Estimation of Alluvial-Fill Thickness in the Mimbres Ground-Water Basin, New Mexico, from Interpretation of Isostatic Residual Gravity Anomalies

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 02-4007

Prepared in cooperation with the
NEW MEXICO OFFICE OF THE STATE ENGINEER

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
square kilometer (km^2)	0.3861	square mile (mi^2)
square kilometer (km^2)	2.471	acre
kilogram per cubic meter (kg/m^3)	0.001	gram per cubic centimeter (g/cm^3)

1 milligal (Mgal) = 0.001centimeter/second/second

Altitude, as used in this report, refers to distance above sea level.

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ABSTRACT

The geologic structure of the Mimbres ground-water basin in southwest New Mexico is characterized by north- and northwest-trending structural subbasins. Sedimentation of Miocene and Pliocene age has filled and obscured the boundaries of these subbasins and formed potentially productive aquifers of varied thickness. The location and depth of the subbasins can be estimated from analysis of isostatic residual gravity anomalies. Density contrasts of various basement lithologies generate complex regional gravity trends, which are convolved with the gravity signal from the Miocene and Pliocene alluvial fill. An iterative scheme was used to separate these regional gravity trends from the alluvial-fill gravity signal, which was inverted with estimated depth-density relations to compute the thickness of the alluvial fill at 1-kilometer spacing. The thickness estimates were constrained by exploratory drill-hole information, interpreted seismic-refraction profiles, and location of bedrock lithology from surficial geologic mapping. The resulting map of alluvial-fill thickness suggests large areas of thin alluvium that separate deep structural subbasins.

INTRODUCTION

Ground water is a principal supply for the domestic, industrial, and agricultural water demands in the Mimbres Basin in southwest New Mexico. In his report on the ground-water supply of the Mimbres Valley, White (1930) stated "It is recognized that overdevelopment would be fatal to the best interests of the community and that future expansion in pumping activities should be guided by as adequate information as it is possible to obtain concerning the extent of this resource." Substantial ground-water withdrawals since the 1930's resulted in ground-water drawdowns of 30 m south of Deming and 40 m east of Columbus by 1970 (Hanson and others, 1994). Land subsidence and associated fissuring south of Deming resulted in abandonment of some agricultural land (Contaldo and Mueller, 1991). To better manage the ground-water resources, the New Mexico Office of the State Engineer needs an improved understanding of the shallow geologic structure of the Mimbres Basin. Thickness variations of the Tertiary and Quaternary alluvium, which composes the principal aquifer system in the basin, influence the three-dimensional flow of ground water in the Mimbres Basin. Ground-water flow simulations of the basin should consider aquifer-thickness variability in geohydrologic conceptualization and numerical discretization.

Purpose and Scope

In 1989, the U.S. Geological Survey, in cooperation with the New Mexico Office of the State Engineer, began a two-part investigation using gravity measurements to study alluvial-basin aquifer systems. In the first part, a gravity database was developed to enable interpretation of shallow crustal geologic structure throughout New Mexico (Heywood, 1992). Because the unconsolidated sedimentary alluvium that fills many structural basins in New Mexico typically has a much lower density than surrounding consolidated sedimentary or igneous rocks, the isostatic residual gravity anomaly is particularly useful for estimating the alluvial thickness in such basins. This report provides an estimation of the thickness of the alluvial-fill aquifer, the principal water supply, in various areas within the Mimbres Basin in the United States. The Mimbres ground-water basin extends into Mexico, but areas south of the international border are not considered in this report.

Within the Mimbres Basin, areas of greater alluvial thickness may contain more ground water, but this water may not be recoverable. Aquifer-system permeability and water-quality characteristics also need to be evaluated but are beyond the scope of this report.

Previous Work

Birch (1980) constructed several two-dimensional regional gravity profile models for New Mexico, one of which crossed the Mimbres Basin. Hanson and others (1994) used well logs, gravity maps, and seismic profiles to estimate the alluvial thickness in different parts of the Mimbres Basin. Their ground-water flow model was two dimensional, and initial estimates of aquifer transmissivity and storativity were not affected by their definition of alluvial thickness. The thickness estimates were used to estimate ground-water flux across several vertical cross sections of the ground-water system for comparison with net recharge estimates. Heywood (1992) documented the isostatic-residual gravity database used for the analysis in this report. Ackerman and others (1994) reprocessed oil industry seismic-refraction lines, which were interpreted by Klein (1995). Several of these seismic lines cross the Mimbres Basin and were used to help constrain this gravity interpretation.

Physiographic Setting

Subbasins and the geographical extent and physiographic features of the Mimbres Basin in southwest New Mexico are depicted in figure 1. Basin extent is defined by the topographically defined surface-water drainage. The limits of the Mimbres ground-water basin within the United States are assumed to correspond with this topographically defined surface-water drainage basin. The northern and western extents of the basin correspond to the Continental Divide; from Reeds Peak in the Black Range, the divide extends through the Pinos Altos Range, the Big Burro Mountains, and the Cedar Mountain Range to the Carizalillo Hills just north of the United States–Mexico border. From the United States–Mexico border, the eastern side of the basin extends northward through the West Potrillo Mountains, Aden Hills, Sleeping Lady Hills, Sierra de las Uvas, and Mimbres Mountains to the Black Range. In the United States, this area encompasses about 11,283 km^2 or 4,356 square miles. Between the mountain ranges, the basin boundary follows the topographic high on the intervening plains. Because the location of the ground-water divide does not correspond exactly to a topographic high, minor differences between the Mimbres ground-water basin and the Mimbres surface-water drainage area may exist.

Ground water in the basin generally flows southward and discharges to a playa south of the Mexican border (Hanson and others, 1994). The climate is typical of the arid desert Southwest: average annual precipitation varies from less than 0.25 m (about 10 in.) on the basin floor to about 0.75 m (about 30 in.) in the mountainous northern areas of the drainage basin.

Geologic Setting

The geologic structure of the Mimbres ground-water basin in southwest New Mexico is characterized by north- and northwest-trending structural subbasins. Sedimentation of Miocene and Pliocene age has filled and obscured the boundaries of these subbasins, which have variable thickness.

The Mimbres Basin is located at the convergence of three tectonic provinces: the Basin and Range, Colorado Plateau, and Rio Grande Rift. The northern section of the basin lies within a “transition zone” to the Colorado Plateau, which is relatively undeformed. The eastern flank of the basin is transitional to the Rio Grande Rift, a region of substantial crustal extension. The remaining southern and western parts of the basin lie within the extensional tectonic environment of the Basin and Range Province. These extensional tectonic environments have generated structural subbasins, or grabens, bounded by normal faults within the Mimbres

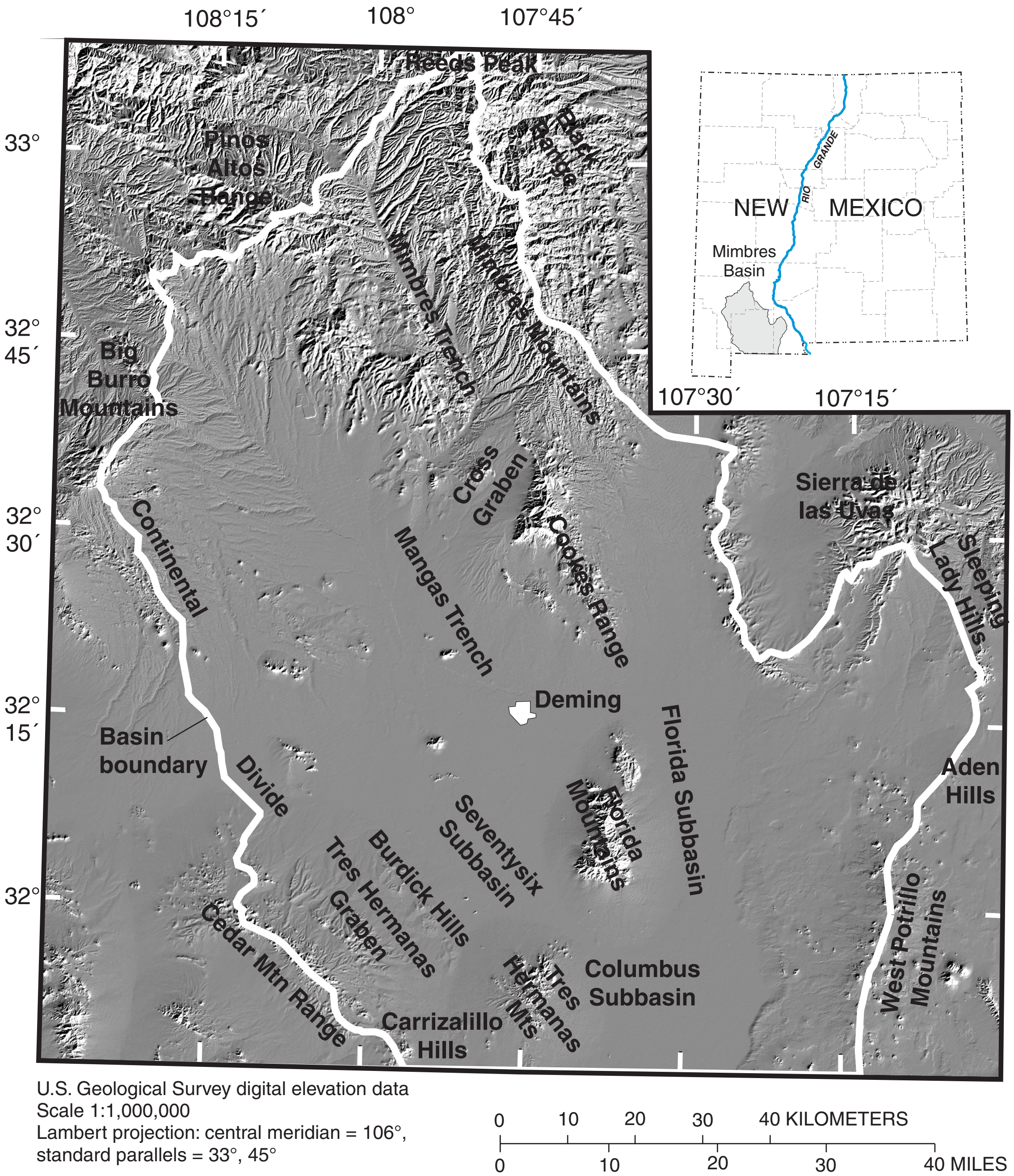


Figure 1. Location of physiographic features and subbasins of the Mimbres Basin.

Basin. Many of these faults have a northwest strike, similar to compressional faults of the Late Cretaceous and early Tertiary Laramide Orogeny. This coincidence of structural trends suggests that some relict structures may have been reactivated in the extensional tectonic environment. Although the tops of intervening horsts (elongate blocks bounded on both sides by normal faults) are occasionally exposed in ranges, such as the Florida Mountains, the locations of graben-bounding faults are generally overlain by alluvium filling the intermontane basins.

The major surficial geologic units that have been mapped in and near the Mimbres Basin area are summarized in table 1. These units were compiled from Anderson and others (1997) and Kennedy and others (2000). For further lithologic summaries and general geologic history of the area, the reader is referred to Hawley (1975), Cather and Johnson (1986), Ross and Ross (1986), Seager and Mack (1986), Clemons and Mack (1988), Mack and Clemons (1988), and Kennedy and others (2000). For this report, these units have been categorized into four lithofacies groups, which are listed in table 1 and depicted in figure 2.

Indurated clastic and carbonate sedimentary, metamorphic, plutonic, and silicic volcanic rocks of Precambrian through Tertiary age (group 4 of table 1 and fig. 2) are considered "bedrock," and the locations of their land-surface outcrop are shown in black in figure 2. These rock types underlie groups 1, 2, and 3 (table 1 and fig. 2), which partially fill the structural grabens. The density contrasts among the various rock types considered bedrock in group 4 are accounted for in the regional isostatic residual gravity field; therefore, explicitly defining them is not necessary.

Basalts of Pliocene age and younger (group 3 in table 1 and fig. 2) occur in large flow fields in the southern Mimbres Basin, as shown in yellow in figure 2. These basalts may overlie the basin-filling alluvial deposits (groups 1 and 2) and may be as much as 100 m thick. The density of homogenous basalt is typically in the range of 2,700 to 3,100 kg/m^3 (Milsom, 1989). Because these basalts are probably interbedded with lower density alluvial sediments, the bulk density used to represent these basalts in the gravity model varies with depth from 2,120 to 2,420 kg/m^3 (table 2).

The basin-fill alluvium was subdivided into two groups on the basis of age and depositional environment. Group 1 lithofacies, shown in magenta in figure 2, are typically older and more lithified than lithofacies in group 2 (shown in blue) and have slightly higher average density. Typical depositional environments of group 1 lithofacies are piedmonts or basin floors. The Gila Group and the lower and middle units of the Santa Fe Group are representative of group 1 lithofacies. Densities of these deposits increase with depth of burial from 2,000 to 2,300 kg/m^3 (table 2). Group 1 deposits probably are the most voluminous of the three basin-fill lithofacies groups, though this is not apparent in figure 2 because these deposits may be overlain by the younger basin-fill alluvium of group 2.

Group 2 lithofacies are generally younger and less dense than those of group 1 and include late Quaternary deposits of major streams as well as eolian, basin-floor, and piedmont deposits. The upper Santa Fe Group typifies deposits of this lithofacies group. Densities increase with depth of burial from 1,800 to 2,100 kg/m^3 (table 2).

Acknowledgments

Dr. John Hawley provided invaluable insight for the author's understanding of the geologic setting and sedimentation of Quaternary age.

ISOSTATIC RESIDUAL GRAVITY FIELD IN THE MIMBRES BASIN

For this study, existing gravity measurements and corresponding values of isostatic residual gravity in and near the Mimbres Basin were obtained from the New Mexico database developed by Heywood (1992). These data were interpolated with MINC (Webring, 1981), a program that minimized the second horizontal derivative of the interpolated potential field. The portion of the isostatic residual gravity surface within the lateral boundaries of the Mimbres Basin, horizontal location of measurement points, and surrounding topography (depicted in shaded relief) are shown in figure 3. As explained by Heywood (1992), the colors on the isostatic residual gravity map (fig. 3) represent variations in the Earth's gravity field caused by density

Table 1. *Geologic units in the Mimbres Basin area*

Symbol	Description	Lithofacies group (fig. 2)
	Quaternary and Tertiary	
Qe	Eolian deposits	2
Qa	Alluvium	2
Qoa	Older alluvial deposits	1
Qp	Piedmont alluvial deposits	2
Qb	Basalt and andesite flows and local vent deposits	3
Qv	Basaltic volcanics; tuff rings, cinders, and proximal lavas	3
Qbo	Basalt or basaltic andesite	3
QTg	Gila Group: includes Mimbres Formation and several informal units	1
QTp	Older piedmont alluvial deposits and shallow basin fill	1
QTs	Upper Santa Fe Group	2
QTsf	Upper Santa Fe Group, undivided	2
	Tertiary	
Tnv	Neogene volcanic rocks	4
Tnb	Basalt and andesite flows; Neogene	3
Tpb	Basalt and andesite flows; Pliocene	3
Tus	Upper Tertiary sedimentary units	2
Tuau	Lower Miocene and uppermost Oligocene basaltic andesites	4
Tui	Miocene to Oligocene silicic to intermediate intrusive rocks; dikes, stocks, plugs, and diatremes	4
Turp	Upper Oligocene rhyolitic pyroclastic rocks (ash-flow tuffs)	4
Turf	Upper Oligocene silicic (or felsic) flows and masses and associated pyroclastic rocks	4
Tual	Upper Oligocene andesites and basaltic andesites	4
Tlrp	Lower Oligocene silicic pyroclastic rocks (ash-flow tuffs)	4
Tlrf	Lower Oligocene silicic (or felsic) flows, domes, and associated pyroclastic rocks and intrusions	4
Tos	Oligocene and upper Eocene sedimentary and volcaniclastic rocks with local andesitic to intermediate volcanics	1
Tlv	Lower Oligocene and Eocene volcanic rocks, undifferentiated	4
Tli	Quartz monzonites in the Silver City Range, intermediate intrusives of the Cookes Range	4
Tv	Middle Tertiary volcanic rocks, undifferentiated	4
Tps	Paleogene sedimentary units	1
Tuv	Volcanic and some volcaniclastic rocks, undifferentiated	4
Tla	Lower Tertiary andesite and basaltic andesite flows and associated volcaniclastic units	4
Ti	Tertiary intrusive rocks, undifferentiated	4
Tsf	Lower and middle Santa Fe Group	1
	Tertiary and Cretaceous	
TKi	Paleogene and Upper Cretaceous intrusive rocks	4
TKav	Andesitic volcanics	4

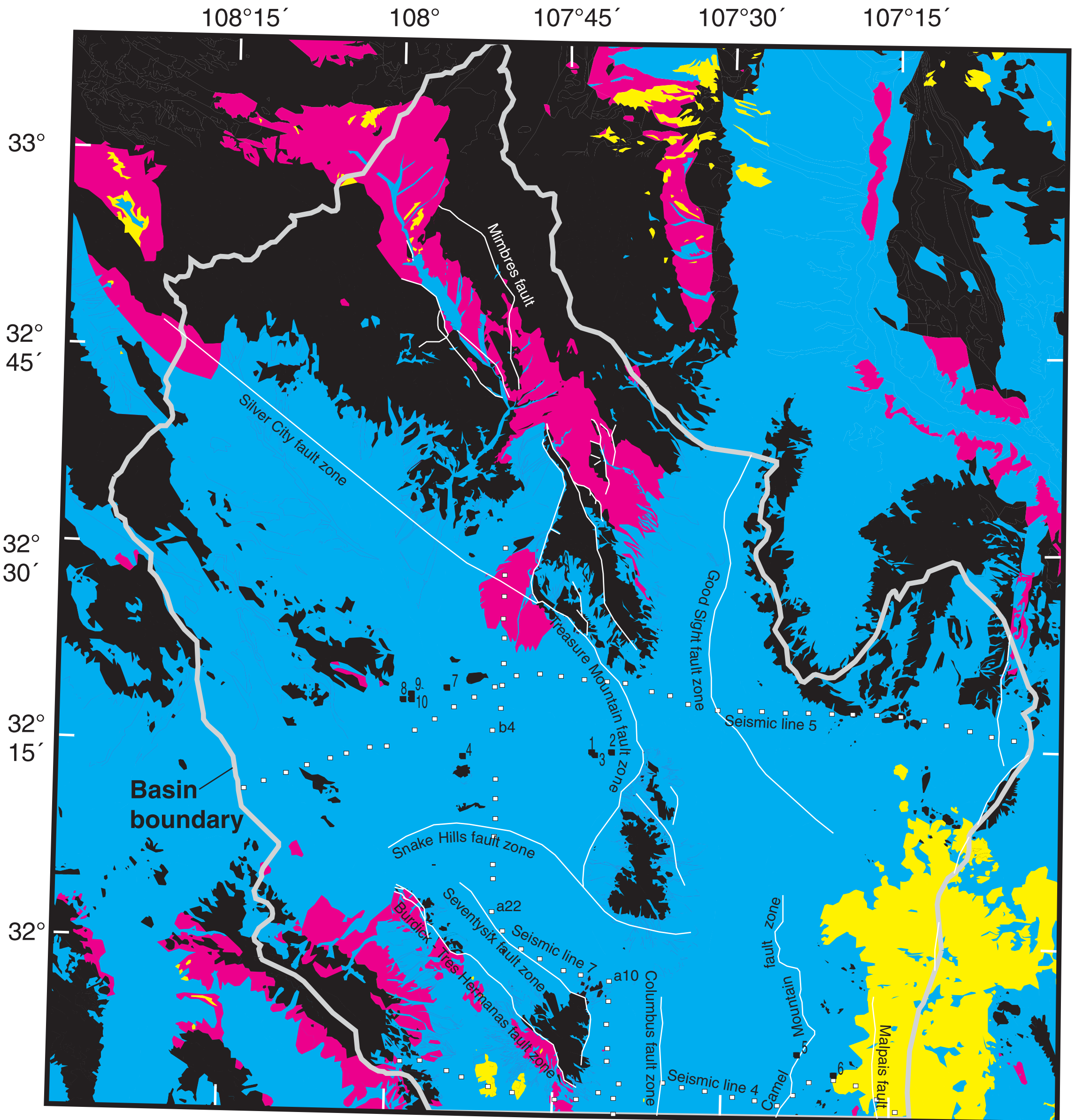
Table 1. *Geologic units in the Mimbres Basin area--Concluded*

Symbol	Description	Lithofacies group (fig. 2)
	Cretaceous	
Kbm	Mancos Shale or Beartooth Quartzite	4
Ku	Upper Cretaceous, undivided	4
Kl	Lower Cretaceous, undivided	4
	Paleozoic	
P𝒫	Permian and Pennsylvanian rocks, undivided	4
Pa	Abo Formation, Permian	4
Pz	Paleozoic rocks, undivided	4
Pys	Yeso Formation, Permian	4
Ph	Hueco Formation, Permian	4
𝒫	Pennsylvanian rocks, undivided	4
M	Mississippian rocks, undivided	4
MD	Mississippian and Devonian rocks, undivided	4
D	Percha Shale	4
SO	Silurian and Ordovician rocks, undivided	4
SOC	Silurian through Cambrian rocks, undivided	4
OCp	Ordovician-Cambrian plutonic rocks of Florida Mountains	4
	Precambrian	
Yp	Middle Proterozoic plutonic rocks	4

Table 2. *Depth intervals and densities for lithofacies groups 1, 2, and 3 in the Mimbres Basin*

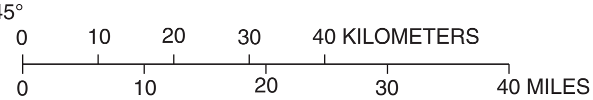
[>, greater than]

Depth interval (meters below land surface)	Density (kilograms per cubic meter)		
	Group 1	Group 2	Group 3
0 - 100	2,000	1,800	2,420
101 - 200	2,100	1,900	2,120
201 - 1,200	2,200	2,000	2,320
> 1,200	2,300	2,100	2,420



U.S. Geological Survey digital elevation data
Scale 1:1,000,000
Lambert projection: central meridian = 106°, standard parallels = 33°, 45°

Geology and faults from Anderson and others (1997) and Kennedy and others (2000)



EXPLANATION

- Bedrock (group 4 lithofacies)
- Basalt (group 3 lithofacies)
- Older alluvium of Quaternary age (group 1 lithofacies)
- Younger alluvium of Quaternary age (group 2 lithofacies)
- Exploration drill-hole location and number (table 3)
- Trace of seismic-refraction lines and locations of shot points

Figure 2. Surficial geology of the Mimbres Basin area and locations of seismic-refraction lines and deep exploratory drill holes.

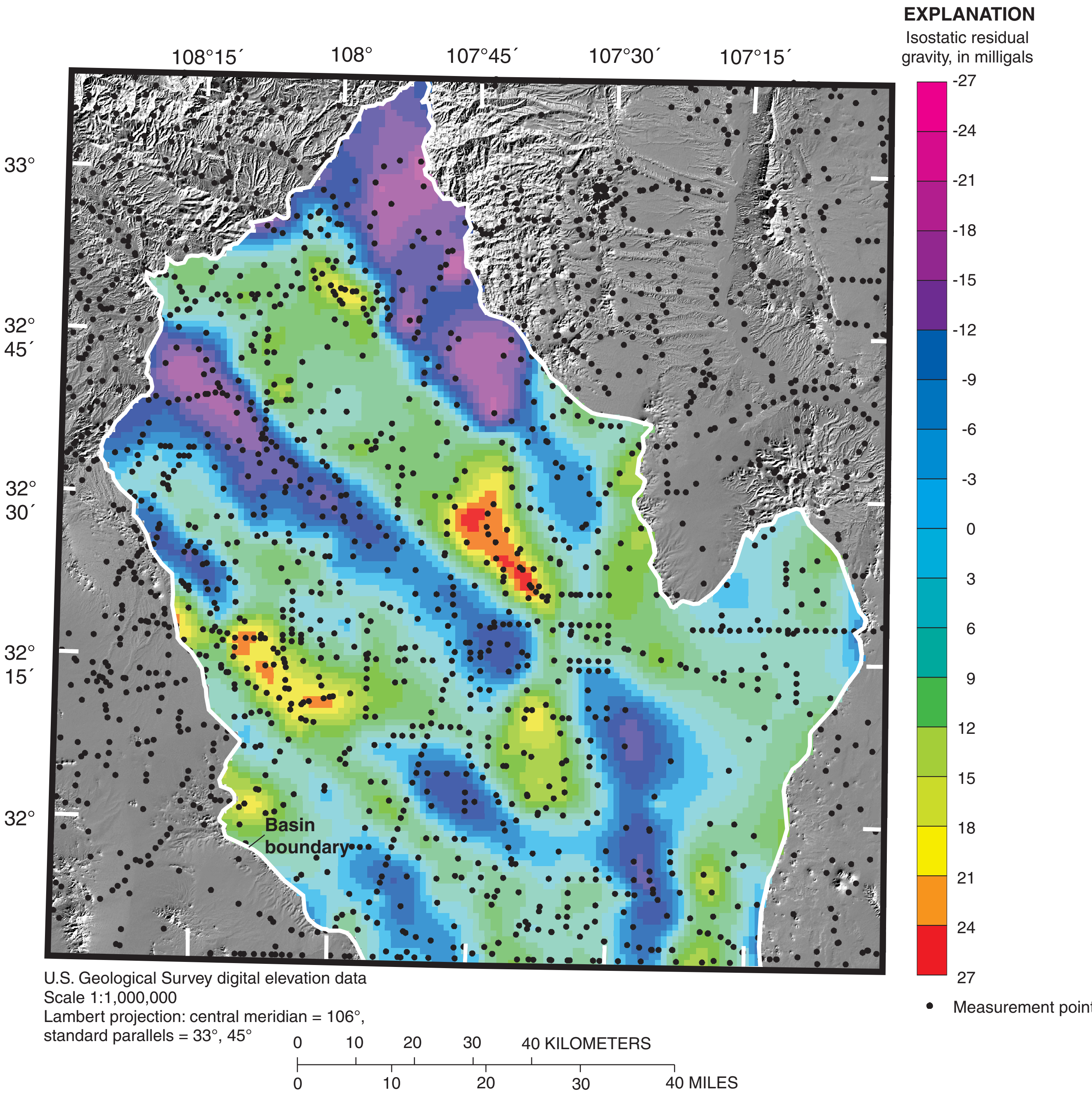


Figure 3. Measurement points and isostatic residual gravity in the Mimbres Basin.

variations in rocks composing the Earth's crust.[1] Positive anomalies (shades of green to red) result from rocks denser than the Bouguer reduction density of 2,670 kg/m^3 (Heywood, 1992), whereas negative anomalies (shades of blue to magenta) result from rocks of lower density. The patterns and magnitudes of these anomalies may be used to interpret crustal structure, such as the location of Quaternary alluvial subbasins bounded by buried faults.

Potential fields, such as the isostatic residual gravity field discussed in this report, are mathematically continuous surfaces. Readers unfamiliar with potential field theory may consult texts such as those by Garland (1979), Dobrin and Savit (1988), Milsom (1989), and Telford and others (1990). The calculations described in this report were performed on a computer that required discrete representation of the surfaces as grids. The grids used in this study are two-dimensional arrays of values at a constant horizontal spacing of 1,000 m. Grids generated with MINC (Webring, 1981) and subsequently calculated or derivative grids were identically georeferenced in a Lambert Conformal Conic Projection. The magnitude of the isostatic residual gravity field in areas with a paucity of measurement points is poorly constrained and thus precluded geologic interpretation in some areas.

Separation of Anomalies

Estimation of basin-fill alluvial thickness from gravity anomalies in the Mimbres Basin is complicated by the presence of substantial quantities of volcanic rocks of Tertiary age that also have the low densities that generate negative gravity anomalies. To quantitatively estimate the thickness of the basin-fill alluvium, it was necessary to separate the gravitational effect of the basin-fill alluvium from that of Tertiary volcanic rocks as well as consolidated sedimentary rocks of Mesozoic and Paleozoic age. This separation was accomplished through an iterative process similar to that described by Jachens and Moring (1990), Saltus and Jachens (1995), and Langenheim and Jachens (1996). The process is summarized in the steps below to obtain a first approximation of basin-fill thickness at each grid location. The basin-fill thickness is the sum of the thicknesses *h* for each successive "slab" or depth interval defined in table 2.

(1) Mapped geologic units were separated into four lithofacies groups (table 1), as previously discussed, according to the stratigraphic classifications of Anderson and others (1997) and Hawley (in Kennedy and others, 2000).

(2) A subset of the gravity measurement data set consisting of measurements collected above group 3 lithofacies was extracted from the main gravity data set. These data were gridded using the minimum curvature algorithm MINC (Webring, 1981) to generate a potential surface, B_0. This surface was a first approximation of the anomalous isostatic residual gravity from the "basement" rocks.

(3) The anomalous gravitational potential of the low-density basin fill, F_0, was first approximated by subtracting the basement field, B_0, from the total isostatic residual gravity field I (fig. 3). The value of F_0 at each grid location was then inverted by the appropriate depth-density relation (table 2) and the infinite slab formula from Garland (1979)

$$\Delta g = 2\pi\rho G h \qquad (1)$$

where Δg is the anomalous gravitational potential of the infinite slab, in meters per second squared; π is the constant 3.14; ρ is the difference in density of the slab interval from the Bouguer reduction density, in kilograms per cubic meter; G is the universal gravitational constant, in cubic meters per kilogram second squared (6.67×10^{-11} $m^3kg^{-1}\ s^{-2}$); and h is the slab thickness, in meters.

(4) A revised estimate of the anomalous gravitational potential, F_1, of the grid of basin-fill thickness, T, was calculated using the depth-density relations (table 2) by a Fast-Fourier Transform technique (Parker, 1972). The anomalous gravity values of the basement rocks data subset used in step 2 were adjusted to account for the

[1] The isostatic residual gravity field was derived from Bouguer gravity anomaly data by removing the gravitational effect of the compensating mass that supports topographic loads. The thickness of this compensating mass was calculated using averaged digital topography by assuming a crustal thickness for sea-level topography of 20 km, crustal density of 2,670 kg/m^3, and a density contrast between the crust and upper mantle of 0.3 kg/m^3. The reader is referred to Heywood (1992) for more information.

influence of the low-density basement fill on those gravity measurements. This adjusted set was then regridded to generate B_1, a revised estimate of the basement gravity field.

(5) As in step 3, the basement gravity field, B_n, was subtracted from the total isostatic residual gravity field, I, to obtain an improved estimate of the anomalous gravity field, F_n, from the basin fill. (The subscript n is an iteration identifier.) This field was inverted as in step 3 to obtain an updated estimate of basin-fill thickness, T_n.

Steps 4 and 5 were repeated for six iterations, which was sufficient to separate the "basement" and "basin-fill" isostatic residual gravity fields. The calculated basin-fill thickness was then imported into a geographic information system (GIS) to facilitate visualization and comparison with constraining seismic-refraction data (Ackerman and others, 1994; Klein, 1995) and drill-hole data (Clemons, 1986; Broadhead, 1991). The location and depth to bedrock in the deep exploratory drill holes (fig. 2) used to constrain the depth calculation are presented in table 3. Locations of drill holes and traces of seismic-refraction profiles are shown in figure 2.

Following comparison of calculated basin-fill thickness to the constraining information, density profile modification and other adjustments were made and steps 1 through 5 were repeated. The depth-density relations for lithofacies groups used for the final thickness calculation (fig. 4) are presented in table 2. For the size of geologic structures in the Mimbres Basin, locations more than 3 km from a known gravity measurement do not warrant estimation of alluvial-fill thickness from gravity data alone. To discourage such interpretation, these areas are depicted in black in figure 4. Calculated thickness near these areas should likewise be interpreted with caution. Readers may obtain digital gravity or magnetic data (Kucks and others, 2001) for New Mexico through the Internet at *http://greenwood.cr.usgs.gov/pub/open-file-reports/ofr-01-0061/data*.

Density Profiles

Information regarding the density of alluvial-fill deposits is typically obtained by analyzing drill cuttings, borehole density logs, or borehole gravity measurements. However, no such data were available for the alluvial-fill sediments in the Mimbres Basin. Although borehole density logs are available for some deep exploratory drill holes listed in table 3, these measurements were collected in deeper "bedrock" lithologies and therefore provide no information on density variations within the basin fill. The relation of rock

Table 3. *Location and depth to bedrock of deep exploration drill holes in the Mimbres Basin*

Well number (fig. 2)	Well name (fig. 2)	Well location		Bedrock depth (meters below land surface)
		North latitude	West longitude	
1	City of Deming #2	32°14.65'	-107°42.05'	1,250
2	McSherry #1	32°14.65'	-107°40.28'	1,244
3	City of Deming #1	32°14.43'	-107°41.80'	1,288
4	Hurt Ranch #1	32°14.15'	-107°53.63'	610
5	Skelly #1-A	31°51.87'	-107°23.27'	1,417
6	Sunray Mid-Continent #1	31°50.35'	-107°19.98'	152
7	Cockrell #1	32°18.93'	-107°54.57'	70
8	Guest & Wolfson #1 Diana	32°18.05'	-107°58.63'	27
9	Sycor Newton #1	32°19.37'	-107°57.37'	61
10	Seville Trident	32°18.40'	-107°58.28'	0

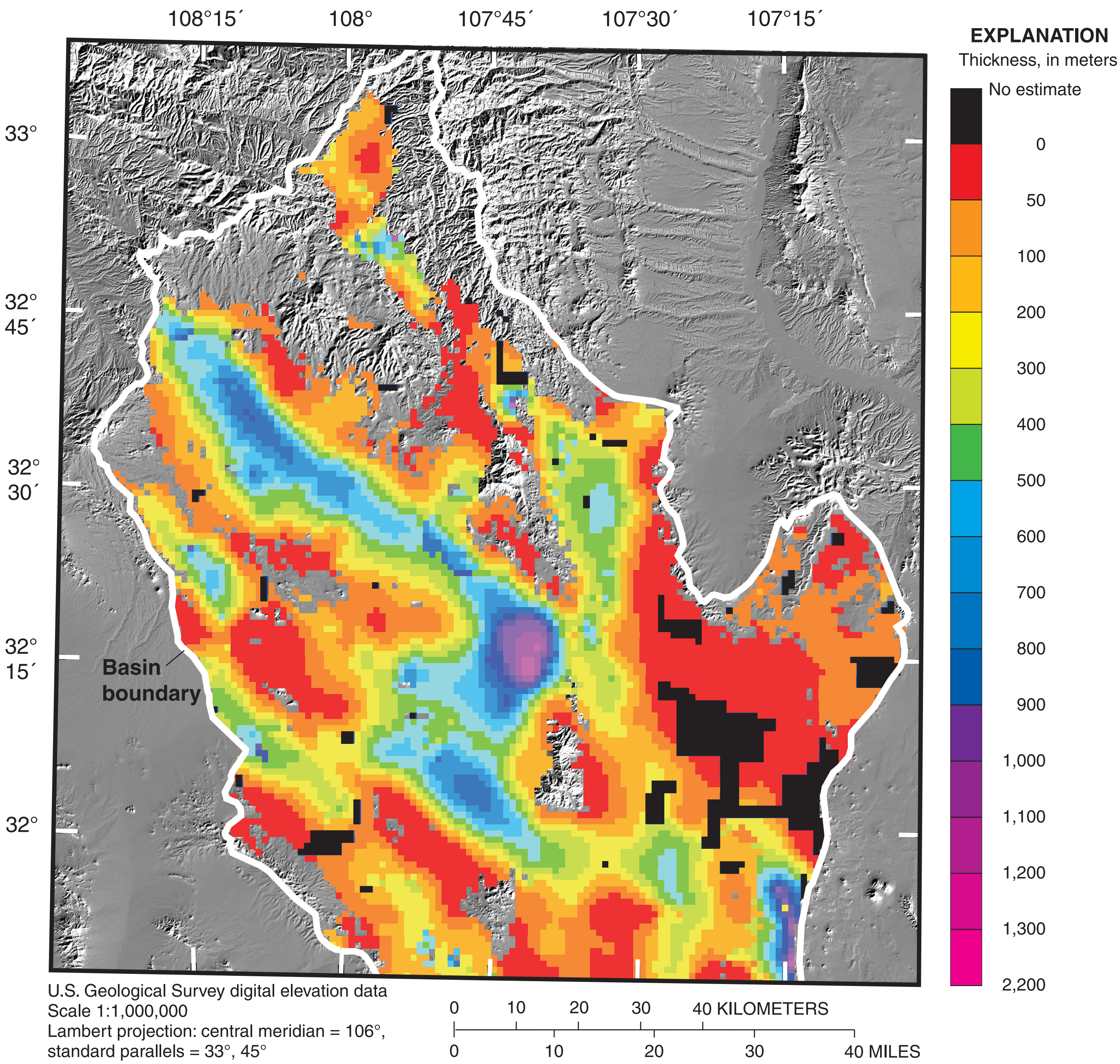


Figure 4. Estimated thickness of alluvial fill in the Mimbres Basin.

density to depth for the alluvial-fill deposits was therefore estimated by analogy with similar deposits elsewhere in New Mexico and the Western United States. Birch (1980, 1982) correlated density measurements using numerous wells to their presumed lithologic age. In his two-dimensional gravity-profile models, Birch used a value of 2,200 kg/m^3 for the Miocene and Pliocene deposits that correspond to the alluvial-fill deposits of this study.

Density-depth relations were assigned to model grid points on the basis of geology as mapped by Anderson and others (1997) and Kennedy and others (2000). Basin-fill rock types were divided into three groups, as described previously. Although density varies among the rocks in the fourth "basement" group, explicitly defining these densities was not necessary because density variations are accounted for in the regional gravity field.

ALLUVIAL-FILL THICKNESS IN STRUCTURAL SUBBASINS

The estimates of alluvial-fill thickness in the Mimbres Basin based on gravity analysis are presented in figure 4. Areas of bedrock outcrop within the basin are depicted in grey shaded relief. Areas devoid of gravity measurements within 3 km are shown in black. A graduated rainbow color scale indicates increasing (red to purple) estimated thickness of basin-fill alluvium.

Large areas in the basin, shown in red in figure 4, probably consist of bedrock overlain by a thin veneer of alluvium. Unless the water table is close to land surface in these areas, they probably do not overlie significant alluvial aquifers. Many of these areas overlie "horsts" that separate the "grabens," or subbasins, which are described separately in subsequent sections of this report. These subbasins attain depths up to 2,200 m (7,200 ft).

Mangas Trench

The Mangas Trench, also termed the San Vicente Subbasin (Kennedy and others, 2000) and the San Vicente half graben (Seager and others, 1982), is bounded on the north and east by the Silver City and Treasure Mountain fault zones (fig. 2) and by northwest-trending normal faults to the south. The southeastern portion of the Mangas Trench near Deming is also known as the Deming Basin (Kennedy and others, 2000). The Mangas Trench produces a prominent negative gravity anomaly (fig. 3) extending northwest from the Deming area to the Continental Divide north of the Big Burro Mountains. Hanson and others (1994) estimated an average thickness of 430 m for the basin-fill aquifer in the Mangas Trench. This gravity analysis suggests as much as 2,200 m of basin fill in the deepest parts of the trench near Deming (fig. 4).

Seventysix Subbasin

The Seventysix Subbasin, also referred to as the Iona Subbasin, is a northwest-trending graben separated from the Tres Hermanas Mountains and Burdick Hills (fig. 1) to the southwest by the Seventysix fault zone. It is bounded on the north by the Snake Hills fault zone (fig. 2). Hanson and others (1994) estimated the average thickness to be 1,070 m for the basin-fill aquifer in the Seventysix Subbasin. Seager (1995) interpreted approximately 200 m of alluvium of Tertiary and Quaternary age to overlie approximately 800 m of Tertiary basaltic andesite, undifferentiated volcanic rocks, and the Lobo Formation, which in turn unconformably overlie a Paleozoic sedimentary sequence. The deep exploratory drill hole "M.R. Young Oil Co. #1 Bisbee Hills" was drilled to a total depth of 2,184 m and penetrated 30 m of alluvium on top of Tertiary volcanic and older sedimentary rocks.

The Seventysix Subbasin is crossed by seismic-refraction line 7 (fig. 2) (Ackerman and others, 1994; Klein, 1995). A northwest-trending portion of this line (between shots 7-a10 and 7-a22) traverses the southwestern margin of the graben near the Seventysix fault zone and flanking pediment of the Tres Hermanas Mountains. A north-trending portion of the seismic line (between shots 7-a22 and 7-b4) crosses the middle of the graben to the flanking horst to the north. A refracting horizon with an average depth of approximately 200 m on both parts of this line probably represents the interface of unconsolidated basin-fill alluvium with underlying consolidated volcanic rocks. This geophysical interpretation agrees with the geologic interpretation of Seager (1995). Because of the paucity of other well-control data, this refracting horizon is the principal constraint on the thickness of basin-fill alluvium in the Seventysix Subbasin. If a layer of basaltic andesite, which may have a relatively high velocity, is present (as suggested by Seager), it may mask deeper, lower velocity layers, preventing reliable interpretation of deeper basin structure from the refraction data. This gravity analysis suggests a maximum basin-fill thickness of 874 m in the Seventysix Subbasin (fig. 4).

Mimbres Trench

The Mimbres Trench is a north-northwest-trending structure that extends from the Cookes Range to the Pinos Altos Range in the northern Mimbres Basin. Hanson and others (1994) estimated an average thickness of 300 m for most of the Mimbres Trench west of the Black Range. The thickness estimated in this study generally agrees with the earlier estimates. The thickest estimates (500-600 m; fig. 4) west of the Black Range are probably artifacts of the gravity interpolation process and are not constrained by drill-hole data.

Cross Graben

The Cross Graben, which connects the Mimbres Trench with the Mangas Trench, is also known as the Dwyer Subbasin (Kennedy and others, 2000). Hanson and others (1994) estimated an average thickness of 150 m for the basin-fill aquifer in this area. This analysis suggests that the basin fill thickens to the southeast up to about 400 m (fig. 4).

Florida Subbasin

The Florida Subbasin is composed of two north-trending structures located northeast and southeast of the Florida Mountains near the central part of the Mimbres Basin. These structures are distinctly separated into northern and southern grabens by an intervening horst just east of the Florida Mountains. The grabens correspond to the Akela and Mesquite Lake Subbasins of Seager (1995). Kennedy and others (2000) suggested that these structures be referred to as the Akela and Mesquite Lake Sections of the Florida Subbasin. Hanson and others (1994) estimated an average thickness of 150 m for the basin-fill aquifer in this subbasin, which is less than that estimated in this analysis. A paucity of gravity measurements to the east of these grabens precludes interpretation in that area.

Tres Hermanas Graben

Located northeast of the Cedar Mountain Range (fig. 1), the Tres Hermanas Graben (also referred to as the Hermanas Basin (Seager, 1995) and the Hermanas Subbasin (Kennedy and others, 2000)) trends northwest from the Mexican border to the Continental Divide. It is separated from the Seventysix Subbasin to the northwest by an intervening horst structure. Hanson and others (1994) estimated an average thickness of 760 m. This gravity analysis suggests that much of the basin is about 200 m thick, with a slightly deeper area to the southeast and a significantly deeper area (in excess of 500 m) to the northwest (fig. 4). A structural high, possibly a horst, appears to separate these deeper regions.

Columbus Subbasin

Hanson and others (1994) estimated the thickness of the alluvial-fill aquifer in the Columbus Subbasin, which is in the southern part of the Mimbres Basin, to vary from 170 to 760 m. Blandford (1987) constructed three hydrostratigraphic cross sections from water-well drill logs in the Columbus Subbasin. Four of these water-well logs were used to constrain the gravity model of basin-fill thickness. Two of the four were used to constrain the depth to the Malpais Basalt underlying the basin fill in the northwest part of the subbasin. This gravity analysis suggests that much of the basin is about 50 m thick, with a maximum basin-fill thickness of about 200 m (fig. 4).

Boundary Areas

This gravity analysis has revealed two additional areas, previously assumed to have bolson-fill thicknesses of about 15 to 30 m (Hanson and others, 1994), that appear to overlie thick alluvial fill. In the southeast corner of the Mimbres Basin on the west flank of the West Potrillo Mountains, Quaternary basalts presumably overlie basin-fill alluvium, which may be 1,000 m thick in some areas (fig. 4). On the western side of the Mimbres Basin, just east of the Continental Divide at N.32°20’, W.108°15’, basin-fill thickness is estimated to be as much as 500 m.

SUMMARY

Isostatic residual gravity anomalies in the Mimbres Basin contain a signal from low-density alluvial fill convolved with regional trends resulting in density variations in basement rocks. When separated from the regional trend, the signal from the alluvial fill may be inverted, assuming depth-density relations, to estimate the thickness of alluvial fill. Seismic-refraction, drill-hole, and surficial geologic data constrain resulting calculations of the alluvial thickness in the Mimbres Basin in southwest New Mexico. Estimates suggest that alluvial thickness beneath much of the Mimbres Basin is less than 100 m. The thickness of alluvial fill in structural grabens is much greater, typically as much as 300 m and locally as much as 2,200 m. Because Tertiary volcanic rocks that may be in proximity to alluvial basin fill have similar densities, differentiating these lithologies in the subsurface solely with gravity data is generally not possible. These estimates were obtained using the known surface distribution of the lithologies with limited subsurface drill-hole and seismic-refraction data.

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