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HYDROGEOLOGY OF THE ORTIZ MOUNTAINS AND VICINITY

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Abstract--Runoff from the Ortiz Mountains recharges sedimentary rocks peripheral to the range at about 1480 acre-feet per year, and moves radially away, draining to Arroyo Tuerto, Arroyo la Joya, Galisteo Creek and the Rio Grande. A small proportion emerges as springs. Transmissivity of the sedimentary beds is markedly enhanced in and near the Golden fault zone. Within the Ortiz range, the small recharge moves vertically, mostly in fractures, under unsaturated conditions; except for the Golden fault zone, which receives large recharge and is saturated to an elevation of about 7200 ft at Carache Canyon, the top of the saturated zone within the mountains may be below 6800 ft. Transmissivity of the fault zone is 400-440 ft^2/day.

INTRODUCTION

This paper summarizes and makes available the results of extensive hydrogeologic studies, including preparation of a single-layer regional ground-water flow model, in and around the Ortiz Mountains. Although little has been published, most of the basic information is available in the files of the State Engineer Office (SEO) in Santa Fe.

The first detailed studies of the hydrogeology of the Ortiz Mountains were by W. K. Summers, for Azcon Corporation and Gold Fields Corporation, beginning in 1976. Gold Fields operated the Ortiz open-pit gold mine from 1980 to 1987; pumping for water supply and dewatering of the mine has been the only significant withdrawal of water in the vicinity. Summers' reports are in SEO files under File No. RG-32970 et al.

The writer's studies, in 1988 through 1993 for Pegasus Gold Corp. and Lac Minerals (USA), Inc., have been related to water supply and dewatering of workings for proposed mining and beneficiation projects in the Carache Canyon area, and farther to the southwest (Fig. 1). These studies, partly in collaboration with James W. Mahar, are in SEO files under File Nos. RG-51887 and RG-50321.

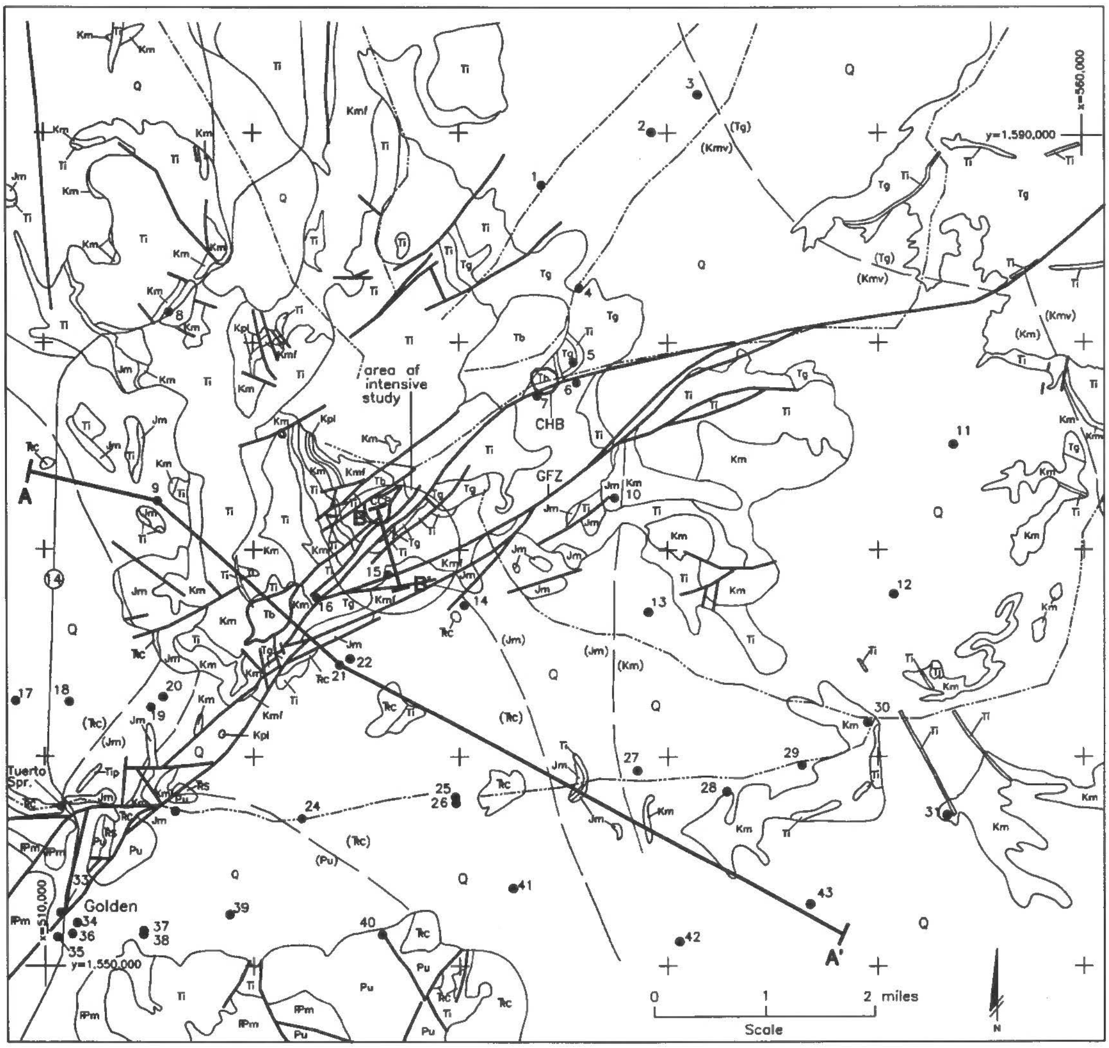

FIGURE 1. Geologic map of Ortiz Mountains and surrounding area, after Bachman (1975) and unpublished mapping by Pegasus Gold Corp. geologists. Heavy lines are faults: GFZ, Golden fault zone. Long-dashed lines are inferred subcrops beneath alluvium. Stratigraphic units: Q, Quaternary-age alluvium, colluvium, and fluvial sediments; Tb, Tertiary breccia (CHB, ore body in Cunningham Hill breccia pipe; CCB, Carache Canyon breccia pipe); Ti, Tertiary intrusive rocks; Tg, Galisteo Formation; Kmv, Mesaverde Group (including Kmf, Menefee Formation; and Kpl, Point Lookout Sandstone); Km, Mancos Shale; Kd, Dakota Sandstone; Jm, Morrison Formation; Je, Entrada Sandstone; Trc, Chinle Formation; Trs, Santa Rosa Sandstone; Pu, Permian rocks, undivided; Psag, San Andres Limestone and Glorieta Sandstone; Py, Yeso Formation; Pa, Abo Formation; Pm, Madera Formation.

HYDROGEOLOGIC PROPERTIES OF ROCK UNITS

The geologic units that constitute the system of aquifers and confining beds are shown on the geologic map and cross-section, Figures 1 and 2. Descriptions of these units may be found in many papers, particularly the studies by Stearns (1953), Disbrow and Stoll (1957), Kelley and Northrop (1975), Bachman (1975) and Maynard et al. (1990); the reports by Summers include a comprehensive summary of the stratigraphy. In this paper, emphasis will be on hydrogeologic properties of the units.

Small supplies for domestic and stock-watering use are obtained from wells in all stratigraphic units shown. Large-capacity wells have been completed in the Madera, San Andres, Glorieta, Morrison, and Mesaverde formations (Table 1). Table 1 includes only those wells (and one spring) for which data as to aquifer or water-quality properties are available; there are many other wells, hundreds of mineral-exploration holes, and many small springs within the area of Figure 1.

Most aquifer tests are summarized in Table 1. Transmissivity values given are for the partial thicknesses of the aquifer open to wells, and where a range is shown, transmissivity was calculated by more than one method, or the analysis was complicated by boundary effects. In some tests, the specific capacity of the well was greater than would be consistent with a storage coefficient in the confined-aquifer range, even though the aquifer is fully saturated and lies beneath lower-conductivity beds. This phenomenon may be attributable to leakage through vertical fractures. In addition to conventional pumping tests of wells in the area surrounding the range, there have been extensive studies (described below) of hydrologic properties and ground-water flow in two areas within the mountain itself.

Madera Formation

The Kelly Replacement well (no. 37, Fig. 1, Table 1) is completed in the Madera. Results of the aquifer test showed the influence of fracture-flow. A 68-hour constant-rate test at 450 gallons per minute (gpm) gave a specific capacity of about 8.4 gallons per minute per foot of drawdown (gpm/ft), and a transmissivity of about 2390 feet squared per day (ft^2/day) based on drawdown measurements after 300 minutes (Table 1). Analysis of recovery data gave a much higher apparent transmissivity, probably influenced by delayed recovery due to refilling of fractures near the water table. The hydraulic conductivity of the Madera is probably much less where the unit is at greater depth and unfractured.

San Andres Limestone, Glorieta Sandstone and Santa Rosa (?) Sandstone

The Iron Vein test well (no. 21, Fig. 1, Table 1) is completed open-hole in the Glorieta Sandstone (1425-1495 ft; depths are below ground level), the San Andres Limestone (1290-1425 ft), the Santa Rosa Sandstone (1070-1180 ft), mudstone beds of the lower part of the Triassic section, and thick andesite porphyry sills. The well is close to the Golden fault zone, and it was hoped that deep ground-water circulation associated with the fault zone had led to enhancement of permeability by solution in the San Andres, but this seems not to be the case. The well was tested for 8 hours at about 50 gpm, with a specific capacity of only about 0.3 gpm/ft. Transmissivity of the entire open interval was estimated at about 75 ft^2/day.

Well TB-14 (no. 18, Fig. 1, Table 1) was tested by W. K. Summers, who estimated transmissivity at 3460 to 5010 ft^2/day. Here the San Andres is beneath the basal Chinle Formation and perhaps beds of the Bernal Formation, but at shallow depth (the well is 275 ft deep), and it is clear that hydraulic conductivity has been enhanced by solution.

Chinle Formation

A test of well TB-11 (no. 24, Fig. 1, Table 1), by Summers, was interpreted to give a horizontal hydraulic conductivity for the 68-ft open interval of about 0.05 ft/day. Summers concluded that "as much as 90 percent of the water was derived from beds overlying or underlying the interval," and that vertical hydraulic conductivity is much larger than the horizontal component, owing to fracturing. Transmissivity of the lower part of the Chinle and Santa Rosa Sandstone, derived from ground-water flow model calibration as described below, is approximately 14 ft^2/day.

Morrison Formation

There have been two tests of wells in the Morrison Formation, one, an injection test by Summers of well LM-1, and the other of well LC-GM-1 (nos. 28 and 20, Fig. 1). LM-1 is far from the Golden fault zone, and probably intersected no fractures; hydraulic conductivity for the 100-ft open interval was estimated at 0.001 ft/day.

Well LC-GM-1 is close to the Golden fault zone, completed in 260 ft (370-630 ft) of yellow, fine-grained sandstone cut by two fracture zones recognized in drilling. The well was tested at 300 gpm, with a one-day specific capacity of 28 gpm/ft and a transmissivity estimated at 16,000 ft^2/day. The apparent transmissivity is doubtless a reflection of fracture flow.

Mancos Shale

The Mancos is not commonly considered an aquifer, but sandstone beds within it may yield water to wells, and igneous intrusions may create local fracture networks which enhance permeability; six wells listed in Table 1 tap the Mancos. Well TB-8 (no. 12, Fig. 1, Table 1) was tested by Summers. The pumping rate was 1.5 to 3.6 gpm, over a total of 6.4 hours, and the specific capacity of the well ranged from 0.11 down to 0.03 gpm/ft of drawdown. Transmissivity was estimated at 2.0 to 5.6 ft^2/day. Transmissivity of the Mancos Shale and Morrison Formation, away from the Golden fault zone, was estimated by model calibration at about 6 ft^2/day.

Mesaverde Group

Seven wells shown on Figure 1 tap the Mesaverde Group, which includes the Point Lookout Sandstone, Menefee Formation and Harmon Sandstone (Table 1). Well OR-3 (no. 5, Fig. 1, Table 1) and the New Las Norias well (no. 4) were tested by Summers. Transmissivity was 60 to 441 ft^2/day for the former and 58 to 75 ft^2/day for the latter, but both wells are in an area of complex structure and much fracturing, close to the Cunningham Hill breccia pipe, and hydraulic conductivity is probably greater than would be found in unfractured Mesaverde rocks.

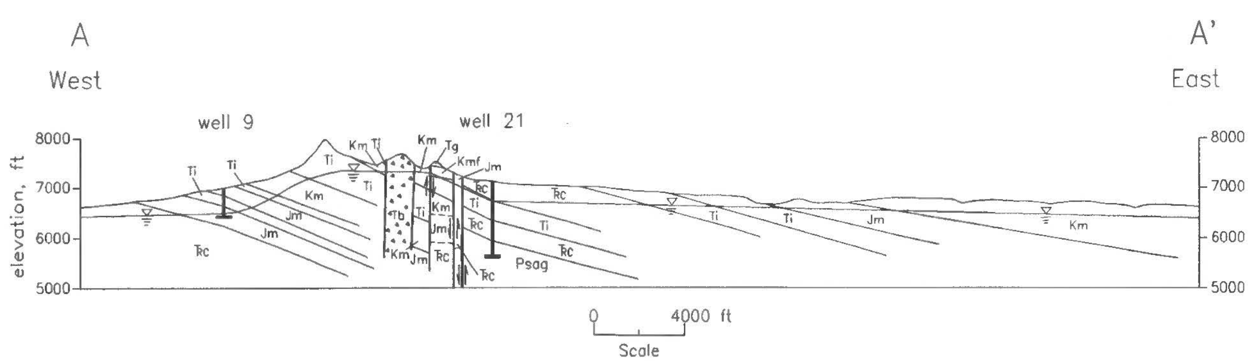

FIGURE 2. Cross-section A-A'. See Figure 1 for line of section and explanation of symbols.

TABLE 1. Summary of records of wells, aquifer tests, and chemical quality of water in Ortiz Mountains and vicinity.

Map index number	Name	Total depth, ft	Aquifer (symbols as Fig. 1)	Elevation, ft.	Depth to water, ft	Date of Measurement	Pumping rate during test, gpm	Transmissivity, ft²/day	Total dissolved solids, mg/l	Reference to SEO File No. for data
1	OBW-2	242	Kmv	6658	51	8-88	--	--	356	RG-32970
2	OBW-4	333	Kmv	6354	73	5-84	--	--	710	RG-32970
3	Pinon 2	700	Kmv	6316	102	8-88	--	--	--	RG-32970
4	New Las Norias	375	Kmv, Ti	6780	41	6-84	14.2	58-75	1091	RG-32970
5	OR-3	566	Kmv	7066	329	6-84	47-150	60-441	685	RG-32970
6	OR-2	535	Ti	7035	261	2-91	--	--	900	RG-32970
7	OBS-64	768	breccia	7180	380	6-84	103	4000	781	RG-32970
8	New Stagecoach	104	Km	6850	32	1-91	--	--	2882	RG-51887
9	Ball 24, Gypsy Q.	575	Jm	6999	512	1-91	--	--	--	RG-51887
10	TB-10	193	Ti	6871	158	12-91	--	--	1100	RG-51887
11	TB-9	80	Tg or Km	6281	23	10-79	--	--	--	RG-51887
12	TB-8	255	Km	6432	27	10-79	1.5-3.6	2-5.6	412	RG-32970
13	Gage	155	Jm	6753	116	11-84	--	--	650	RG-51887
14	TB-4	410	Trc	7088	315	12-91	--	--	658	RG-51887
15	CC-GM-2	500	Kmv	7340	320	10-92	--	--	988	RG-51887
16	Ball 25	235	Kmv, Ti	7380	dry	before 1979	--	--	--	RG-32970
17	TB-19	260	Trc	6577	195	1-91	--	--	--	RG-51887
18	TB-14	275	Psag	6682	206	1-91	2.4-16.7	3460-5010	>650	RG-51887
19	TB-13	310	Jm	6772	298	3-90	--	--	--	RG-51887
20	LC-GM-1	645	Jm	6840	355	3-90	100-300	16,000?	1780	RG-51887
21	IV-TW-1	1500	Psag	7080	378	3-90	50	75?	526?	RG-51887
22	TB-16	?	Trc	7100	393	2-90	--	--	--	RG-51887
23	TB-12	140	Trc	6592	31	1-91	--	--	--	RG-51887
24	TB-11	235	Trc	6730	157	1-91	2.5-8.6	22-610	343	RG-51887
25	TB-18	350	Trc	6815	248	10-79	--	--	--	RG-32970
26	TB-18A	?	Trc	6815	255	10-79	--	--	--	RG-32970
27	TB-1	465	Jm	6617	394	10-79	--	--	--	RG-32970
28	LM-1	690	Jm	6565	280	1-91	0.04	K=0.001 ft/day	2041	RG-32970
29	TB-5	300	Km	6520	117	3-79	--	--	--	RG-32970
30	TB-6	?	Km	6417	29	10-79	--	--	--	RG-32970
31	Bullmill Camp	104	Km	6408	8	1-91	--	--	--	RG-51887
32	Tuerto (Spring)	--	Trc	6480	--	--	5	--	1200±	RG-51887
33	Gilavez	14	Qal	6620	9	10-90	--	--	--	RG-51887
34	Henderson East	--	Pm	6670	33	8-91	--	--	--	RG-50321
35	Henderson West	--	Pm	6645	32	8-91	--	--	--	RG-50321
36	Henderson House	100	Pm	6660	49	8-91	--	--	--	RG-50321
37	Kelly	600	Pm	6819	--	8-91	--	--	--	RG-50321
38	Kelly Replacement	635	Pm	6819	104	8-91	450	2390	400±	RG-50321
39	TB-15	250	Pu, Pm	6846	154	11-79	--	--	--	RG-50321
40	TB-17	450	Pu?	7080	324	11-79	--	--	--	RG-32970
41	TB-3	442	Trc	6887	307	1-91	--	--	--	RG-51887
42	TB-2	595	Trc	6700	454	1-91	--	--	--	RG-51887
43	TB-7	528	Km?	6690	450	3-79	--	--	--	RG-32970

Galisteo Formation

The Galisteo was not tested. Transmissivity derived from model calibration, for the area north and east of the Ortiz Mountains in which the Galisteo is likely to furnish water to wells, is 6 to 31 ft²/day.

Dikes and sills

Several pressure-injection tests of Tertiary intrusive rocks are summarized in a following section and in Table 2.

Cunningham Hill breccia

The breccia pipe includes tuffs and volcanic breccia, fringed by felsitic porphyry and quartzite breccias; the stock intrudes Mesaverde Group beds. The Cunningham Hill (Ortiz Mine) ore body is in one of the quartzite breccias (Nicholson, 1979, p. 27).

A well completed in the Cunningham Hill breccia ore body before mining began (OBS-63; Summers report, SEO File No. RG-32970) produced 39.5 gpm during a 7-day test; hydraulic conductivity was estimated at 5.3 ft²/day. This well is not included in Table 1 because the well and surrounding rock have been removed by mining.

Well OBS-64 (no. 7, Fig. 1, Table 1) was completed in the breccia pipe, but outside the limit of mining, and became a supply well for the operation. It is located in the fracture zone associated with the Golden fault zone. Summers tested the well. A step-drawdown test gave inconclusive results, in that the well continued to develop during pumping,

TABLE 2. Summary of pressure-injection and slug-test results, Carache Canyon area of Ortiz Mountains. Depth is vertical depth to midpoint of 40-ft test interval in angle hole, unless otherwise noted.

Geologic unit or structure	Depth, ft	Flow rate, gpm	Hydraulic conductivity, ft²/day
pressure-injection tests			
Golden fault zone	185	1.3 - 54.2	0.02 - 0.39
North Golden fault	445	5.0 - 91.0	0.44 - 0.57
trachytic latite dike	470	0.5 - 4.5	0.004 - 0.02
breccia pipe	550	43.2 - 58.0	0.26 - 0.29
	630	0.0 - 0.09	0.0 - 0.0004
	420 - 660	50.6 - 75.8	0.053 - 0.056
breccia/Menefee contact	480	1.8 - 4.2	0.01 - 0.02
minor fault in latite-andesite sill	393	2.9 - 10.6	0.023 - 0.052
	524	3.8 - 33.5	0.023 - 0.14
Menefee Formation	246	5.9 - 17.9	0.07 - 0.11
	297	0.0 - 0.18	0.0 - 0.001
Point Lookout Sandstone	328	0.5 - 6.8	0.005 - 0.037
Mancos Shale/sill contact	459	1.4 - 3.7	0.01 - 0.02
slug tests (Bouwer-Rice)			
Galisteo Formation	417-503		1.73
Mancos Shale	532-586		0.072
	553-558		0.009
Mancos Sh. (siltstone)	705-711		0.004
Mancos Sh./Point Lookout contact	365-405		0.014

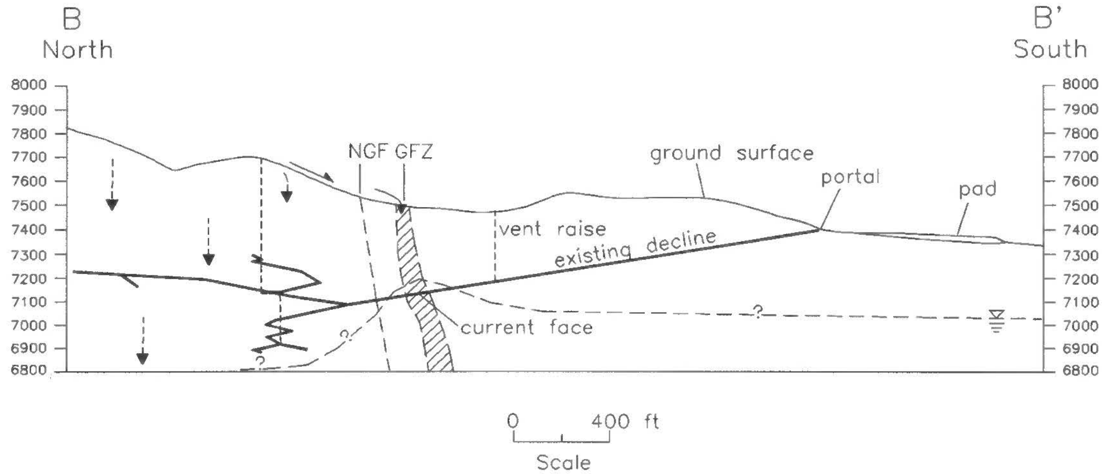

FIGURE 3. Cross-section B-B' along line of Carache Decline; workings shown to north of Golden fault zone (GFZ) are planned. Solid-line arrows represent flow on surface and recharge to Golden fault zone; dashed-line arrows represent vertical flow under unsaturated conditions. Dashed line indicates water table. NGF, North Golden fault. See Figure 1 for line of section.

but a test at a slowly declining rate (from 110 to about 95 gpm), with two observation wells, was interpreted to show a transmissivity of about 4000 ft^2/day (Table 1). Hydraulic conductivity of the breccia was estimated at 5 to 10 ft/day, depending on the estimate of saturated thickness contributing to the well.

Carache Canyon breccia

The Carache Canyon breccia, unlike the Cunningham Hill breccia, consists of angular fragments and blocks of shale and sandstone of the Mesaverde Group and Mancos Shale, and latite-andesite porphyry sills, in a matrix of black, clayey rock flour. The hydraulic conductivity of the breccia as a whole is low, about 0.05 ft/day in one pressure-injection test of a 240-ft-long interval of open hole (Table 2), although individual blocks of sandstone may have much higher conductivity.

GEOLOGIC STRUCTURE

The Ortiz Mountains are the expression of a series of thick Tertiary (30-34 Ma) latite-andesite porphyry sills, intruded into the sequence of Mesozoic sedimentary rocks, and penetrated by several late breccia pipes (Figs. 2 and 3). Sedimentary beds surrounding the mountains dip to the northeast at 5 to 10°. A prominent fault zone, locally called the Golden fault zone but actually an extension of the regional Tijeras fault (e.g., Kelley and Northrop, 1975), lies along the southeast margin of the range. The Golden fault zone, the complex network of other faults associated with it, and the fracturing that accompanies the faults, are important controls on ground-water flow. The role of the Golden fault zone is discussed below.

GROUND-WATER FLOW

Ground-water in sedimentary rocks surrounding the Ortiz Mountains

Potentiometric contours for the area surrounding the Ortiz Mountains are shown on Figure 4. The water-level information from which the contours were derived comes primarily from measurements in wells within the Ortiz Mine Grant, and USGS and SEO records; a summary of the data, which includes records of about 500 wells and springs, may be found under SEO File No. RG-51887. Recharge to the ground-water system occurs principally in the mountain-front of the Ortiz range, and in and bordering San Pedro Mountain and South Mountain. The work of Anderholm (1994, p. 21) near Santa Fe indicates little or no direct recharge at lower elevations in the area of Figure 4.

Flow is, in general, radially away from the mountains, and toward the principal drainages and the Estancia Valley. Arroyo La Joya and Arroyo Tonque are ground-water drains.

Rates of recharge at the periphery of the Ortiz range have been estimated through ground-water flow modeling. A single-layer model was prepared and adjusted to reproduce the steady-state distribution of ground-water head, and then to reproduce the response of water levels to pumping at the Ortiz Mine during 1980 through 1986. The variables in the calibration process were transmissivity and recharge rate, with values for storage coefficient assumed.

The recharge rates were compared with estimates from an analysis (by Summers), based on stream-gaging records, of the ground-water discharge to Galisteo Creek, allocating the origin of all of the inflow to the south side of the creek to recharge bordering the part of the Ortiz range where ground-water flow is tributary to the creek. The results were approximately the same as those derived from the flow model, but each method has serious weaknesses. In the model-based estimate, the assumption of storage coefficient introduces a large potential error that influences the drawdowns in wells. In the other estimate, the proportion of inflow from the each side of Galisteo Creek must be assumed, and this may also lead to error.

Recharge was estimated at an average of 176,000 ft^3/day (1480 acre-ft/yr) for the entire periphery of the mountain range, or roughly 12,000 ft^3/day per mile of mountain-front.

Ground-water within the Ortiz Mountains

Ground water conditions have been examined in two areas within the range: the Cunningham Hill breccia pipe and vicinity at the eastern end

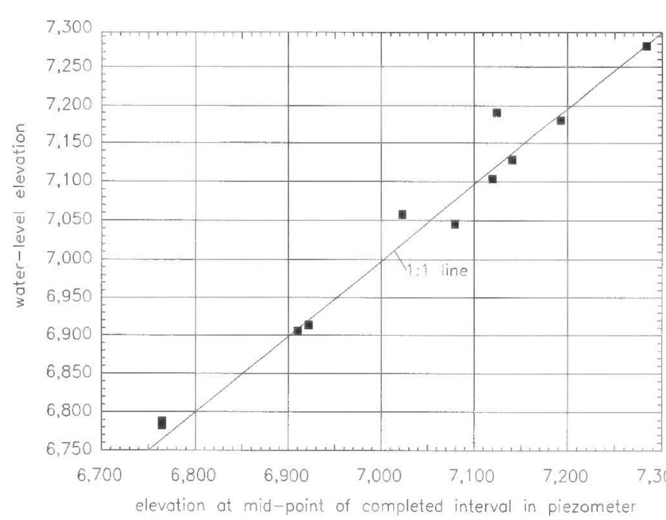

FIGURE 4. Plot of water-level elevation versus elevation of mid-point of screened interval for piezometers in the vicinity of Carache Decline.

of the range, site of the Ortiz Mine, and the area of the Carache Canyon Decline and the Carache breccia pipe (Fig. 1).

Cunningham Hill area

Reports by W. K. Summers describe the Cunningham Hill area. Summers found that,

> Ground water in the Ortiz Mountains occurs in and is transmitted through fractures. Two fracture domains are evident: One occurs within the Tijeras Structural Zone; the other lies on either side. Within the structural zone, hydraulic conductivities of the rocks range from 1 to more than 100 gpd/ft^2 and the specific yield is about 0.005; outside the structural zone, the hydraulic conductivity of the rocks ranges downward from 1. to 0.001 gpd/ft^2 and the specific yield is 0.001 [from Abstract, 1977 report].

Carache Decline area

The Carache Decline (Figs. 1, 3) is an exploratory tunnel about 1720 ft long; proposed extensions of the workings would add about 4661 ft. The present (February 1995) face is within the Golden fault zone. As the decline was originally proposed, all of the workings would have been northwest of the Golden fault zone, and the drilling information available at the time indicated that they would have been entirely in unsaturated rocks. It was recognized that water would be found in fractures and permeable beds, but in general the workings were expected to be self-draining.

The course of the Carache Decline as it was actually driven in 1990 was somewhat different from that of the original proposal, however, and the tunnel intersected the Golden fault zone; a water flow of about 43 gpm was encountered. The operator applied for a permit, under the New Mexico Mine Dewatering Act, to pump a total of up to 122 acre-ft from the workings during a one-year period of underground exploration. Estimation of the inflow to the workings became an issue.

A concentrated study of the hydrogeology of an area of about 90 acres in the vicinity of the Carache Decline was undertaken (Fig. 1). The work included: (1) evaluation of the records of 146 air-reverse-circulation (RVC) mineral-exploration holes (a total of 87,530 ft of vertical and angle drilling) drilled since mid-1989; (2) geologic information from 161 vertical and angle core-holes (162,253 ft in total); (3) five slug tests in piezometers, and 13 pressure-injection tests; (4) evaluation of the inflows to the decline during driving to the present face; (5) a "pumping test" conducted by draining the decline and maintaining a constant water-level for about 9.1 days; and (6) interpretation of the records, which included the period of the pumping test, of 12 piezometers. Records of these studies may be found in State Engineer Office files (File No. RG-50321).

Logs of the air-reverse-rotary holes showed, for each one-foot interval, whether the hole was "dry," "damp," or producing water, and gave estimates of the rates of water production where it existed. Many of the RVC holes were logged as "dry" at bottom-hole elevations well below 6800 ft.

The five slug tests gave hydraulic conductivity values for the Galisteo Formation and the Mancos Shale. The Bouwer-Rice (1976) method, for unconfined conditions, was selected because the test intervals are in the unsaturated zone. The conductivity values are those that would apply under saturated conditions. In the Galisteo Formation at least, these values are probably much greater than the conductivities that actually govern flow in the unsaturated zone.

Pressure-injection tests gave values for saturated hydraulic conductivity for typical rock types, and for several fault zones (Table 2). The tests followed standard methods (e.g., Hunt, 1984), and were at the relatively high pressures required to give conductivity values at the standard 10 bars. The results undoubtedly lead to overestimates of hydraulic conductivity because of opening of fractures by the injection of fluid itself.

Hydraulic conductivity of the Golden fault zone itself was estimated, by the Dupuit relation, from the water-level response in a piezometer in the fault zone during the pumping from the Carache Decline. The pumping rate was a nearly constant 41.1 gpm, once the tunnel had been drained; the piezometer was about 150 ft from the tunnel. The pre-pumping head above the tunnel was assumed equivalent to the water-level elevation in the tunnel before pumping began. The hydraulic conductivity of the fracture zone associated with the almost-vertical Golden fault, estimated at approximately 100 ft wide, was calculated at 0.8 to 2.2 ft/day, depending on the assumption as to saturated thickness. Transmissivity calculated for the fracture zone, however, is in the narrower range 400 to 440 ft^2/day.

The pattern that emerges from the work is that except for the Golden fault zone, flow is vertical, under unsaturated conditions, to great depth within the mountain range (Fig. 3). Flow on the surface recharges the Golden fault zone, and the recharge supports a ground-water ridge along the fault zone. The hydraulic gradient is very steep along its sides. Flow within the fault zone is toward discharge at Tuerto Spring, which rises where the fault zone crosses Arroyo Tuerto (Fig. 1), and into the sedimentary rocks adjacent to the Ortiz range to the northeast.

Drilling may not have reached the water table near the core of the mountains. Information from the piezometers in the Carache area, including a vertical hole to 920 ft (water-level about 892 ft, elevation 6783), shows that ground-water head is approximately the same as well-screen elevation in all cases (Fig. 4); it follows that the vertical-direction hydraulic gradient is about unity, and that flow is downward and under unsaturated conditions except for isolated accumulations in fractures. The top of continuous saturation within the mountains is likely to lie below 6800 ft elevation, even though the water table is several hundred feet higher in the Golden fault zone on the southeast border of the range (Fig. 5).

The relatively low gradients that would be inferred if the top of the saturated zone is near 6800 ft over a large area within the mountain range do not imply that hydraulic conductivity is high, but rather that very little water is flowing. Fracture apertures close with depth, and hydraulic conductivity at 1000 ft or more is likely to be several orders of magnitude less than it is near the surface.

GROUND-WATER QUALITY

A very general indication of chemical quality is given, in terms of total dissolved solids concentration (TDS), in Table 1. Full chemical analyses are available for most of the wells for which TDS is given, and many analyses are available for some wells, in State Engineer Office records under the file numbers indicated.

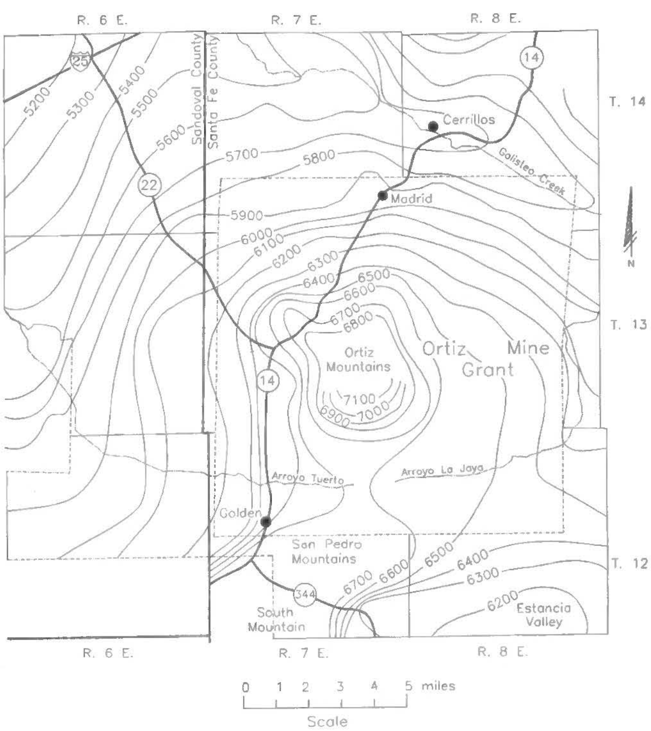

FIGURE 5. Water-table map of Ortiz Mountains and surrounding area.

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