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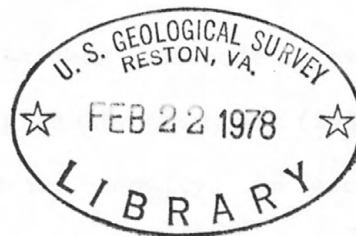
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by

James W. Schmoker and Bruce A. Kososki

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This report is preliminary and has not been  
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Geological Survey standards and nomenclature.

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Principal facts for borehole gravity stations in  
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In August of 1976, borehole gravity surveys were conducted by the U.S. Geological Survey at the Nevada Test Site in the Ue10j, Ue7ns, and Ue5n test wells. The work was done in cooperation with the Lawrence Livermore Laboratory. The U.S. Geological Survey-LaCoste and Romberg<sup>1/</sup> borehole gravity meter was used in the logging program (McCulloh and others, 1967a; McCulloh and others, 1967b). The primary objective of this work was to obtain data for the determination of in situ formation densities utilizing an instrument not significantly affected by casing, borehole rugosity, or other near-borehole conditions. A secondary objective was to obtain duplicate data, by reoccupying subsurface stations, so that the precision and repeatability of borehole gravity data could be studied.

A detailed discussion of the relationship between borehole gravity measurements and mass distributions in the earth is given by McCulloh (1966). In the absence of complicating factors, the formation density, in g/cm<sup>3</sup>, between two points in a borehole is given by:

$$\rho = 39.185 (F - \Delta g / \Delta z) \quad (1)$$

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<sup>1/</sup> Use of brand names in this report is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

where  $\Delta g/\Delta z$  is the measured gradient of gravity between the two points in mgal/ft, and F is the free-air gradient of gravity, also expressed in mgal/ft.

Caution should be exercised in utilizing equation (1) to compute densities from the borehole gravity data presented in this report. Tower measurements indicate that the free-air gradient at the Nevada Test Site is often lower than the so-called "normal" value of 0.09406 mgal/ft. In addition, the Tertiary volcanic rocks and/or dense Paleozoic rocks underlying the alluvial fill may be steeply dipping, whereas equation 1 is derived from the assumption of horizontal contacts.

Tables 1, 2, and 3 record the data associated with each subsurface gravity station in the three wells. Well coordinates are based on the Nevada State Grid (Central Zone). The column headings are explained in the following list:

Station number:	A numbering of borehole gravity stations in the order recorded.
Depth:	Depth of stations in feet and (meters). Datum is ground level.
Time:	Greenwich mean time of each gravity reading, which is seven hours ahead of local P.D.T. at the Test Site.
Uncorrected gravity:	Observed gravity in milligals, referenced to an arbitrary base, uncorrected for tide, terrain, and drift effects.
Tide correction:	Theoretical correction for earth tides in milligals.
Terrain correction:	Terrain correction in milligals calculated

for a density of  $2.67 \text{ g/cm}^3$  out to a distance of 71,996 ft (21,944 m), which corresponds to zone M of Hammer's terrain correction system (Hammer, 1939).

Drift correction: A correction for linear instrument drift, derived from station reoccupations.

Corrected gravity: Observed gravity in milligals, referenced to an arbitrary base, corrected for tide, terrain, and drift effects.

Uel0j is located near the northern edge of Yucca Flat (figure 1). It was drilled to a total depth of 2,380 ft (725 m), with casing temporarily set to about 1,600 ft (488 m). The water table was at 2,080 ft (634 m), thus formations logged with the borehole gravity meter were not water saturated. The logged interval comprises 195 ft (59 m) of alluvium, 830 ft (253 m) of Tertiary welded tuffs, and 555 ft (169 m) of dolomite believed to be the Smoky member of the Cambrian Nopah formation. Figure 2, the gamma-ray log of the Uel0j well, shows the contacts of these rock units.

Borehole gravity stations were chosen so that the density contrast across the tuff-dolomite contact and the density of the underlying dolomite could be determined. The well intersects the Paleozoic surface on the western flank of a structural nose that dips about 5 degrees south. The dip of the contact to the west is approximately 33 degrees (D. L. Healey, oral commun., 1978). Tower measurements, made by the Lawrence Livermore Laboratory at each of the three sites, indicate a free-air gradient of  $0.0912 \text{ mgal/ft}$  at the Uel0j location, which would lower densities derived from borehole gravity data approximately  $0.11 \text{ g/cm}^3$  compared to a similar calculation using the assumed

"normal" free-air gradient of 0.09406 mgal/ft.

Ue7ns is located near the eastern edge of Yucca Flat (figure 1). It was drilled to a total depth of 2,205 ft (672 m) and cased. The water table was at 1,970 ft (600 m). The logged interval consists of 260 ft (79 m) of alluvium, 1,390 ft (424 m) of Tertiary welded tuffs, and 522 ft (159 m) of silty and shaly limestone of the Ordovician Pogonip limestone. Figure 3, the gamma-ray log of the Ue7ns well, shows the contacts of these rock units.

Borehole gravity stations were chosen so that the density contrast between the tuff and the limestone, and the limestone density, could be determined. The tuff-limestone contact dips west-southwest at approximately 17 degrees (D. L. Healey, oral commun., 1978). The measured free-air gradient at the site is 0.0922 mgal/ft.

Ue5n is located on Frenchman Flat (figure 1). It was drilled to a total depth of 1,687 ft (514 m) and cased. The water table was at 702 ft (214 m). The well penetrates friable Quaternary alluvium which partially fills the graben responsible for the Frenchman Flat topographic feature. Tuffaceous sediments comprise the bulk of the alluvium. Paleozoic rocks are thought to lie a minimum of several thousand feet below the deepest borehole gravity station. No gamma-ray or SP logs are available for the Ue5n well.

Borehole gravity stations were chosen at intervals of approximately 50 ft (15 m), with some adjustments based on the driller's log, so that the in situ density of the graben fill could be determined. The rugosity of the borehole made the conventional density log unreliable. The measured free-air gradient at the Ue5n well site is 0.0905 mgal/ft.

## REFERENCES

- Hammer, Sigmund, 1939, Terrain corrections for gravimeter stations: Geophysics, v.4, no.3, p. 184-193.
- McCulloh, T. H., 1966, The promise of precise borehole gravimetry in petroleum exploration and exploitation: U.S. Geol. Survey Circ. 531, 12 p.
- McCulloh, T. H., LaCoste, L. J. B., Schoellhamer, J. E., and Pampeyan, E. H., 1967a, The U.S. Geological Survey-LaCoste and Romberg precise borehole gravimeter system--Instrumentation and support equipment, in Geological Survey research 1967: U.S. Geol. Survey Prof. Paper 575-D, p. D92-D100.
- McCulloh, T. H., Schoellhamer, J. E., Pampeyan, E. H., and Parks, H. B., 1967b, The U.S. Geological Survey-LaCoste and Romberg precise borehole gravimeter system--Test results, in Geological Survey research 1967: U.S. Geol. Survey Prof. Paper 575-D, p. D101-D112.

Table 1.

Test well Uel0j, Nevada Test Site, Nye County, Nevada. Logged August 7-8, 1976.

Well coordinates N-887,003 E-670,453. Ground level datum; elevation 4573.4 ft (1393.97 m).

Station number	Depth ft	Depth m	Time	Uncorrected gravity	Tide correction	Terrain correction	Drift correction	Corrected gravity
1	651.8	198.67	1630	127.037	0.104	2.918	- 0.100	129.959
2	651.8	198.67	1648	127.011	0.115	2.918	- 0.096	129.948
3	651.8	198.67	1703	126.989	0.124	2.918	- 0.093	129.938
4	651.8	198.67	1724	126.980	0.134	2.918	- 0.088	129.944
5	651.8	198.67	1825	126.937	0.147	2.918	- 0.075	129.927
6	746.0	227.38	1841	131.232	0.147	3.106	- 0.070	134.415
7	840.3	256.12	1856	135.419	0.145	3.288	- 0.064	138.788
8	901.0	274.62	1932	138.066	0.134	3.401	- 0.054	141.547
9	960.0	292.61	1945	140.671	0.128	3.508	- 0.049	144.258
10	1024.0	312.12	1959	143.296	0.121	3.622	- 0.044	146.995
11	1050.0	320.04	2020	143.929	0.108	3.667	- 0.038	147.666
12	1100.0	335.28	2030	145.071	0.102	3.753	- 0.030	148.896
13	1150.0	350.52	2038	146.243	0.096	3.838	- 0.027	150.150
14	1208.2	368.26	2049	147.568	0.088	3.934	- 0.023	151.567
15	1256.1	382.86	2059	148.644	0.080	4.011	- 0.019	152.716
16	1323.0	403.25	2109	150.131	0.071	4.117	- 0.016	154.303
17	1357.1	413.64	2120	150.893	0.062	4.171	- 0.012	155.114
18	1402.1	427.36	2129	151.912	0.054	4.240	- 0.010	156.196
19	1450.0	441.96	2138	152.976	0.047	4.312	- 0.007	157.328
20	1500.0	457.20	2147	154.124	0.039	4.387	- 0.005	158.545
21	1540.2	469.45	2158	155.015	0.029	4.446	- 0.003	159.487
22	1580.0	481.58	2206	155.910	0.022	4.503	- 0.001	160.434
23	1580.0	481.58	2215	155.915	0.014	4.503	0.002	160.434
24	1540.2	469.45	2226	155.033	0.004	4.446	0.003	159.466
25	1500.0	457.20	2235	154.152	- 0.004	4.387	0.005	158.540
26	1450.0	441.96	2247	153.023	- 0.013	4.312	0.007	157.329
27	1402.1	427.36	2257	151.976	- 0.022	4.240	0.010	156.204
28	1357.1	413.64	2305	150.969	- 0.028	4.171	0.012	155.124
29	1323.0	403.25	2319	150.217	- 0.038	4.117	0.016	154.312
30	1256.1	382.86	2329	148.728	- 0.045	4.011	0.019	152.713
31	1208.2	368.26	2338	147.663	- 0.051	3.934	0.022	151.568
32	1150.0	350.52	2350	146.348	- 0.059	3.838	0.026	150.153
33	1100.0	335.28	2359	145.178	- 0.064	3.753	0.030	148.897
34	1050.0	320.04	0007	144.035	- 0.068	3.667	0.033	147.667
35	1024.0	312.12	0015	143.385	- 0.072	3.622	0.036	146.971
36	1050.0	320.04	0029	144.048	- 0.078	3.667	0.038	147.675
37	1024.0	312.12	0040	143.393	- 0.082	3.622	0.044	146.977
38	960.0	292.61	0049	140.795	- 0.084	3.508	0.049	144.268
39	901.0	274.62	0100	138.190	- 0.087	3.401	0.054	141.558
40	840.3	256.12	0112	135.513	- 0.089	3.288	0.064	138.776
41	746.0	227.38	0124	131.307	- 0.091	3.106	0.070	134.392
42	651.8	198.67	0133	127.022	- 0.091	2.918	0.075	129.924
43	0.5	0.15	0153	96.114	- 0.090	1.366	0.084	97.474



Table 2.

Test well Ue7ns, Nevada Test Site, Nye County, Nevada. Logged August 9, 1976.

Well coordinates N-855,600 E-693,700. Ground level datum; elevation 4367.7 ft (1331.27m).

Station number	Depth ft	Depth m	Time	Uncorrected gravity	Tide correction	Terrain correction	Drift correction	Corrected gravity
1	1270.0	387.10	1532	58.286	- .017	1.531		59.800
2	1370.1	417.61	1545	62.659	- .006	1.596		64.249
3	1470.1	448.09	1557	66.937	.004	1.659		68.600
4	1538.0	468.78	1607	69.279	.013	1.701		70.993
5	1572.0	479.15	1616	70.691	.021	1.722		72.434
6	1650.0	502.92	1628	73.485	.032	1.769		75.286
7	1696.0	516.94	1637	74.784	.040	1.797		76.621
8	1752.0	534.01	1650	76.226	.051	1.830	N	78.107
9	1800.1	548.67	1700	77.470	.060	1.858	E	79.388
10	1846.0	562.66	1709	78.639	.067	1.884	G	80.590
11	1900.0	579.12	1720	80.001	.076	1.915	L	81.992
12	1960.0	597.41	1731	81.546	.085	1.948	I	83.579
13	2007.0	611.73	1740	82.685	.091	1.974	G	84.750
14	2048.0	624.23	1751	83.729	.099	1.997	I	85.825
15	2101.9	640.66	1800	85.106	.105	2.026	B	87.237
16	2172.1	662.06	1815	86.892	.113	2.063	L	89.068
17	2172.1	662.06	1851	86.896	.129	2.063	E	89.088
18	2101.9	640.66	1904	85.084	.133	2.026		87.243
19	2101.9	640.66	1959	85.078	.136	2.026	D	87.240
20	2048.0	624.23	2009	83.698	.134	1.997	R	85.829
21	2007.0	611.73	2020	82.648	.132	1.974	I	84.754
22	1960.0	597.41	2028	81.500	.129	1.948	F	83.577
23	1900.0	579.12	2039	79.961	.125	1.915	T	82.001
24	1846.0	562.66	2047	78.587	.122	1.884		80.593
25	1800.1	548.67	2058	77.402	.116	1.858		79.376
26	1752.0	534.01	2108	76.157	.111	1.830		78.098
27	1696.0	516.94	2122	74.648	.102	1.797		76.547
28	1752.0	534.01	2137	76.194	.092	1.830		78.116
29	1696.0	516.94	2150	74.714	.082	1.797		76.593
30	1650.0	502.92	2205	73.426	.070	1.769		75.265
31	1572.0	479.15	2238	70.664	.042	1.722		72.428



Table 3.

Test well Ue5n, Nevada Test Site, Nye County, Nevada. Logged August 11, 1976.  
Well coordinates N-754,460 E-706,415. Ground level datum; elevation 3112.2 ft  
(948.60 m).

Station number	Depth ft m	Time	Uncorrected gravity	Tide correction	Terrain correction	Drift correction	Corrected gravity
1	65.7	20.03 1644	54.239	- .019	- 2.260		51.960
2	100.0	30.48 1702	55.685	- .006	- 2.200		53.479
3	150.0	45.72 1715	57.809	.003	- 2.113		55.699
4	200.0	60.96 1726	59.866	.012	- 2.027		57.851
5	250.0	76.20 1736	61.988	.020	- 1.942		60.066
6	300.2	91.50 1746	64.073	.028	- 1.858		62.243
7	349.8	106.62 1757	66.174	.036	- 1.776		64.434
8	400.0	121.92 1808	68.293	.044	- 1.694	N	66.643
9	450.0	137.16 1823	70.385	.055	- 1.613	E	68.827
10	500.1	152.43 1835	72.542	.063	- 1.533	G	71.072
11	550.0	167.64 1846	74.656	.070	- 1.453	L	73.273
12	600.0	182.88 1856	76.822	.076	- 1.374	I	75.524
13	655.0	199.64 1907	79.182	.082	- 1.287	G	77.977
14	700.0	213.36 1920	81.073	.088	- 1.217	I	79.944
15	750.0	228.60 1930	82.874	.093	- 1.139	B	81.828
16	800.2	243.90 1939	84.764	.096	- 1.061	L	83.799
17	850.0	259.08 1950	86.571	.100	- 0.984	E	85.687
18	900.0	274.32 2000	88.459	.102	- 0.907		87.654
19	940.0	286.51 2009	89.920	.104	- 0.845	D	89.179
20	1010.0	307.85 2024	92.494	.106	- 0.738	R	91.862
21	1050.0	320.04 2033	93.934	.107	- 0.677	I	93.364
22	1100.0	335.28 2043	95.775	.107	- 0.601	F	95.281
23	1150.0	350.52 2053	97.572	.106	- 0.525	T	97.153
24	1200.0	365.76 2103	99.378	.105	- 0.449		99.034
25	1250.0	381.00 2114	101.201	.103	- 0.373		100.931
26	1300.2	396.30 2124	102.973	.100	- 0.297		102.776
27	1350.0	411.48 2134	104.722	.097	- 0.222		104.597
28	1400.1	426.75 2145	106.470	.093	- 0.146		106.417
29	1450.0	441.96 2155	108.229	.089	- 0.071		108.247
30	1010.0	307.85 2232	92.557	.069	- 0.738		91.888
31	500.1	152.43 2302	72.534	.049	- 1.533		71.050
32	65.7	20.03 2338	54.175	.022	- 2.260		51.937

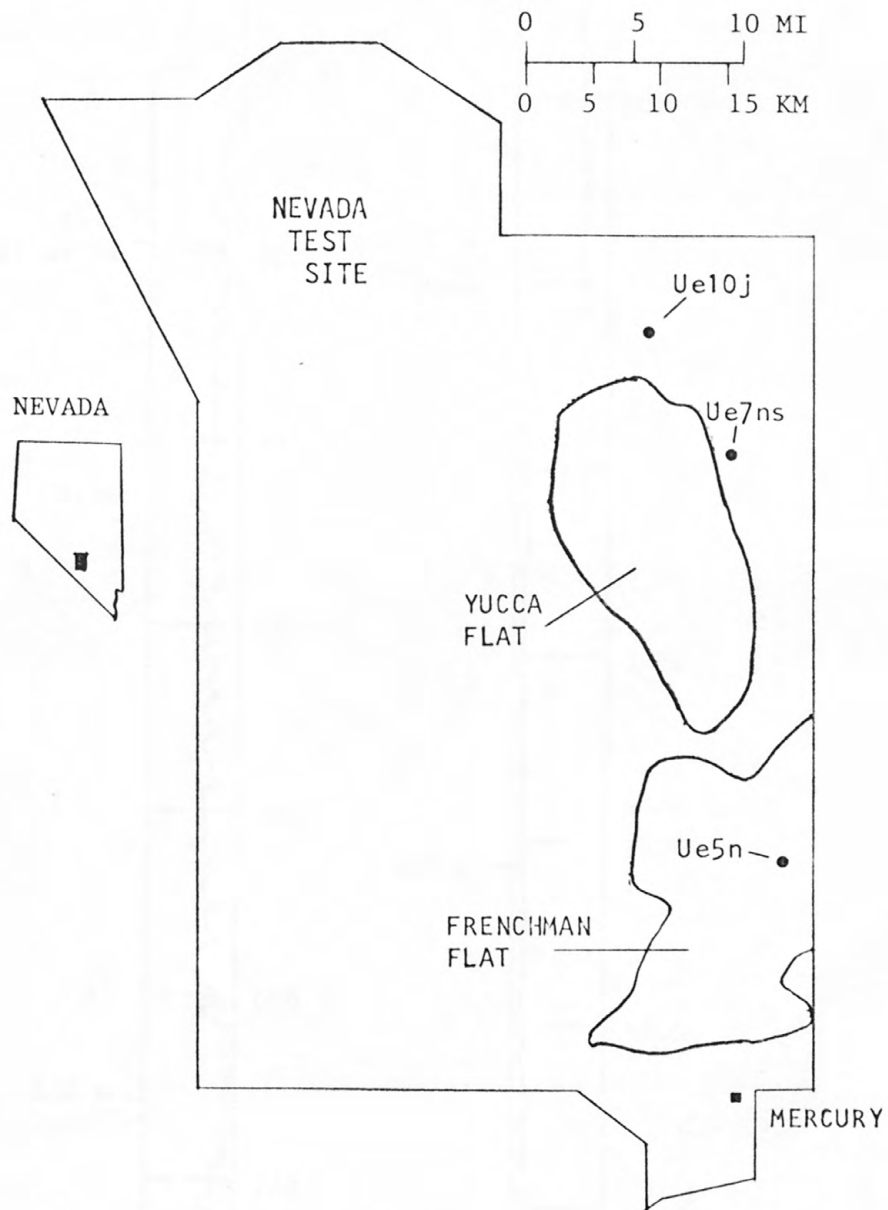


Figure 1. Index map of the Nevada Test Site, showing locations of borehole gravity surveys.

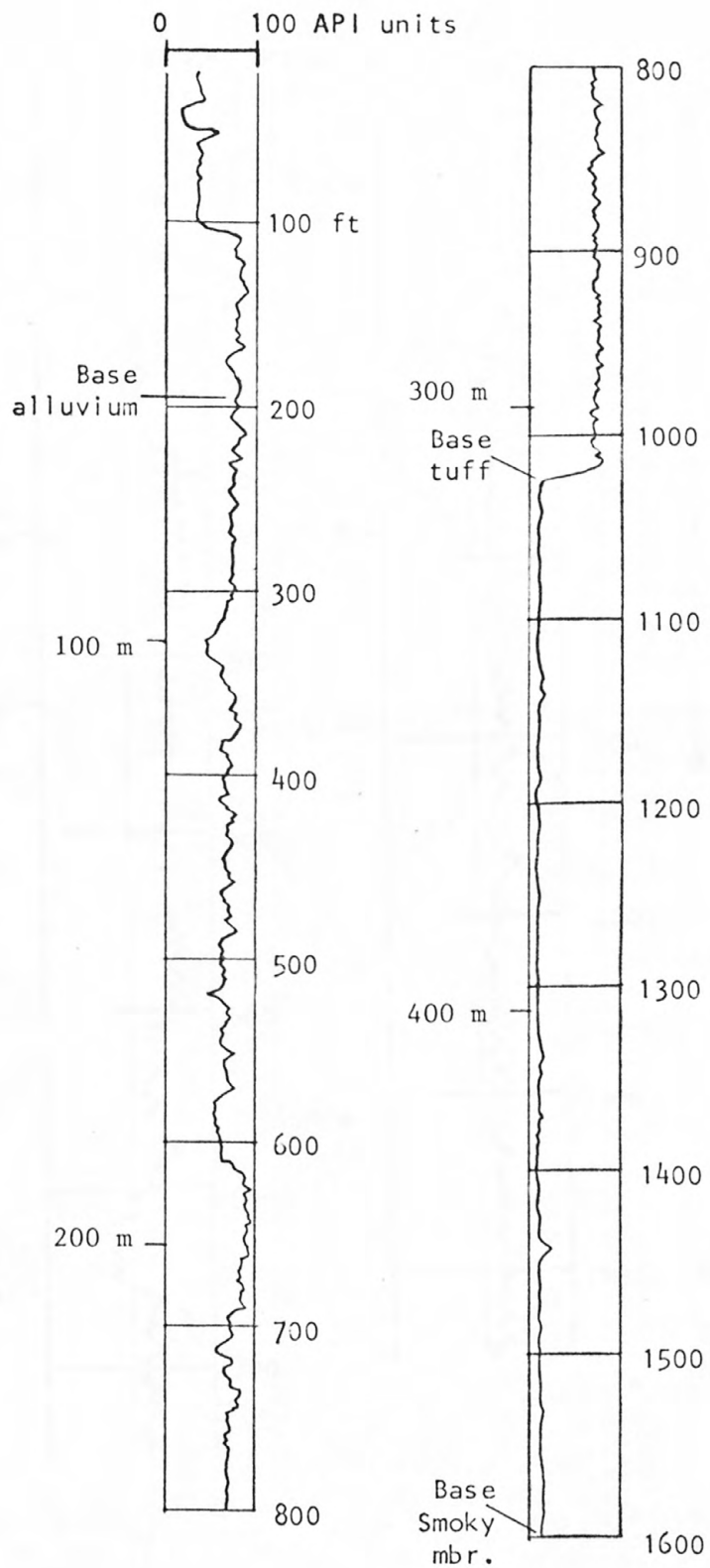


Figure 2. Gamma-ray log, Nevada Test Site Ue10j well.

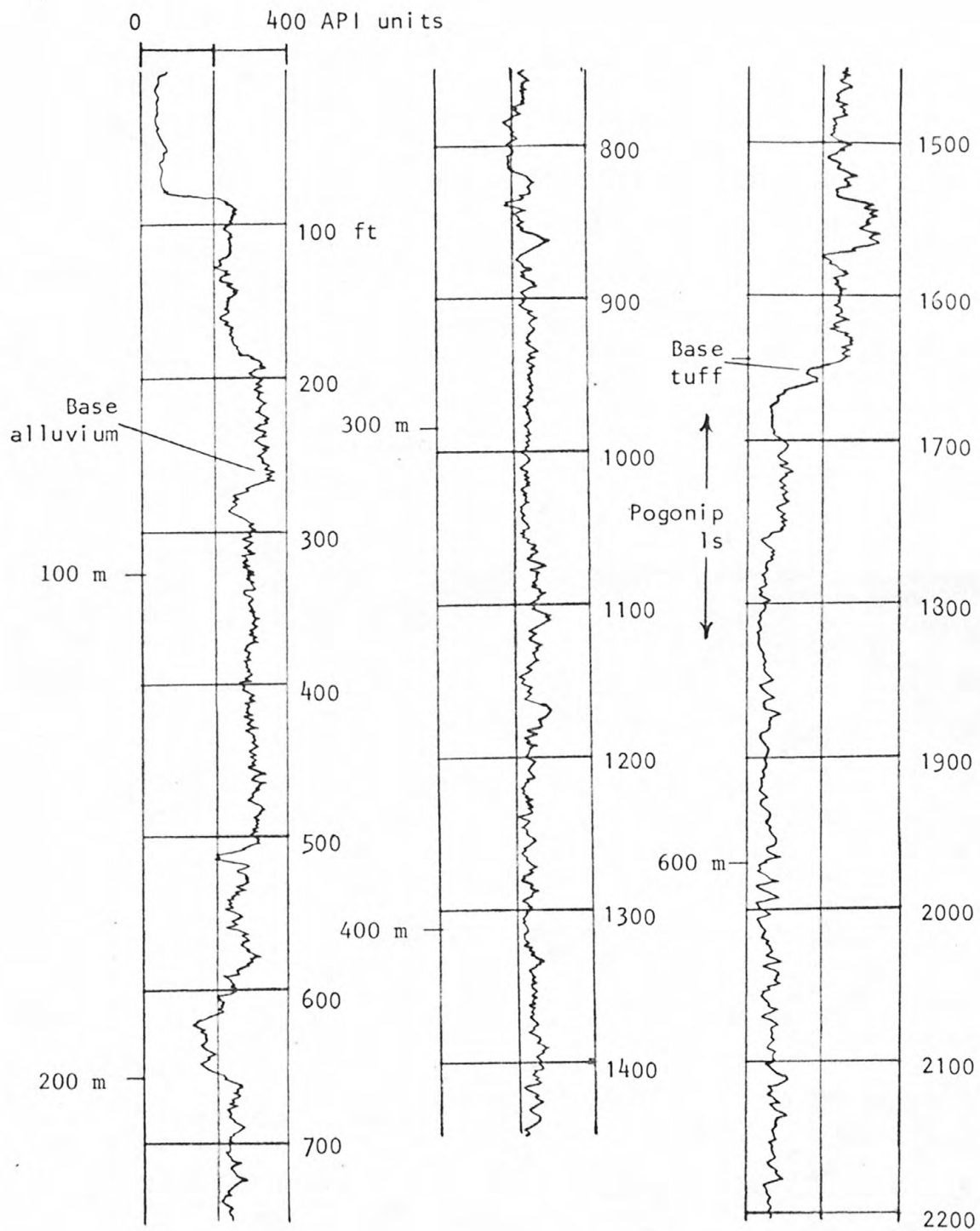


Figure 3. Gamma-ray log, Nevada Test Site Ue7ns well.

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