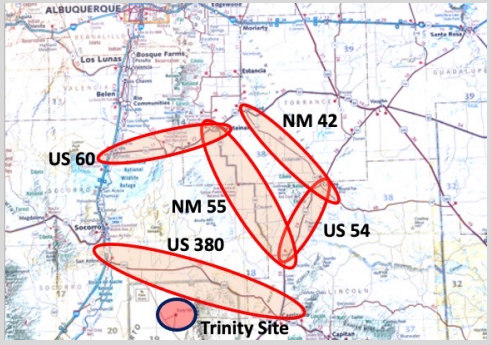
Does New Mexico deserve Downwinder Status:

Definitely yes, as evident *via* plutonium isotopes in 2023 soil samples

Introduction/objective: to investigate whether plutonium from the July 16, 1945 Trinity Test can be identified in contemporary soils and dusts near the Trinity Site. A proof-of concept study was conducted *via* a small-scale July 2023 collection of soil samples along five public highways transecting the areas reported to be most affected (refer to $^{239+240}$Pu deposition inventory map from Beck *et al*., 2020). More-distant soil samples were obtained from the Carson National Forest near Truchas, New Mexico.

Study method: surface soils (0-10 cm) were collected from the canopies below large conifers having stationary, well-developed soil horizons. Transects were completed along NM 42, US 54, NM 55, US 60, and US 380. Samples were analyzed by mass spectrometry for $^{239+240}$Pu activities to determine quantities present, and for ^{240}Pu/^{239}Pu atom ratios to determine origins of the contained plutonium. ***Ubiquitous "stratospheric fallout" Pu exhibits a ^{240}Pu/^{239}Pu of 0.18; Trinity Test Pu has a ratio of 0.02. Intermediate ratios signify mixing.***

Findings: All five highway transects clearly exhibit Pu that is distinguishable from stratospheric fallout; the Trinity site accounts for > 50% of the Pu atoms at multiple close-in locations along the NM42, NM 55 and US 380 transects. ***The presence of Trinity Pu at specific locations indicates past deposition/exposure at those locations.*** "Plutonium fingerprinting" provides critical "ground truthing" of models that reconstruct the geospatial distribution of Trinity fallout. The results confirm that New Mexico soils show mixing of Trinity fallout Pu, stratospheric fallout Pu, and minor contributions of regional/tropospheric fallout Pu from the Nevada Test Site.



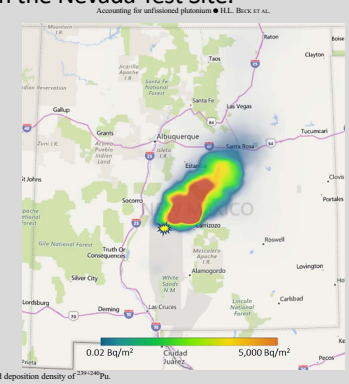
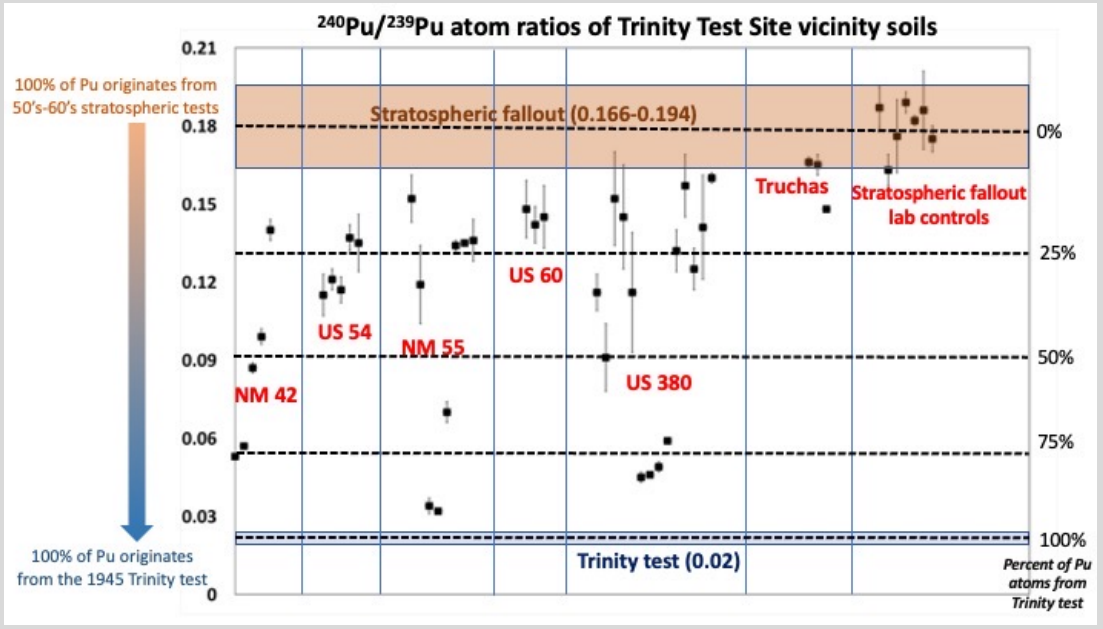
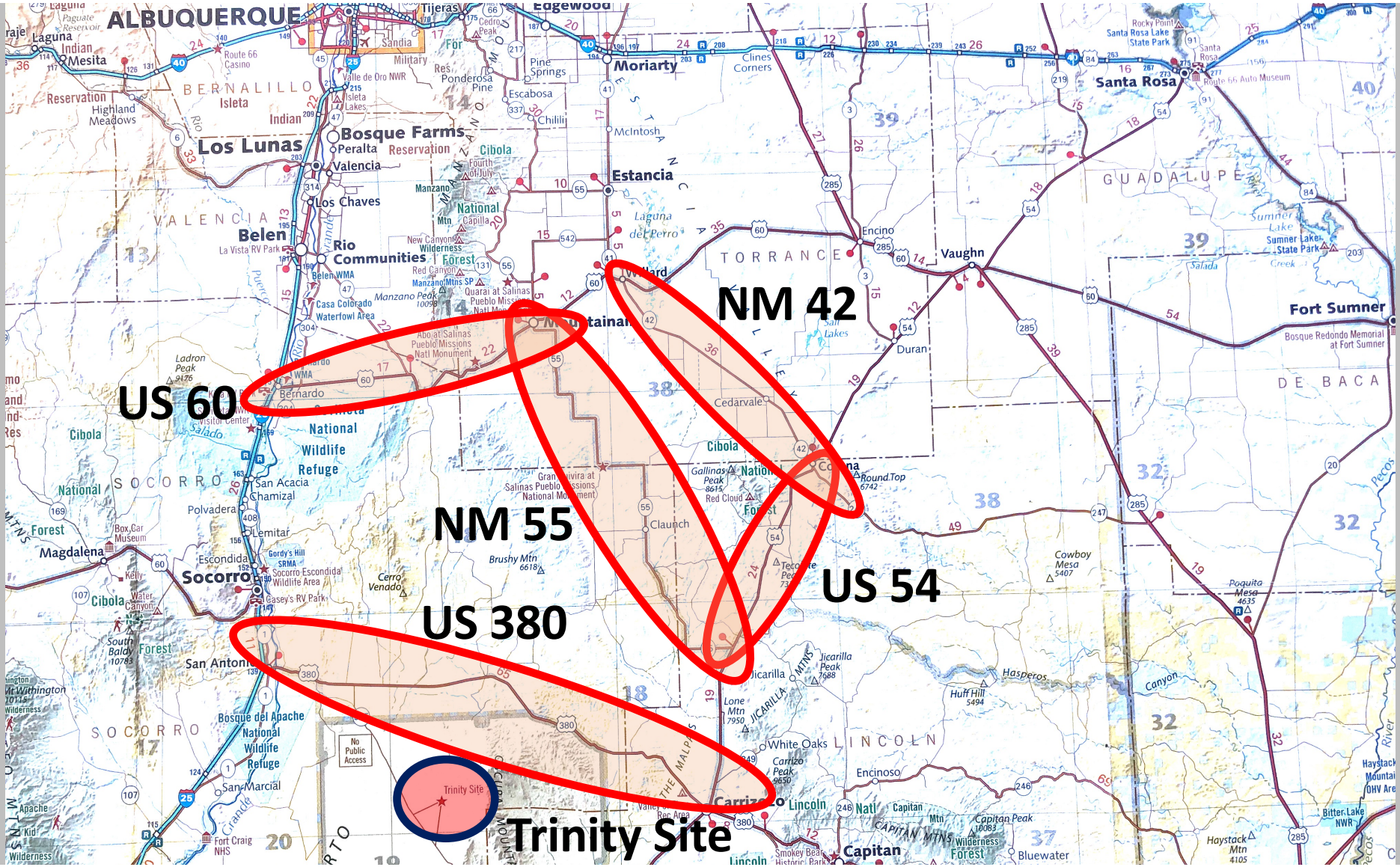


Fig. 6. Calculated deposition density of $^{239+240}$Pu.

NORTHERN ARIZONA UNIVERSITY

Michael E. Ketterer, Professor Emeritus, Department of Chemistry and Biochemistry
Northern Arizona University , Flagstaff AZ 86011-5698 USA
+1 (928) 853 7188 Michael.Ketterer@nau.edu **or** Michael.e.Ketterer@gmail.com




US 60
NM 42
NM 55
US 54
US 380
Trinity Site
ALBUQUERQUE
Los Lunas
Bosque Farms
Belen
Rio Communities
Socorro
Magdalena
San Antonio
Estancia
Moriarty
Santa Rosa
Encino
Vaughn
Fort Sumner
Duran
Cedarvale
Claunch
Carrizozo
Lincoln
White Oaks
Capitan
Bosque del Apache National Wildlife Refuge
San Acacia National Wildlife Refuge
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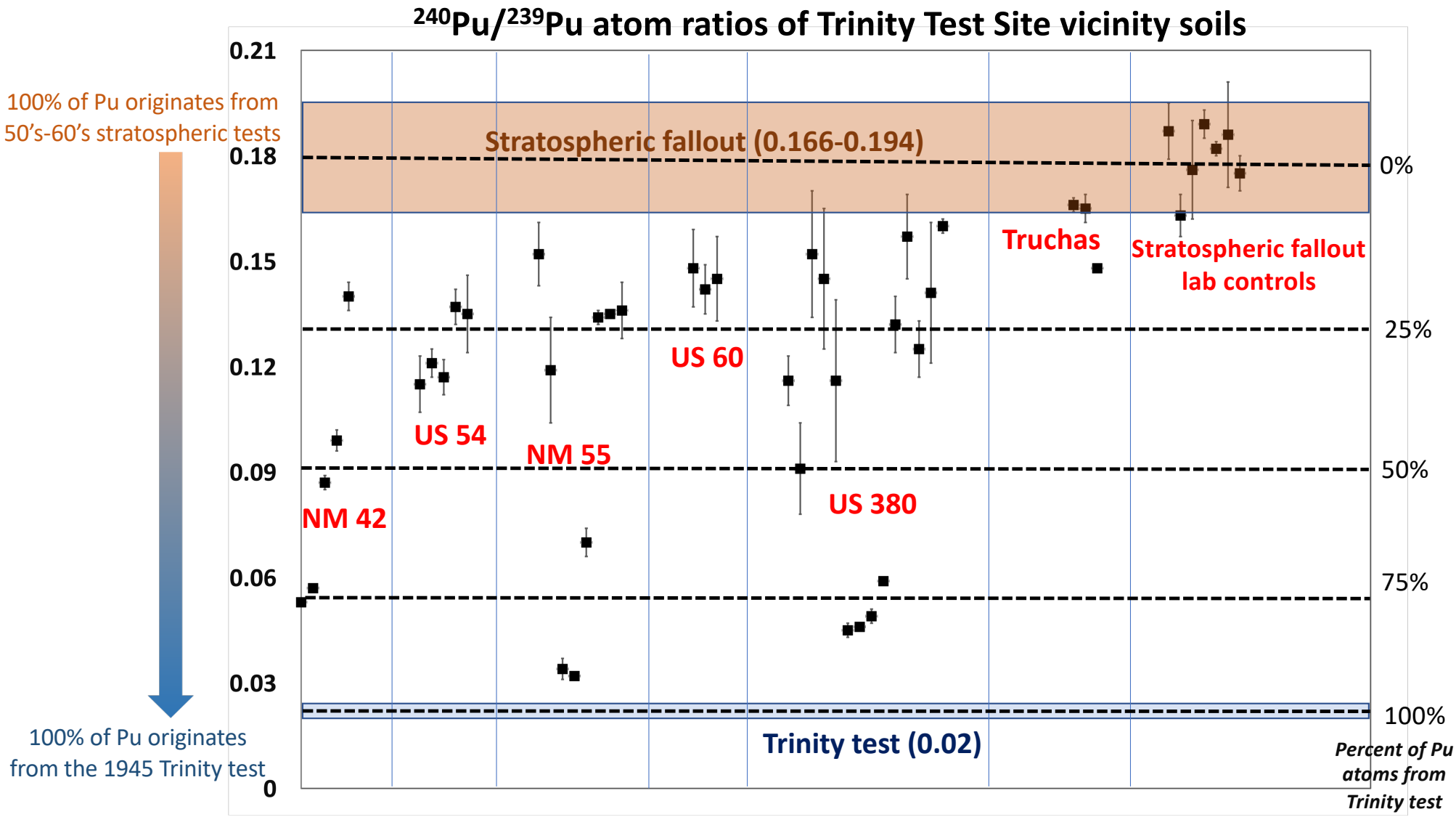
$^{240}Pu/^{239}Pu$ atom ratios of Trinity Test Site vicinity soils
100% of Pu originates from 50's-60's stratospheric tests
100% of Pu originates from the 1945 Trinity test
0.21
0.18
0.15
0.12
0.09
0.06
0.03
0
Stratospheric fallout (0.166-0.194)
Trinity test (0.02)
NM 42
US 54
NM 55
US 60
US 380
Truchas
Stratospheric fallout lab controls
0%
25%
50%
75%
100%
Percent of Pu atoms from Trinity test

Accounting for Unfissioned Plutonium from the Trinity Atomic Bomb Test

Harold L. Beck,[1] Steven L. Simon,[2] André Bouville,[3] and Anna Romanyukha[4]

Abstract—**The Trinity test device contained about 6 kg of plutonium as its fission source, resulting in a fission yield of 21 kT. However, only about 15% of the ^{239}Pu actually underwent fission. The remaining unfissioned plutonium eventually was vaporized in the fireball and after cooling, was deposited downwind from the test site along with the various fission and activation products produced in the explosion. Using data from radiochemical analyses of soil samples collected postshot (most many years later), supplemented by model estimates of plutonium deposition density estimated from reported exposure rates at 12 h postshot, we have estimated the total activity and geographical distribution of the deposition density of this unfissioned plutonium in New Mexico. A majority (about 80%) of the unfissioned plutonium was deposited within the state of New Mexico, most in a relatively small area about 30–100 km downwind (the Chupadera Mesa area). For most of the state, the deposition density was a small fraction of the subsequent deposition density of $^{239+240}$Pu from Nevada Test Site tests (1951–1958) and later from global fallout from the large US and Russian thermonuclear tests (1952–1962). The fraction of the total unfissioned ^{239}Pu that was deposited in New Mexico from Trinity was greater than the fraction of fission products deposited. Due to plutonium being highly refractory, a greater fraction of the ^{239}Pu was incorporated into large particles that fell out closer to the test site as opposed to more volatile fission products (such as ^{137}Cs and ^{131}I) that tend to deposit on the surface of smaller particles that travel farther before depositing. The plutonium deposited as a result of the Trinity test was unlikely to have resulted in significant health risks to the downwind population.**

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Key words: ^{239}Pu; fallout; nuclear weapons; plutonium

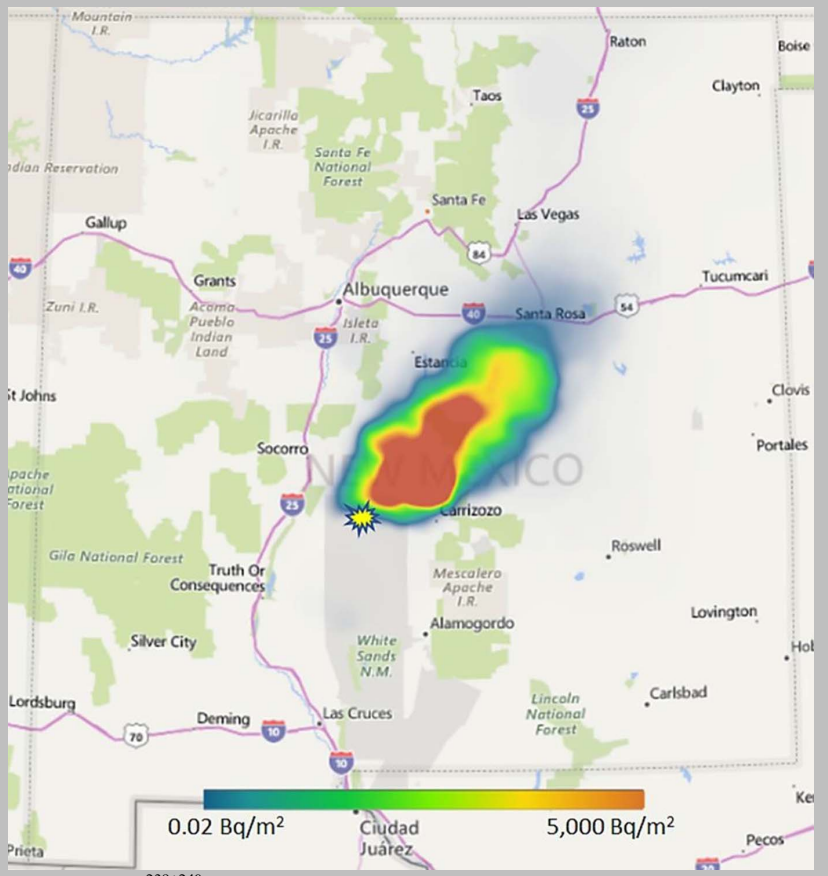

Fig. 6. Calculated deposition density of $^{239+240}$Pu.

Lab ID	Field ID	Location	Bq/kg	Bqkg sd	240/239	240239 sd
1	NM-9	Truchas	1.03	0.01	0.166	0.002
2	NM-19	Truchas	2.52	0.02	0.165	0.004
3	NM-24	Truchas	3.64	0.01	0.148	0.001
12	NM-49	State Highway 42	0.173	0.002	0.053	0.001
13	NM-50	State Highway 42	0.561	0.005	0.057	0.001
14	NM-57	State Highway 42	0.877	0.007	0.087	0.002
15	NM-60	State Highway 42	1.69	0.02	0.099	0.003
16	NM-61	State Highway 42	0.338	0.006	0.140	0.004
17	NM-64	US Highway 54	0.112	0.003	0.115	0.008
18	NM-69	US Highway 54	0.82	0.01	0.121	0.004
44	NM-69 dup	US Highway 54	0.80	0.01	0.117	0.005
19	NM-71	US Highway 54	0.103	0.003	0.137	0.005
20	NM-73	US Highway 54	0.31	0.01	0.135	0.011
21	NM-77	State Highway 55	0.48	0.01	0.152	0.009
22	NM-79	State Highway 55	0.127	0.005	0.119	0.015
23	NM-82	State Highway 55	1.10	0.01	0.034	0.003
45	NM-82 dup	State Highway 55	1.06	0.01	0.032	0.001
24	NM-83	State Highway 55	0.30	0.01	0.070	0.004
25	NM-84	State Highway 55	0.132	0.006	0.134	0.002
26	NM-85	State Highway 55	0.30	0.01	0.135	0.001
27	NM-86	State Highway 55	0.205	0.002	0.136	0.008
28	NM-87	US Highway 60	0.109	0.004	0.148	0.011
29	NM-88A	US Highway 60	0.46	0.01	0.142	0.007
30	NM-88B	US Highway 60	0.33	0.01	0.145	0.012
31	NM-90	US Highway 380	0.026	0.003	0.116	0.007
32	NM-92	US Highway 380	0.026	0.002	0.091	0.013
33	NM-93	US Highway 380	0.096	0.004	0.152	0.018
34	NM-94	US Highway 380	0.113	0.002	0.145	0.020
35	NM-95	US Highway 380	0.026	0.002	0.116	0.023
36	NM-96	US Highway 380	0.71	0.01	0.045	0.002
46	NM-96 dup	US Highway 380	0.68	0.01	0.046	0.001
37	NM-98	US Highway 380	0.74	0.01	0.049	0.002
38	NM-100	US Highway 380	1.07	0.01	0.059	0.001
39	NM-101	US Highway 380	0.083	0.002	0.132	0.008
40	NM-102	US Highway 380	0.63	0.01	0.157	0.012
41	NM-103	US Highway 380	0.074	0.004	0.125	0.008
47	NM-103 dup	US Highway 380	0.078	0.001	0.141	0.020
42	NM-104	US Highway 380	0.73	0.01	0.160	0.002
51	Urseren	Switzerland fallout	0.99	0.01	0.187	0.008
Fl9	Urseren	Switzerland fallout	1.08	0.03	0.163	0.006
Fl10	Urseren	Switzerland fallout	0.98	0.03	0.176	0.014
54	IAEA-447	Russia fallout	5.15	0.03	0.189	0.004
55	IAEA-447	Russia fallout	5.05	0.06	0.182	0.002
Fl11	IAEA-447	Russia Fallout	5.20	0.08	0.186	0.015
60	WashComp	Cascades, Washington	2.44	0.05	0.175	0.005
53	GM-23	Grand Mesa, Colorado	7.7	0.2	0.143	0.010
Fl12	GM-23	Grand Mesa, Colorado	7.3	0.1	0.140	0.009
56	NV-9	Nevada	2.1	0.1	0.059	0.009
57	RF-26	Rocky Flats	458	4	0.049	0.002
59	Wojtek 224	Poland fallout	10.9	0.1	0.206	0.004

Experimental summary. Soil samples were obtained using a hand trowel from the top 10 cm of stationary accumulation beneath large vegetation (e.g., juniper trees). Material was dried and sieved to obtain a < 0.2 mm fraction of soil. Nominal 25 g soil aliquots were dry-ashed at 450° C to remove all organic matter, then leached overnight at 75° C with 70 mL of 8 M aqueous nitric acid. ***Note:*** this acid leaching procedure does not recover all "refractory", silica-bound Pu and likely, significantly under-recovers Trinity-derived Pu. Accordingly, the results likely understate the magnitude of the Trinity effect. Pu was separated using TEVA resin, and quadrupole ICPMS with a high-efficiency de-solvating nebulizer system was used to analyze $^{239+240}$Pu activity vs. an added ^{242}Pu tracer; ^{240}Pu/^{239}Pu atom ratios were also measured in the samples. The experimental procedures follow those reviewed in Ketterer and Szechenyi (2008).

Controls were analyzed in the same batch to validate the $^{239+240}$Pu and ^{240}Pu/^{239}Pu results in the unknown New Mexico samples. Laboratory controls known to contain "stratospheric fallout" Pu from Switzerland, IAEA-447, and the Cascades (Washington, USA) gave results in good agreement with the northern Hemisphere mid-latitude stratospheric fallout ^{240}Pu/^{239}Pu of 0.180 ± 0.014 (Kelley *et al.*, 1999). The $^{239+240}$Pu activities found in IAEA-447 (Moss Soil, Russia) agree well with the certified range of 5.3 ± 0.2 Bq/kg, albeit note that the $^{239+240}$Pu in IAEA-447 originates from stratospheric fallout and is recoverable using acid leaching. Samples from the Grand Mesa Plateau, Colorado, near Rocky Flats in Colorado, and near the Nevada Test Site exhibit, as expected, "weapons-grade" ^{240}Pu/^{239}Pu ratios.

Future work. Further work will extend the geographic coverage of existing samples into areas west, south and east of the Trinity site as well as, will investigate a large number of more-distant locations within New Mexico to better understand the relative contributions of Trinity vs. global (stratospheric) fallout vs. NTS regional fallout to the plutonium inventories in New Mexico soils. The Trinity Pu deposition contains much refractory Pu not amenable to dissolution with 8 M HNO_3 as was used in preliminary work. Future work will utilize various molten salt fusions for quantitative dissolution of ~ 5 gram soil sub-samples.

Additional studies are needed to characterize the anticipated micron-size Pu-rich particles likely present in surface soils, and amenable to facile airborne dispersion. Much sampling/analytical work is needed to understand the characteristics of soil Pu near the Trinity Site, in its present forms found in New Mexican soils nearly eight decades after the 16 July 1945 test.

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