UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

BOREHOLE-GRAVITY SURVEYS IN BASIN-FILL DEPOSITS OF CENTRAL AND SOUTHERN ARIZONA

by

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INTRODUCTION

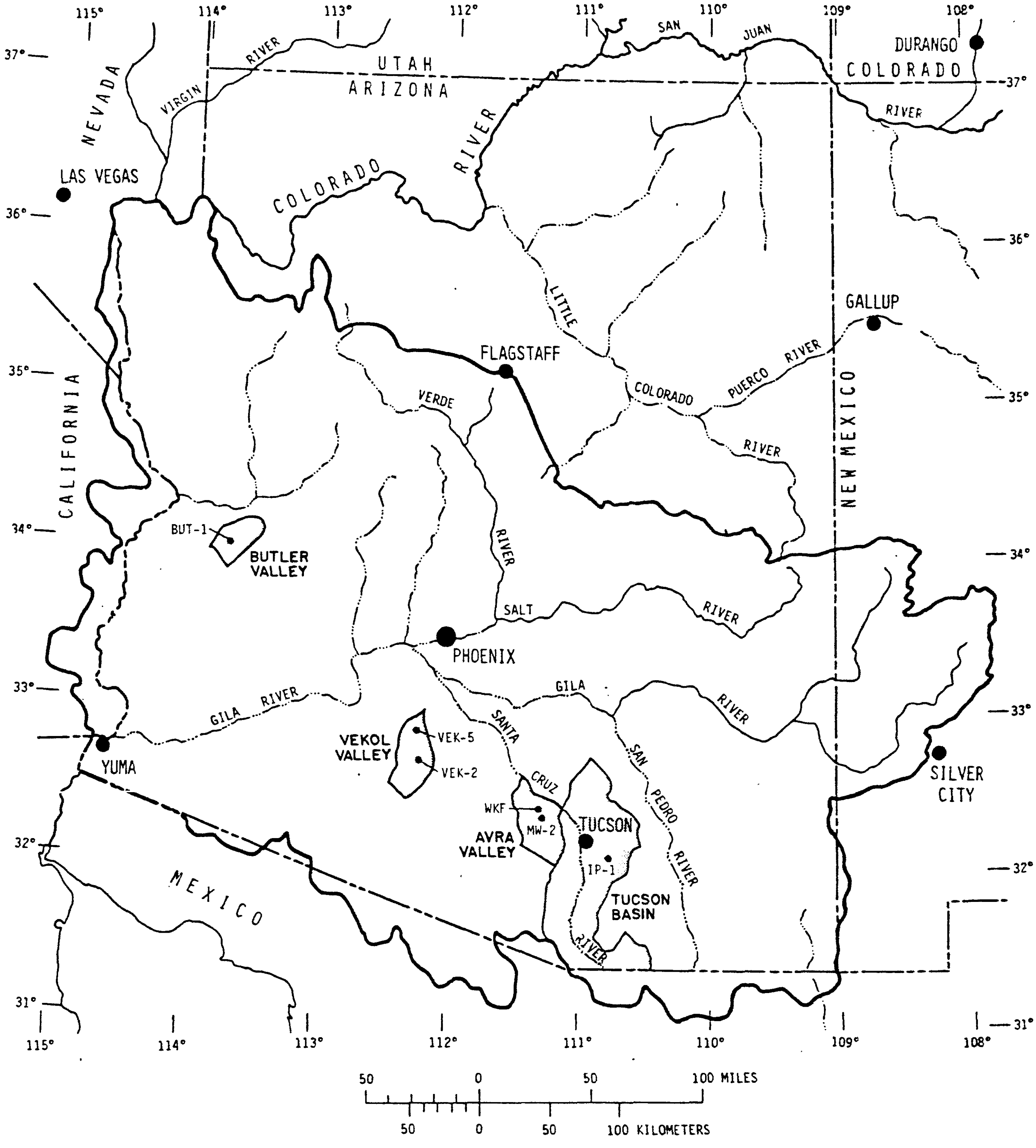
The borehole-gravity surveys described here were undertaken as part of the Southwest Alluvial Basins Study, which is one of a number of U.S. Geological Survey planned or ongoing regional aquifer studies. The objective of the borehole-gravity surveys was to investigate general relations between density and depth in the basin-fill deposits of central and southern Arizona. Such deposits form the major aquifers of the region and store large volumes of ground water.

Basin-fill deposits penetrated by six wells in Butler Valley, Vekol Valley, Avra Valley, and the Tucson basin (fig. 1), in central and southern Arizona, were logged in January, 1980, with the U.S. Geological Survey-LaCoste and Romberg borehole gravity meter. These cased wells were originally drilled for water supplies or for aquifer tests.

Subsurface depths in this report are given in feet, in conformance with common usage and understanding of well data. The multiplying factor to convert feet to meters in 0.3048.

GEOLOGIC SETTING

The borehole-gravity data described here are from intermontane basins (grabens) in or adjacent to the Sonoran Desert section of the Basin and Range physiographic province (Fenneman, 1931). Mountains (horsts) bounding the basins consist of igneous, metamorphic, and sedimentary rocks ranging from Precambrian through Cenozoic in age (Wilson and others, 1969).



EXPLANATION

BOUNDARY OF SOUTHWEST ALLUVIAL BASINS STUDY

• BUT-1 WELL—BUT-1 is well designation

Figure 1.--Locations of wells logged in this study.

The basin-fill deposits, described by Scarborough and Peirce (1978, p. 253) as "the sedimentary group that was deposited in basins created by the Basin and Range disturbance", are up to about 9,000 ft thick (Eberly and Stanley, 1978, p. 938). They consist of gravel, sand, silt, and clay, and locally include interbedded volcanic rocks and evaporites (Scarborough and Peirce, 1978). In general, the clastic sediments grade from coarse grained at basin margins to fine grained in the centers. Basin-fill deposits in the study area have not been formally named except in the Tucson basin, where Davidson (1973) subdivided them into the Tinaja beds of Miocene and Pliocene age and the Fort Lowell Formation of Pleistocene age.

BOREHOLE-GRAVITY MEASUREMENTS

The U.S. Geological Survey-LaCoste and Romberg borehole gravity meter (described by McCulloh, LaCoste, and others, 1967; McCulloh, Schoellhamer, and others, 1967) was used to carry out borehole-gravity surveys in the six wells located in Figure 1. The borehole gravity meter has a radius of investigation of tens of feet. Density values derived from borehole-gravity measurements are not significantly influenced by casing, borehole rugosity, or formation damage caused by drilling.

Fundamentals of borehole-gravity logging and data interpretation, considerations of the effective radius of investigation, and applications to geologic problems have been discussed by many authors, including Smith (1950), Goodell and Fay (1964), Howell, Heintz, and Barry (1966), McCulloh (1966), Healey (1970), Beyer (1971), Jageler (1976), Hearst and McKague (1976), and Schmoker (1977a, b, 1978, 1979).

Subsurface gravity stations were located where wire-line or drillers' logs indicated variations in formation properties. Additional stations were located between formation breaks to establish details of density variations. Densities determined from borehole-gravity measurements become more accurate as vertical station separation increases, so that station selection involves a tradeoff between stratigraphic detail and density accuracy (Schmoker, 1978).

Drift control for the borehole-gravity surveys was established by station reoccupations; tidal corrections and terrain corrections were applied to the borehole-gravity data. Principal facts for the borehole-gravity measurements of this study are tabulated in Tables 1-6.

In the absence of complicating structural factors, the relation between formation density and measurements of gravity in a borehole is given by (McCulloh, 1966):

$$\rho = 39.124(F - \Delta g / \Delta z) \qquad (1)$$

where ρ is the average formation density between two vertically separated points in the borehole (g/cm^3), F is the free-air vertical gradient of gravity (mgals/ft), Δg is the measured difference in gravity between the vertically separated points (mgals), and Δz is the vertical separation (ft).

Table 1.--
Well WKF, Avra Valley
Logged January 19, 1980

Station	Depth (feet)	Greenwich mean time	Uncorrected gravity (milligals)	Tide correction (milligals)	Terrain correction (milligals)	Corrected gravity (milligals)
1	19.9	18:43	2,651.161	-0.014	+0.030	2,651.177
2	50.0	19:00	2,652.568	-.004	+.033	2,652.597
3	75.1	19:14	2,653.562	+.004	+.036	2,653.602
4	100.1	19:26	2,654.611	+.010	+.040	2,654.661
5	144.0	19:37	2,656.493	+.015	+.047	2,656.555
6	194.0	19:49	2,658.548	+.020	+.054	2,658.622
7	245.0	20:01	2,660.696	+.025	+.061	2,660.782
8	286.0	20:15	2,662.389	+.029	+.067	2,662.485
9	326.0	20:29	2,664.030	+.032	+.073	2,664.135
10	365.0	20:47	2,665.474	+.034	+.078	2,665.586
11	406.0	21:00	2,666.960	+.035	+.083	2,667.078
12	420.0	21:13	2,667.465	+.034	+.085	2,667.584
13	462.0	21:26	2,669.049	+.032	+.090	2,669.171
14	505.0	21:39	2,670.614	+.030	+.095	2,670.739
15	548.0	21:50	2,672.231	+.027	+.100	2,672.358
16	610.0	22:02	2,674.578	+.023	+.108	2,674.709
17	674.0	22:14	2,676.996	+.018	+.115	2,677.129
18	746.0	22:20	2,679.486	+.016	+.123	2,679.625
19	815.1	22:32	2,681.879	+.010	+.131	2,682.020
20	860.1	22:41	2,683.432	+.006	+.136	2,683.574
21	910.1	22:50	2,685.152	+.001	+.142	2,685.295
22	970.0	22:56	2,687.224	-.003	+.149	2,687.370
23	1,030.0	23:08	2,689.345	-.009	+.155	2,689.491
24	1,088.0	23:18	2,691.369	-.015	+.162	2,691.516
25	1,145.0	23:29	2,693.383	-.022	+.168	2,693.529
26	1,224.1	23:38	2,696.151	-.028	+.177	2,696.300
27	1,285.0	23:48	2,698.288	-.034	+.183	2,698.437
28	970.0	24:07	2,687.278	-.046	+.149	2,687.381
29	746.0	24:23	2,679.555	-.055	+.123	2,679.623
30	462.0	24:42	2,669.157	-.066	+.090	2,669.181
31	245.0	25:01	2,660.827	-.075	+.061	2,660.813
32	19.9	25:21	2,651.287	-.083	+.030	2,651.234

Table 2.--
Well MW-2, Avra Valley
Logged January 21, 1980

Station	Depth (feet)	Greenwich mean time	Uncorrected gravity (milligals)	Tide correction (milligals)	Terrain correction (milligals)	Corrected gravity (milligals)
1	99.4	15:54	2,636.673	-0.084	+0.070	2,636.659
2	140.0	16:19	2,638.389	-.090	+.081	2,638.380
3	180.0	16:28	2,640.162	-.091	+.092	2,640.163
4	220.0	16:38	2,641.823	-.091	+.102	2,641.834
5	260.0	16:48	2,643.477	-.091	+.113	2,643.499
6	300.0	16:59	2,645.147	-.091	+.123	2,645.179
7	333.0	17:13	2,646.506	-.089	+.132	2,646.549
8	365.0	17:26	2,647.902	-.086	+.140	2,647.957
9	408.0	17:42	2,649.536	-.082	+.151	2,649.605
10	460.0	17:57	2,651.469	-.076	+.164	2,651.557
11	510.0	18:08	2,653.363	-.072	+.177	2,653.468
12	560.0	18:23	2,655.200	-.065	+.189	2,655.324
13	600.1	18:32	2,656.726	-.060	+.199	2,656.865
14	650.0	18:44	2,658.541	-.054	+.210	2,658.697
15	700.0	18:53	2,660.336	-.049	+.222	2,660.509
16	750.1	19:01	2,662.090	-.044	+.234	2,662.280
17	800.0	19:12	2,663.858	-.037	+.245	2,664.066
18	850.0	19:20	2,665.583	-.032	+.257	2,665.808
19	900.0	19:29	2,667.270	-.027	+.268	2,667.511
20	950.1	19:38	2,668.951	-.021	+.279	2,669.209
21	1,000.0	19:48	2,670.613	-.014	+.290	2,670.889
22	750.1	20:04	2,662.059	-.005	+.234	2,662.288
23	510.0	20:21	2,653.320	+.006	+.177	2,653.503
24	300.0	20:34	2,645.096	+.013	+.123	2,645.232
25	99.4	20:46	2,636.583	+.020	+.070	2,636.673
26	49.7	20:54	2,634.408	+.024	+.057	2,634.489
27	19.9	21:03	2,633.037	+.028	+.049	2,633.114
28	99.4	21:20	2,636.570	+.036	+.070	2,636.676

Table 3.--
Well IP-1, Tucson basin
Logged January 23, 1980

Station	Depth (feet)	Greenwich mean time	Uncorrected gravity (milligals)	Tide correction (milligals)	Terrain correction (milligals)	Corrected gravity (milligals)
1	99.9	15:55	2,542.724	-0.040	+0.122	2,542.806
2	150.0	16:09	2,544.794	-.046	+.138	2,544.886
3	195.0	16:20	2,546.671	-.051	+.148	2,546.768
4	235.0	16:29	2,548.302	-.054	+.154	2,548.402
5	275.0	16:42	2,549.844	-.059	+.158	2,549.943
6	314.0	16:57	2,551.404	-.064	+.161	2,551.501
7	333.0	17:06	2,552.165	-.066	+.163	2,552.262
8	365.0	17:24	2,553.388	-.070	+.164	2,553.482
9	400.1	17:36	2,554.645	-.072	+.165	2,554.738
10	445.0	17:52	2,556.357	-.074	+.166	2,556.449
11	489.0	18:08	2,558.073	-.074	+.167	2,558.166
12	518.0	18:33	2,559.162	-.073	+.167	2,559.256
13	560.0	18:53	2,560.691	-.070	+.167	2,560.788
14	603.0	19:07	2,562.246	-.067	+.167	2,562.346
15	650.0	19:20	2,564.078	-.063	+.166	2,564.181
16	702.0	19:30	2,565.985	-.060	+.165	2,566.090
17	760.0	19:44	2,568.032	-.055	+.164	2,568.141
18	800.0	19:59	2,569.526	-.049	+.163	2,569.640
19	850.0	20:09	2,571.287	-.045	+.162	2,571.404
20	890.1	20:18	2,572.692	-.040	+.161	2,572.813
21	930.0	20:25	2,574.151	-.037	+.161	2,574.275
22	980.1	20:35	2,575.887	-.032	+.160	2,576.015
23	760.0	20:58	2,567.976	-.020	+.164	2,568.120
24	518.0	21:16	2,559.082	-.010	+.167	2,559.239
25	333.0	21:31	2,552.206	-.001	+.163	2,552.368
26	99.9	21:50	2,542.746	+.010	+.122	2,542.878
27	50.0	22:01	2,540.644	+.016	+.099	2,540.759
28	20.0	22:16	2,539.524	+.024	+.080	2,539.628
29	99.9	22:26	2,542.744	+.030	+.122	2,542.896

Table 4.--
Well BUT-1, Butler Valley
Logged January 25, 1980

Station	Depth (feet)	Greenwich mean time	Uncorrected gravity (milligals)	Tide correction (milligals)	Terrain correction (milligals)	Corrected gravity (milligals)
1	213.9	15:52	2,867.073	-0.011	+0.231	2,867.293
2	245.0	16:05	2,868.376	-.014	+.251	2,868.613
3	290.0	16:17	2,870.220	-.017	+.279	2,870.482
4	335.0	16:29	2,872.044	-.020	+.307	2,872.331
5	384.0	16:41	2,874.003	-.023	+.338	2,874.318
6	426.0	16:52	2,875.675	-.026	+.364	2,876.013
7	468.0	17:08	2,877.306	-.030	+.389	2,877.665
8	532.0	17:20	2,879.500	-.034	+.427	2,879.893
9	566.0	17:33	2,880.807	-.037	+.447	2,881.217
10	604.0	17:50	2,882.237	-.042	+.469	2,882.664
11	651.0	18:01	2,883.862	-.045	+.495	2,884.212
12	690.0	18:12	2,885.047	-.048	+.517	2,885.513
13	740.0	18:20	2,886.837	-.051	+.545	2,887.331
14	796.0	18:30	2,888.686	-.053	+.575	2,889.208
15	847.0	18:40	2,890.308	-.056	+.602	2,890.854
16	914.0	18:49	2,892.458	-.057	+.637	2,893.038
17	965.0	18:58	2,894.067	-.059	+.664	2,894.672
18	1,020.0	19:07	2,895.797	-.061	+.692	2,896.428
19	1,069.0	19:15	2,897.358	-.063	+.716	2,898.011
20	1,118.0	19:23	2,899.010	-.064	+.740	2,899.686
21	1,165.0	19:31	2,900.732	-.065	+.763	2,901.430
22	914.0	19:43	2,892.459	-.066	+.637	2,893.030
23	690.0	19:58	2,885.063	-.067	+.517	2,885.513
24	651.0	20:06	2,883.784	-.067	+.495	2,884.212
25	426.0	20:24	2,875.700	-.067	+.364	2,875.997
26	213.9	20:41	2,867.060	-.066	+.231	2,867.225
27	172.0	20:59	2,865.310	-.064	+.204	2,865.450
28	137.0	21:13	2,863.902	-.061	+.182	2,864.023
29	92.0	21:26	2,861.925	-.058	+.155	2,862.022
30	50.0	21:40	2,860.308	-.055	+.132	2,860.385
31	20.0	21:52	2,858.999	-.051	+.117	2,859.065
32	213.9	22:05	2,867.024	-.046	+.231	2,867.209

Table 5.--
Well VEK-5, Vekol Valley
Logged January 28, 1980

Station	Depth (feet)	Greenwich mean time	Uncorrected gravity (milligals)	Tide correction (milligals)	Terrain correction (milligals)	Corrected gravity (milligals)
1	425.0	22:00	2,749.361	-0.072	+0.162	2,749.451
2	475.0	22:15	2,751.042	-.075	+.174	2,751.141
3	530.0	22:27	2,752.858	-.077	+.189	2,752.970
4	590.0	22:36	2,754.791	-.079	+.204	2,754.916
5	655.0	22:47	2,756.916	-.080	+.221	2,757.057
6	720.0	22:55	2,759.045	-.080	+.237	2,759.202
7	760.0	23:06	2,760.341	-.080	+.248	2,760.509
8	830.0	23:17	2,762.624	-.080	+.265	2,762.809
9	900.1	23:26	2,764.913	-.079	+.283	2,765.117
10	956.0	23:35	2,766.748	-.077	+.297	2,766.968
11	1,020.0	23:47	2,768.827	-.075	+.313	2,769.065
12	1,090.0	23:54	2,771.078	-.073	+.330	2,771.335
13	1,146.1	24:03	2,772.805	-.070	+.344	2,773.079
14	1,206.0	24:12	2,774.655	-.067	+.359	2,774.947
15	1,248.0	25:21	2,776.105	-.063	+.369	2,776.411
16	1,314.0	24:33	2,778.383	-.057	+.385	2,778.711
17	1,360.0	24:43	2,779.892	-.052	+.395	2,780.235
18	1,443.1	24:51	2,782.481	-.048	+.415	2,782.848
19	1,524.0	25:00	2,784.914	-.042	+.434	2,785.306
20	1,573.0	25:11	2,786.532	-.035	+.445	2,786.942
21	1,248.0	25:38	2,776.118	-.015	+.369	2,776.472
22	956.0	26:09	2,766.707	+.010	+.297	2,767.014
23	720.0	26:28	2,758.985	+.027	+.237	2,759.222
24	425.0	26:56	2,749.285	+.052	+.162	2,749.499
Overnight—January 29, 1980						
25	425.0	16:06	2,749.436	-.029	+.162	2,749.569
26	355.0	16:22	2,747.103	-.022	+.144	2,747.225
27	300.0	16:39	2,745.085	-.015	+.130	2,745.200
28	250.0	17:04	2,743.228	-.006	+.117	2,743.339
29	195.0	17:15	2,741.086	-.002	+.104	2,741.188
30	150.0	17:27	2,739.231	+.001	+.094	2,739.326
31	100.0	17:36	2,737.204	+.003	+.083	2,737.290
32	50.0	17:47	2,735.201	+.005	+.073	2,735.279
33	20.0	17:59	2,734.142	+.007	+.067	2,734.216
34	195.0	18:14	2,741.073	+.008	+.104	2,741.185
35	425.0	18:28	2,749.391	+.009	+.162	2,749.562

Table 6.--
Well VEK-2, Vekol Valley
Logged January 30, 1980

Station	Depth (feet)	Greenwich mean time	Uncorrected gravity (milligals)	Tide correction (milligals)	Terrain correction (milligals)	Corrected gravity (milligals)
1	475.0	19:38	2,690.046	+0.015	+0.143	2,690.204
2	520.0	19:53	2,691.738	+.011	+.151	2,691.900
3	560.0	20:00	2,693.287	+.010	+.158	2,693.455
4	625.0	20:13	2,695.766	+.006	+.170	2,695.942
5	690.0	20:20	2,698.196	+.004	+.181	2,698.381
6	760.0	20:31	2,700.787	-.001	+.193	2,700.979
7	850.0	20:39	2,704.227	-.004	+.208	2,704.431
8	928.0	20:49	2,707.190	-.008	+.220	2,707.402
9	1,012.0	20:56	2,710.343	-.011	+.234	2,710.566
10	1,100.0	21:05	2,713.729	-.015	+.247	2,713.961
11	1,154.0	21:14	2,715.839	-.020	+.256	2,716.075
12	1,210.0	21:22	2,718.029	-.024	+.264	2,718.269
13	1,270.0	21:31	2,720.296	-.028	+.273	2,720.541
14	1,325.0	21:40	2,722.382	-.033	+.281	2,722.630
15	1,400.0	21:49	2,725.346	-.038	+.293	2,725.601
16	1,475.0	21:58	2,728.207	-.042	+.303	2,728.468
17	1,550.0	22:08	2,731.124	-.048	+.314	2,731.390
18	1,620.0	22:17	2,733.822	-.052	+.324	2,734.094
19	1,695.0	22:24	2,736.710	-.056	+.335	2,736.989
20	1,765.0	22:30	2,739.368	-.059	+.345	2,739.654
21	1,840.0	22:39	2,742.363	-.063	+.356	2,742.656
22	1,900.0	22:46	2,744.698	-.066	+.364	2,744.996
23	1,960.0	22:54	2,747.074	-.069	+.372	2,747.377
24	1,550.0	23:16	2,731.173	-.078	+.314	2,731.409
25	1,210.0	23:32	2,718.082	-.083	+.264	2,718.263
26	850.0	23:51	2,704.315	-.087	+.208	2,704.436
27	475.0	24:06	2,690.091	-.089	+.143	2,690.195
28	430.5	24:18	2,688.337	-.090	+.134	2,688.381
29	365.0	24:29	2,685.577	-.090	+.121	2,685.608
30	296.0	24:38	2,682.556	-.089	+.107	2,682.574
31	226.0	24:46	2,679.364	-.088	+.092	2,679.368
32	160.0	24:55	2,676.247	-.087	+.077	2,676.237
33	110.0	25:05	2,673.831	-.085	+.065	2,673.811
34	62.0	25:16	2,671.627	-.081	+.052	2,671.598
35	20.0	25:24	2,669.578	-.078	+.041	2,669.541
36	226.0	25:36	2,679.360	-.073	+.092	2,679.379
37	475.0	25:53	2,690.116	-.064	+.143	2,690.195

In the study area, the free-air gradient of gravity is slightly distorted by regional mass anomalies associated with horst (high density) and graben (low density) structure. In each well surveyed, the theoretical free-air gradient of 0.09406 mgals/ft was corrected for such structure by modeling the gravity effect of a two-dimensional polygon representing the estimated regional configuration of the graben in which the well was located. The magnitude of this correction varied with estimated graben structure, location of the well within the graben, and well depth, but was generally small. The correction lowered the theoretical free-air gradient by 0.00015 to 0.00079 mgals/ft, resulting in a lowering of calculated densities (equation 1) of 0.006 to 0.031 g/cm^3.

DENSITIES OF BASIN-FILL DEPOSITS

Densities of the basin-fill deposits logged in this study, calculated from borehole-gravity data, are listed in Table 7 and plotted in Figure 2. Densities above the water table range from 1.73 to 2.26 g/cm^3, and densities below the water table range from 2.01 to 2.46 g/cm^3. The depth-density plots (fig. 2) show density layers, reflecting individual depositional sequences. In general, densities of the basin fill increase with depth from the surface to about 800 ft and then remain constant or even decrease with additional depth, as shown by the plot of average density versus depth (fig. 3) and the plots of individual wells (fig. 2).

Table 7.--Densities of basin fill calculated from borehole-gravity data.

Well IP-1 Well depth, 1,000 feet Depth to water, 316 feet		Well WKF Well depth, 1,302 feet Depth to water, 365 feet		Well MW-2 Well depth, unknown Depth to water, 364 feet Well obstructed at 1,100 feet		Well VEK-2 Well depth, 2,045 feet Depth to water, 440 feet		Well VEK-5 Well depth, 1,995 feet Depth to water, 345 feet Well obstructed at 1,573 feet		Well BUT-1 Well depth, 1,520 feet Depth to water, 215 feet Well obstructed at 1,167 feet	
Depth interval (feet)	Density (grams per cubic centimeter)	Depth interval (feet)	Density (grams per cubic centimeter)	Depth interval (feet)	Density (grams per cubic centimeter)	Depth interval (feet)	Density (grams per cubic centimeter)	Depth interval (feet)	Density (grams per cubic centimeter)	Depth interval (feet)	Density (grams per cubic centimeter)
20- 50	2.174	20- 50	1.828	20- 50	1.858	20- 62	1.734	20- 50	2.264	20- 50	1.944
50- 100	1.988	50- 75	2.108	50- 99	1.944	62- 110	1.846	50- 100	2.076	50- 92	2.141
100- 150	2.024	75- 100	2.017	99- 140	2.004	110- 160	1.752	100- 150	2.057	92- 137	1.926
150- 195	2.013	100- 144	1.986	140- 180	1.919	160- 226	1.794	150- 195	2.031	137- 172	2.071
195- 235	2.051	144- 194	2.057	180- 220	2.029	226- 296	1.858	195- 250	2.120	172- 214	2.008
235- 275	2.142	194- 245	2.017	220- 260	2.035	296- 365	1.930	250- 300	2.194	214- 245	2.005
275- 314	2.086	245- 286	2.049	260- 300	2.020	365- 430	1.994	300- 355	2.209	245- 290	2.041
314- 333	2.082	286- 326	2.060	300- 333	2.039	430- 475	2.055	355- 425	2.340	290- 335	2.058
333- 365	2.157	326- 365	2.219	333- 365	1.943	475- 520	2.175	425- 475	2.325	335- 384	2.079
365- 400	2.249	365- 406	2.250	365- 408	2.163	520- 560	2.129	475- 530	2.349	384- 426	2.087
400- 445	2.158	406- 420	2.260	408- 460	2.195	560- 625	2.153	530- 590	2.381	426- 468	2.127
445- 489	2.122	420- 462	2.196	460- 510	2.168	625- 690	2.182	590- 655	2.361	468- 532	2.304
489- 518	2.179	462- 505	2.247	510- 560	2.211	690- 760	2.198	655- 720	2.359	532- 566	2.142
518- 560	2.222	505- 548	2.201	560- 600	2.160	760- 850	2.149	720- 760	2.371	566- 604	2.176
560- 603	2.232	548- 610	2.191	600- 650	2.227	850- 928	2.160	760- 830	2.364	604- 651	2.377
603- 650	2.122	610- 674	2.195	650- 700	2.245	928-1,012	2.176	830- 900	2.362	651- 690	2.361
650- 702	2.213	674- 746	2.318	700- 750	2.280	1,012-1,100	2.140	900- 956	2.354	690- 740	2.243
702- 760	2.266	746- 815	2.318	750- 800	2.263	1,100-1,154	2.118	956-1,020	2.368	740- 796	2.355
760- 800	2.183	815- 860	2.323	800- 850	2.300	1,154-1,210	2.117	1,020-1,090	2.381	796- 847	2.403
800- 850	2.269	860- 910	2.327	850- 900	2.331	1,210-1,270	2.168	1,090-1,146	2.434	847- 914	2.391
850- 890	2.274	910- 970	2.319	900- 950	2.337	1,270-1,325	2.164	1,146-1,206	2.430	914- 965	2.412
890- 930	2.216	970-1,030	2.291	950-1,000	2.346	1,325-1,400	2.100	1,206-1,248	2.286	965-1,020	2.417
930- 980	2.290	1,030-1,088	2.308			1,400-1,475	2.154	1,248-1,314	2.286	1,020-1,069	2.402
		1,088-1,145	2.292			1,475-1,550	2.126	1,314-1,360	2.354	1,069-1,118	2.328
		1,145-1,224	2.304			1,550-1,620	2.139	1,360-1,443	2.420	1,118-1,165	2.214
		1,224-1,285	2.301			1,620-1,695	2.140	1,443-1,524	2.461		
						1,695-1,765	2.160	1,524-1,573	2.344		
						1,765-1,840	2.084				
						1,840-1,900	2.124				
						1,900-1,960	2.097				

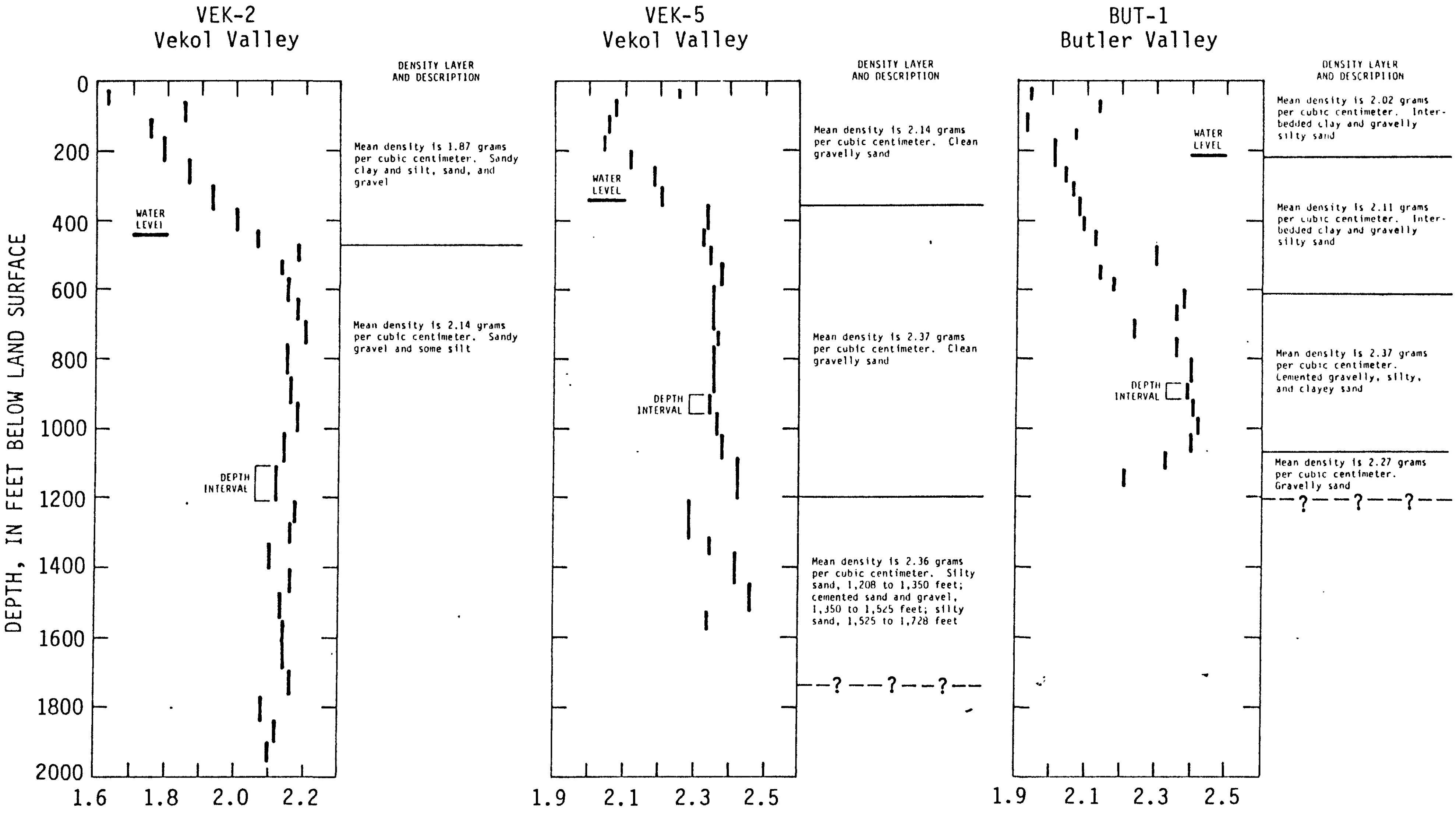


Figure 2.--Densities of basin fill calculated from borehole-gravity data.

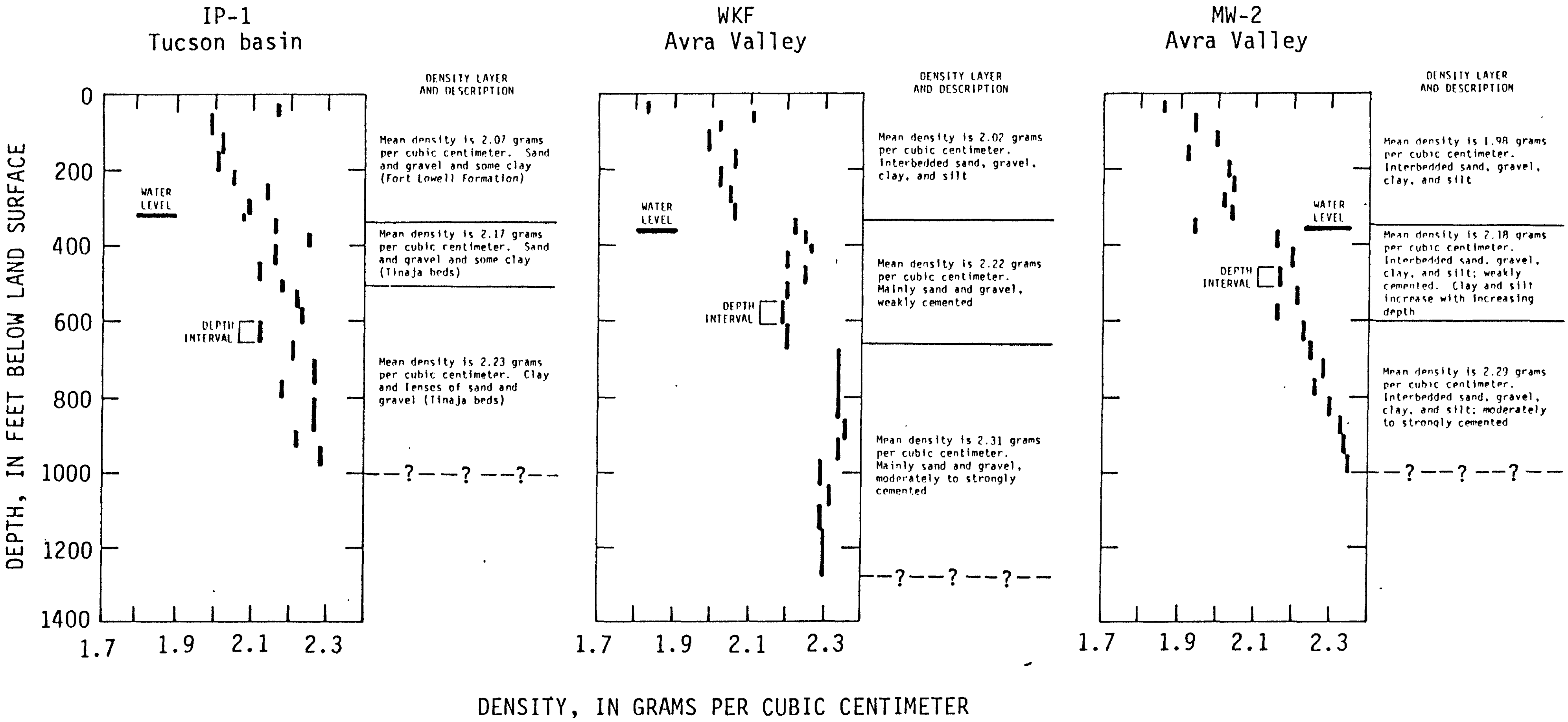
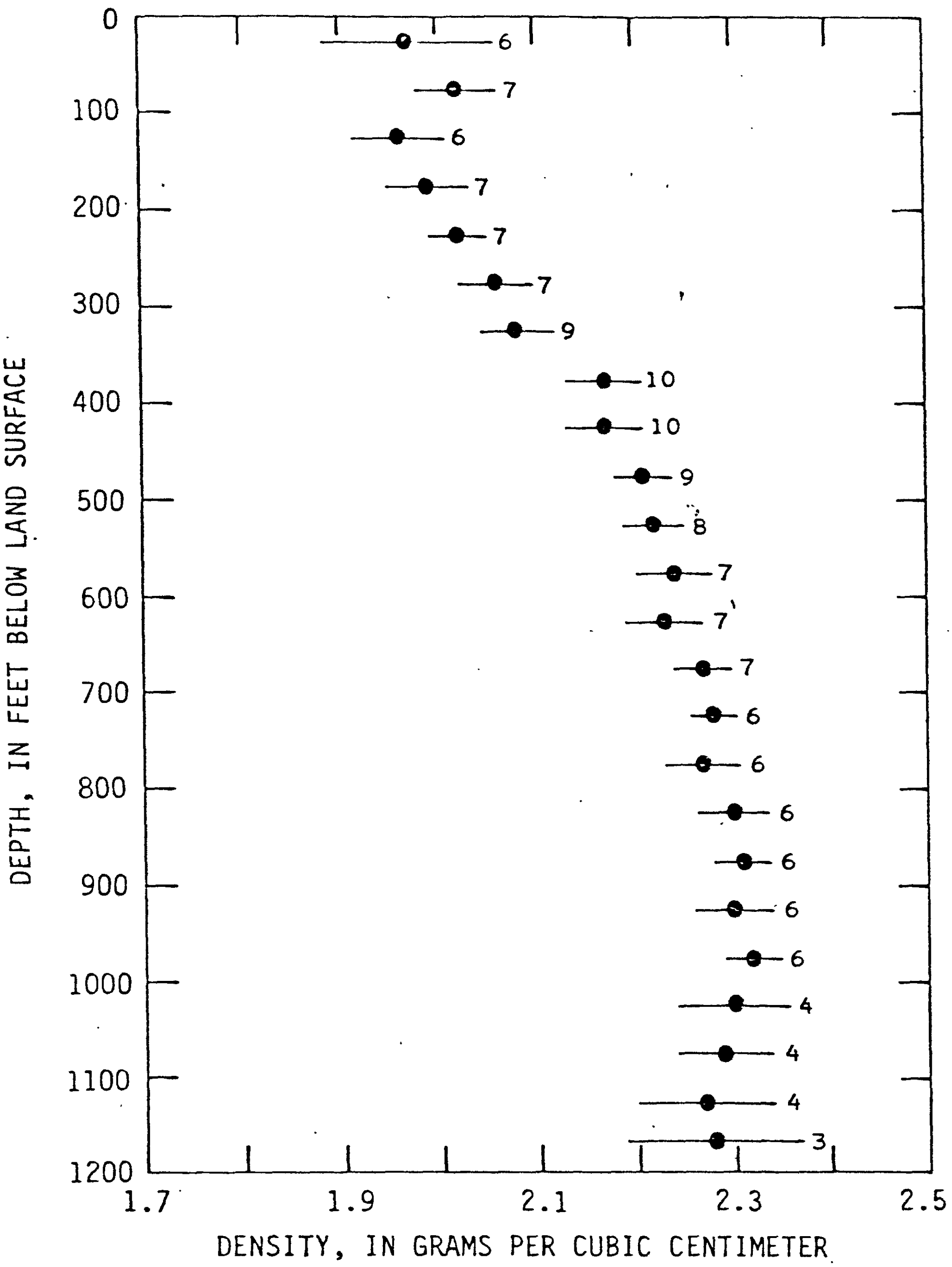


Figure 2.--Continued.



EXPLANATION

7 MEAN DENSITY—Numeral, 7, is number of data points used to calculate the mean density. Half the length of the line is the standard error of the sample mean

Figure 3.--Mean density of the upper 1,200 feet of basin-fill deposits.

Figure 4 compares basin-fill densities measured in this study with depth-density curves given by other investigators. Curve A is from borehole-gravity measurements reported by Healey (1970) for the upper 2,000 ft of basin fill in Hot Creek Valley, Nevada. Curve B, modified from Eaton and others (1972), is based on conventional density-log data from central Arizona. Curve C is based on well-sample data reported by Mattick and others (1973) for Cenozoic deposits in the Colorado River delta. Curves A, B, and C are within the range of densities measured in this study.

Lateral and vertical changes in grain density, porosity, and water saturation, which produce changes in the density of basin fill, are a function of the local geologic history of an area and do not necessarily correlate from basin to basin or even within a basin (i.e., Avra Valley, fig. 2). Lacking knowledge of subsurface density in a given basin in the region, however, curve D of Figure 4 could be used as a first approximation of the depth-density relation.

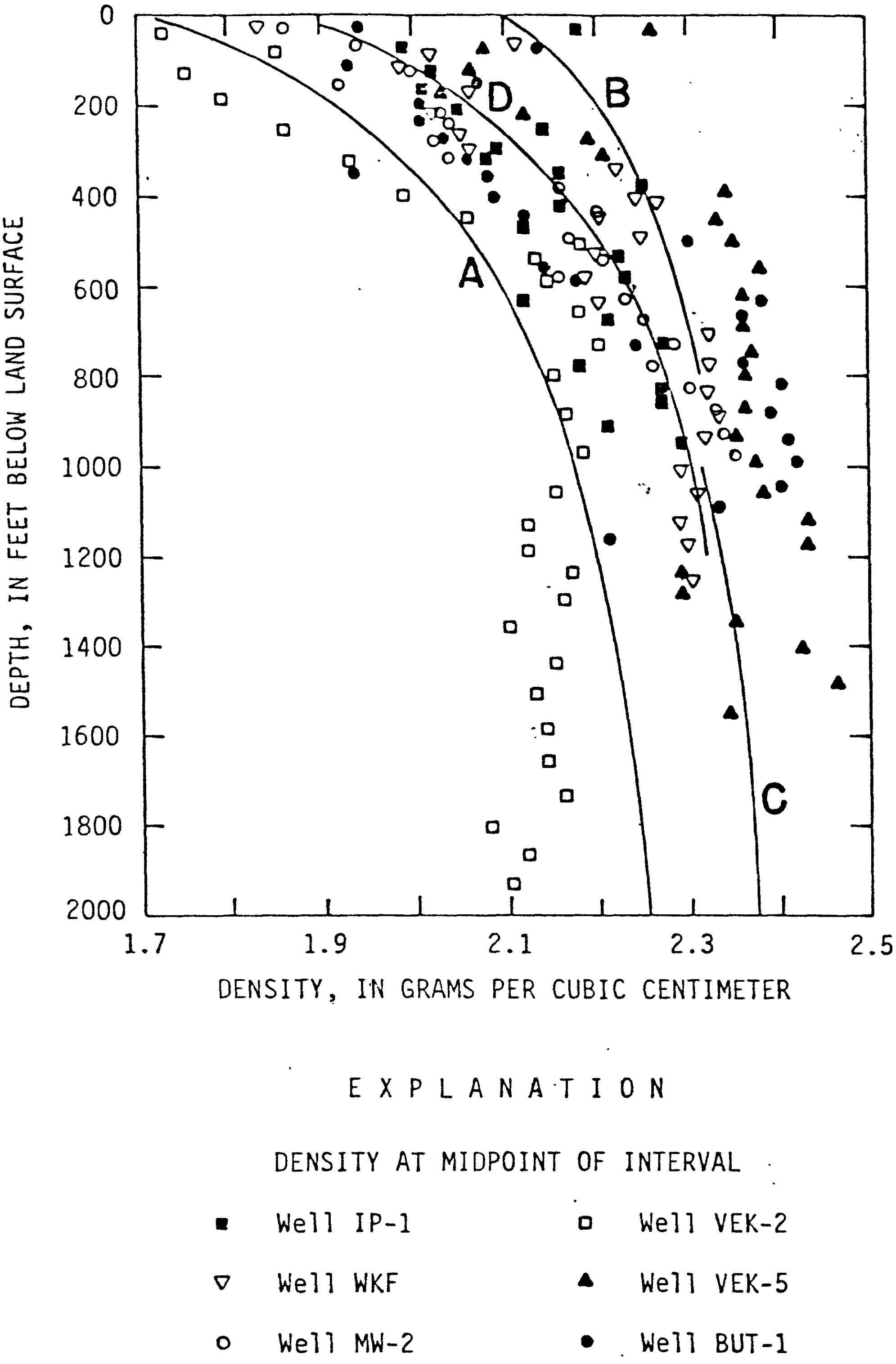


Figure 4.--Comparison of the density of basin-fill deposits in parts of Arizona and Nevada. Data for curve A from Healey (1970). Curve B modified from Eaton and others (1972, fig. 11). Data for curve C from Mattick and others (1973, fig. 4). Data for curve D from Figure 3 of this study.

POROSITIES OF BASIN-FILL DEPOSITS

Porosity, ϕ , was computed for intervals below the water table from the borehole-gravity density, ρ , using the equation:

$$\phi = 100(\rho_G - \rho)/(\rho_G - \rho_F) \quad (2)$$

where ρ_G is the estimated average grain density and ρ_F is the pore-fluid density (g/cm^3). Pores were assumed to be filled with water of density 1.00 g/cm^3; grain densities of 2.50, 2.65, and 2.80 g/cm^3 were used. The porosity calculation is quite sensitive to grain density and error in this parameter is a major source of porosity uncertainty. A grain density of 2.65 g/cm^3 probably best represents the basin fill. Grain densities of 2.50 and 2.80 g/cm^3 are thought to represent upper and lower limits.

Table 8 lists average porosities, calculated from the borehole-gravity data, of the water-saturated density layers shown in Figure 2. Such data can be used to estimate volumes of ground water in place.

In some instances, porosity also shows a positive correlation with hydraulic conductivity and so is related to potential aquifer production. In Avra Valley (well WKF), for example, preliminary results of a three-dimensional mathematical model of the ground-water system indicate that the density layer between 326 and 674 ft, with a mean porosity of about 26 percent, is from two to four times more permeable than the underlying density layer (674-1,285 ft) with a mean porosity of about 21 percent (D. R. Pool, U.S. Geological Survey, oral commun., 1980).

Table 8.--Porosities of basin-fill deposits calculated from borehole-gravity data.

Well	Depth interval ft	Mean density g/cm^3	Average porosity, percent: Grain density 2.50 g/cm^3	Grain density 2.65 g/cm^3	Grain density 2.80 g/cm^3
IP-1	333-518	2.17	22	29	35
	518-980	2.23	18	25	32
MW-2	365-600	2.18	21	28	34
	600-1,000	2.29	14	22	28
WKF	326-674	2.22	19	26	32
	674-1,285	2.31	13	21	27
VEK-2	475-1,960	2.14	24	31	37
VEK-5	355-1,206	2.37	9	17	24
	1,206-1,573	2.36	9	18	24
BUT-1	214-604	2.11	26	33	38
	604-1,069	2.37	9	17	24
	1,069-1,165	2.27	15	23	29

Vekol Valley is divided into two parts by a buried ridge of consolidated rock (Wilson, 1979, p. 8). The mean porosity of the saturated basin fill is about 18 percent in the northern part (VEK-5) and about 31 percent in the southern part (VEK-2). Aquifer tests and results of a preliminary model of the ground-water system indicate that basin-fill deposits in the southern part are two to four times more permeable than those in the northern part (R. P. Wilson, U.S. Geological Survey, oral commun., 1980).

It must be strongly emphasized that there can be many exceptions to the positive correlation between porosity and hydraulic conductivity. Hydraulic conductivity depends on factors such as grain size and grain-size distribution, pore-throat geometry, fracture density, etc. It is only when such factors remain approximately constant that increasing porosity correlates with increasing capacity of the rock to transmit fluid.

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