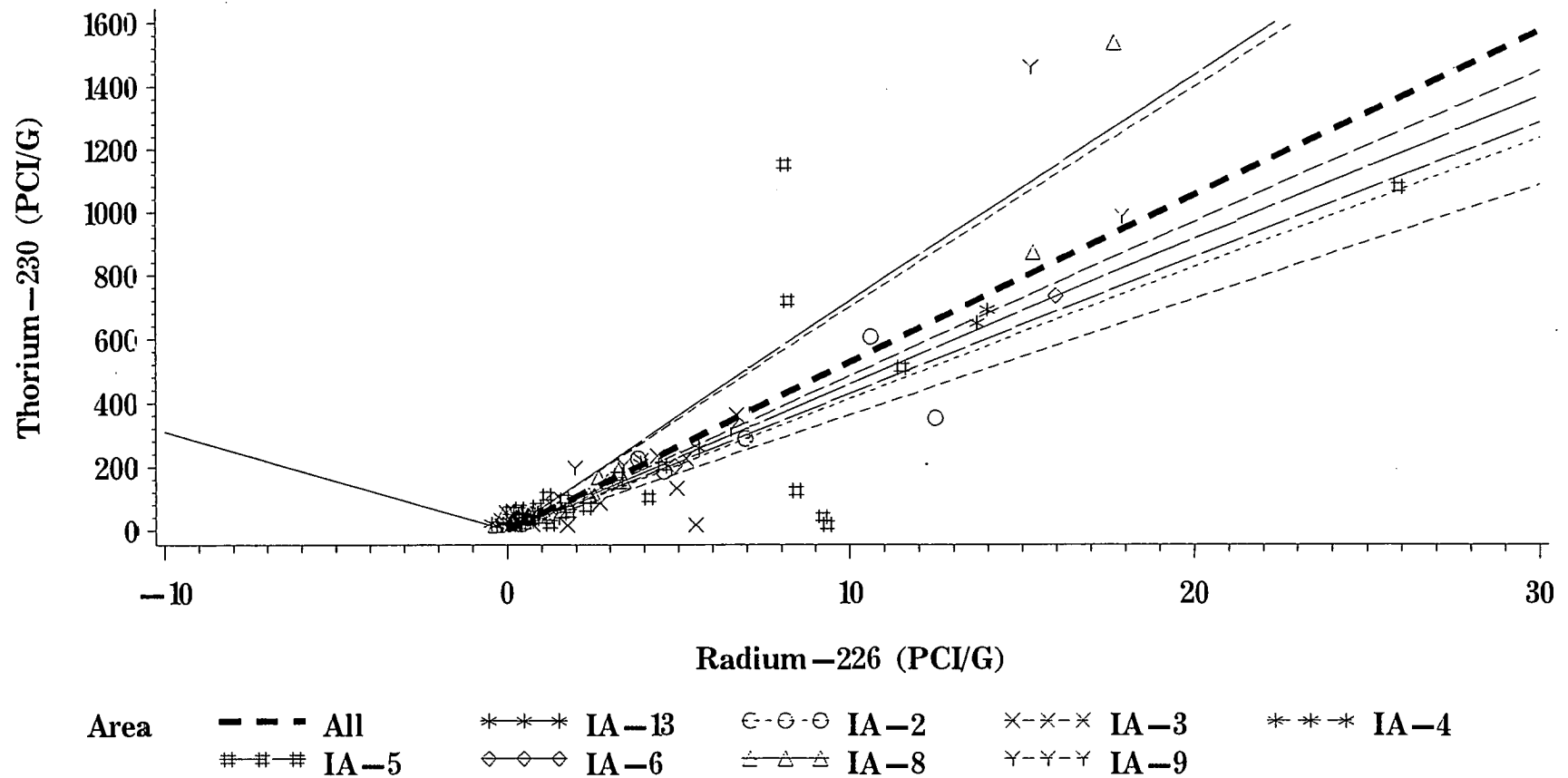


Figure 3. Relationship between Thorium-230 and Radium-226.

1998 SLAPS Soil Characterization Data
 Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
 Background Subtracted—Zero Intercept

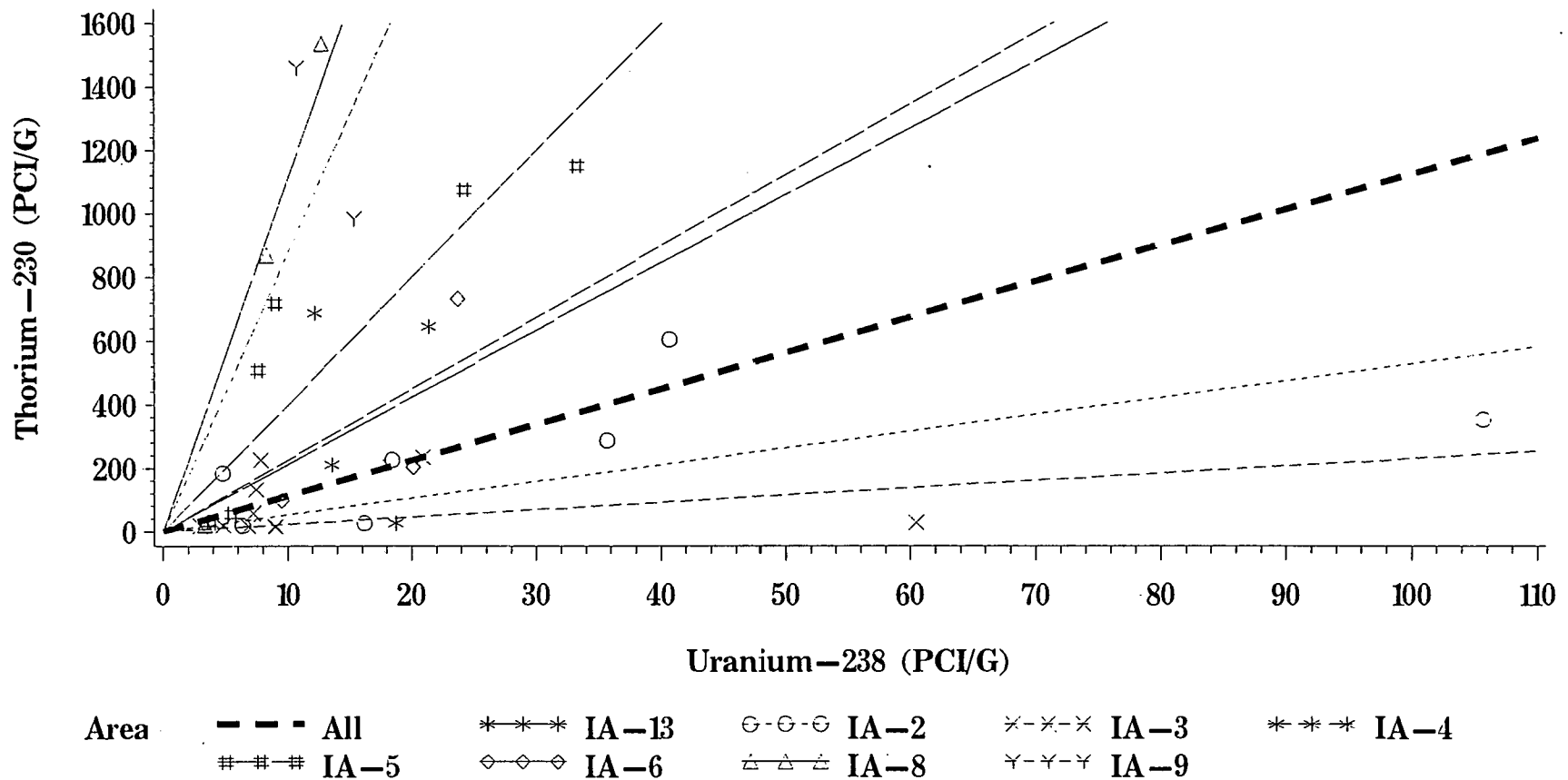
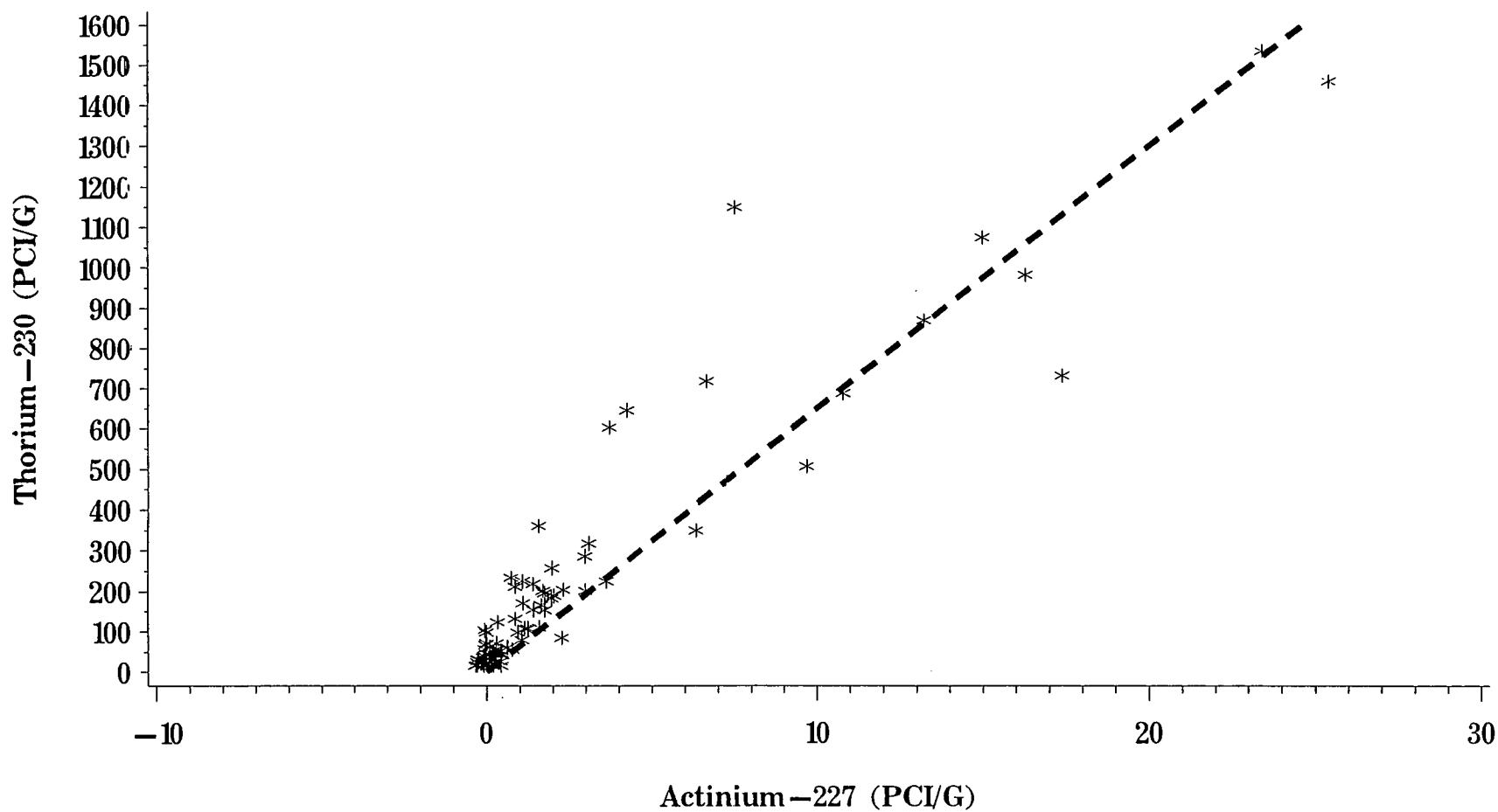
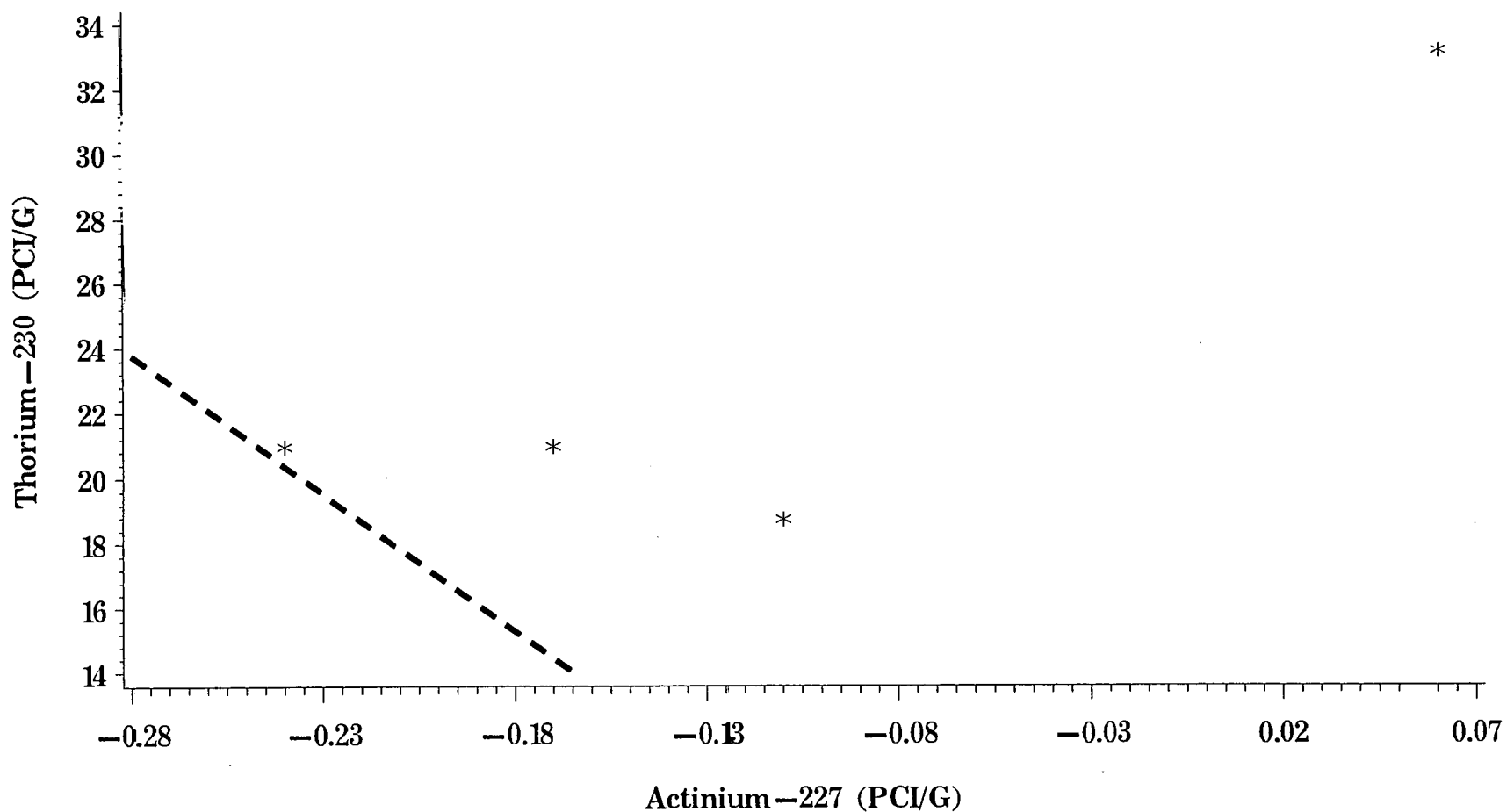


Figure 4. Relationship between Thorium-230 and Uranium-238.

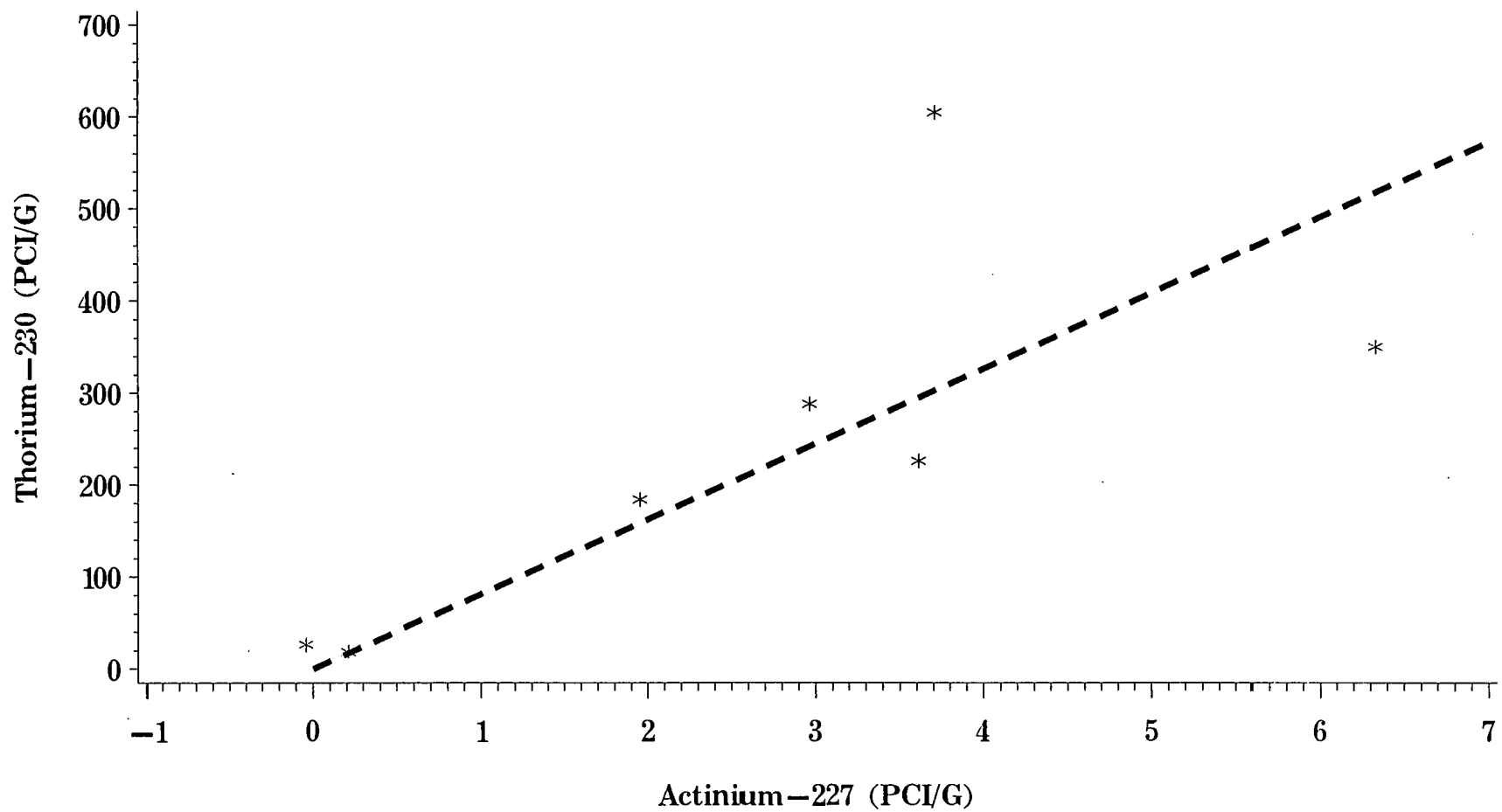
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= All



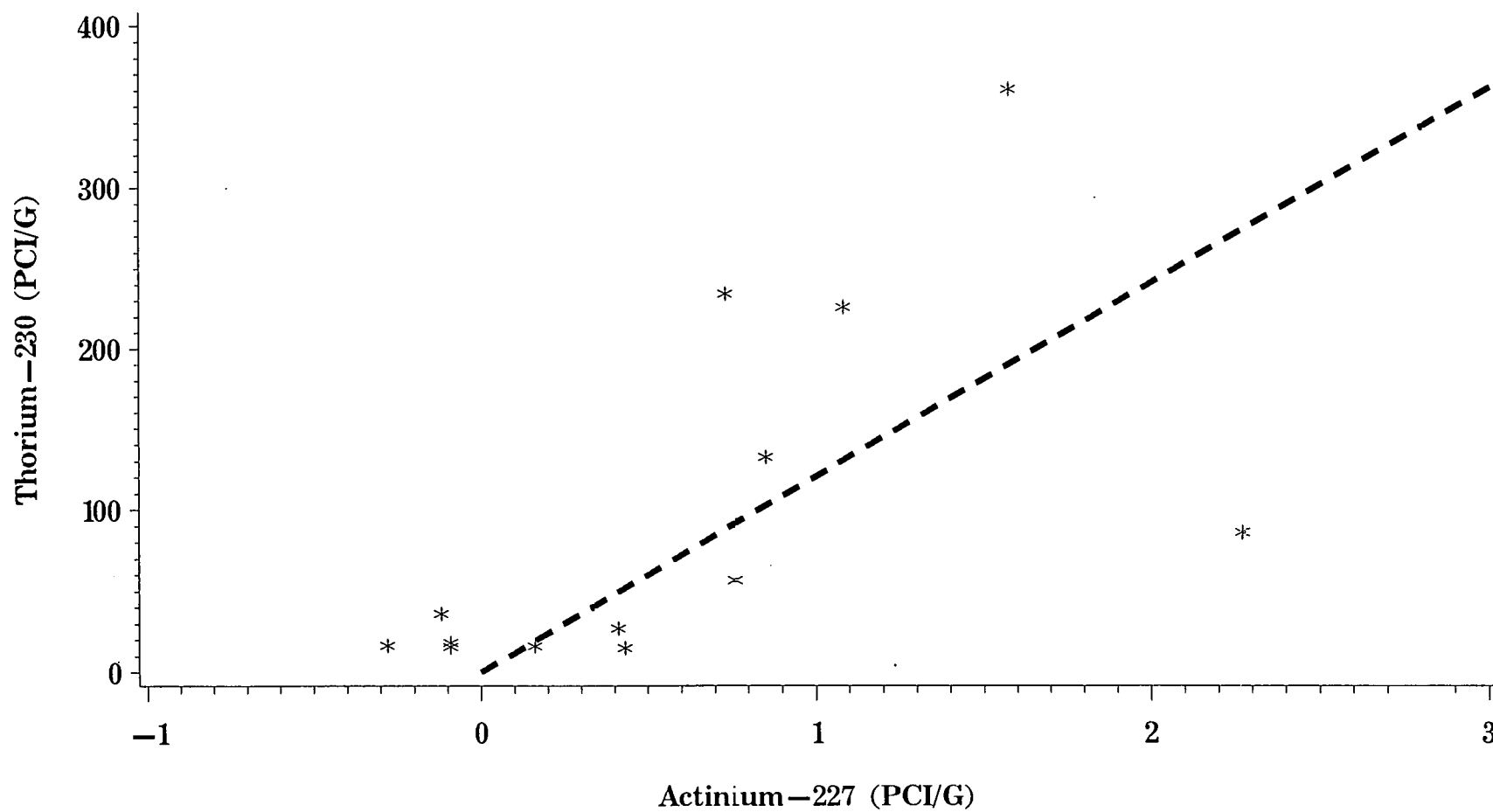
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area = IA-13



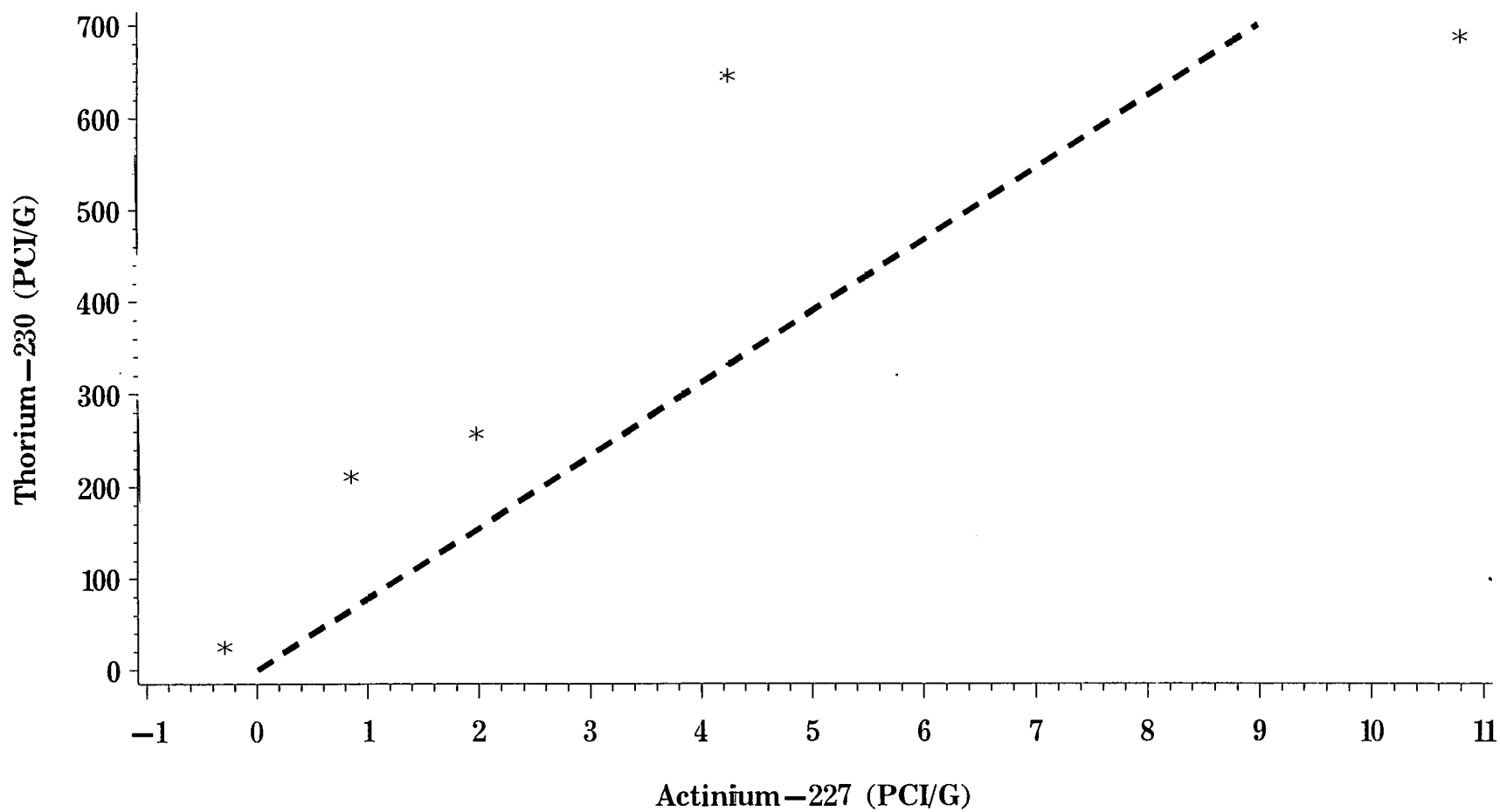
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= IA-2



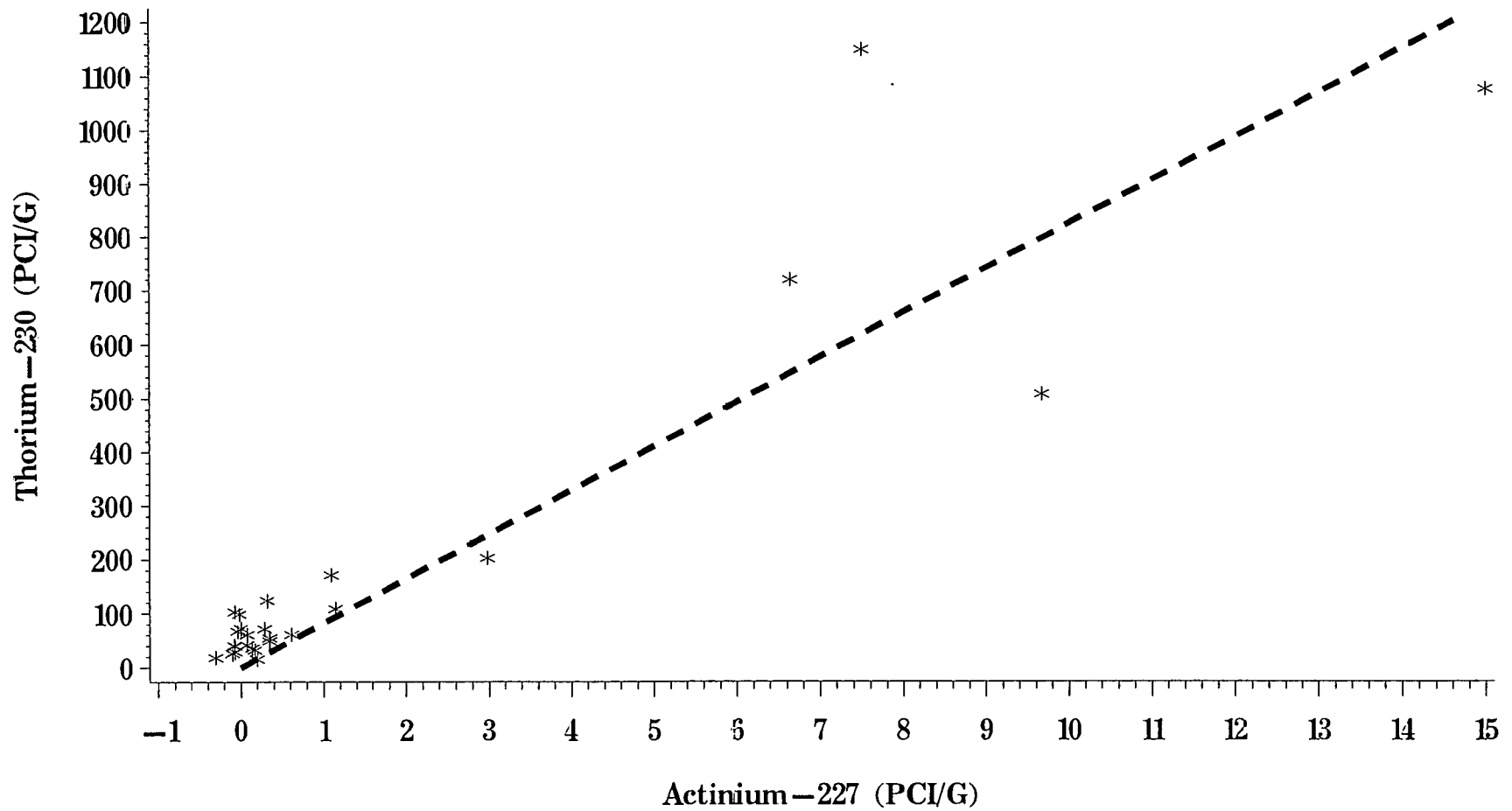
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= IA-3



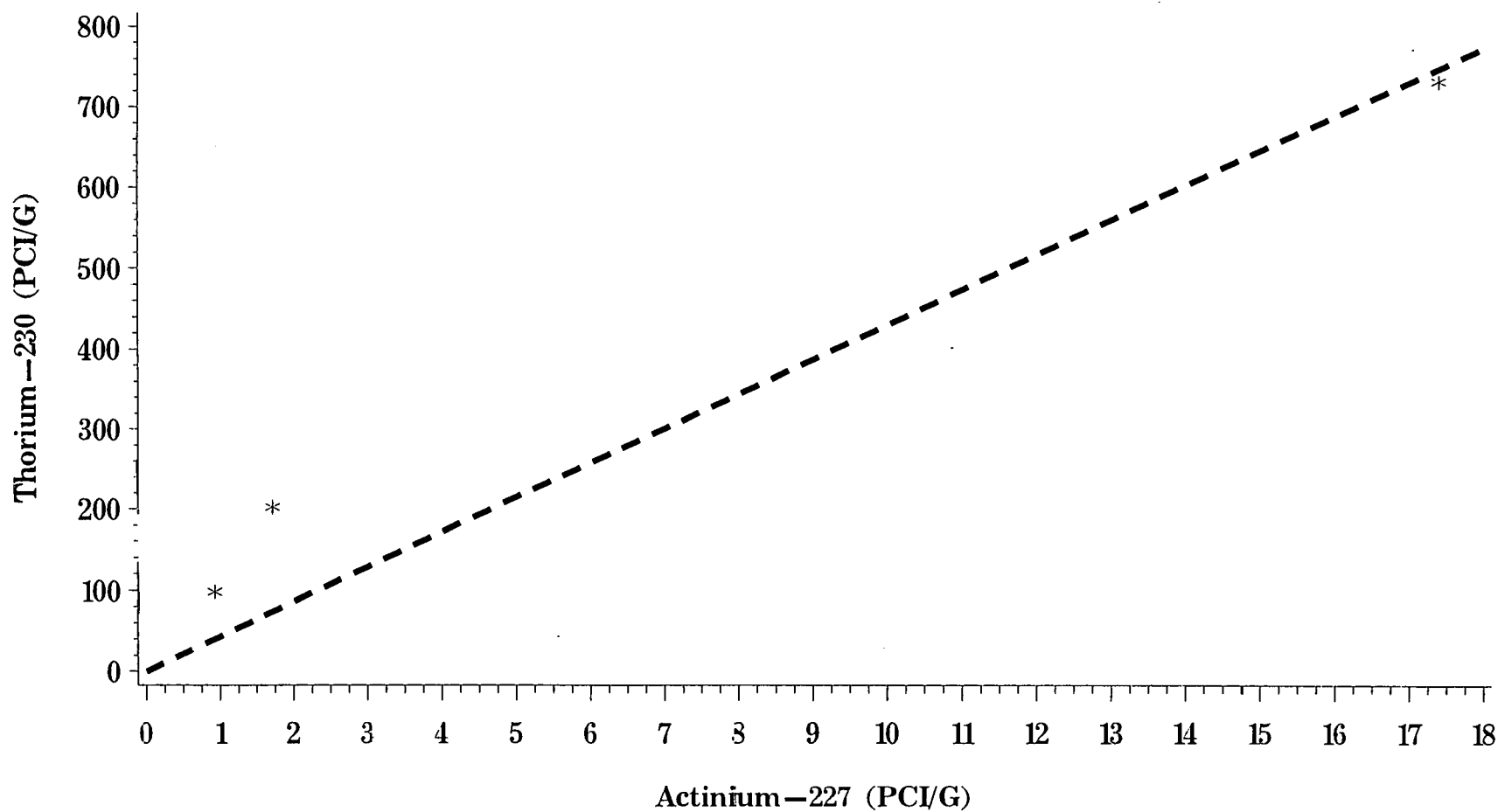
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= IA-4



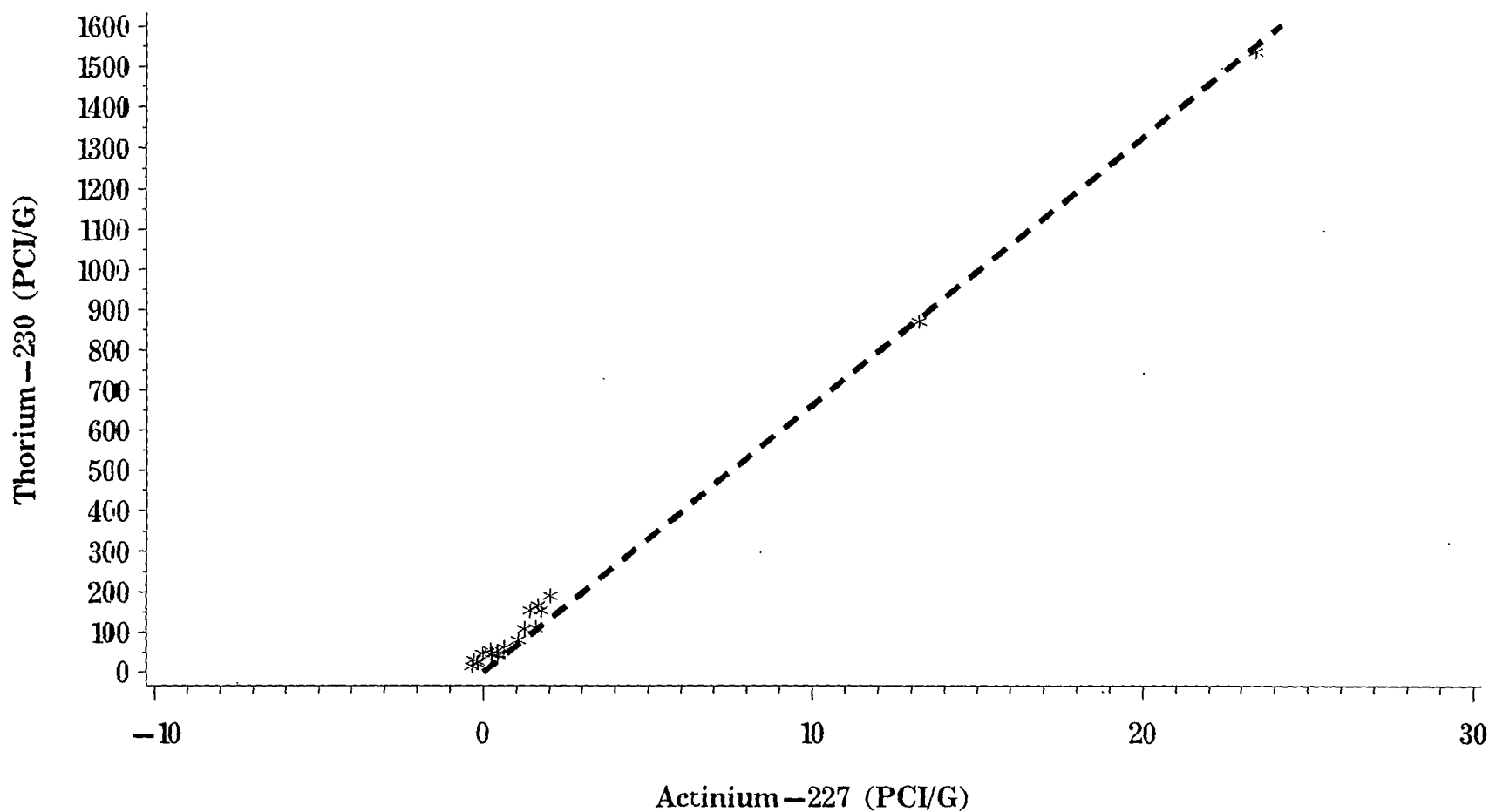
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= IA -5



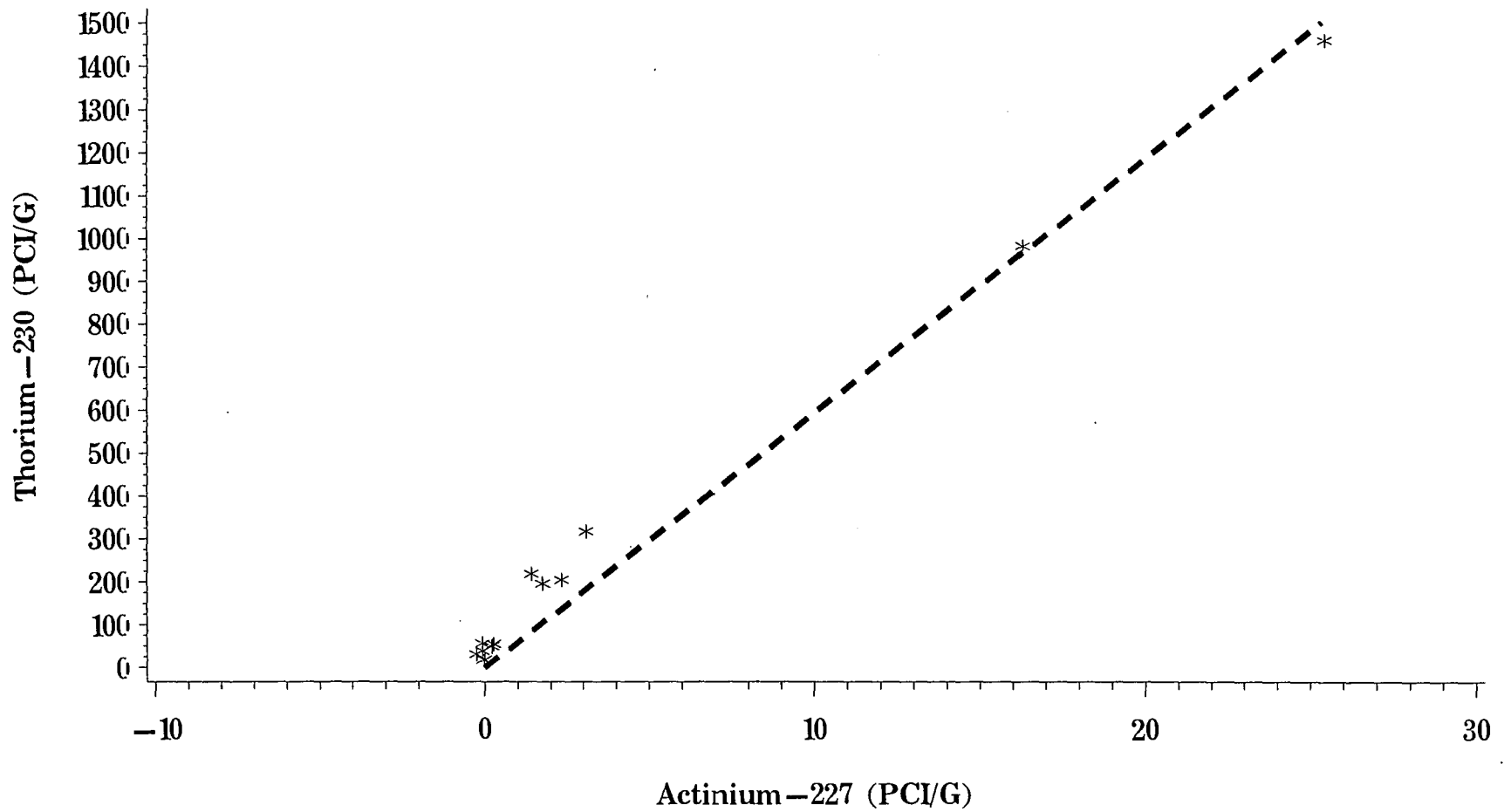
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= IA-6



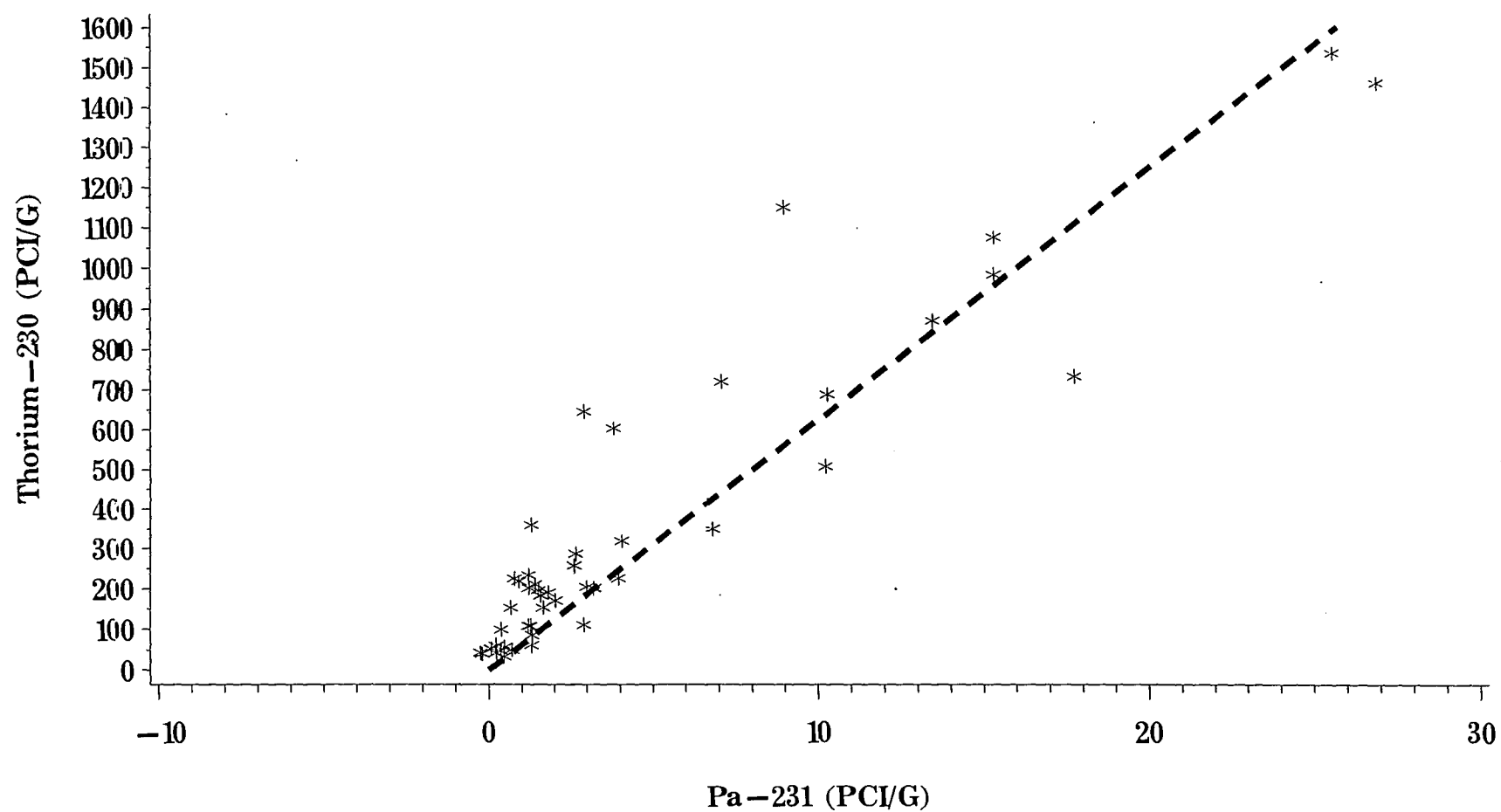
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= 1A-8



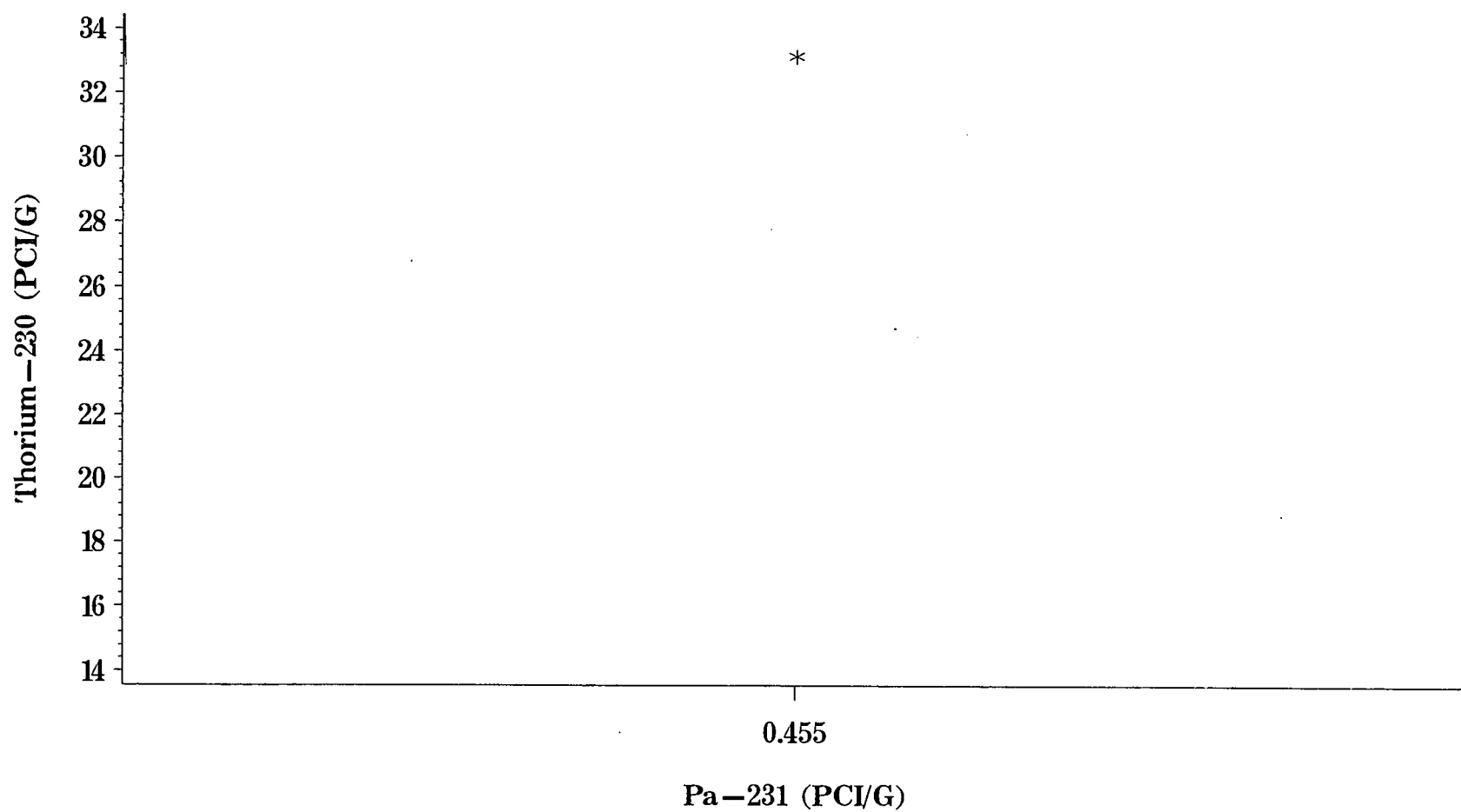
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= IA-9



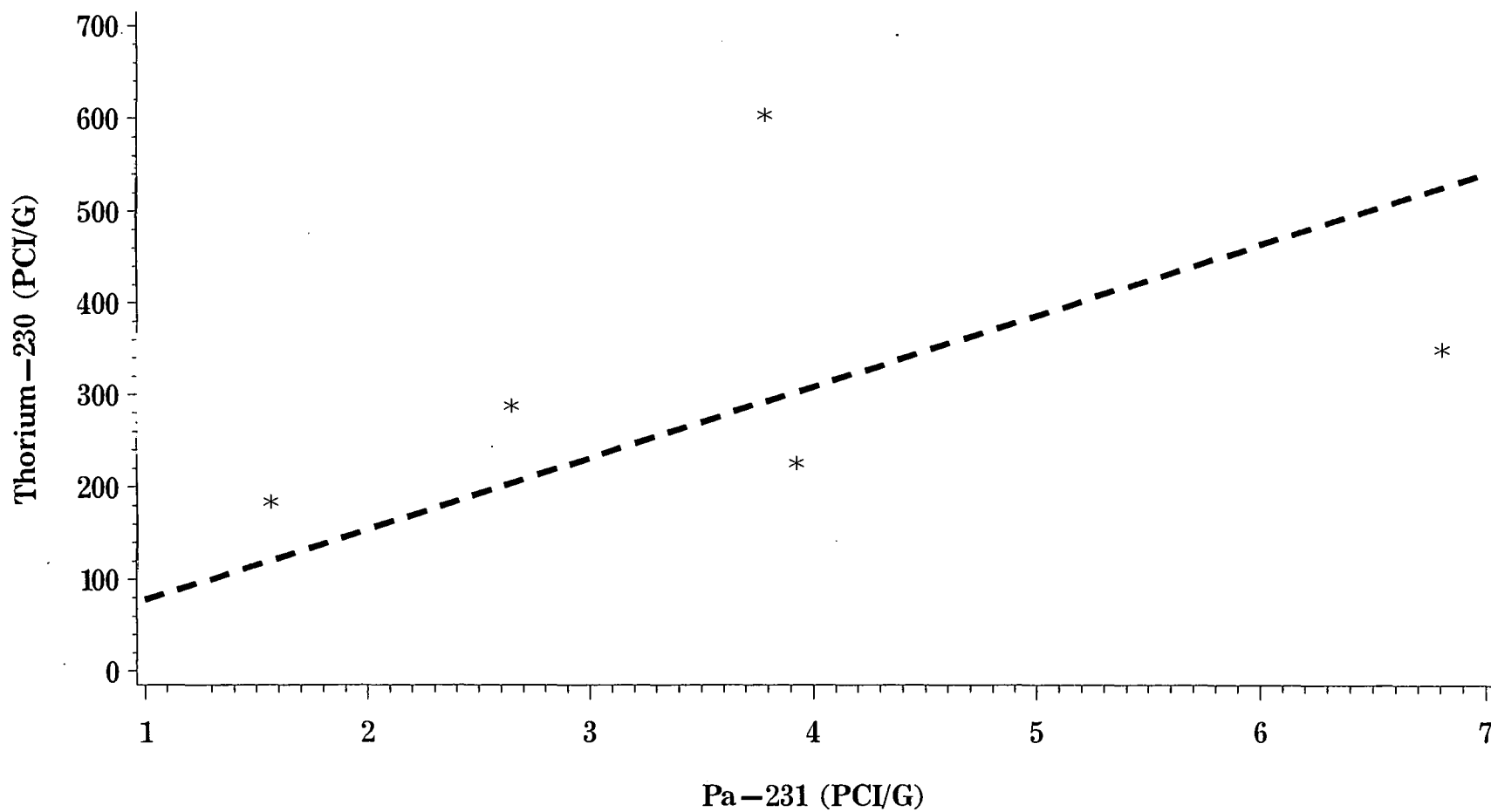
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= All



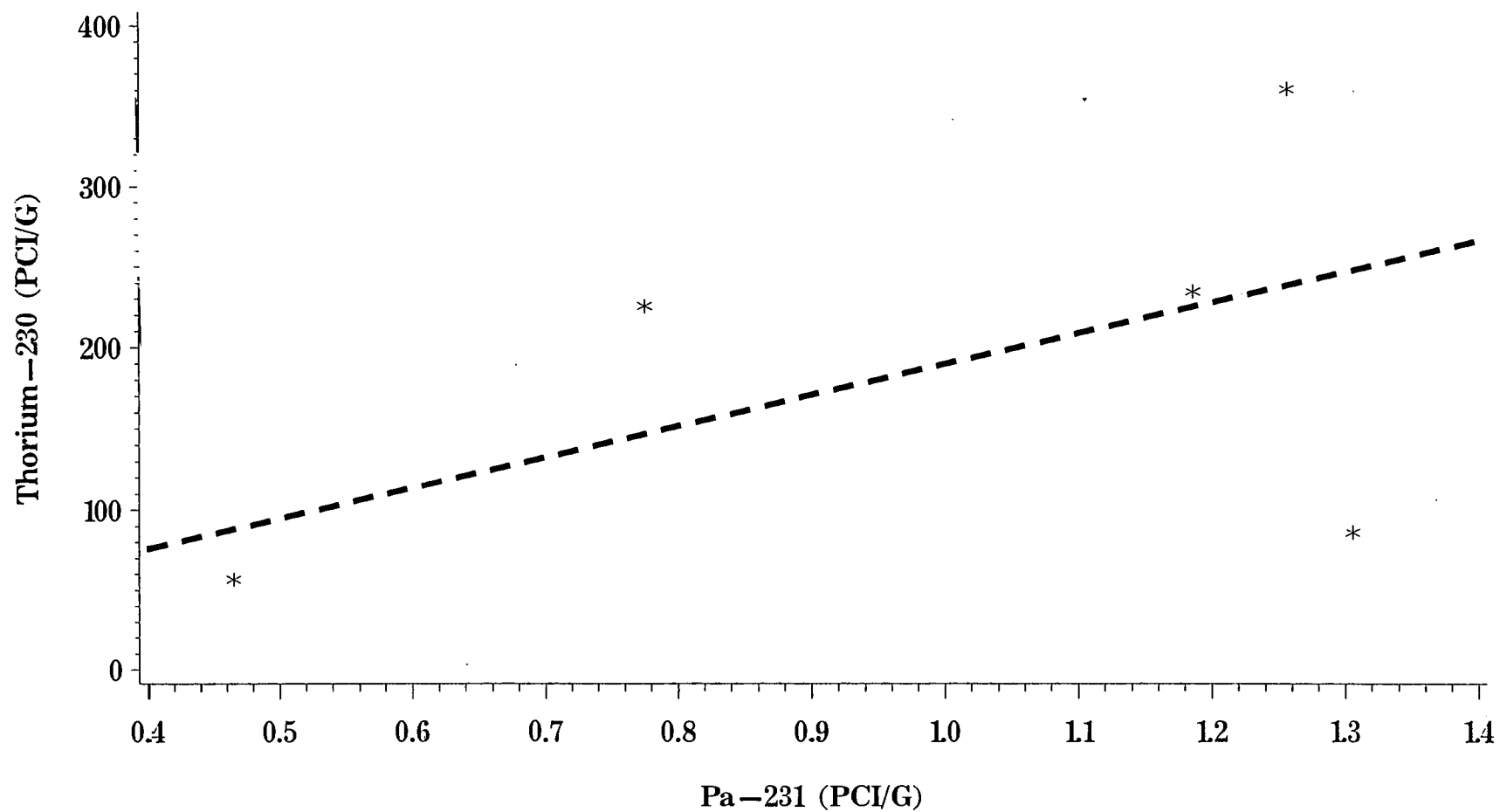
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area = 1A-13



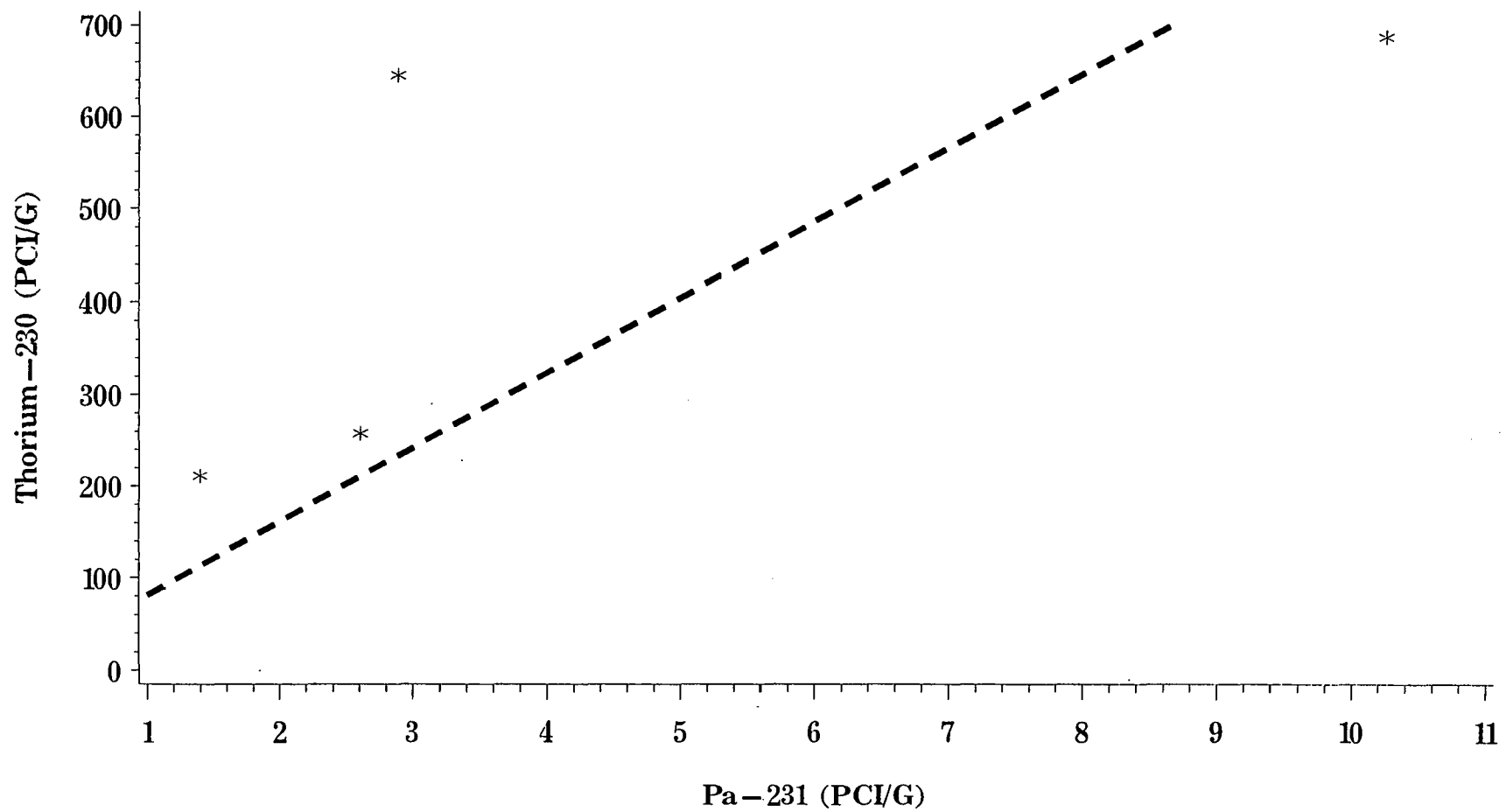
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= IA-2



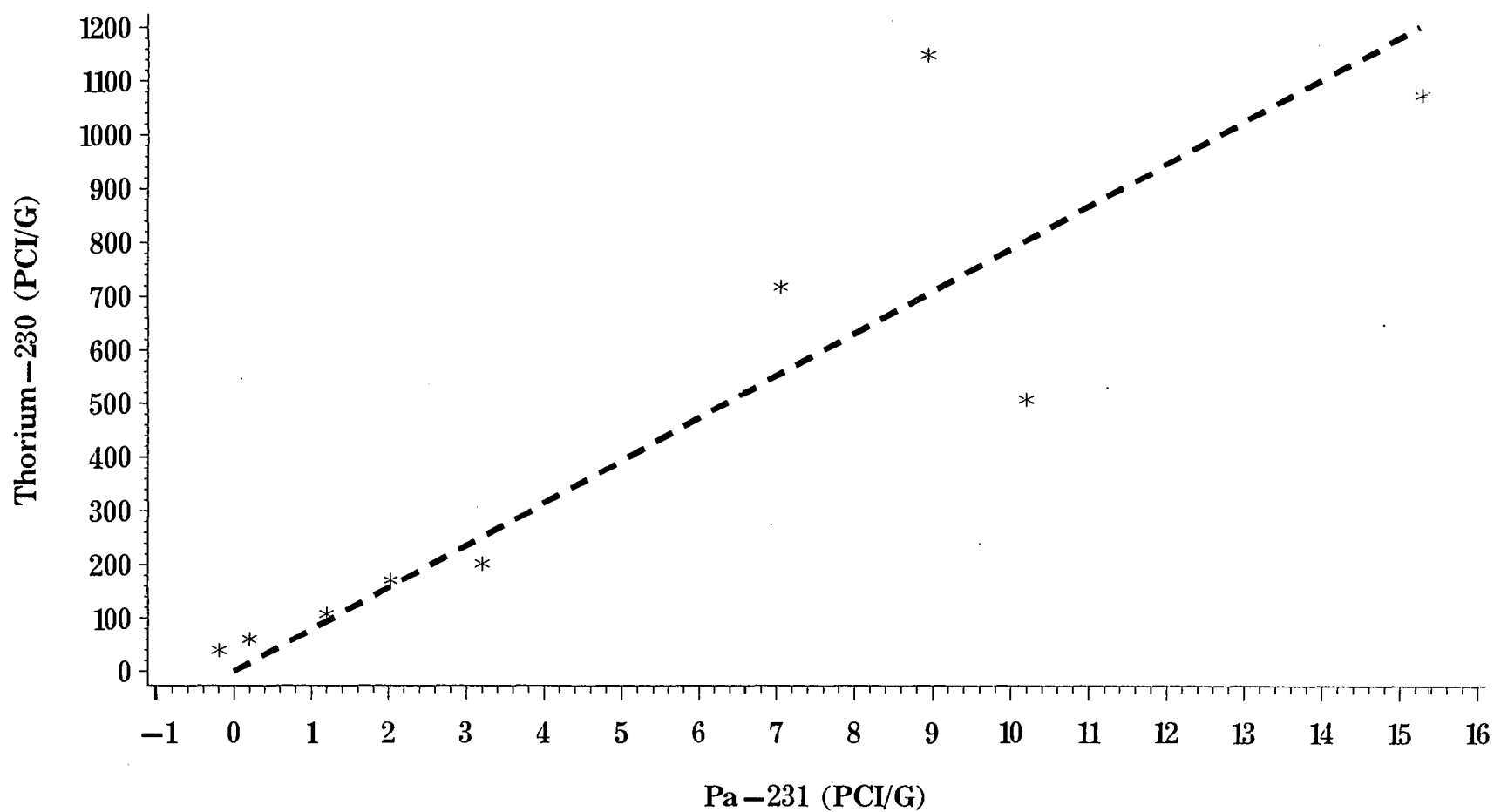
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= IA-3



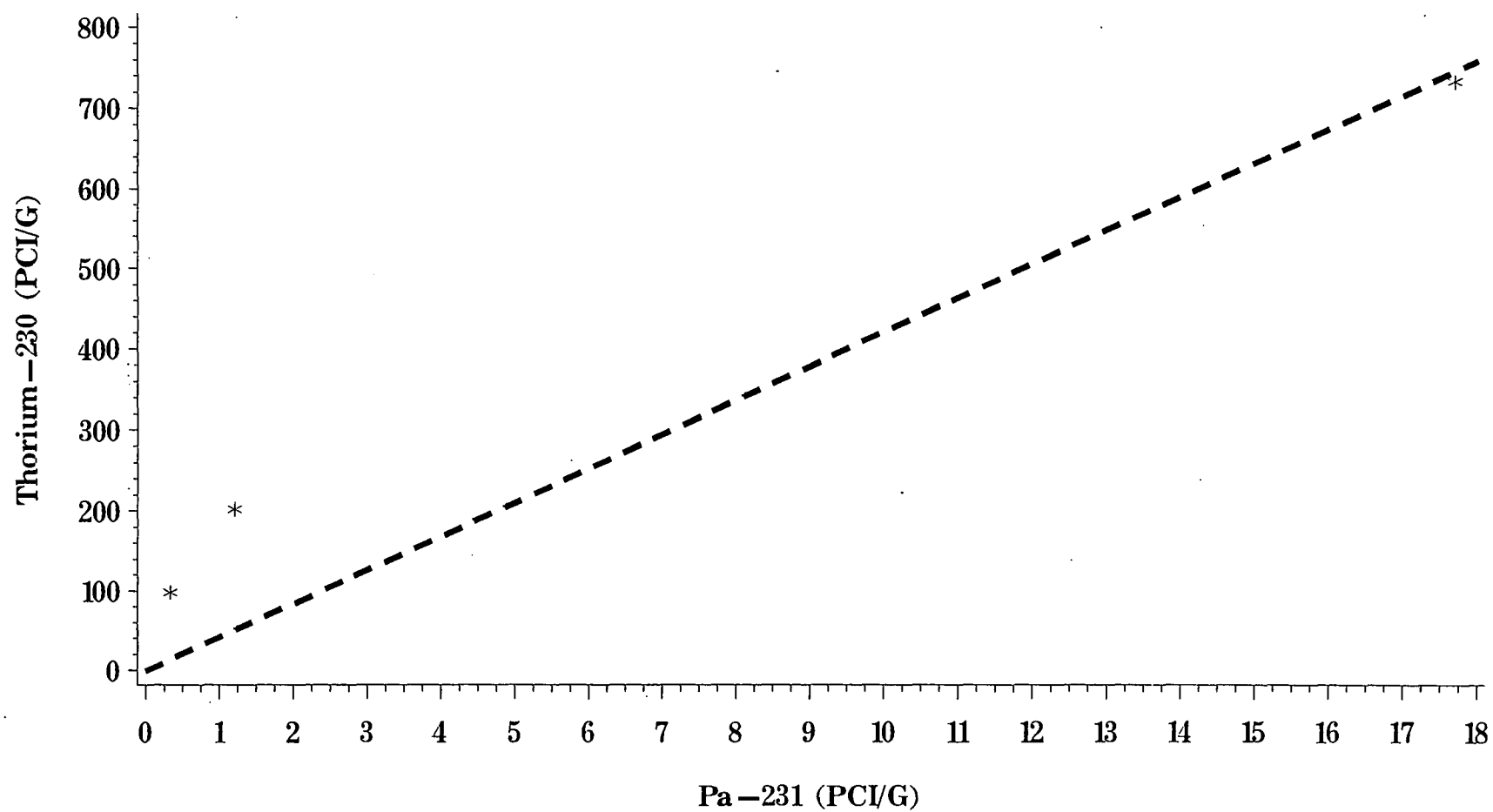
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= IA-4



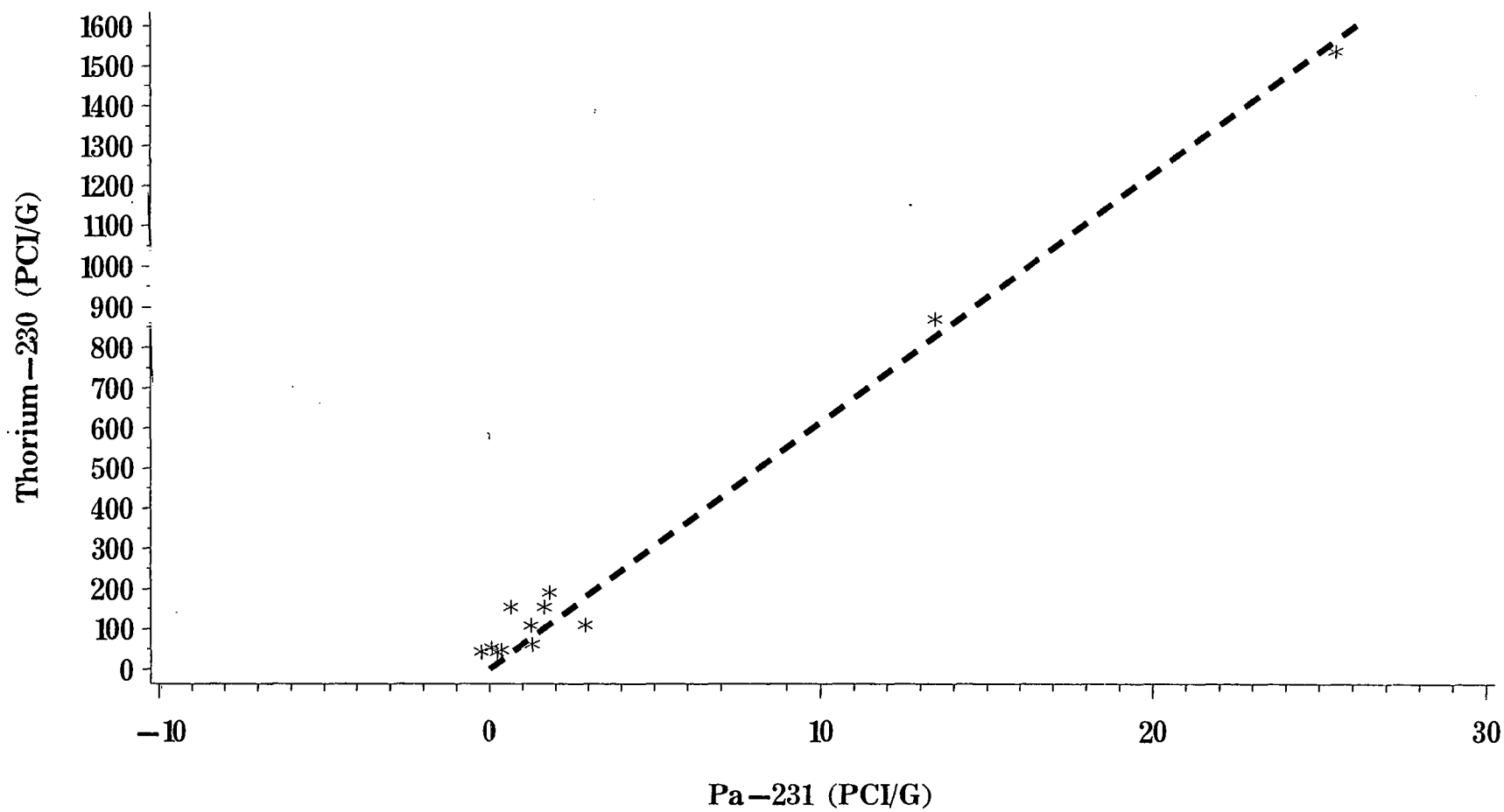
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= 1A-5



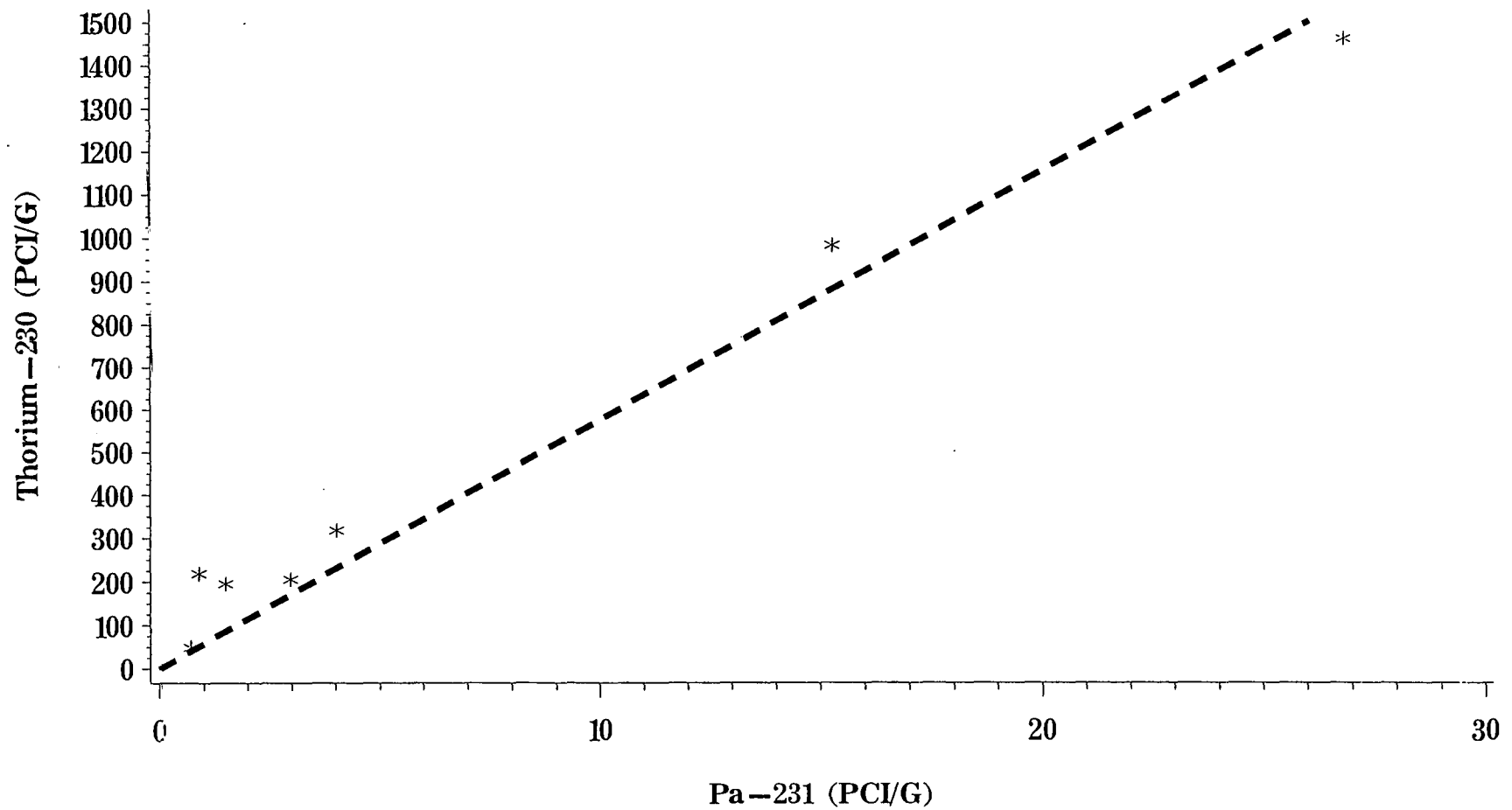
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= IA-6



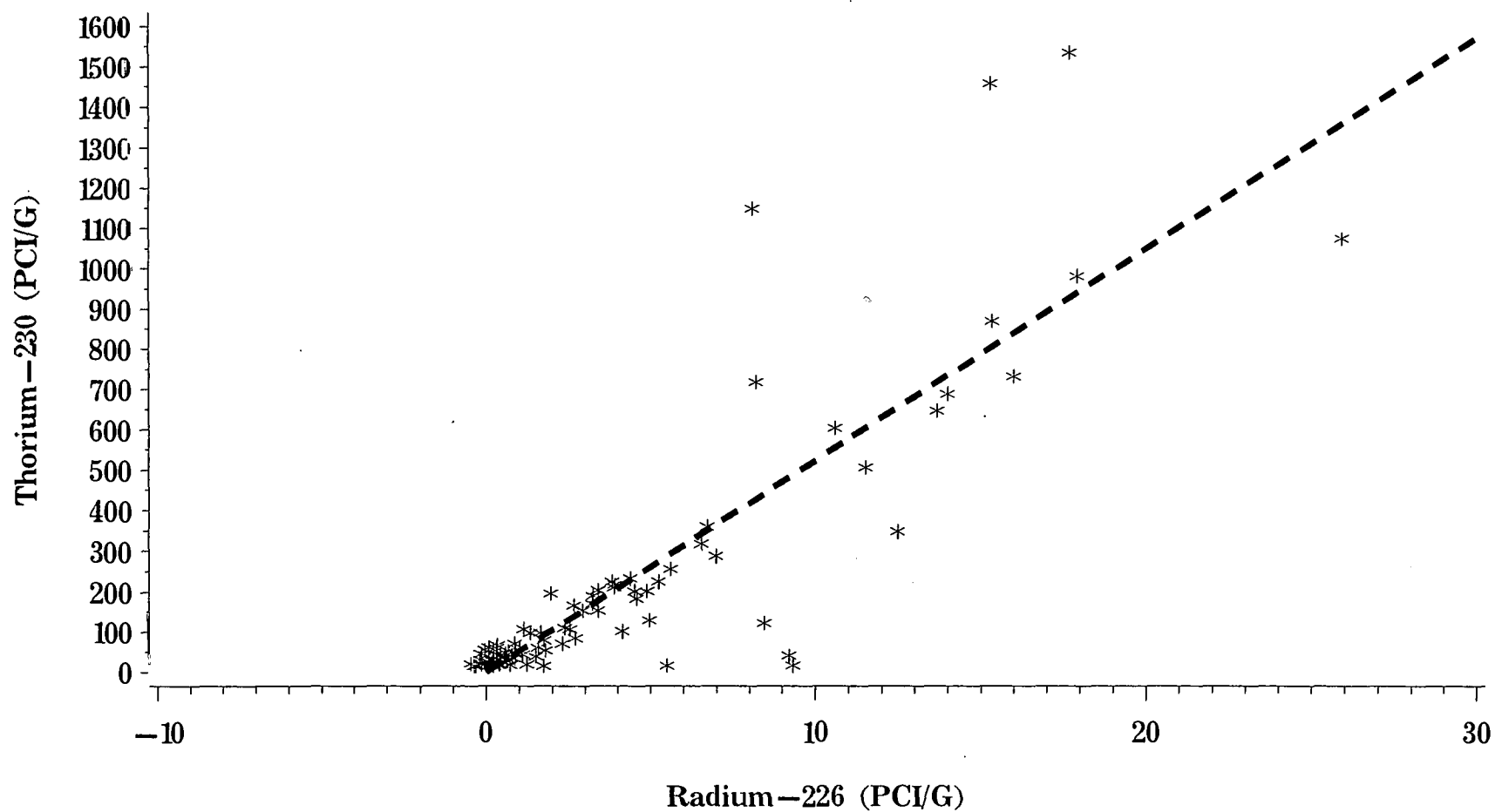
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= IA-8



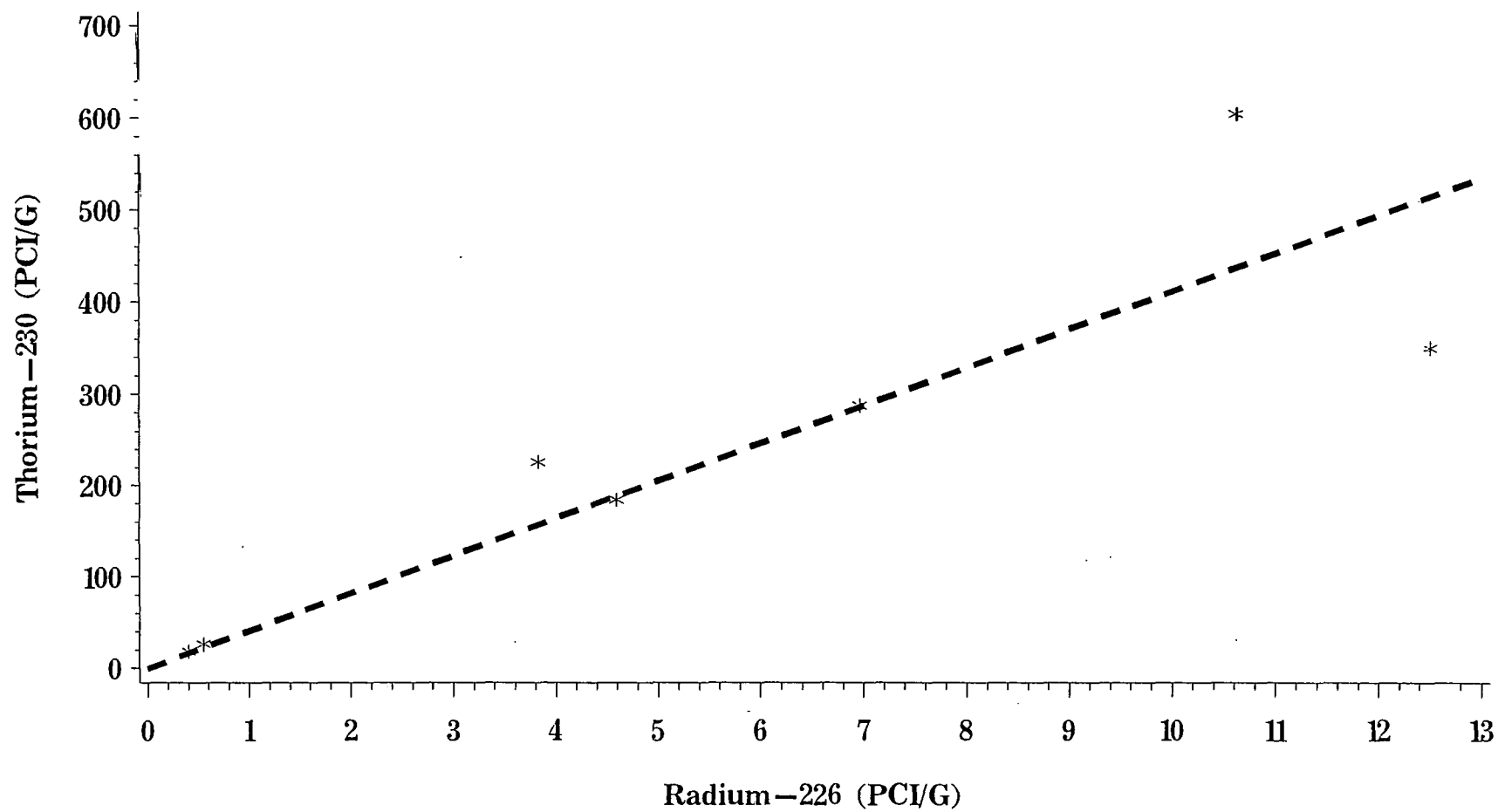
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= IA-9



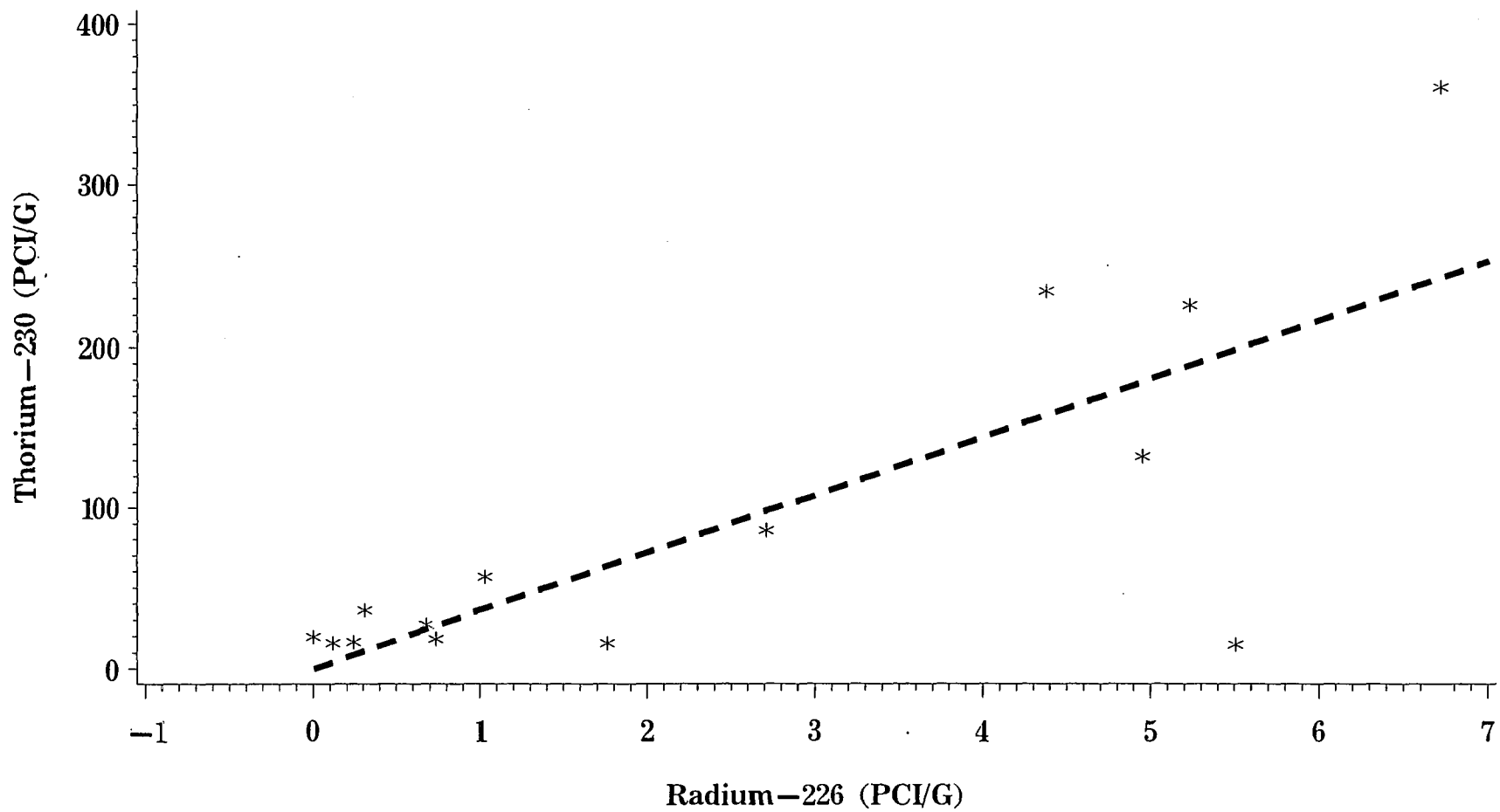
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= All



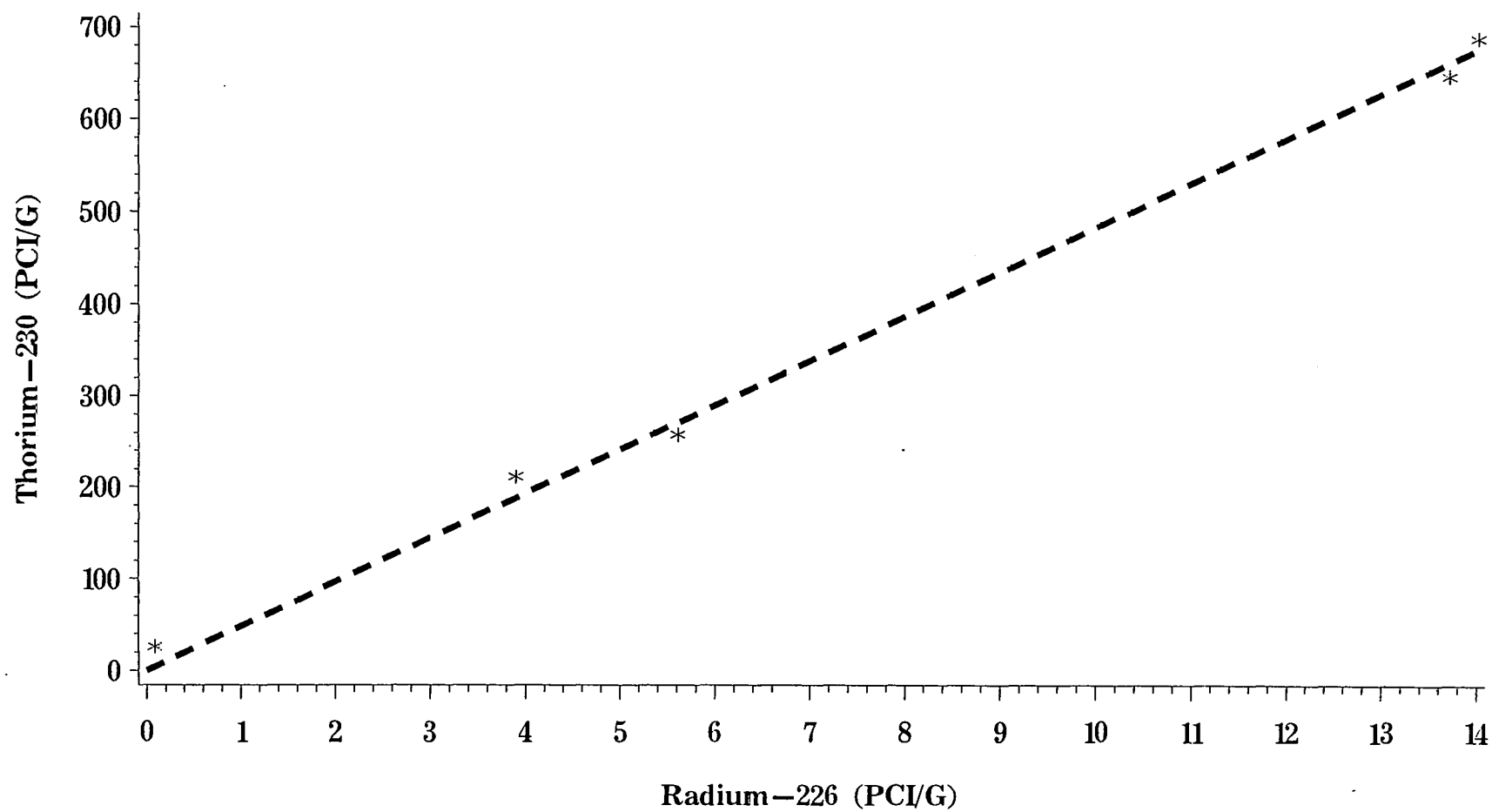
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= IA-2



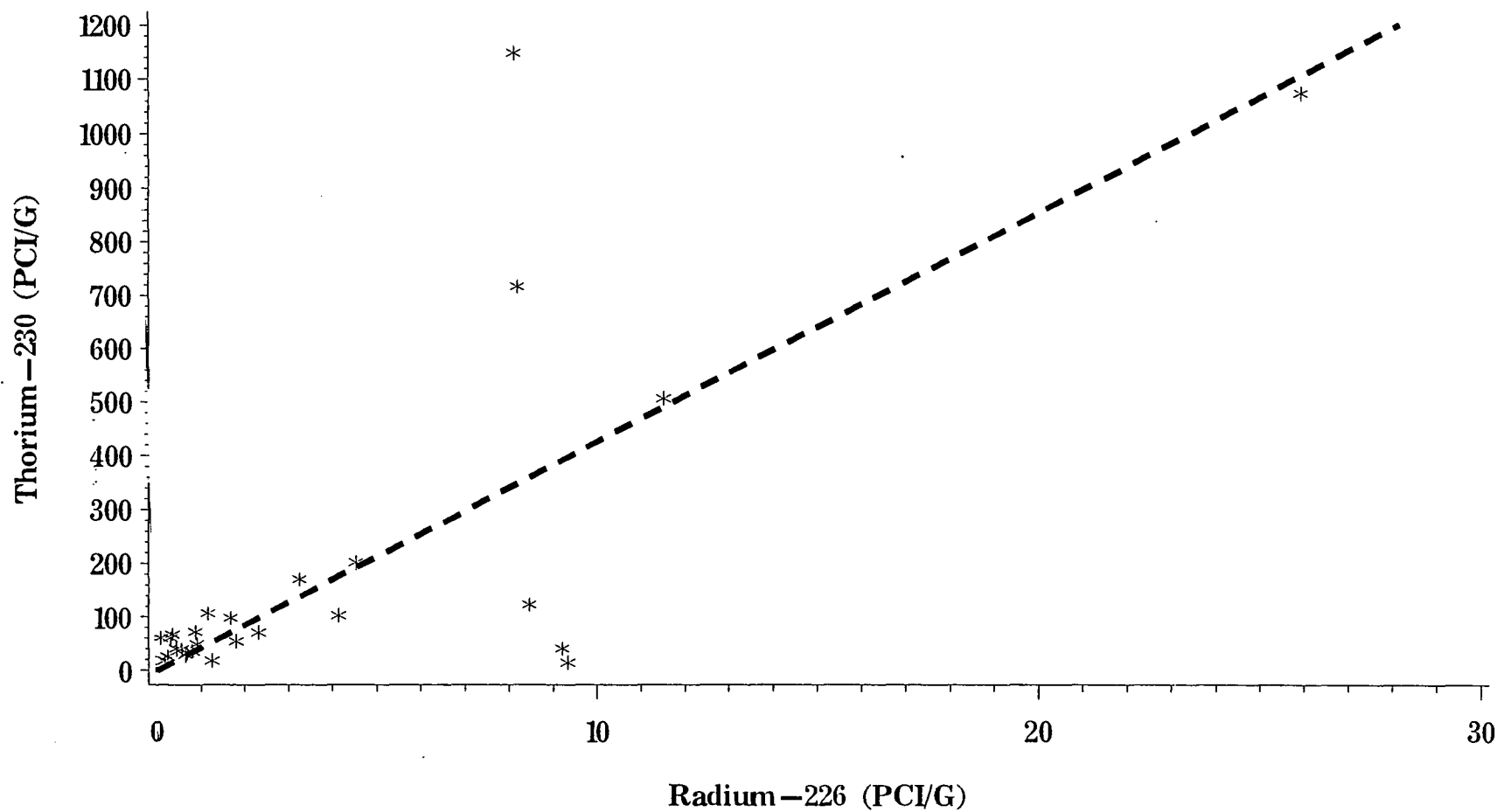
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= 1A-3



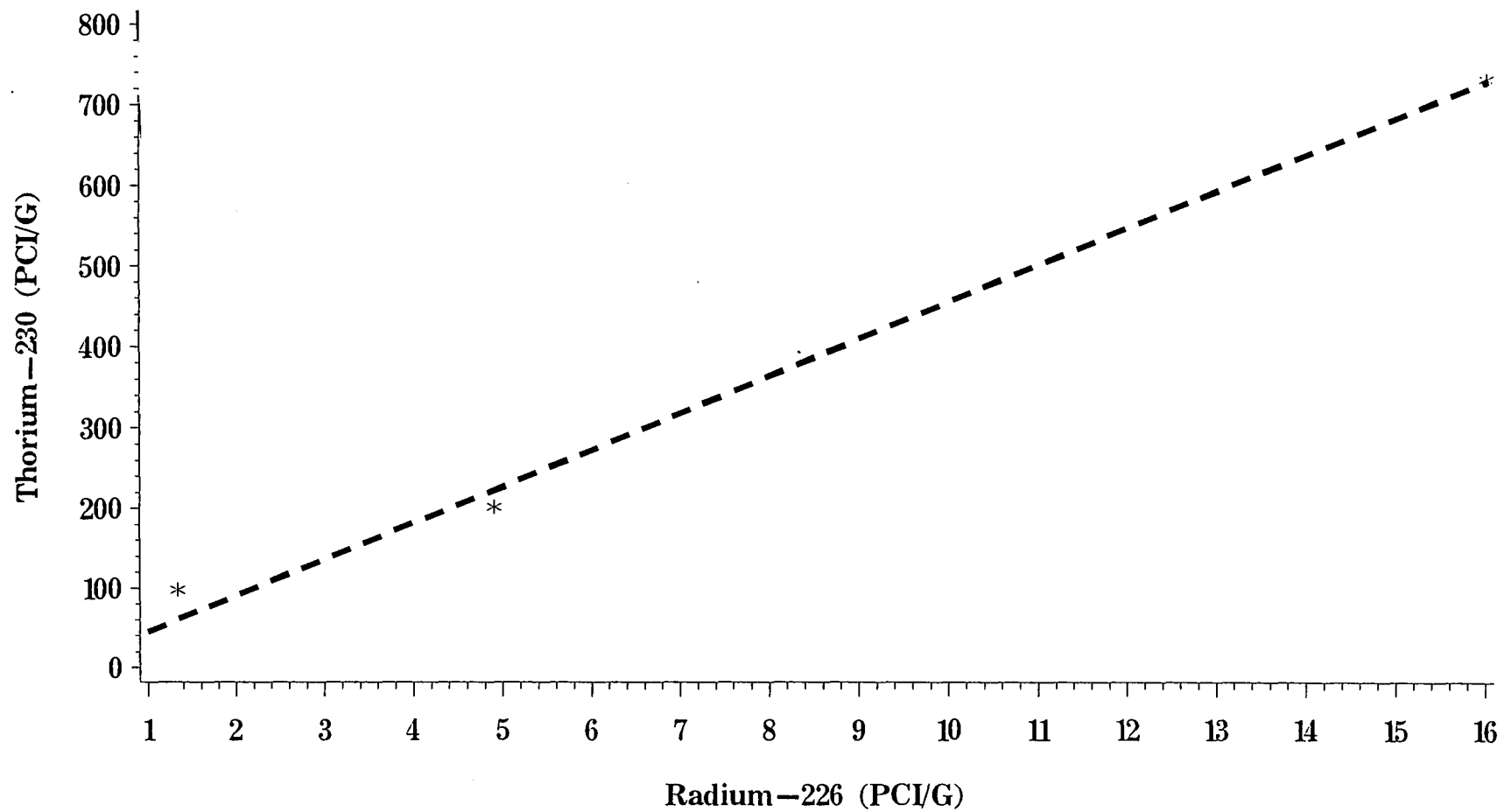
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area = 1A-4



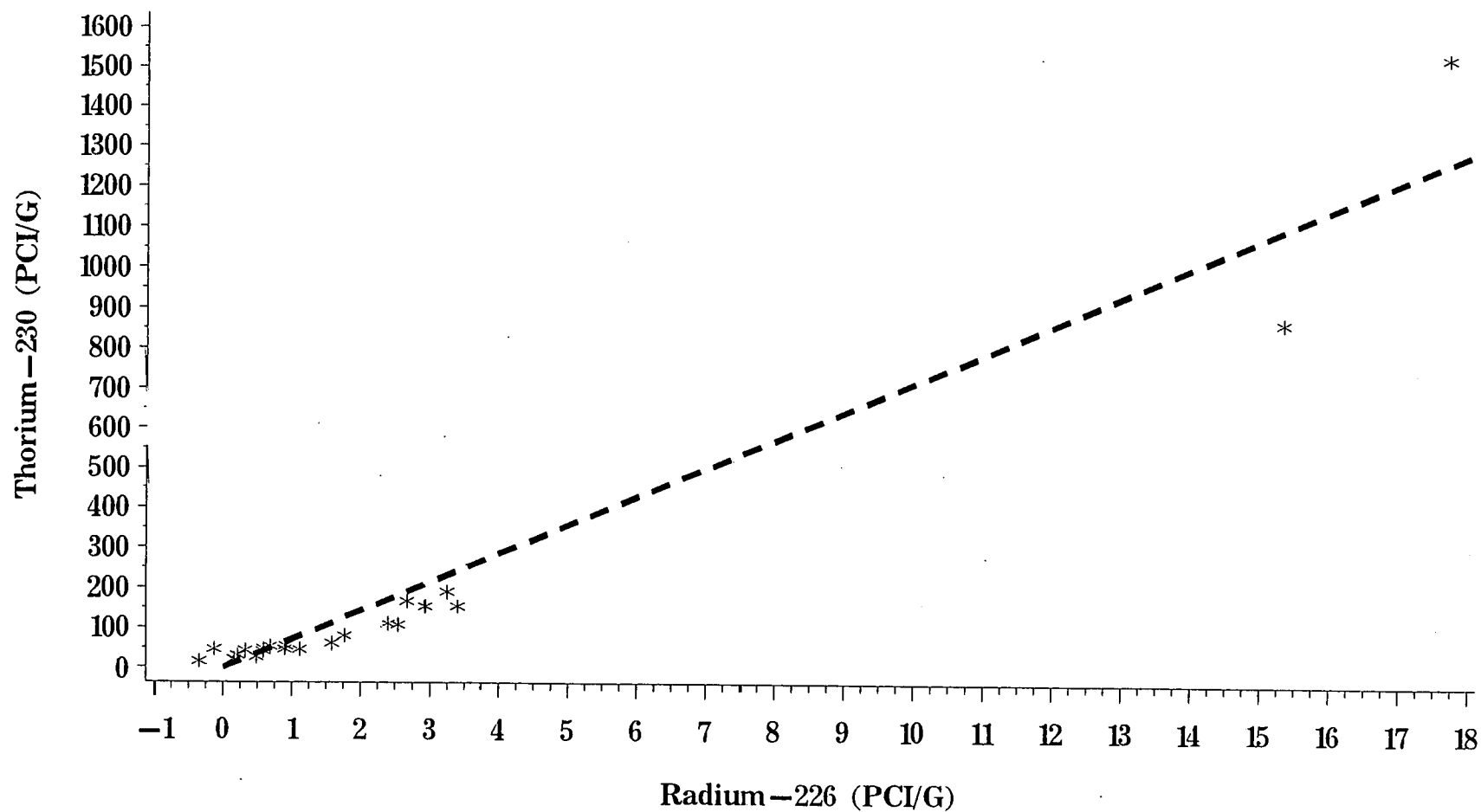
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area = 1A-5



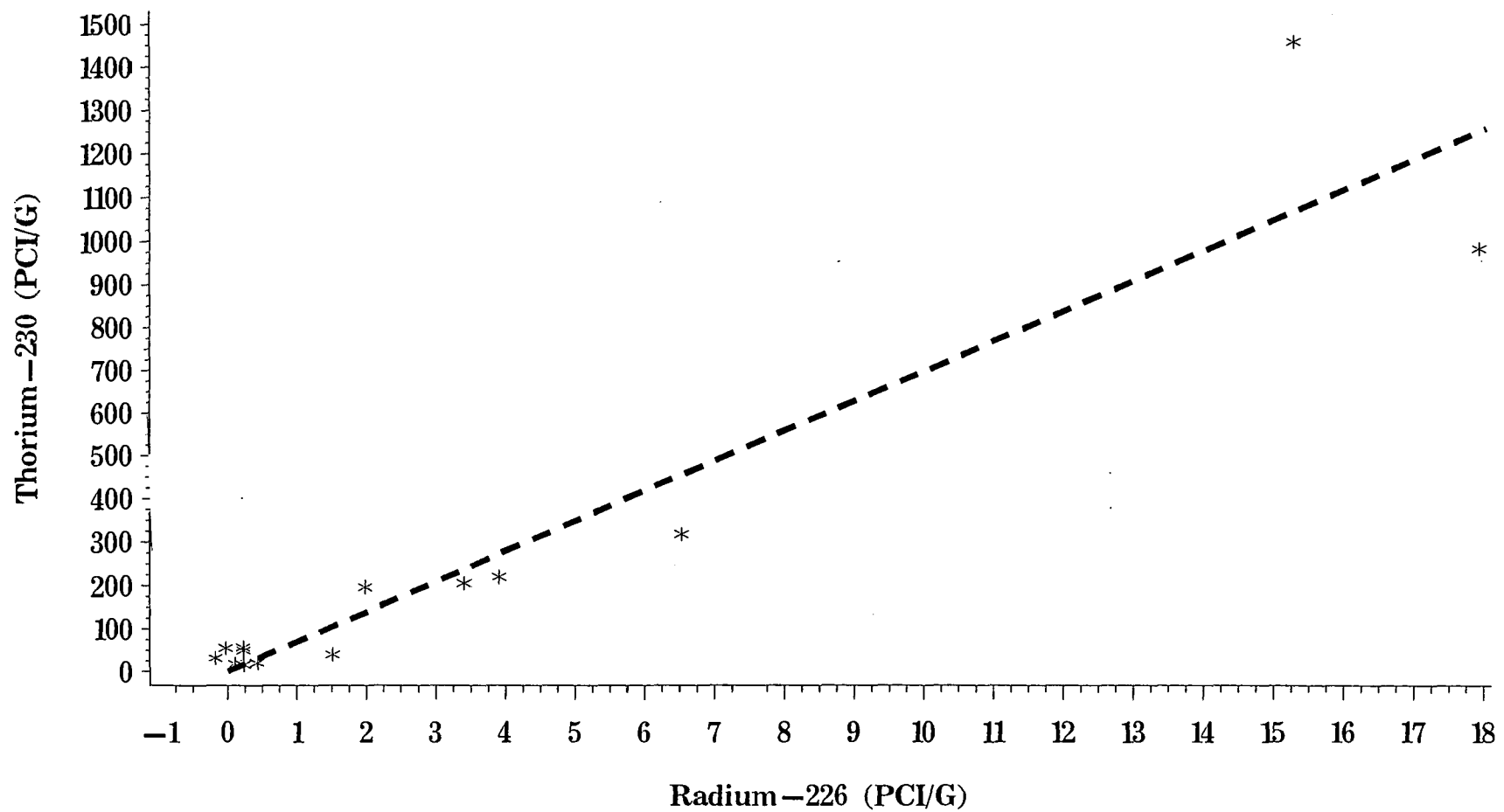
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= IA-6



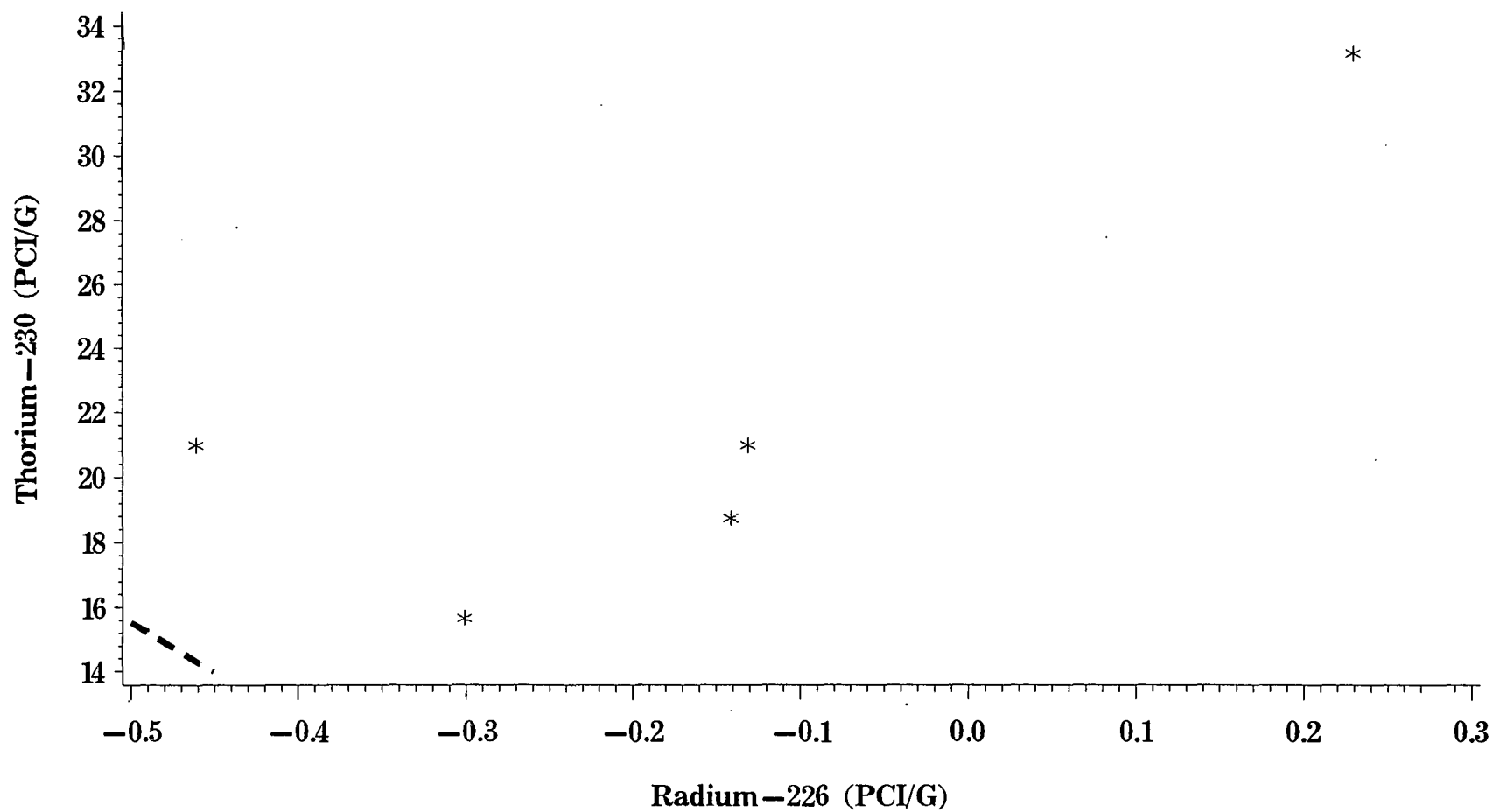
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= 1A-8



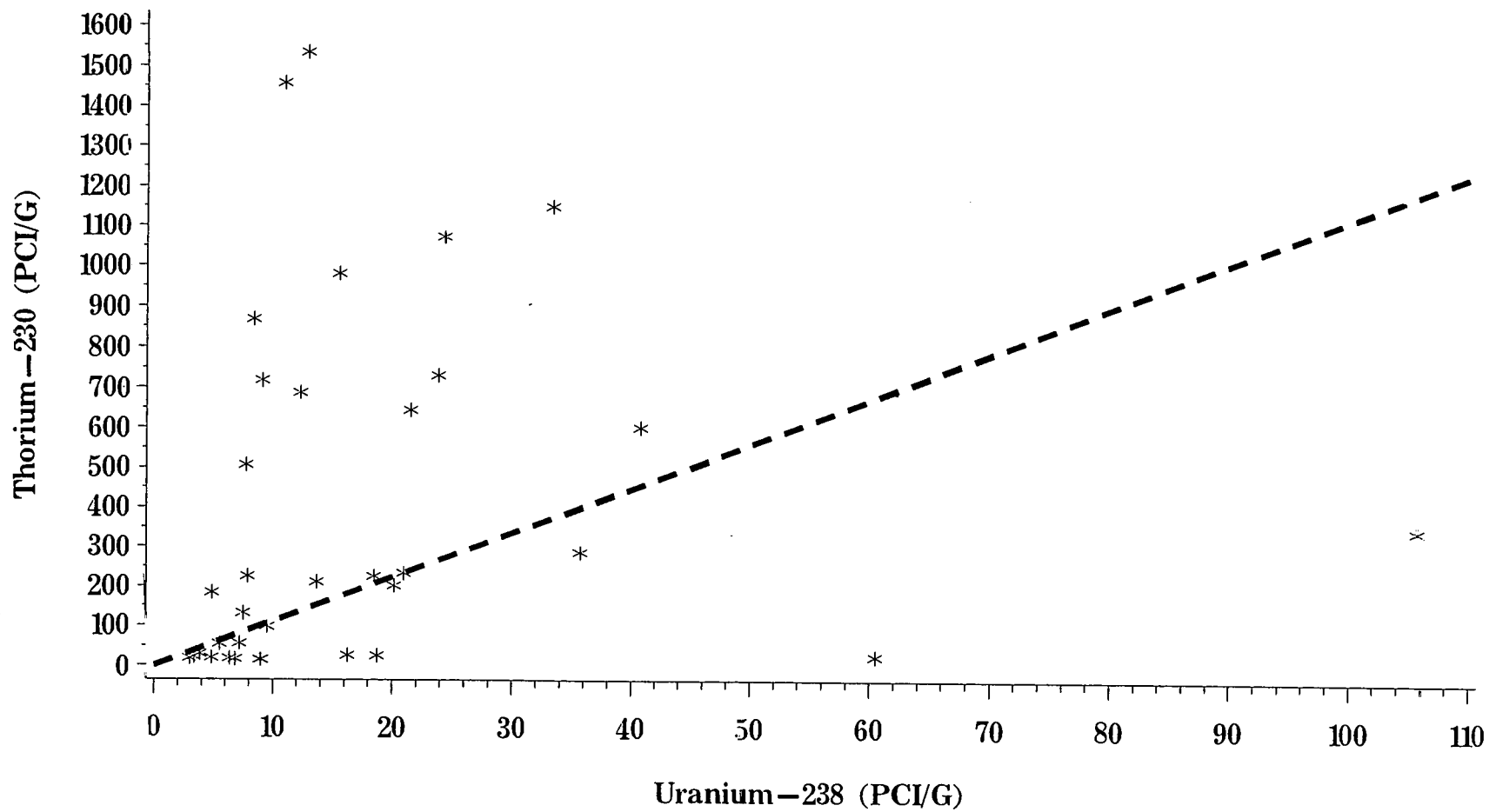
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= IA-9



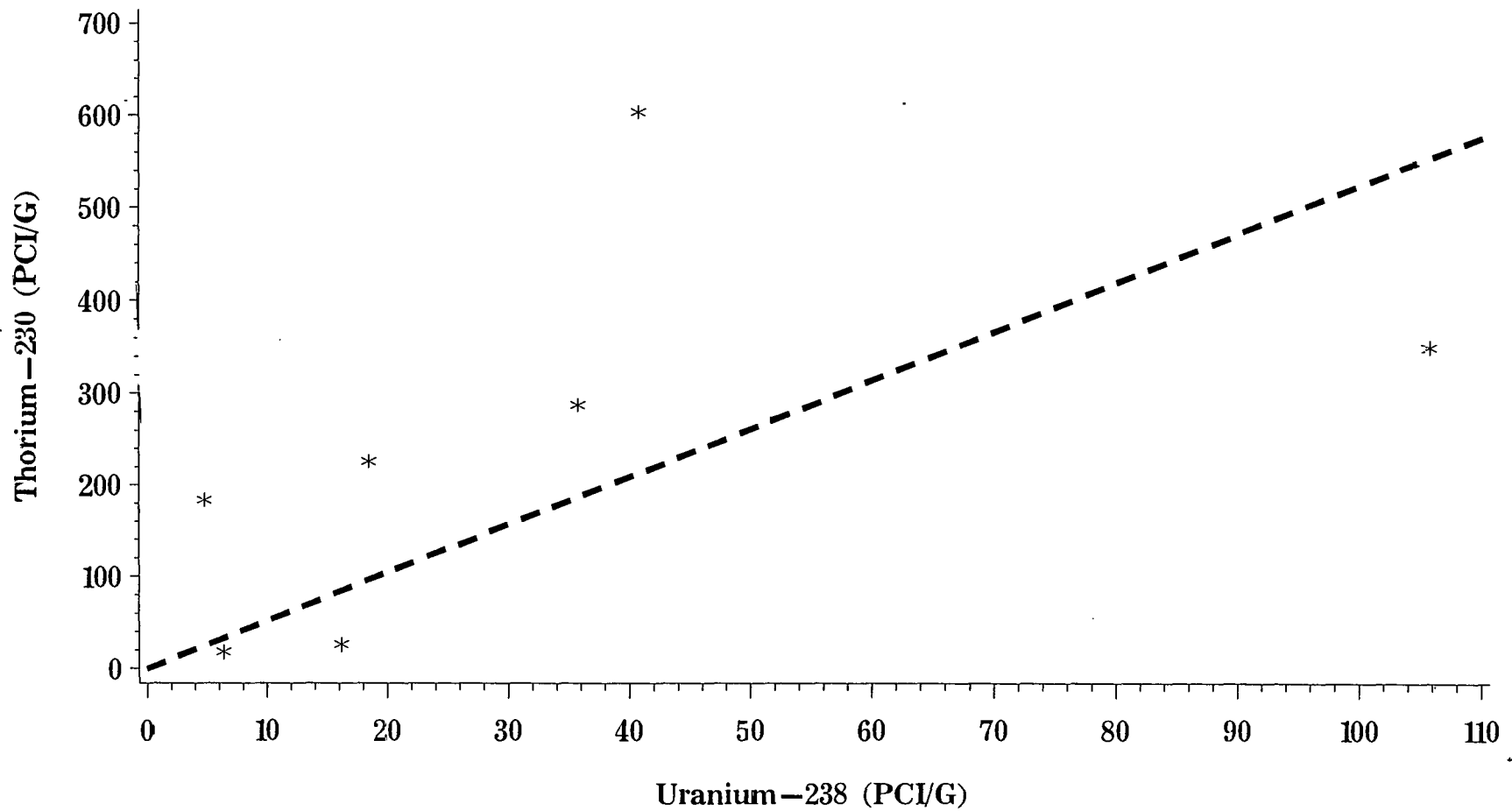
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= IA-13



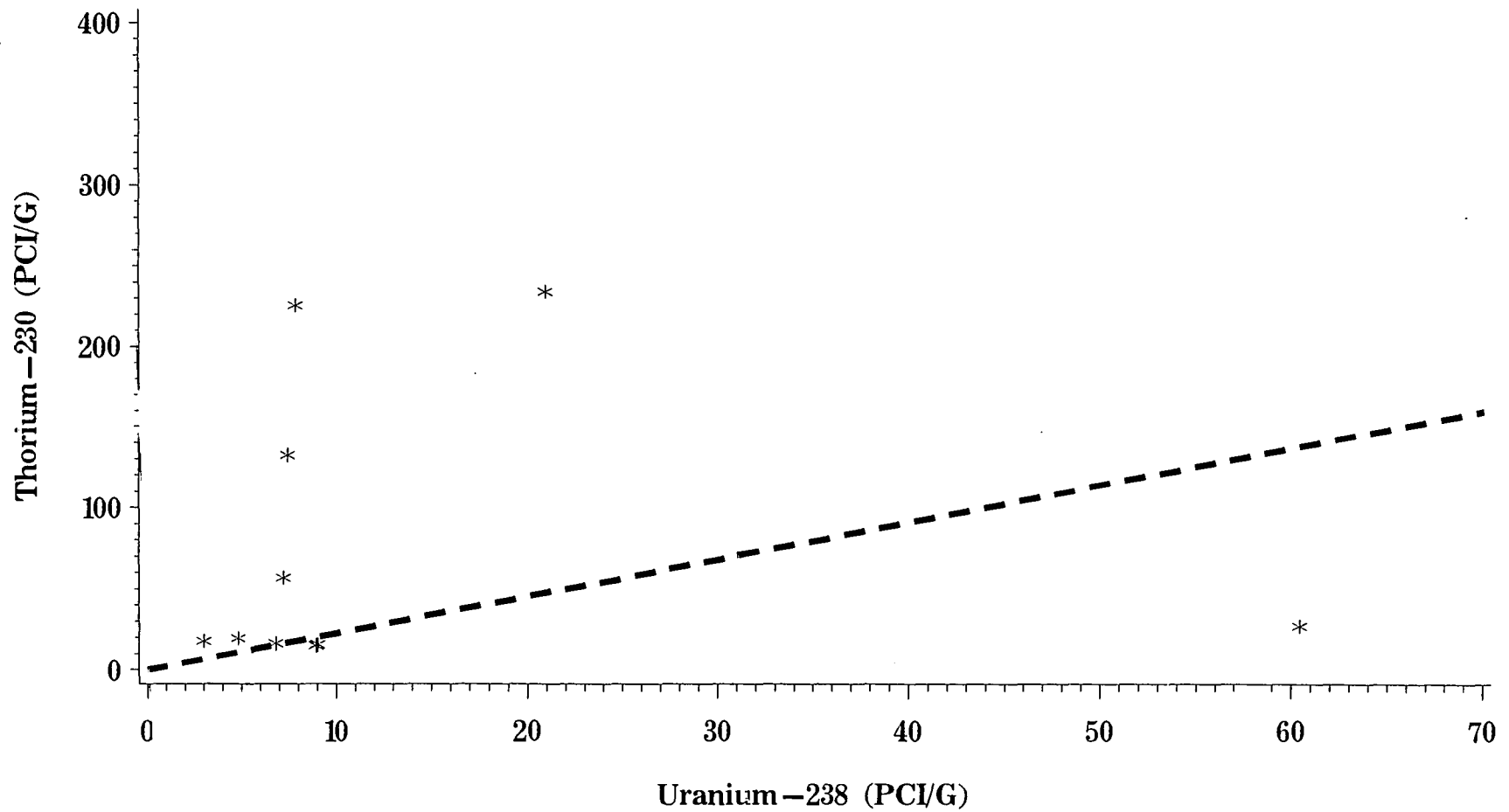
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= All



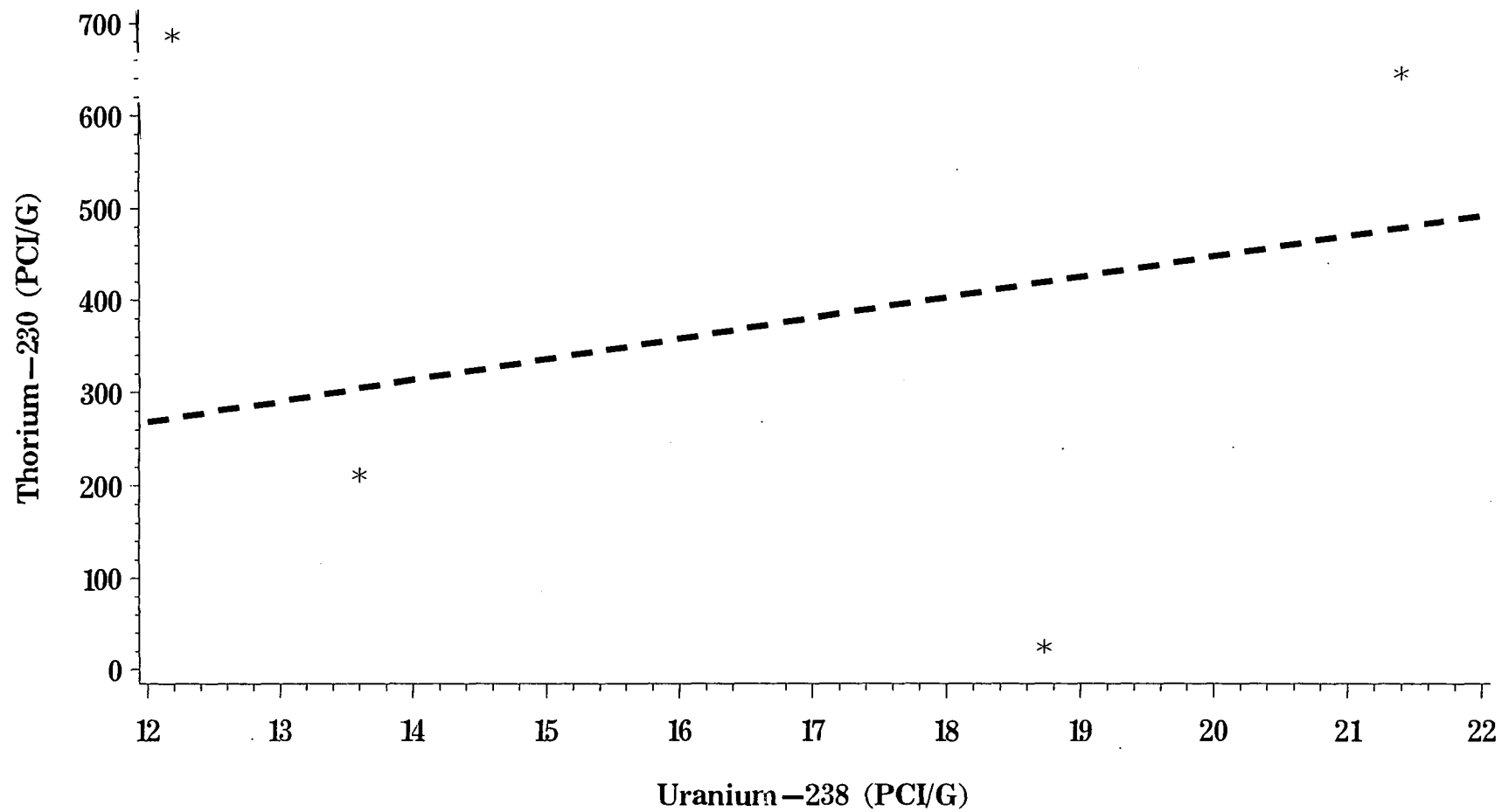
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= IA -2



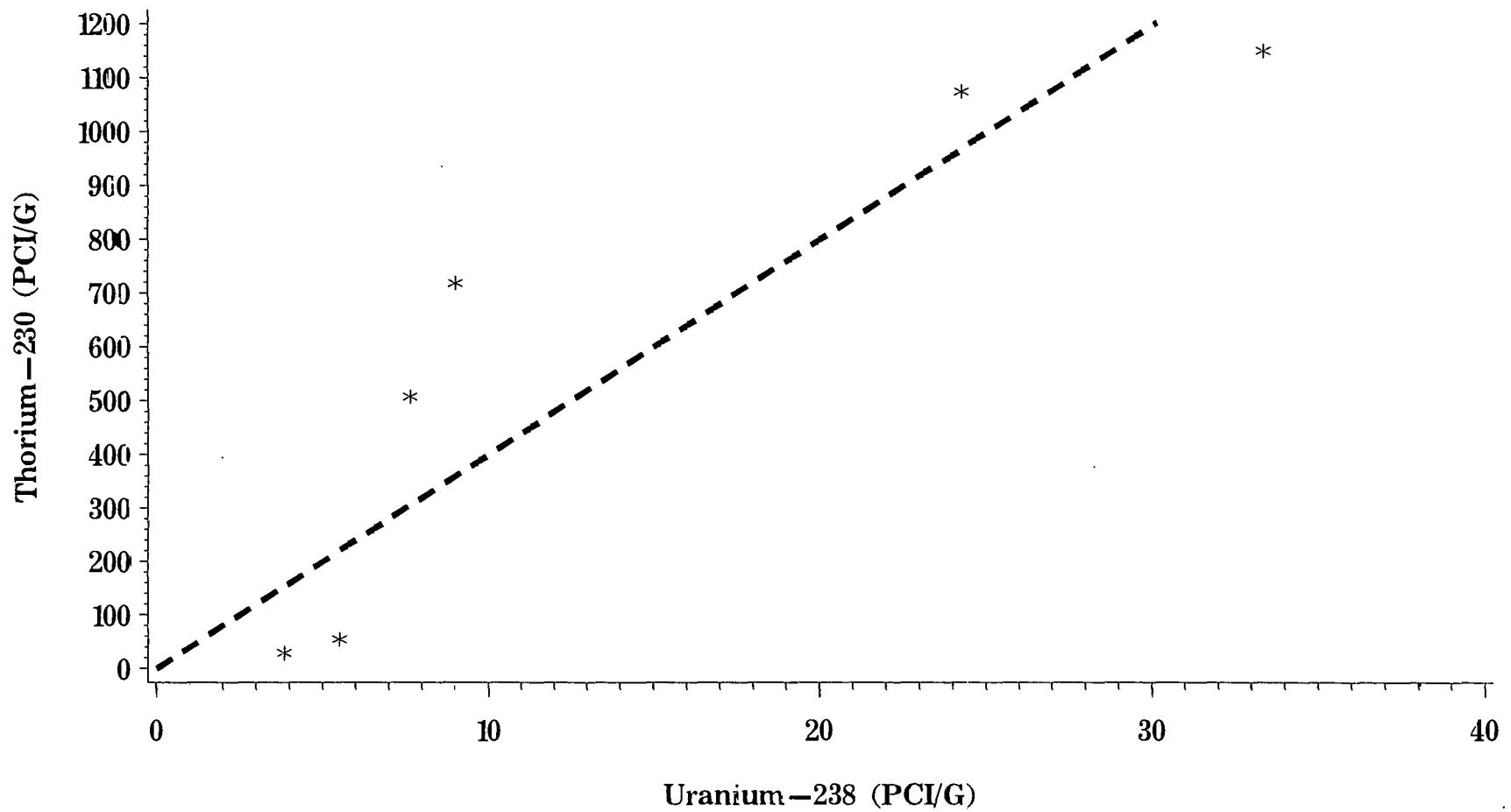
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= IA -3



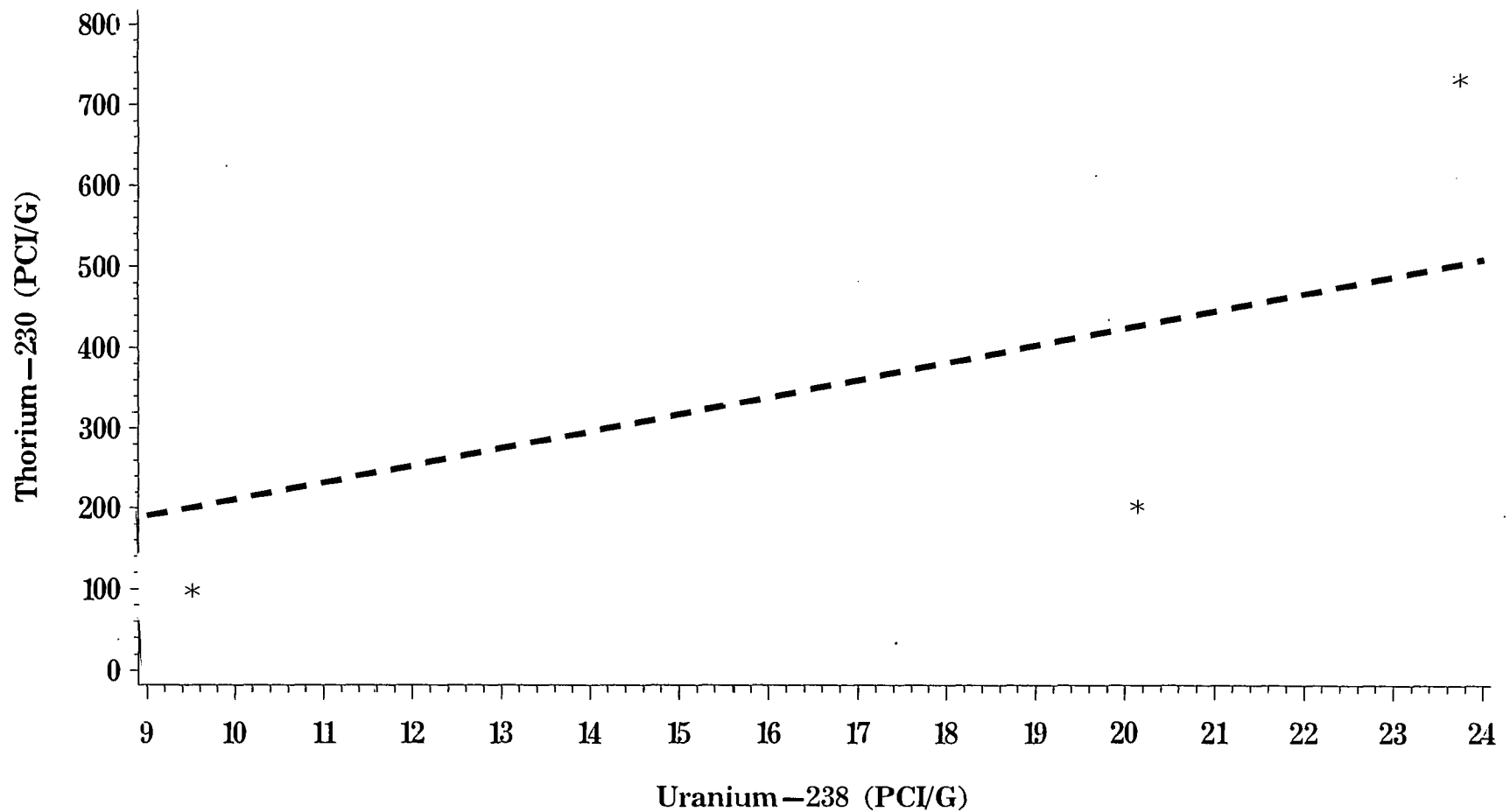
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= IA-4



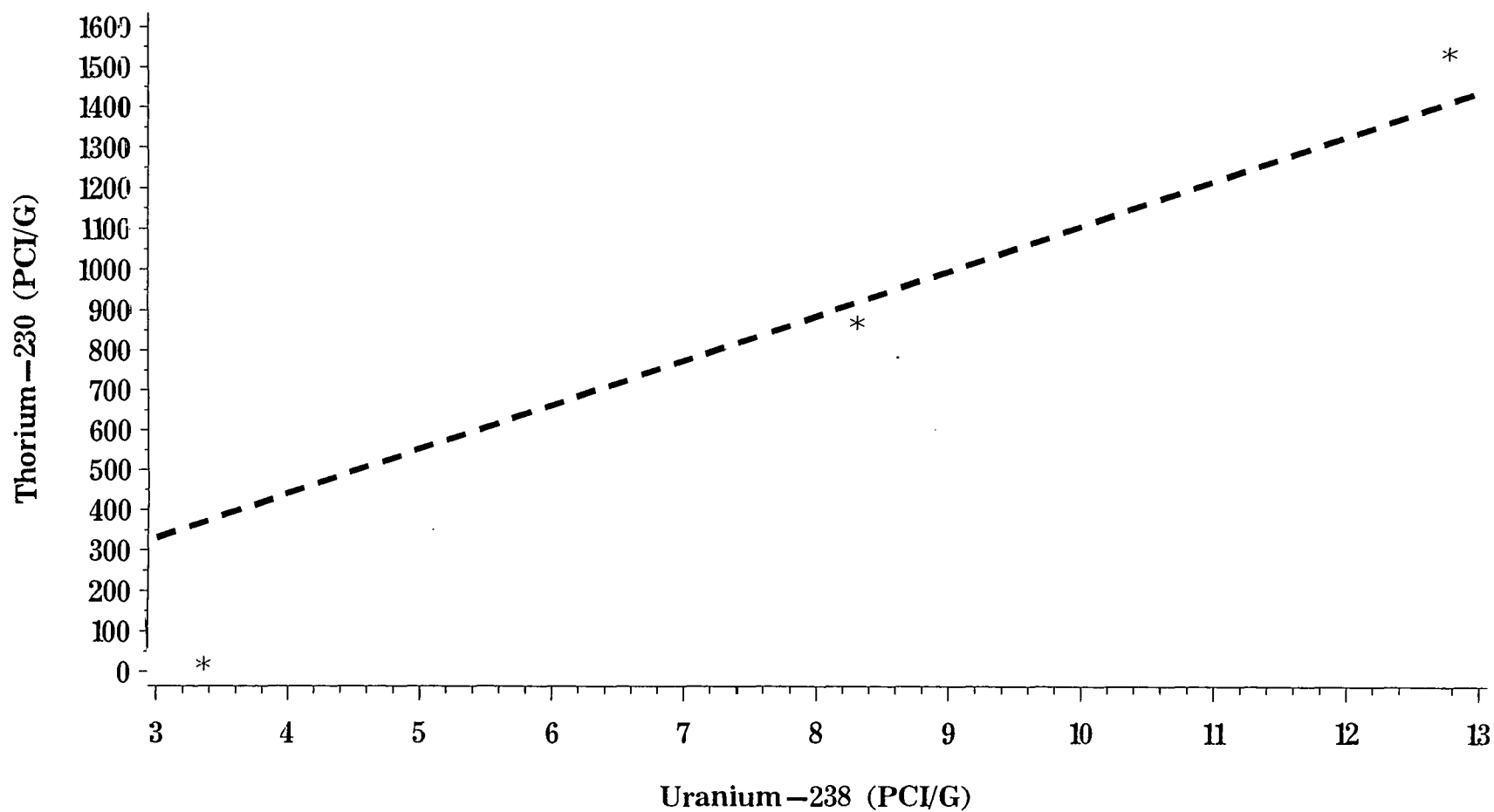
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= IA-5



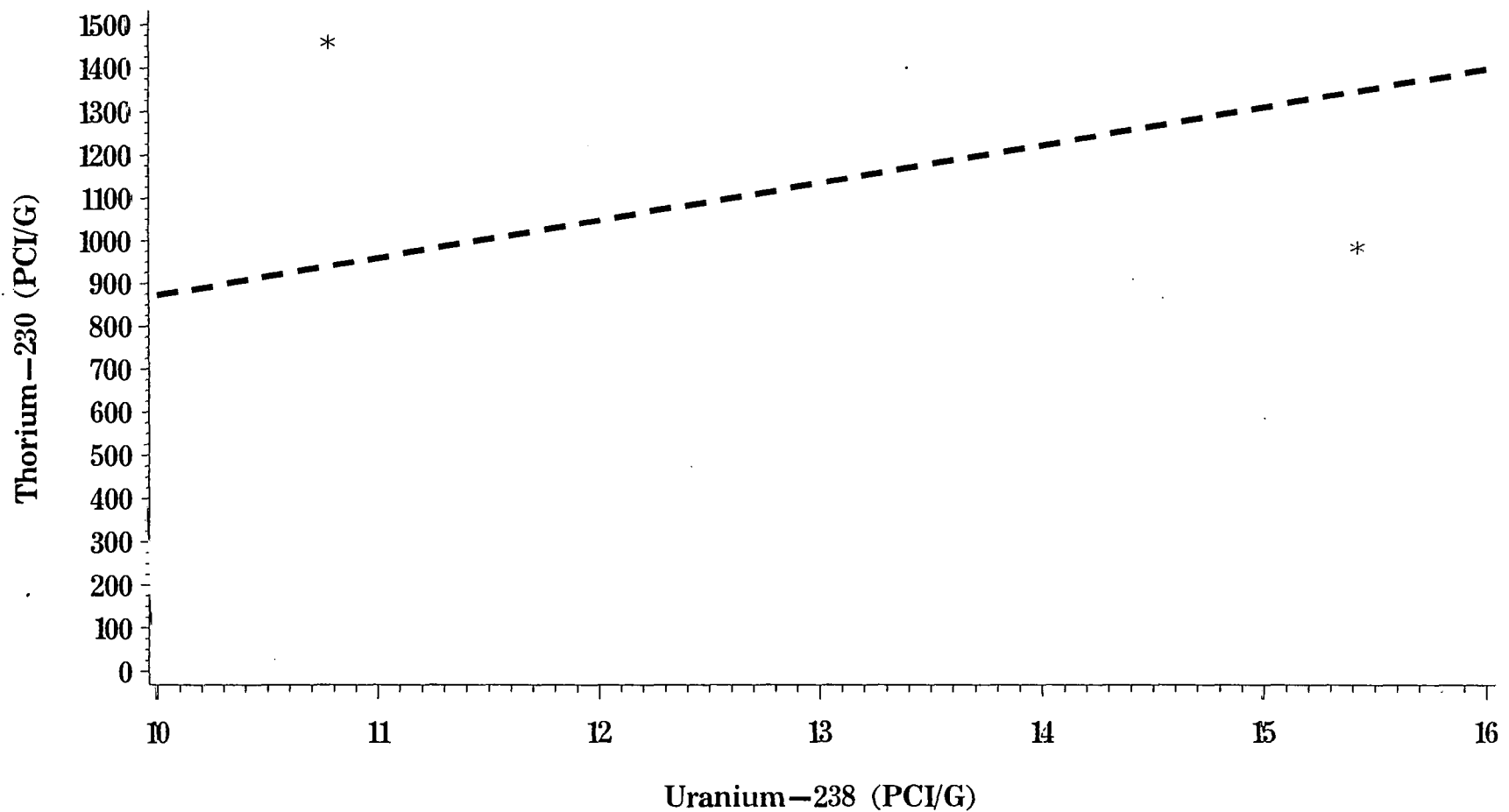
1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= IA-6



1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= 1A-8



1998 SLAPS Soil Characterization Data
Th-230 > 15 and < 2000 pCi/g with 3 Outliers Removed
Background Subtracted—Zero Intercept
Area= IA-9



FUSRAP Document Management System

Year ID
00 3603

Further Info?
☐

Operating Unit
St. Louis Sites

Site
SLAPS

Area

MARKS Number
FN:1110-1-8100g

Primary Document Type
Site Management

Secondary Document Type
Sampling/Analysis Data & Plans

Subject or Title

Correlations of Isotopes in Soil Samples from the SLAPS 1998 Characterization

Author/Originator
Jim Moos

Company
SAIC

Date
4/15/1999

Recipient(s)
Distribution

Company (-ies)
FUSRAP

Version
Final

Original's Location
Central Files

Document Format
paper

Confidential File?
☐

Comments

Include in which AR(s)?

- ☒ North County
☐ Madison
☐ Downtown
☐ Iowa

ETL
1.12

SAIC number

Filed in Volume
1

Bechtel ID

