HYDROGEOLOGY AND WATER RESOURCES OF THE CUBA QUADRANGLE, SANDOVAL AND RIO ARRIBA COUNTIES, NEW MEXICO

by

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ABSTRACT

The Cuba Quadrangle is on the extreme eastern side of the San Juan Basin with parts of the area in the San Pedr Mountain and on the extreme southwestern flank of the Chama Basin. The area has a semiarid climate and water is an important factor in controlling the development of the area. Presently most surface water has been appropriated leaving ground water the major source of future water supplies. Because of the geologic structure of the area the ground-water potential is good. Presently terrace gravels, alluvium, the Cuba Mesa Member of the San Jose Formation and the Poleo Sandstone Member of the Chinle Formation are the major aquifers being utilized. The quantity of water which may be produced from terrace gravels and alluvium is limited but the quality of water obtained from them generally contains less than 600 ppm total dissolved solids. The Cuba Mesa Member of the San Jose and the Poleo Sandstone Member of the Chinle are the most extensively developed aquifers. Proper well construction and sanitation are very important obtaining good quality water from these aquifers. The Ojo Alamo Sandstone is used to a limited extent as an aquifer bu generally it yields water which is very high in sulfate. Potential aquifers which are not presently developed but would be expected to yield significant quanities of potable water are the Cliff House Sandstone, Point Lookout Sandstone Dakota Sandstone, and Madera Formation.

Many of the aquifers are recharged by infiltration of precipition and snow-melt, and to a lesser extent by bed loss from the many streams in the area. Much of this water moves through the area and does not discharge in the study area.

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INTRODUCTION

The San Juan Basin is an energy-resource-rich area which is presently being developed. Near Grants and Gallup, New Mexico, large deposits of uranium are being mined and further exploration is discovering new deposits. Coal is being mined in many areas in the basin and other coal reserves have been discovered and mines proposed. Because the basin has a semiarid climate, water is an important factor in controlling the development of these resources. Presently most surface water has been appropriated leaving ground water the major source of future water supplies.

In 1974 the New Mexico Bureau of Mines and Mineral Resources, the United States Geological Survey, and the New Mexico State Engineer engaged in a study of the San Juan Basin's hydrogeology and water resources. The Bureau's responsibility in this study is to evaluate the hydrogeology of the Basin. To complete this each aquifer was studied at a regional scale, cross sections were prepared, and the petrography of selected rock units was studied. In addition to the regional portion of this study four 15'-quadrangle-sized areas were studied in detail to evaluate the hydrogeology and water resources on a local scale. The location of each quadrangle was chosen so a unique situation or problem in the basin could be studied.

The purpose of this investigation was to study in detail the hydrogeology and water resources of the Cuba 15'

Quadrangle. This area was picked because the hydrogeology and water resources of the eastern side of the San Juan Basi had not been studied in detail for quite some time and because of the expected increase in population due to the development of energy resources in the area. The specific objectives of this study were to evaluate the ground-water potential of the many aquifers in the area and to estimate the effect San Pedro Mountain may have in contributing recharge to the Basin.

LOCATION

The Cuba 15' Quadrangle is located in southwestern Rio Arriba County and in northwestern Sandoval County (fig. 1). The area is bounded by latitudes 36° and 36° 15′ North and longitudes 106° 45′ and 107° West. The area contains the San Pedro Wilderness Area and is composed mainly of U. S. Forest Service land but also contains private land and the towns of Cuba, La Jara, Regina, Gallina, and Capulin. The area is on the extreme eastern side of the San Juan Basin with parts of the area in the San Pedro Mountain and on the extreme southwestern flank of the Chama Basin.

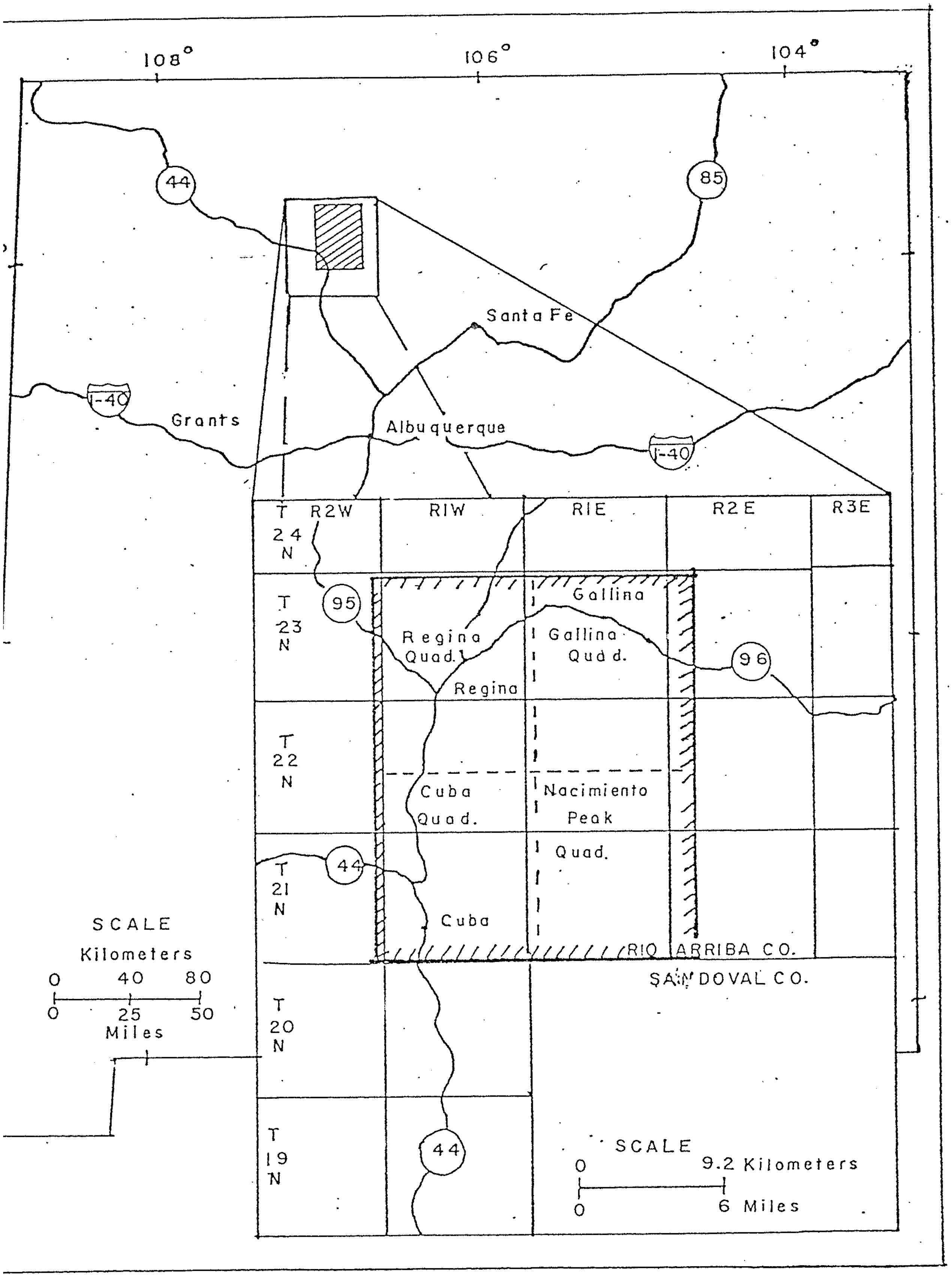

Figure 1. Location of study area(hachured); base modified from Gibson (1975).

APPROACH AND METHODS

The study is based on geologic and hydrologic data collected in the field, water quality and petrographic data obtained in the laboratory, and published data compiled from the literature on the area.

In the field, the geology was studied by checking existing maps, mapping the unmapped part of the area (Regina 7.5' Quadrangle), measuring five stratigraphic sections (Appendix A), and collecting representative rock samples of the major aquifers. The water resources of the area were studied by talking with local residents to get a better understanding of the availability of water and water quality problems in the area. Thirty-one water samples were collected from selected wells and springs. Where possible, depth to water and the depth of the wells were measured (Appendix D).

In the laboratory, seven rock samples were studied in thin section with a petrographic microscope (Appendix B) and ten samples were disaggregated and their texture analyzed with sieves and hydrometer (Appendix C). Thirty-one water samples were chemically analyzed for major dissolved constituents by the New Mexico Bureau of Mines and Mineral Resources Chemistry Laboratory (Appendix E). Six well logs were examined as an aid in drawing geologic cross-sections and estimating individual formation thicknesses (Appendix F).

A search through the existing literature dealing with the geology and water resources of the area was carried out. This yielded much information of the physiography, geology, hydrology, and water resources of the area.

Most quantitative information in this report is given in metric units, followed by British equivalents in parentheses. The conversion factors used in this report are presented in Appendix G. Approximate values, both metric and British, have been rounded and thus may not be exactly equivalent.

PHYSIOGRAPHY

The study area was divided into three provinces: Hogback Belt, Chama Slope, San Pedro Mountain (fig. 2). Although these provinces were recognized on the basis of their unique hydrogeologic setting (as will be shown below), they are also physiographically distinct and thus provide a useful approach to the following discussion.

Hogback Belt

The Hogback Belt is located on the western side of the province (fig. 2). Near the mountain front sandstone cuestas or hogbacks separated by broad valleys, formed by the less erosion-resistant shales, are the dominant landforms south of the Rio Puerco and north of San Jose Creek. Farther west from the mountain front the dip of the strata decreases and

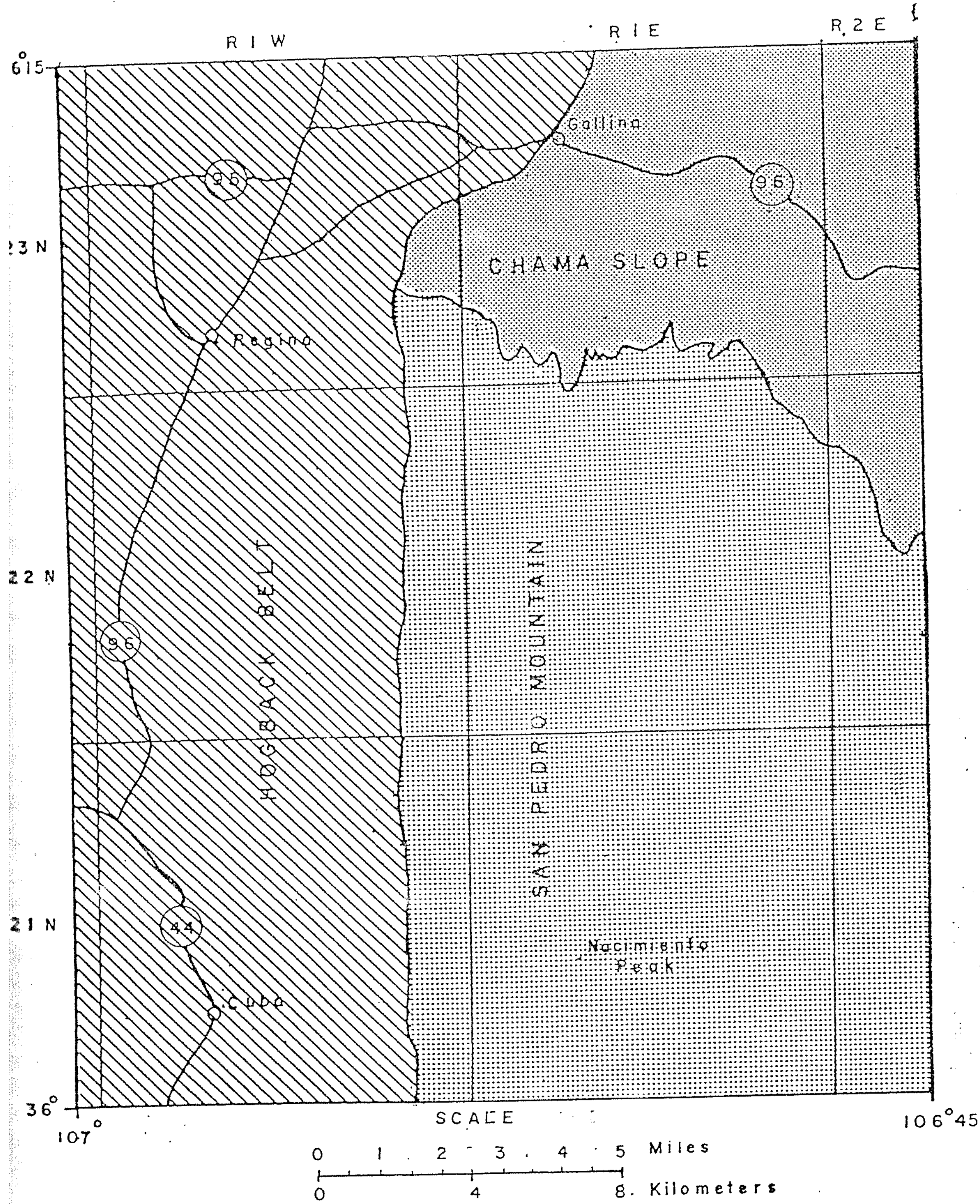

Figure 2. Hydrogeologic provinces of the study area.

sandstone-capped mesas are the predominant landform. Between the Rio Puerco and San Jose Creek large west-sloping gravel terraces predominate. In this province several deep stream valleys have cut through the terraces exposing the steeply dipping sedimentary rocks below.

Chama Slope

This province is in the northeast portion of the study area and is dominated by gently to moderately dipping Mesozoic and Paleozoic sedimentary rocks; dip is northward off San Pedro Mountain. In this province sandstones form large cuestas or mesas and the less resistant shales form large valleys between them. The province is heavily forested except where the land has been cleared for farming. The Chama Slope is on the extreme southwestern flank of the Chama Basin and is separated from the San Juan Basin by the Archuleta Anticlinorium.

San Pedro Mountain

Most of the eastern side of the study area is in the San Pedro Mountain province. This province is the northernmost extention of the Nacimiento Uplift. Elevations range from approximately 2680 - 3220 m (8800 - 10,590 ft). The Nacimiento Fault scarp was arbitrarily chosen as the western boundary of the province and the contact between the Madera Limestone and the Abo Formation was arbitrarily chosen as the northern boundary. With the exceptions of the western margin and local stream-cut valleys, the province has little topographic relief. The province is the headwaters for the Rio Puerco, Rio de las Vacas, and Rio Gallina, and is drained by many other smaller streams. The province is underlain by Mississippian and Pennsylvanian sedimentary rocks and Precambrian igneous and metamorphic rocks. The bedrock is generally covered with a thin veneer of alluvium or colluvium.

CLIMATE

The study area has a varied climate as a result of its varied topography. The U. S. Forest Service operates a weather station for the U. S. Weather Bureau in Cuba. For a thirteen-year period (1963 - 1978) the average annual precipitation was 32.33 cm (12.73 in), with most of the precipitation occurring during the months of July, August, and September as a result of afternoon orographic thunderstorms. The average annual temperature for Cuba is approximately 8° C (46° F) with July being the warmest month and December and January being the coolest months (U. S. Weather Bureau Files, Albquerque, New Mexico, weather data).

ACKNOWLEDGEMENTS

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GEOLOGIC SETTING

STRATIGRAPHIC FRAMEWORK

Precambrian metamorphic and igneous rocks; Paleozoic, Mesozoic, and Tertiary sedimentary rocks; and Quaternary sediments are exposed in the study area (Table 1).

Table 1. Generalized stratigrphic column for Cuba Quadrangle; modified from Baltz (1967).

Erathem	System	Series	Lithologic Unit	Thickness meters (f
Cenozoic	Quaternary	Recent and Pleistocene	Alluvium	0 - 42 (0 - 140
			Unconformity	
	Quaternary or Tertiary	Pleistocene or Pliocene	Terrace Gravel	0 - 35 (0 - 110
			Unconformity	
	Tertiary	Eocene	Abiquiu Fm.	0 - 15 (0 - 50)
			Unconformity	
			San Jose Fm.	61+ - 610 (200+ - 20
			Unconformity	
		Paleocene	Nacimiento Formation	175 - 304 (537 - 100
			Ojo Alamo Sandstone	27 - 60 (90 - 195)
Mesozoic	Cretaceous		Unconformity	
			Kirtland Shale/ Fruitland Fm.	35 - 58 (116 - 190
			Pictured Cliffs Ss.	0 10 (0 - 33)
			Lewis Shale	304 - 610 (1000 - 20
			Cliff House Sandstone	5 - 15 (16 - 50)
			Menefee Formation	76 - 106 (250 - 350
			Point Lookout Sandstone	45 - 75 (150 - 250)
			Mancos Shale	548 - 670 (1800 - 22
			Dakota Sandstone	50 - 80 (165 - 265)
			Unconformity	
	Jurassic		Morrison Formation	80 - 245 (265 - 805
			Todilto Formation	30 - 35 (100 - 115
			Entrada Formation	70 - 85 (230 - 280
			Unconformity	
	Triassic		Chinle Formation	177 - 300 (580 - 10
			Unconfornity	
Paleozoic	Permian		Yeso Formation	0 - 45 (0 - 150)
			Abo Formation	45 - 884 (150 - 290
			Unconformity	
	Pennsylvanian		Madera Formation	120 - 475 (400 - 15
			Unconformity	
	Mississippian		Arroyo Penasco Fm.	0 - 40 (0 - 130)
			Unconformity	
	Precambrian			

The Paleozoic rocks consist of limestones, sandstones, conglomeratic sandstones, and shales. The Mississippian and Pennsylvanian strata are of marine origin. The Permian, Triassic, and Jurassic strata were deposited in continental settings. The Cretaceous strata consist of sandstone and shale deposited during a series of transgressions and regressions of a major sea present during Late Cretaceous time. The Tertiary strata consist of sandstones, conglomeratic sandstones, shales, and a volcanic chert which were deposited in continental environments.

Several papers have summarized portions of the stratigraphy in the study area. A paper by Baltz (1967) discusses the stratigraphy of the interval including Point Lookout Sandstone through Recent deposits. Gibson (1975) discussed the stratigraphy of the Madera Formation through Mancos Shale in the Gallina 7.5' Quadrangle. Renick (1931) discussed the stratigraphy of the Madera Formation through Recent deposits in western Sandoval County. A paper by Woodward and others (1977) presents a detailed discussion of the Precambrian rocks of the northern portion of the Nacimiento Uplift.

STRUCTURAL FRAMEWORK

The study area includes parts of the east-central portion of the San Juan Basin, the northern portion of the Nacimiento Uplift, and the southwestern flank of the Chama

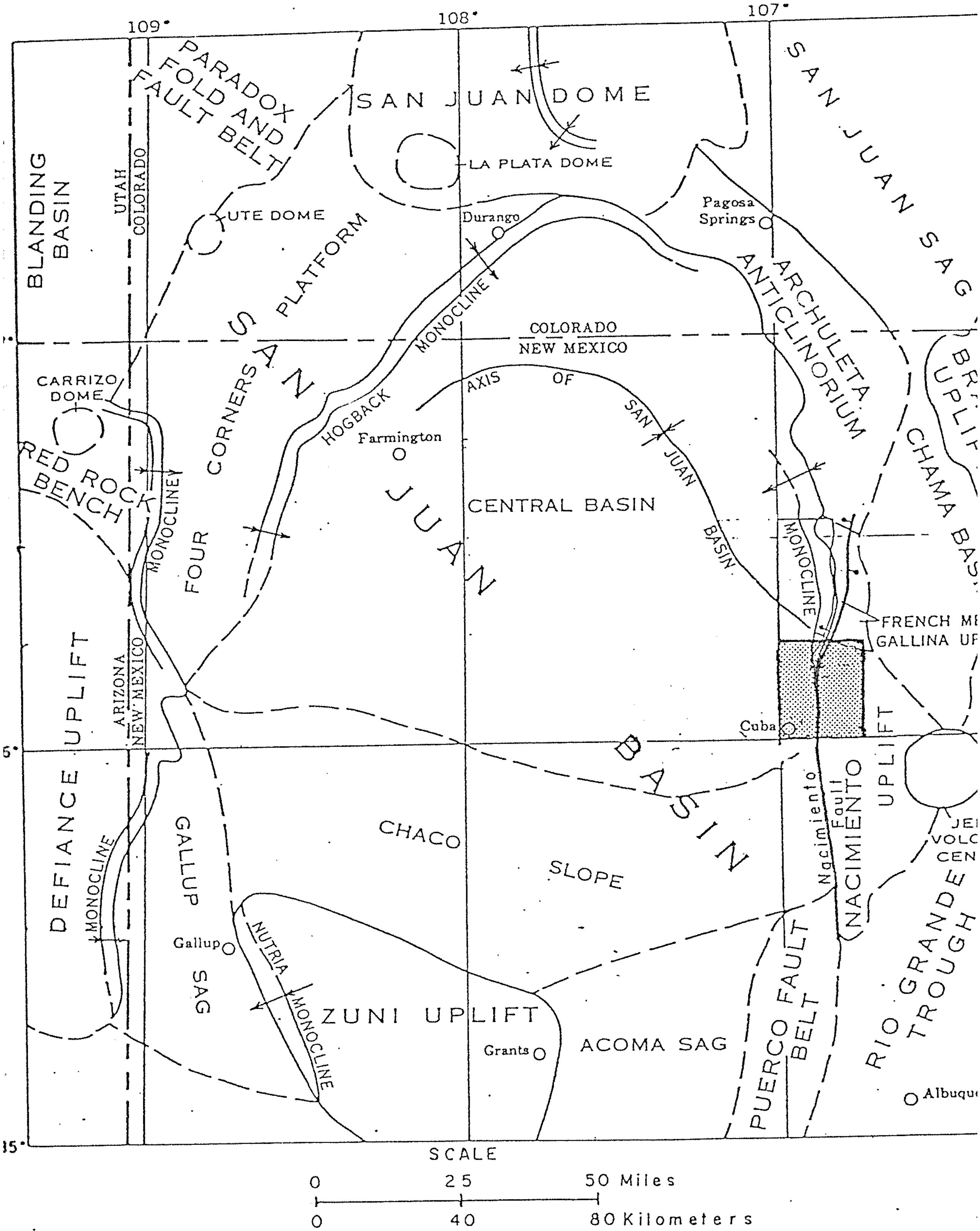


Figure 3. Structural elements of the San Juan Basin; modified from Baltz (1967, fig. 5); study area stippled.

Basin (fig. 3). Kelley (1950) first defined the San Juan Basin and its boundaries. The San Juan Basin is separated from the Nacimiento Uplift by the Nacimiento Fault and from the Chama Basin by a monoclinial flexure on the western side of the French Mesa-Gallina Uplift (Kelley and Clinton, 1960)

Baltz (1967, Plate 7) reported a series of north- to northwest- plunging anticlines and synclines on the eastern side of the San Juan Basin including the area covered by thi study. These structures began to form before deposition of the San Jose Formation and continued to form during deposition of that unit (Baltz, 1967, p. 60). Because the area is extensively covered with terrace gravels these anticlines and synclines are not readily observable but usir stratigraphic relationships and subsurface data they can be recognized (Baltz, 1967, p. 60). A large anticline plunges northward off the northern margin of San Pedro Mountain. This anticline has been referred to as "the Nacimiento nose" (Gibson, 1975, p. 135).

The north-south trending Nacimiento Fault forms the eastern boundary of the San Juan Basin in the study area. The fault generally consists of several fault planes which join and splay throughout the study area (fig. 4). Hutson (1958, p. 32) reported that the fault plane is very nearly vertical and has a dip of 83° SE in sec. 24, T23N, R1W. Woodward and others (1972, p. 2386) stated "At deep stratigraphic and structural levels the Nacimiento Fault is steep but flattens upward. The fault tends to be steep whe

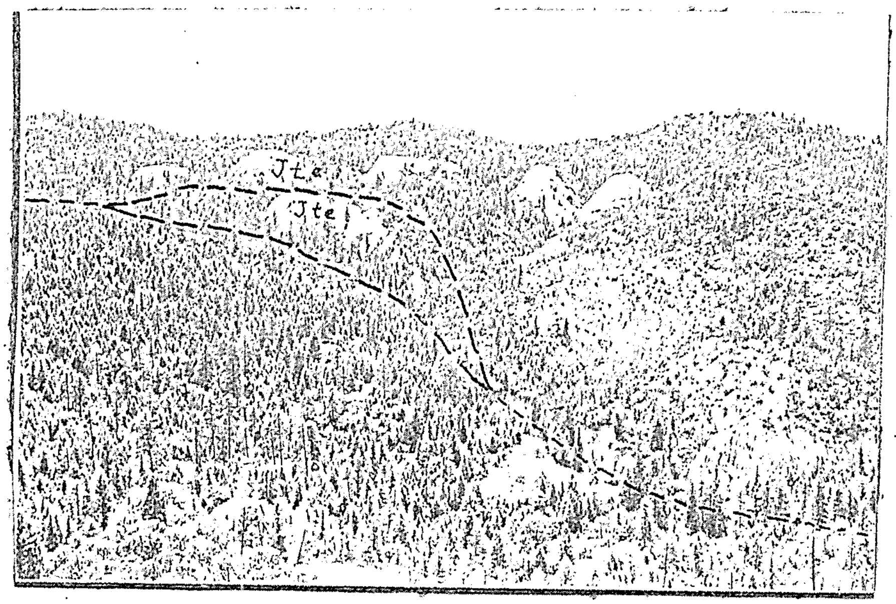


Figure 4. Area where Nacimiento Fault splays repeating the Todilto Limestone and Entrada Sandstone (Jte); view southwest from NE 1/4, sec. 24, T23N, R1W.

there is little stratigraphic separation, but dips more gently where there is greater displacement." Baltz (1967, p. 62) estimated the maximium displacement of the Nacimiento Fault to be 3,948 m (10,000 ft; Plate 1). Woodward and others (1972, p. 2393) discussed several smaller normal faults in the Vallecito de Rio Puerco area which are older than the Nacimiento Fault (Plate 1).

The northern portion of San Pedro Mountain is truncated by a northwest-trending normal fault named the "San Pedro Mountain Fault" by Hutson (1958, p. 33), who also reported that this fault extends west of the Nacimiento Fault to sec. 34, T23N, R1W. Baltz (1967, p. 76) reported that Hutson had been mistaken and that the San Pedro Mountain Fault terminates at the Nacimiento Fault. Baltz (1967, p. 77) stated that "...the San Pedro Mountain fault is probably a rotational normal fault hinged at the southeast end. The fault was produced probably by local vertical and horizontal tension forces during down buckling and north-northeastward shift of the San Juan Basin along the Nacimiento and Gallina faults." Along the northern end of the Nacimiento Uplift (near the Rio Gallina) several normal faults are present (Plate 1). Gibson (1975, p. 135) explained that these faults were caused "...by tensional force perpendicular to the anticlinal axis."

GEOLOGY AND WATER-BEARING CHARACTERISTICS OF STRATIGRAPHIC UNITS

In this section rock units are described in descending stratigraphic order. The amount of detail in the description of each unit depends on the amount of data collected in the field and the importance of the unit as an aquifer or potential aquifer in the study area. A more detailed description of the stratigraphic characteristics of the important aquifers and adjacent units is given in Appendix A

QUATERNARY DEPOSITS

Alluvium and Colluvium (Recent and Pleistocene)

Many of the stream valleys in the area contain alluvium which consists of pebbles, sand, silt, and clay-size particles and is generally coarser grained near the mountain front. The thickness of the alluvium ranges from zero near the upper reaches of the major streams to 43 m (140 ft) or more in sec. 20, T21N, R 1 W as reported by Baltz and West (1967, p. 73). Bryan and McCann (1936) reported that a well in La Jara penetrated 15.5m (51 ft) of valley fill and a wel in Cuba penetrated 26.5 m (87 ft) of valley fill. A driller's log of a well in the NE 1/4 of sec. 15, T23N, R1E indicates 12.2 m (40 ft) of alluvium (New Mexico State Engineer's Office Files).

In the San Pedro Mountain province alluvium is less than 12 m (40 ft) and generally ranges from 0 - 4 m (0 - 13 ft) thick. In this area the exposed igneous and metamorphic rocks are extensively fractured near the surface. The alluvium is recharged in the early spring and late summer as a result of infiltration of snow melt and precipitation. This water is stored in the ground-water system and slowly discharges into the perennial streams in the San Pedro Mountain area.

Chemical analyses of water from the alluvium and two streams in the San Perdo Mountain area show that water in alluvium is of good quality generally less than 600 ppm total dissolved solids (Table 2). The quality of water from the two streams is probably a good estimate of the quality of water in the alluvium in the San Perdo Mountain area (samples SA-2 and SA-3, Table 2). In general wells completed in alluvium would yield significant quantities of potable water for domestic use. Baltz and West (1967, p. 34) reported yields for wells completed in alluvium in the study area ranging from 1.1×10^{-2} - 9.8×10^{-2} m^3/minute (3-26 gpm). Colluvium occurs along the margins of San Pedro Mountain and along most of the terraces and ridges of the area. The colluvium ranges from deposits of boulders, cobbles, and pebbles of igneous, metamorphic, and sedimentary rocks near the mountain front to generally fine-grained slope-wash deposits along the sides of the gravel terraces and ridges of the area. The colluvium is generally less than 1 m (3.3 ft)

Table 2. Chemical analyses of streams and ground water from alluvium, Cuba Quadrangle. Sample numbers correspond to those in Appendix E; see Plate 2 for locations. Under sample type St = Stream, We = Well. Concentrations given as parts per million; nd = not detectable, -- = constituent not analyzed for, TDS = total dissolved solids. Addition.1 chemical information given in Appendix E.

Sample Number	Sample Type	HCO_3	Cl	So_4	Na	K	Mg	Ca	Fe	Si	TDS
SA-2	St	25	1.91	nd	2.03	0.35	0.46	6	--	5.3	38
SA-3	St	30	1.9	21	1.3	0.4	5.4	16	--	1.7	67
SA-11	We	168	2.8	99		0.6	7.8	64	1.75	1.25	287
SA-34	We	92	5.1	18	10.5	1.0	4.5	26	--	--	87
BZ-44	We	475	20.0	714	470		6.7	45	--	14	1510
BZ-88	We	373	7.0	174	63		28.0	98	0.86	17	568

thick but along the mountain front the deposits may be much thicker.

QUATERNARY/LATE TERTIARY DEPOSITS

Terrace Gravels (Pleistocene or Pliocene)

Terrace gravels of Quaternary or Late Tertiary age occur along the margins of San Pedro Mountain. These gravels were deposited on the beveled surfaces of Paleozoic, Mesozoic, and Tertiary rocks and have slopes ranging from 2 - 10 . Erosion has dissected these terraces in many places, exposing the older sedimentary, igneous, and metamorphic rocks below. In a paper on the upper Rio Puerco pediments Bryan and McCann (1936) described two major pediment surfaces on the eastern side of the mountain front (fig. 5). The La Jara pediment surface (they explained) is approximately 61 m (200 ft) above the present grade and the Rio Leche pediment is approximately 27.4 m (90 ft) above the present grade. Terraces on the northern margin of San Pedro Mountain near Gallina Plaza range from 2225 - 2316 m (7300 - 7600 ft) in elevation.

The gravels are generally less than 35 m (110 ft) thick, and primarily consist of pebbles, cobbles, and boulders of metamorphic and igneous rock types derived from San Pedro Mountain although the terraces on the north side of San Pedro Mountain near Gallina contain limestone pebbles and cobbles derived from the Mississippian and Pennsylvanian limestones

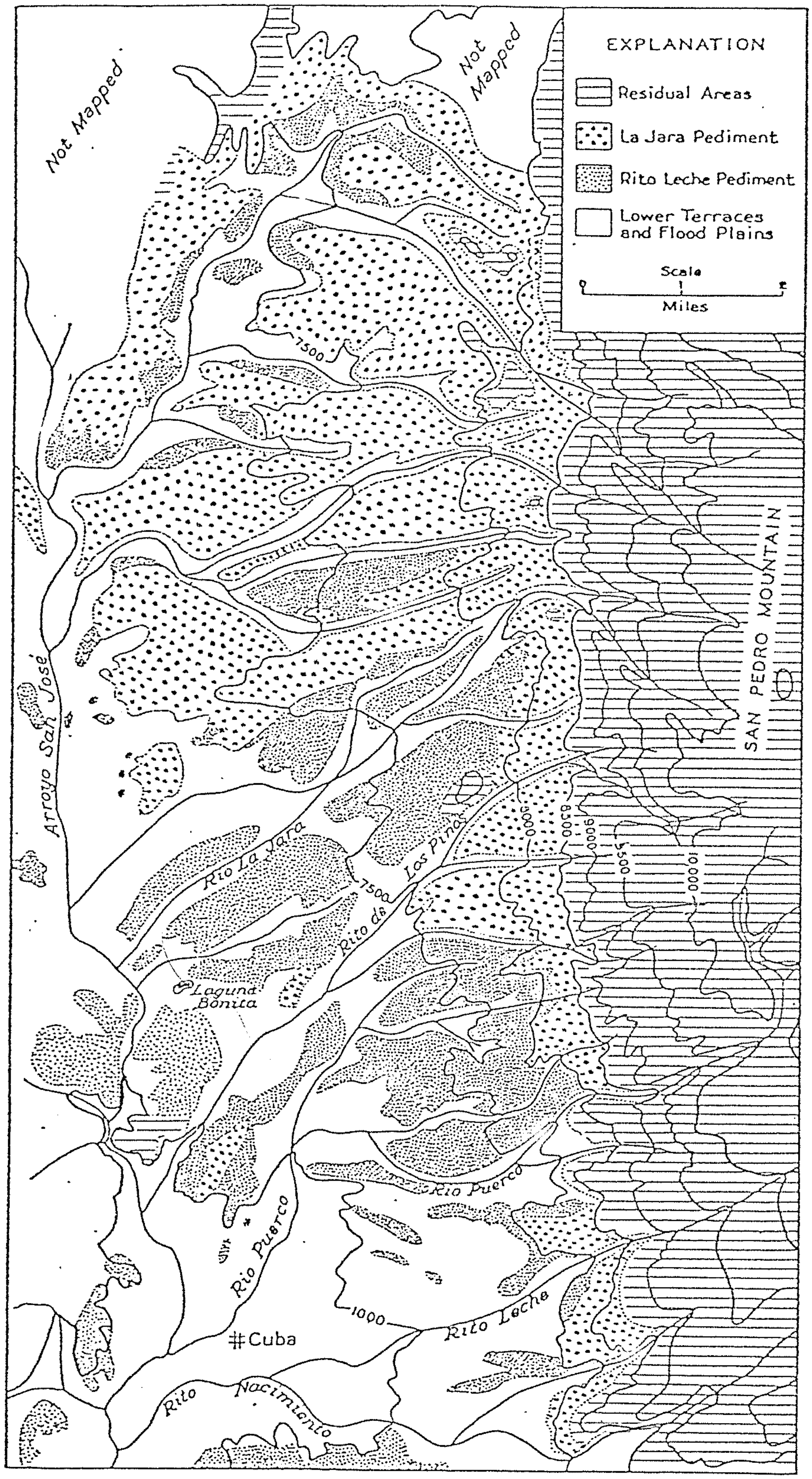


Figure 5. Remnants of the La Jara and Rito Leche pediments near Cuba, New Mexico; from Bryan and Mc Cann (1936, p. 157).

of the area. The gravels also contain sand, silt, and clay-size particles and are poorly sorted. The average grain size of the terrace deposits generally decreases away from the mountain front.

Many of the terraces contain minor amounts of ground water, where the water is perched on impermeable strata. Springs and seeps issue from many of these terraces especially in the area east of Cuba. Several wells dug into the terraces produce domestic water supplies. Most of the springs which issue from the terraces are at the lowest margin of the terrace remnant. Many area residents reported that most of the springs flow all year with highest flows in the spring and late summer. This is probably in response to the increase in infiltration of snow melt and precipitation during these times of the year.

Springs which issue from the terrace gravels and wells tapping them generally yield good quality water (Table 3). Water quality is generally better near the mountain front due to the shorter residence time for the water there. The terraces are recharged by infiltration of precipitation and by bed loss from the many streams which cross the terraces.

TERTIARY DEPOSITS

Regina Member, San Jose Formation (Eocene)

Table 3. Chemical analyses of ground water from terrace gravels, Cuba Quadrangle. Sample numbers correspond to those in Appendix B; see Plate 2 for locations. Under sample type Sp = Spring, We = Well. Concentrations given as parts per million; nd = not detectable, -- = constituent not analyzed for, TDS = total dissolved solids. Additional chemical information given in Appendix E.

Sample Number	Sample Type	HCO_3	Cl	SO_4	Na	K	Mg	Ca	Fe	Si	TDS
SA-4	We	117	1.0	20	4.0	0.4	0.85	41	0.21	10	141
SA-5	Sp	76	2	10	5.6	1.5	0.24	24	2.1	0.04	80
SA-6	We	213	12	50	22.4	0.2	1.37	75	5.0	0.05	253
SA-10	We	160	30.6	131	26.5	1.5	0.66	32	9.0	2.5	355
SA-20	Sp	155	3.8	nd	15	1.5	7.4	17	0.05	6.2	122
BZ-7	We	173	2.3	12	8.3		10	40	--	28	186

The Regina Member of the San Jose Formation consists of variegated shales and siltstones with some interbedded very fine to coarse-grained sandstones. The Regina interfingers with the Cuba Mesa Member of the San Jose Formation and varies in thickness throughout the study area. A measured section east of the study area in sections 28, 32, and 33, T21N, R2W documents this extensive interfingering relationship (section SA-5, Appendix A). A well in sec. 28, T23N, R1W penetrated 356.6 m (1170 ft) of Regina (Appendix F) and approximately 91 m (300 ft) of Regina is exposed in outcrop just west of the well. Baltz (1967, p. 50) reported that in sec. 17, T24N, R1W the Regina is 499.9 m (1640 ft) thick.

In the Regina area many unsuccessful water wells have been drilled in the Regina Member. An 83.8-m- (273-ft-) deep well in sec. 19, T23N, R1W and several wells north of La Jara obtained water in the Regina, (sample BZ-40, Appendix B; Baltz and West, 1967, p. 74). Baltz and West (1967, p. 78) reported a spring issuing from a sandstone in the Regina, in the SW 1/4, sec. 22, T23N, R1W, which yields approximately $0.95 \times 10^{-3} m^3/min$ (0.25 gpm; sample BZ-S-18, Appendix B). Chemical analysis of the water issuing from this spring yielded 960 ppm total dissolved solids (sample BZ-S-18, Appendix E). In general the Regina would not be expected to yield significant quantities of potable water in the study area.

Cuba Mesa Member, San Jose Formation (Eocene)

The Cuba Mesa Member is the lowest member of the San Jose Formation. It consists of medium- to coarse-grained, moderately well sorted sandstone which locally contains clay lenses. A sample from near the top of this unit consisted of a medium-grained, poorly sorted, strongly fine-skewed sandstone (sample SA-TSJCM-1, Appendix D). The thickness of this unit varies throughout the area as a result of an erosional unconformity at the base of the unit in some areas near the mountain front and an interfingering relationship with overlying and underlying units (section SA-5, Appendix A). At the type section on the north end of Cuba Mesa, Baltz (1967, p. 46) reported the Cuba Mesa to be 238.4 m (782 ft) thick and near the mountain front he (p. 47) estimated the unit to be less than 46 m (150 ft) thick. This abrupt thinning of the Cuba Mesa was observed in the field at several locations but lateral tracing of the Cuba Mesa is not possible along most of the mountain front due to lack of exposures.

The Cuba Mesa is an important aquifer near its outcrop belt north of Cuba and has good potential as an aquifer near Regina but has not been extensively used because of the great thickness of the overlying Regina Member. A test hole in sec. 28, T23N, R1W (Appendix F) encountered the top of the unit 360 m (1180 ft) below the ground surface and penetrated 155.5 m (510 ft) of the unit; the water level was 64.6 m (212 ft) below the ground surface. This well was the only well out of four wells drilled by the Regina Mutual Water Association that penetrated the Cuba Mesa. The other wells were drilled to a depth of 3Ø5 m (1ØØØ ft) and abandoned (R Dennis, Dennis Engineering, personal communication, 1979).

The chemical quality of water in the Cuba Mesa varies from well to well (Table 4). It can be seen that the water in some areas contains considerable amounts of iron. Local residents reported that the taste of the water seems to improve the longer the well is used and the more the well i pumped. Comparison of analyses made in 1959 and 1978 of water from the same well seems to document this (samples SA-13 and BZ-66, Appendix E). The dissolved iron in the water dropped from 14 ppm in 1959 to 1.35 ppm in 1978.

Nacimiento Formation (Paleocene)

The Nacimiento Formation consists of variegated carbonaceous shales and claystones with interbedded sandstones and lignites. Baltz (1967, p. 38) reported that the Nacimiento Formation is 163.7 m (537 ft) thick in the center of sec. 11, T21N, R1W and estimated that the formati thickens to as much as 3Ø5 m (1ØØØ ft) in sec. 34, T23N, R1W. Along the mountain front the Nacimiento varies considerably in thickness as a result of the angular and erosional unconformity between it and the overlying San Jos Formation. Baltz (1967, p. 39) reported that the Nacimient Formation generally contains more sandstone north of T22N, R1W than is seen near the south end of Mesa de Cuba and may contain as much as 5Ø percent sandstone north of T23N.

Table 4. Chemical analyses of ground water from the Cuba Mesa Member of the San Jose Formation, Cuba Quadrangle. Sample numbers correspond to those in Appendix B; see Plate 2 for locations. Under sample type We = Well. Concentrations given in parts per million; nd = not detectable, -- = constituent not analyzed for, TDS = total dissolved solids. Additional chemical information given in Appendix E.

Sample Number	Sample Type	HCO_3	Cl	SO_4	Na	K	Mg	Ca	Fe	Si	TDS
SA-7	We	222	24	86	17.8	1.35	1.83	96	2.0	5.5	314
SA-12	We	410	18	37	42.5	1.2	11.8	100	1.6	5.2	430
SA-13	We	497	6	97	99	3.8	16	78	1.35	3.15	496
SA-16	We	161	21	253	22.5	3.2	27.5	78	22	7.5	446
SA-17	We	215	23	70	15	1.7	14.5	68	3.4	0.4	319
SA-18	We	168	15	33	12.2	6.5	8.6	49	1.7	0.5	217
SA-22	We	207	23	466	73	1.3	59	85	27	6.8	812
SA-24	We	122	5.7	254	18.6	2.6	295	78	15	6.4	466
SA-30	We	362	1	199	49	3.3	36.5	96	1.0	33	566
BZ-66	We	474	4	97	104	3.6	19	77	14	15	569
BZ-69	We	154	14	93	29	0.4	9.7	62	0.11	28	323

Baltz and West (1967) reported on two wells completed in the Nacimiento Formation. One of the wells was dry and the other one probably received most ot its water from overlying alluvium. Because of the generally fine-grained nature of the Nacimiento Formation, the lateral discontinuity of its sandstones, and the poor exposure of the unit in the recharge area, the Nacimiento Formation is generally not considered an aquifer in the study area. Locally sandstone beds in the Nacimeinto Formation may contain water and north of T22N, R1W the unit may contain considerable amounts of water, but the underlying Ojo Alamo Sandstone and the overlying San Jose Formation would be much more dependable aquifers.

Ojo Alamo Sandstone (Paleocene)

The Ojo Alamo Sandstone generally consists of two beds of grayish-orange, medium- to coarse- grained, poorly cemented sandstones which are separated by an interval of olive-gray shale. Representative samples of the upper and lower sandstones were determined to be medium-grained, poorly sorted, strongly fine-skewed, K-feldspar-bearing arkoses (samples SA-II-11 and SA-II-13, Appendices C and D). A sample from the SW 1/4, sec. 28, T29N, R12W consisted of a fine-grained, very poorly sorted, lithic arkose (Stone, 1979, p. 15). Locally the sandstones contain abundant olive-gray clay galls and in many areas contain significant amounts of clay matrix. Crossbedding is common in some areas as well as conglomeratic layers which contain pebbles ranging from 3 - 7 cm (1 - 3 in). Local residents report that pyrite is found in drill cuttings of wells in the Ojo Alamo; the iron-stained nature of the Ojo Alamo in outcrop is probably due to oxidation of this pyrite. A measured section in the SE 1/4, sec. 22, T21N, R1W yielded a thickness of 11.6 m (38.0 ft) for the lower sandstone, 7.2 m (23.6 ft) for the middle shale, and 12.6 m (41.3 ft) for the upper sandstone (section SA-2, Appendix A). A well in sec. 10, T23N, R1W penetrated 59.4 m (195 ft) of Ojo Alamo Sandstone (Appendix F). Baltz (1967, p. 32) reported that on the north side of San Jose Creek in sec. 34, T23N, R1W the Ojo Alamo Sandstone is approximately 27 m (90 ft) thick. This large variation in thickness is probably due to the unconformable contact of the Ojo Alamo Sandstone with the underlying Kirtland Shale/Fruitland Formation (undivided). Baltz (1967, p. 34) suggested that on the eastern side of the San Juan Basin as much as 426.7 m (1400 ft) of Kirtland Shale/Fruitland Formation may have been eroded prior to deposition of the Ojo Alamo. Baltz (1967, p. 34) also pointed out that there is evidence suggesting local uplift and erosion during deposition of the Kirtland Shale/Fruitland Formation on the eastern side of the Basin and that this may explain the large difference in thickness of these units on the eastern and western sides of the San Juan Basin.

The sandstones of the Ojo Alamo are generally good aquifers because of their coarse-grained nature. Near Cuba the Ojo Alamo Sandstone is found close to the surface and is therefore the main aquifer in the area. The aquifer is generally artesian as a result of the underlying shales of the Kirtland Shale/Fruitland Formation and the overlying shales and siltstones of the Nacimiento.

In 1957 an aquifer test was performed by Foster and Bushman (1957) on a well in the SW 1/4, SE 1/4, NW 1/4, sec. 28, T21N, R1W which was completed in the Ojo Alamo. At this location the Ojo Alamo consists of two sandstones separated by a shale. The upper sandstone was found to be 12.5 m (41 ft) thick, the shale 5.5 m (18 ft) thick, and the lower sandstone 17.4 m (57.1 ft) thick. The data obtained from this test, (Appendix H) were analyzed using the Jacob Straight Line Method (figs. 6 and 7). The transmissivities obtained were 12.1 m^2/day (130 ft^2/day) for the drawdown tes and 9.29 m^2/day (100.0 ft^2/day) for the recovery test. The storativity calculated was 2.77 $X10^{-3}$. In June 1979, the author performed an aquifer test on a well in sec. 6, T20N, R1W which was reportedly completed in the upper sandstone of the Ojo Alamo. The upper sandstone was reported to be screened its total thickness of 7.6 m (25 ft). Recovery dat from the test (Appendix H) yielded a transmisivity of 8.45 m^2 /day (91.0 ft^2/day; fig 8). A specific capacity of 3.4 $X10^{-3}$ l /minute (0.274 gpm/ft) was calculated at 7 hours 55 minutes after pumping was started. The transmissivity value calculated agrees well with the transmissivity values reported for the Ojo Alamo by Brimhall (5 - 15 m^2/day (56 - 164 ft^2/day, 1973).

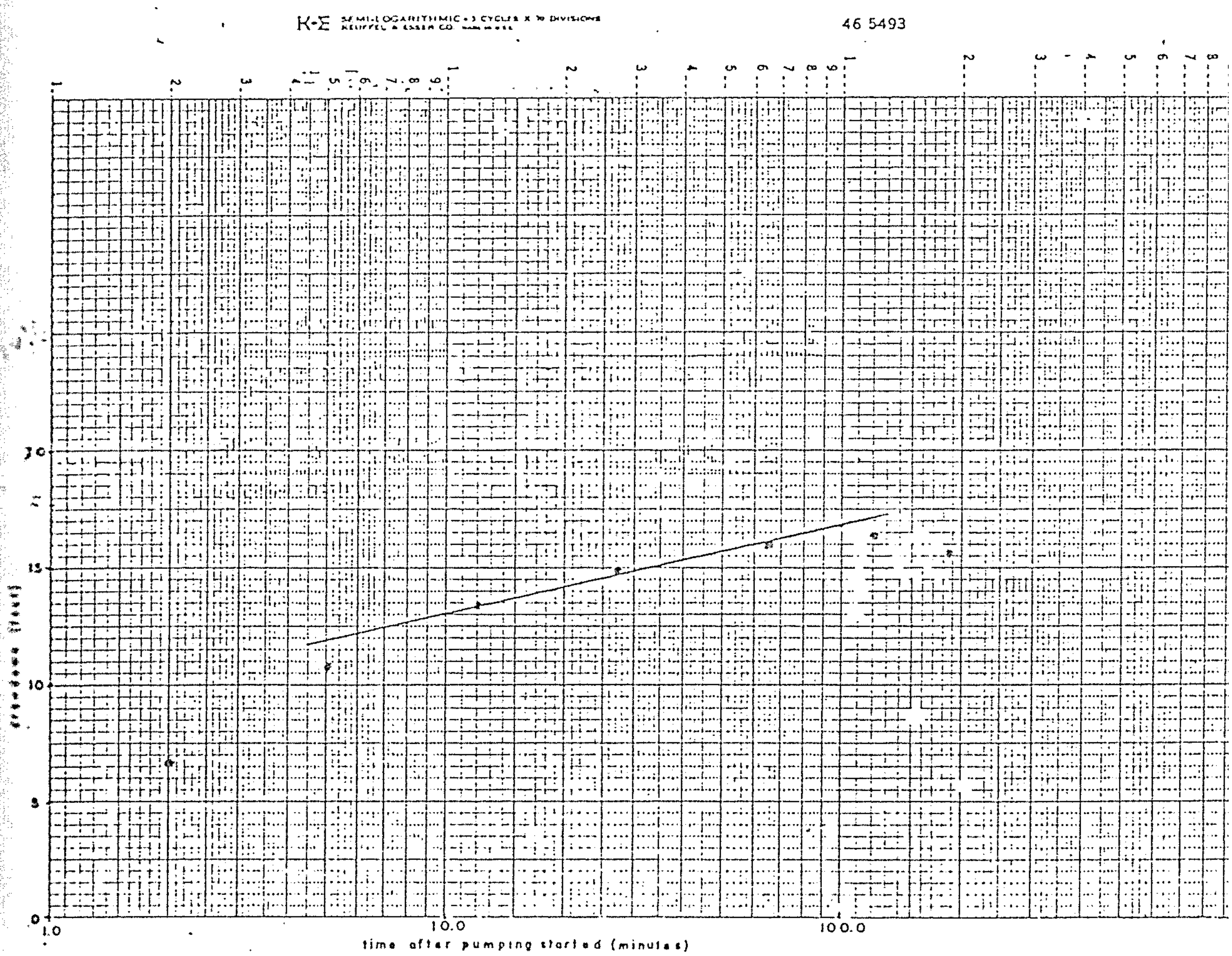


Figure 6. Graph of drawdown data for test of Ojo Alamo Sandst in sec. 28, T21N, R1W; see Appendix H for list of data; from Bushman and Foster (1957).

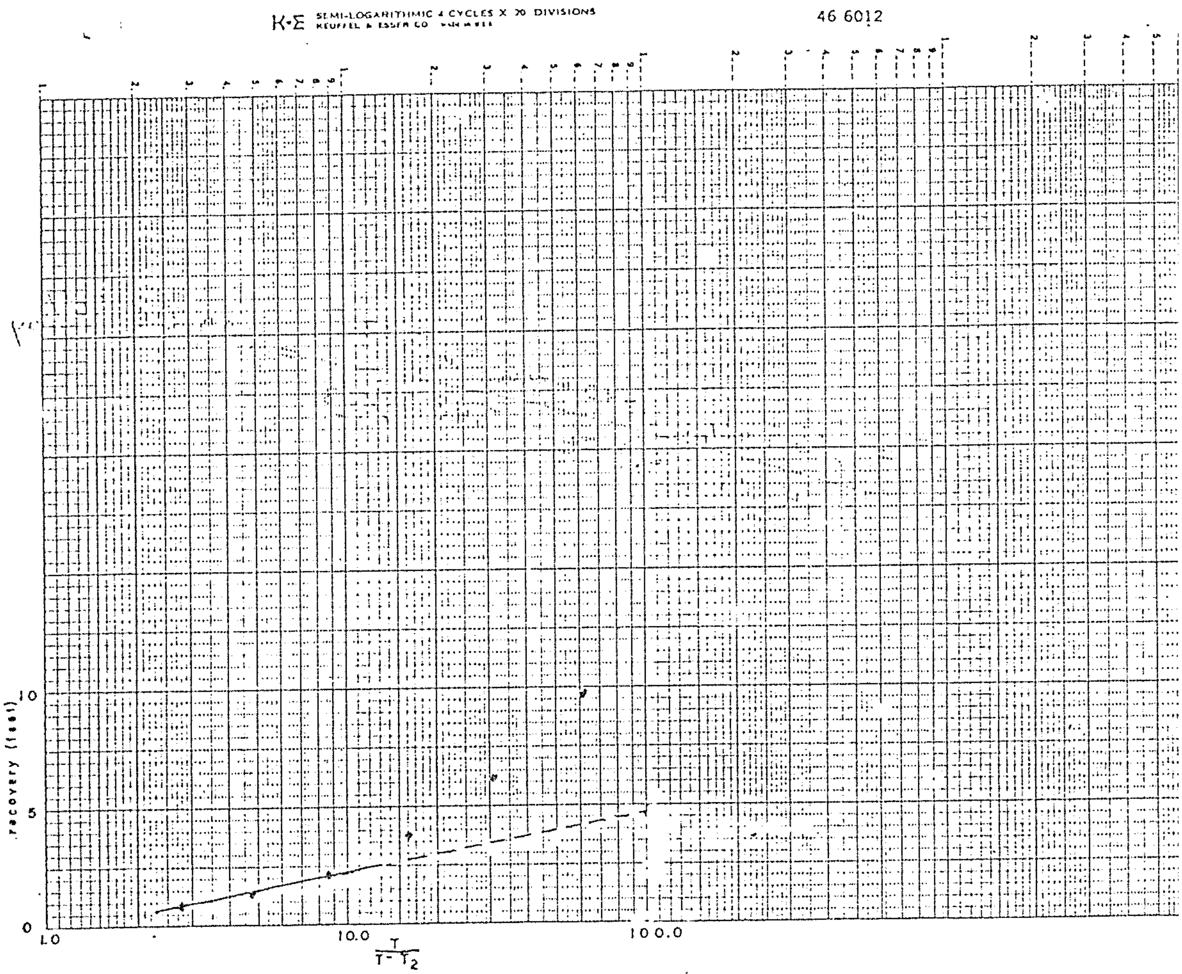


Figure 7.— Graph of recovery data for test of Ojo Alamo Sandstone, in sec. 28, T21N, R1W; see Appendix H for list of data; from Bushman and Foster (1957).

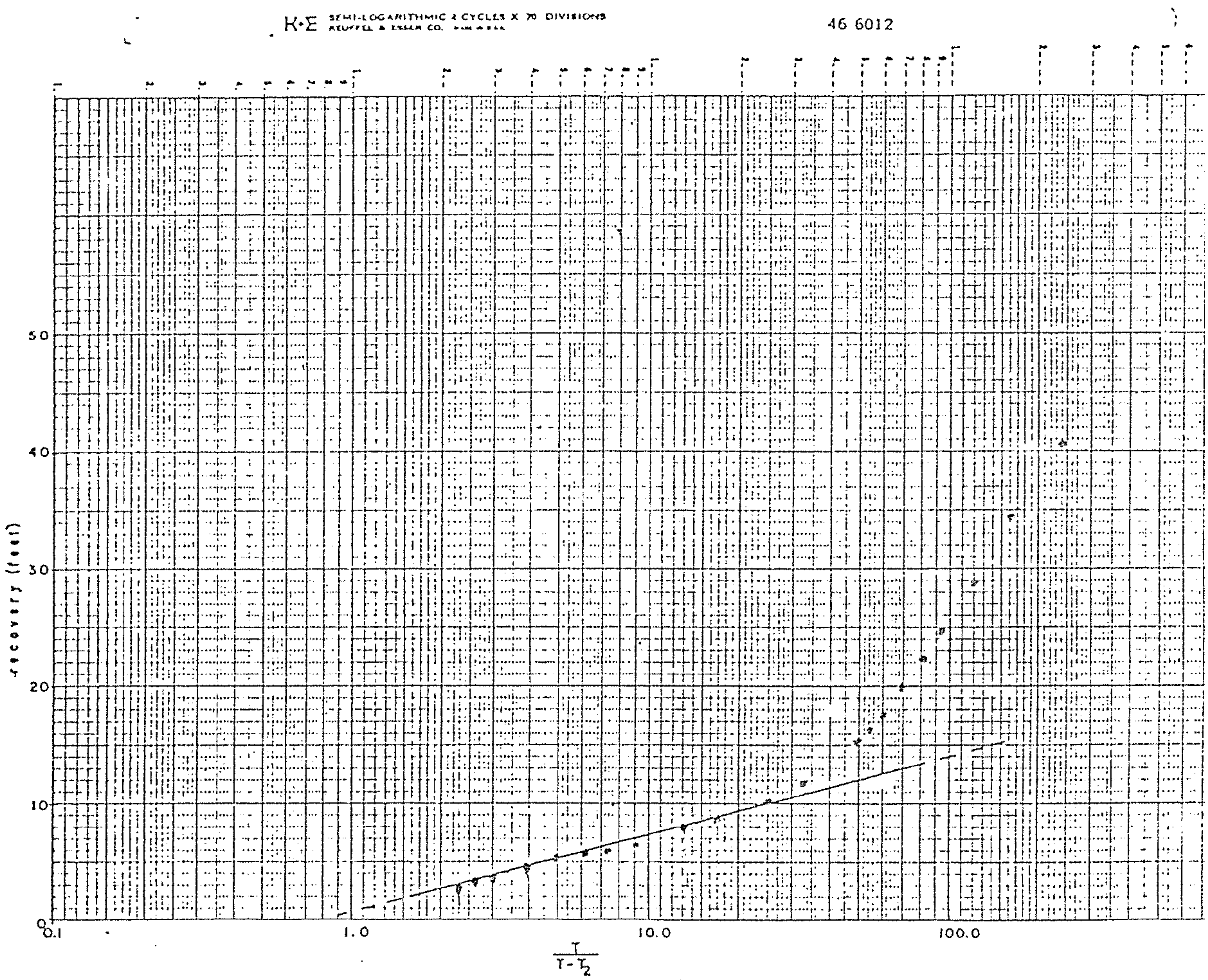


Figure 8. Graph of recovery data for test of Ojo Alamo Sandstone, in sec. 6, T20N, R1W; see Appendix H for list of data.

The Ojo Alamo is generally artesian but no flowing wells were observed in the study area. Water has been encountered in the Ojo Alamo in the Mesa Portales area southwest of the study area in many uranium test holes but only one test hole yielded flowing water (Dale Carlson, Triple S Exploration, personal communication, 1979).

The quality of water from the Ojo Alamo varies from one place to another (Table 5). The water has a high sulfate content and generally is poor in quality very close to recharge areas or areas where the Ojo Alamo crops out.

CRETACEOUS DEPOSITS

Kirtland Shale/Fruitland Formation/Pictured Cliffs Sandstone

These units are undifferentiated in this study because of their complex stratigraphic relationships and poor exposure in the study area.

The Pictured Cliffs Sandstone consists of interbedded yellowish-gray, olive-gray, and grayish- orange claystones, silty shales, and sandstones with some local thin- bedded limestones. One sample of this unit was determined to be poorly sorted, strongly fine-skewed muddy sandstone (sample SA-II-4, Appendix D). The Pictured Cliffs in this area is not well developed and consists mainly of a zone of interbedded sandstone and shale between the Lewis Shale and the Fruitland Formation.

Table 5. Chemical analyses of ground water from the Ojo Alamo Sandstone, Cuba Quadrangle. Sample numbers correspond to those in Appendix B; see Plate 2 for locations; Under sample type We = Well. Concentrations given as parts per million; nd = not detectable, -- = constituent not analyzed for, TDS = total dissolved solids. Additional chemical information given in Appendix E.

Sample Number	Sample Type	HCO_3	Cl	SO_4	Na	K	Mg	Ca	Fe	Si	TDS
SA-14	We	497	4.3	370	324	5.6	6.9	2.4	0.01	--	962
BZ-91	We	254	38	521	92	4.4	20	208	2.1	22	1030
BZ-93	We	608	31	2430	624		126	480	0.36	21	4010
BZ-98	We	405	26	631	74		65	240	--	17	1250

The Kirtland Shale/Fruitland Formation (undivided) consists of olive-gray carbonaceous claystones and orange-gray, fine- to medium-grained sandstones. Two samples of this interval were determined to be poorly sorted, strongly fine-skewed, muddy sandstones (samples SA-II-6 and SA-II-8, Appendix D). Locally the sandstones contain siliceous pebbles and silicified wood. The thickness and position of the sandstone and claystone units within the Kirtland/Fruitland vary from one area to another because of the mode of deposition of these units: non-marine coastal- and alluvial-plain deposition (Molenaar, 1977). In some areas near Mesa Portales southwest of the study area, sandstones of the Kirtland/Fruitland are directly overlain by sandstones of the Ojo Alamo Sandstone (Dale Carlson, Triple S Exploration, personal communication, 1979). The sandstones in these units are sometimes quite resistant to erosion, as can be seen in the common corners of sections 10, 11, and 15, T23N, R1W. This sandstone has been called Kirtland by Baltz (1967) and Ojo Alamo Sandstone by Fassett (1977). It is the author's belief that this sandstone is Kirtland because of the type of wood replacement, the large amount of carbonaceous material, and the coarse-grained nature of the unit.

There has been much debate about the stratigraphic relationships and extents of the Pictured Cliffs Sandstone, Fruitland Formation, and Kirtland Shale in the Hogback Belt north of Cuba because of poor exposure and the thin nature of the Pictured Cliffs in this area. It is beyond the scope of this study to settle this debate and the reader is referred to articles by Baltz (1967) and Fassett and Hinds (1971) for a more complete discussion.

The thickness of these units varies throughout the area. A measured section in the SW 1/4, NW 1/4, sec. 23 and SE 1/4 NE 1/4, sec. 22, T21N, R1W (section SA-2, Appendix A) yielde a thickness of 7.3 m (24ft) for the Pictured Cliffs and 35.4 m (116.1 ft) for the Kirtland/Fruitland. North of this area very few outcrops completely expose these units, making correlation very difficult. Baltz (1967, p. 25) reported that the sequence is approximately 67 m (220 ft) thick, which includes 9.4 m (31 ft) of sandstone and shale equivalent to the Pictured Cliffs in the SW 1/4, NE 1/4 sec. 34, T23N, R1W. Thicknesses reported on scout cards on file at the New Mexico Bureau of Mines and Mineral Resources for the Kirtland/Fruitland are 57.9 m (190 ft) in sec. 21, T22N, R2W and 47.7 m (156.5 ft) in section 10, T23N, R1W.

North and west of the study area the Pictured Cliffs is generally thicker and consists of fine-grained sandstone which yields significant quantities of natural gas and saline water. In the study area the Pictured Cliffs is relatively thin and very fine-grained and thus would not yield appreciable quantities of potable water.

No wells were found in the study area which obtained water from the Kirtland/Fruitland interval. Some sandstones in the upper part of the section may yield impotable water.

In areas where these upper sandstones are directly overlain by sandstone of the Ojo Alamo, the combined sandstone interval may yield significant quantities of water. Although this condition has not been observed in outcrop, it may occur at places in the study area.

Lewis Shale

The Lewis Shale consists of olive-gray shale with some interbedded siltstone and very fine grained sandstone. In siltstones and concretionary zones fossil ammonites and pelecypods are well preserved and very abundant. In many locations along the mountain front the Lewis contains intraformational faults, which were a result of the tension caused by the abrupt bending of the strata along the Nacimiento Fault. A well in sec. 23, T21N, R2W penetrated 475.5 m (1560 ft) of Lewis (Appendix F).

No wells were found in the study area that obtained water from the Lewis Shale. Low permeabilities would be expected for the Lewis as a result of the fine-grained nature of the deposit. South of the study area significant quantities of water were produced from the Lewis (Dana Duncan, McCurdy Consultants, personal communication, 1978). This water was found in areas where the Lewis is extensively fractured near the Nacimiento front. This situation may also exist in the study area although the quality of this water would not be expected to be very good.

Cliff House Sandstone

The Cliff House Sandstone consists of light-brown to orangish-brown, fine- to medium-grained, well-sorted sandstone. Locally the sandstone is iron stained and contains carbonaceous material. A sample of the Cliff House from sec. 13, T22N, R13W was determined to be a coarse silt, medium-grained, well-sorted subarkose (Stone, 1979, p. 15). Southwest of the study area the Cliff House intertongues as many as six times with the overlying Lewis Shale, (Molenaar, 1977). This intertonguing relationship was not observed in the study area, but an intertonguing relationship was observed between the Cliff House and Menefee Formation north of the study area in the SE 1/4, sec. 34, T26N, R1E. The Cliff House varies in thickness throughout the study area; in a measured section in the NE 1/4, sec. 11, T23N, R1W it is 5.5 m (18.1 ft) thick (section SA-1, Appendix A). Renick (1931, p. 43) measured 11.3 m (37 ft) of Cliff House in the SE 1/4, sec. 35, T21N, R1W. A well in the NE 1/4, sec. 23, T21N, R2W penetrated 13 m (43 ft) of Cliff House (Appendix F) and a scout card on file in the New Mexico Bureau of Mines and Mineral Resources reports the Cliff House to be 33.5 m (110 ft) thick in sec. 21, T22N, R2W.

No wells were found in the study area which obtained water from the Cliff House; this unit would be expected to yield potable water but because it is thin it would probably not yield significant quantities of water.

Menefee Formation

The Menefee Formation consists of interbedded olive-gray siltstones, dark-green claystones, fine- to medium-grained sandstones and thin coals. Carbonaceous plant fragments are very abundant throughout the unit. A measured section in the NE 1/4, sec. 11, T23N, R1W (section SA-1, Appendix A) presents a detailed description of the upper 88.7 m (291 ft) of the Menefee. A section measured by Renick (1931, p. 44) in the SE 1/4, sec. 35, T21N, R1W yielded a thickness of 105.9 m (347.3 ft) for the Menefee. The Menefee thickens to the south and west of the study area; a well in the NW 1/4, sec. 20, T18 N, R4W (Appendix F) penetrated 354.8 m (1164 ft) of this unit. Because the Menefee was deposited in a continental nearshore environment, characterized by numerous streams and swamps, the sandstones in this unit are laterally discontinuous and are generally less than 10 m (33 ft) thick.

No wells were found in the study area that obtained water from the Menefee Formation although the sandstones in the unit would probably contain small amounts of water. Renick (1931, p. 35) reported porosities of 24.69 and 13.71 percent for two samples of sandstone from the Menefee collected south of the study area. Wells drilled in the sandstones and fractured coals in the Menefee south of Torreon, New Mexico, encountered oil and very poor quality water (Dave Tabet, New Mexico Bureau of Mines and Mineral Resources, personal communication, 1978). This poor quality is probably due to the presence of sulfide minerals and the large amount of clays and carbonaceous material in the Menefee. Water derived from the sandstones and fractured coals in the study area would also be expected to be of poor quality.

Point Lookout Sandstone

The Point Lookout Sandstone consists of gray to tan, medium- to fine-grained, moderately well sorted sandstone. Several samples of the Point Lookout from sec. 5, T29N, R16W consisted of very fine to coarse grained, moderately sorted arkose (Stone, 1979, p. 15). A section measured by Renick (1931, p. 47) in the SE 1/4, sec. 35, T21N, R1W yielded a thickness of 54.7 m (179.5 ft) for the Point Lookout. A well in sec. 23, T21N, R1W (Appendix F) penetrated 73.5 m (241 ft) and a section measured by Shetiwy (1978, p. 223-225) in the SE 1/4, sec. 1, T23N, R1W yielded a thickness of 46.2 m (151.6 ft) for the Point Lookout.

Although the Point Lookout would be expected to yield potable water, no wells were found in the study area which obtained water from this unit. Renick (1931, p. 35) reported a porosity of 28.32 percent for a sample of the Point Lookout from the NW 1/4, sec. 20, T19N, R1W. Several aquifer tests in the Torreon area, southwest of the study area yielded transmissivities on the order of 10^{-2} - 10^{-3} m^2/day (10^{-1} -10^{-2} ft^2/day) (Steve Craigg, New Mexico Tech Graduate Student, personal communication, 1979). The total-dissolved-solids content of the water from the wells in the Torreon area completed in the Point Lookout ranged from 415 - 667 ppm (Stone and Craigg, 1979). Wells completed in the Point Lookout in the study area would be expected to yield water o equal or better quality because of a similar position relative to recharge areas and the similar lithology of the Point Lookout in the two areas.

Mancos Shale

The Mancos Shale consists mainly of olive-green shales. Near the middle of the unit a sandy siltstone interbedded with shale aproximately 22-m (70-ft) thick persists throughout the area as a ridge. This portion of the Mancos is often referred to as the Gallup Sandstone or basal Niobrara sandstone by people associated with the oil industry. Several beds of limestone and limy siltstone, up to 1 m (3.3 ft) thick, are found near the top of the lower third of the unit. This interval is generally considered tc be the Greenhorn Limestone Member of the Mancos Shale. The Mancos is 655 m (2150 ft) thick in a well in sec. 23, T21N, R2W (Appendix F) and a scout card on file in the New Mexico Bureau of Mines and Mineral Resources reports a well in sec. 21, T22N, R2W which penetrated 635.8 m (2086 ft) of the Mancos.

A well in sec. 15, T23N, R1E produces small quantities of water used for domestic purposes from an interval below the Gallup or basal Niobrara sandstone (sample SA-15, Appendix B). This water has a total-dissolved-solids concentration of 960 ppm and contains 632 ppm sulfate which is above the recommended limit of 250 ppm (sample SA-15, Appendix E; Hem, 1972). The Gallup or basal Niobrara interval might yield small quantities of water, but generally the Mancos would not be expected to yield significant quantities of potable water due to its very fine grained nature.

Dakota Sandstone

The Dakota Sandstone consists of a lower poorly to moderately sorted, coarse-grained to conglomeratic, highly cross-bedded sandstone (fig. 9) which grades into a carbonaceous, silty shale containing several beds of fine-grained sandstone near the base. Above this silty shale is a very fine to medium-grained sandstone which contains abundant marine trace fossils and symmetrical ripple marks (Siemers and others, 1974). Mineralogically two samples of the lower unit and one sample of the upper unit were determined to be quartzose sedarenite or quartzose sandstone arenite, K-feldspar-bearing subarkose, and K-feldspar-bearing arkose, respectively (samples SA-4-4, SA-4-7, and SA-4-12, Appendix C). Texturally the two samples from the lower unit were determined to be medium-grained, poorly sorted, strongly fine-skewed sandstone and a fine-grained, very poorly sorted, strongly fine-skewed conglomeratic muddy sandstone (samples SA-4-4 and SA-4-7, Appendix D).

Figure 9. Cross-bedding and conglomeratic lense in west-facing cliff of Dakota Sandstone (NW 1/4, sec. 24, T23N, R1W); conglomeratic lense approximately 1.5 m (5 ft) thick.

Several authors (Owen and Siemers, 1977, and Saucier, 1974) have suggested that the lower coarse-grained portion of the Dakota in the study area should be correlated with the Burro Canyon Sandstone. There is much disagreement between authors as to what this lower coarse-grained unit should be called. J. L. Ridgley (USGS, personal communication, 1978) examined several outcrops in the northern portion of the study area and found no Burro Canyon but suggested that the lower unit there was lower Dakota.

The thickness of the Dakota varies throughout the area as a result of its interfingering relationship with the overlying Mancos Shale and the unconformable contact with the underlying Morrrison Formation. A measured section in the NW 1/4, sec. 24, T23N, R1W yielded a thickness of 47.6 m (156.2 ft; section SA-4, Appendix A). Owen and Siemers (1977, p. 181) reported approximately 79 m (260 ft) of Dakota and/or Burro Canyon in a measured section near the Nacimiento Mine in sec. 11, T20N, R1W. A well in the NW 1/4, sec. 21, T21N, R2W penetrated 69.2 m (227 ft) of Dakota (Appendix F).

No wells were found in the study area which obtained water from the Dakota, but the lower portion of the Dakota would be expected to yield significant quantities of potable water. Renick (1931, p. 35) reported porosities of 22.72 and 17.89 percent for samples of Dakota collected south of the study area.

JURASSIC DEPOSITS

Morrison Formation

The Morrison Formation was divided into four members on the basis of lithology. The lowest member consists of grayish-red to pale red, very fine to fine-grained sandstones interbedded with silty claystones. The sandstone beds predominate ranging from 3 - 8 m (9.8 - 26.2 ft) in thickness. The next member consists of a very pale orange to yellowish-gray, kaolinitic, very fine to medium-grained, lenticular sandstone at the base, overlain by pale-red to light-olive-gray claystones, siltstones, sandstones, and some limestone beds. Overlying this member is a light-gray to pale-brown, very fine to coarse-grained, cross-bedded sandstone which in some areas is conglomeratic. The upper member consists of olive-gray to dark-greenish-gray shale. The thickness of each member varies throughout the study area as a result of interfingering of the members and tectonic elimination of beds. Gibson (1975, p. 167-168) measured a section in the NE 1/4, sec. 18, T23N, R1W and reported a thickness of 4.3 m (14 ft) for the upper member, 18.3 m (60 ft) for the sandstone member, 30.5 m (100 ft) for the green shale member, and 27.4 m (90 ft) for the lower member. A scout card on file at the New Mexico Bureau of Mines and Mineral Resources reports that a well in sec. 23, T21N, R1W penetrated 245.4 m (805 ft) of Morrison.

No wells were found in the study area which obtained water from the Morrison, but because of the large amount of sandstone in the unit it has good potential as an aquifer.

Todilto Limestone

The Todilto Limestone consists of gray, thinly bedded, platy limestone at the base which grades upward into massiv gypsum. A measured section in the SW 1/4, sec. 5, T23N, R1 yielded a thickness of 2.1 m (6.9 ft) for the limestone and 33.3 m (109.3 ft) for the upper gypsum (section SA-3, Appendix A). Renick (1931, p. 30) reported the Todilto to 32.2 m (105.5 ft) thick in a measured section in the SW 1/4 sec. 1, T19N, R1W. The Todilto can be considered an aquita in the study area.

Entrada Sandstone

The Entrada Sandstone was divided into three members o the basis of color. The basal member consists of moderate reddish-orange, well sorted, fine-grained, cross-bedded sandstone, the middle member consists of very pale orange, well-sorted, fine-grained, cross-bedded sandstone, and the upper member consists of grayish-orange well-sorted, fine-grained sandstone. A sample of the lower unit was determined to be a very fine grained, poorly sorted, fine-skewed, K-feldspar-bearing subarkose (sample SA-III-4, Appendices C and D). A measured section in the SW 1/4, sec. 5, T23N, R1W yielded a thickness of 56.6 m (185.7 ft) for t lower unit, 9.8 m (32.2 ft) for the middle unit, and 18.3 m (60.0 ft) for the upper unit (section SA-3, Appendix A). Renick (1931, p. 30) reported a measured section in the SW 1/4, sec. 1, T19N, R1W yielded a total thickness of 69.3 m (227.5 ft) for the Entrada.

No wells were found in the study area which obtained water from the Entrada. Berry (1959, p. 81) stated that the transmissibility of the Entrada is quite high, which would contribute to the Entrada's potential as a good aquifer. However, Berry (1959, p. 93) also stated that water in the Entrada near the center of the San Juan Basin is saline. Water obtained from the Entrada in the study area would not be expected to be of very good quality owing to the calcareous nature of the sandstones and the presence of gypsum in the overlying Todilto Limestone.

TRIASSIC DEPOSITS

Chinle Formation

The Chinle Formation is composed of four members in the study area: Agua Zarca Sandstone Member, Salitral Shale Member, Poleo Sandstone Member, and Upper Shale Member (in ascending order).

The Upper Shale consists of dark-red to maroon, interbedded silty claystones, siltstones, and fine- to coarse-grained, poorly sorted sandstones. Gibson (1975, p. 49) estimated that the Upper Shale is approximately 170.7 m

(56Ø ft) thick in the Gallina area. Several wells drilled in the Upper Shale in the Gallina area were dry (Jack Holley, Gallina Water Forman, personal communication, 1979). Throughout the study area the Upper Shale would not be expected to yield water because of its fine-grained nature.

The Poleo Member of the Chinle consists of interbedded, buff, very fine to coarse- grained, moderately well sorted, calcareous sandstone and dark-brown conglomerate. The conglomerate contains chert pebbles up to 7 cm (3 in) in diameter and generally occurs as lenses within the sandstone. A sample of this sandstone was determined to be fine-grained, poorly sorted, strongly fine-skewed, K-feldspar-bearing subarkose (sample S-38, Appendices C and D). A section measured by Gibson (1975, p. 159) yielded a thickness of 44.2 m (145 ft) for the Poleo in the SE 1/4, sec. 16, T23N, R1E. Near Cuba the Poleo ranges from 6 - 41 m (2Ø - 135 ft) in thickness (Woodward and others, 1972).

In the Chama Slope province the Poleo is the major aquifer. Chemical analyses of waters obtained from the Poleo show that the water is of good quality with total dissolved solids ranging from 3Ø7 - 672 ppm (Table 6).

The Salitral Shale Member of the Chinle is composed of purple to maroon shale with minor amounts of coarse- to very coarse grained, limy sandstone. The Salitral varies in thickness throughout the study area; near Cuba the thickness ranges from 93 - 1Ø2 m (3Ø5 - 335 ft; Woodward and others, 1972), whereas, near Gallina its thickness ranges from Ø - 15 m (Ø - 5Ø ft).

Table 6. Chemical analyses of ground water from the Poleo Sandstone Member of the Chinle Formation, Cuba Quadrangle. Sample numbers correspond to those in Appendix E; see Plate 2 for locations. Under sample type We = Well, Concentrations given in parts per million; nd = not detectable, -- = constituent not analyzed for, TDS = total dissolved solids. Additional chemical information given in Appendix E.

Sample Number	Sample Type	HCO_3	Cl	SO_4	Na	K	Mg	Ca	Fe	Si	TDS
SA-21	We	334	15	242	48.4	4.4	29	130	1.0	0.5	672
SA-23	We	207	42	66	73.5	1.4	26.2	18	0.06	4.7	335
SA-25	We	345	16.3	43	58.2	3.8	25	46	1.05	2.3	367
SA-32	We	244	11.2	50	27.0	1.8	13	80	--	--	307

The Salitral would not be expected to yield water because of the fine-grained nature of the deposit.

The Agua Zarca Member of the Chinle consists of light-gray to greenish-gray, medium- to very coarse grained, conglomeratic sandstone with minor amounts of interbedded reddish to maroon shale. Locally the sandstone contains abundant plant material which in some cases has been replaced by copper minerals. The Agua Zarca varies in thickness throughout the study area; in the Nacimiento Mine it is 22.9 - 30.5 m (75 - 100 ft) thick (Talbott, 1974, p. 302). Near Gallina the thickness of the Agua Zarca ranges from 0 - 18.3 m (0 - 60 ft), necessitating mapping it with the Salitral Shale because of the rapid thinning of these two members there.

The Agua Zarca would be expected to yield water throughout the study area where present because of the generally coarse-grained nature of the deposit. Near Gallina the Aqua Zarca and Poleo are probably in contact and behave as a single aquifer because of the absence of the Salitral Shale.

PERMIAN DEPOSITS

Yeso Formation

Several authors have disagreed about the relationships and extents of the Yeso Formation, Cutler Formation, and Abo

Formation in the study area. Wood and Northrup (1946) suggested that Permian rocks south of 36 N latitude should be divided into the Yeso and Abo Formations and that Permian rocks north of that line be referred to the Cutler Formation Baars (1962, p. 168) explained that the two members of the Yeso in north-central New Mexico grade northward and northeastward into Cutler equivalents just south of the stud area. Gibson (1975, p. 27) stated that the Yeso is present in the Gallina 7.5' Quadrangle and that the facies change between Cutler and Abo/Yeso is north of the Gallina quadrangle at approximately 36 12.5' N latitude. Due to th scope of the study, the complexity of the area, and the inability to trace the Yeso from 36 N latitude to the Gallin area, the author was not able to solve this problem. Therefore Gibson's suggestions have been followed on the basis of the evidence he presented and field observations of the author.

The Yeso Formation consists of orangish-brown, very fin to fine-grained sandstone with minor amounts of clay matrix. A section measured by Gibson (1975, p. 161) reported the Yes to be 13.1 m (43 ft) thick in sec. 21, T23N, R1E. Gibson (1975, p. 34) goes on to say that in sec. 19, T23N, R1W the Yeso is 45 m (150 ft) thick; near Cuba its thickness ranges from 3 - 46 m (10 - 150 ft; Woodward, and others, 1972).

No wells were found in the study area which obtained water from the Yeso. The Yeso would be expected to yield only small quantities of water in the study area. Water fro the Yeso would probably contain a large amount of iron and other dissolved solids due to the presence of iron and clay matrix in this unit.

Abo Formation

The Abo Formation is composed mainly of dark-reddish-brown to purplish-red claystone, silty claystone, and siltstone, but locally contains reddish-brown to buff, very fine to very coarse grained sandstone, thin-limestone lenses, and lenses of buff to light-gray conglomeratic sandstone. The conglomeratic sandstone contains clasts of metamorphic and sedimentary rock types having diameters up to 15 cm (6 in) (fig. 10). The thickness of the Abo varies considerably in the study area. Gibson (1975, p. 23) stated, "The formation is an erosional wedge, thinning eastward from 884 m (2900 ft) thick along the west edge of the Gallina 7.5' Quadrangle to about 335 m (1100 ft) thick in sections 25, 26, and 35, T23N, R1E." Near Cuba the thickness of the Abo ranges from 46 - 229 m (150 - 750 ft; Woodward and others, 1972).

The nature of the lower contact of the Abo also differs throughout the study area. Hutson (1958, p. 11) stated that the contact between the Abo and Madera Formations in the SW 1/4 , sec. 30, T23N, R1E is an angular unconformity. Near Cuba and along the Nacimiento front the Abo rests directly on the Precambrian and in the American Parks area the contact is gradational with the Madera Formation, (Plate 1; Steve Hill,

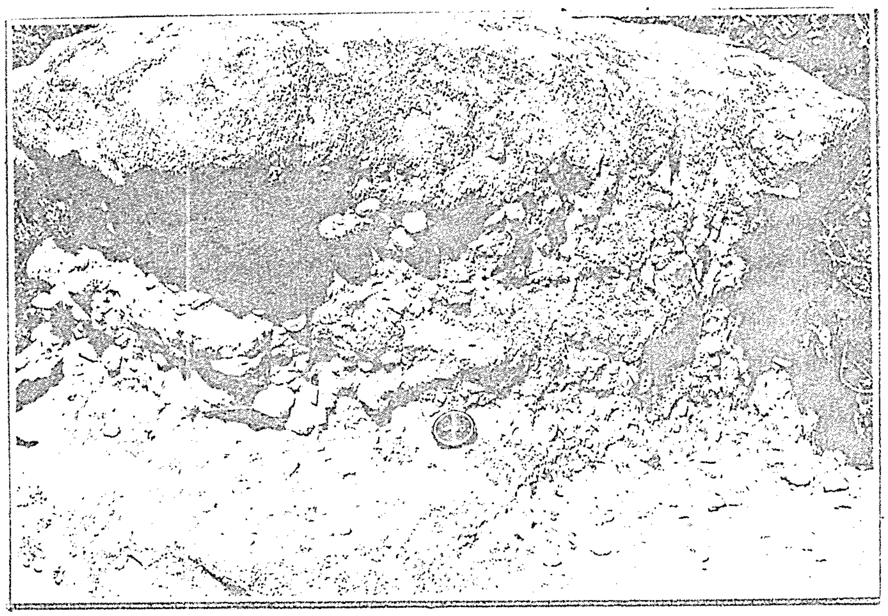


Figure 1Ø. Conglomeratic zone in Abo Formation (sec. 25, T23N, R1W); lense cap 6 cm (3 in) in diameter.

New Mexico Tech graduate student, personnal communication, 1979).

No wells were found in the study area which obtained water from the Abo. Just to the south, however, in sec. 6, T20N, R1W, two springs issue from sandstones in the Abo. One (unnamed) yields less than 3.7 $x10^{-3}$ m^3/minute (1 gpm), the other (Horseshoe Spring) yields significant quantities of water and has been developed by the United States Forest Service. Many Cuba residents obtain their drinking water from this spring because of the poor quality of the water available in the Cuba city water system. Water from this spring contains 298 ppm total dissolved solids (sample SC-1, Appendix E).

The quantity and quality of the water obtained from the Abo would be expected to vary owing to the lenticular nature and great variation in texture and composition of the sandstones in this unit.

PENNSYLVANIAN AND MISSISSIPPIAN DEPOSITS

Madera Formation and Arroyo Penasco Formation

The Madera Formation (Pennsylvanian) and the Arroyo Penasco Formation (Mississippian) have been combined for purposes of discussion because of their similar water-bearing characteristics and the poor exposure and limited extent of the Arroyo Penasco.

The Madera consists of interbedded gray limestones, arkosic limestones, conglomeratic sandstones, sandstones, ar shales. The gray limestones are generally very fossiliferou but in some areas they are recrystallized and contain few fossils. The arkosic limestones are light-gray and contain angular feldspar amd quartz grains up to 4 cm (1.5 in) in diameter. The conglomeratic sandstones and sandstones are yellowish-gray to dark-reddish-brown, very fine to very coarse grained, generally poorly sorted and are locally cross-bedded. The conglomeratic sandstones contain well rounded quartzite clasts up to 10 cm (4 in) in diameter. Th shales are grayish-purple to blackish-red and locally conta silt.

The thickness of the Madera varies considerably throughout the study area as a result of differences in the depositional environments and the extent of the post-Madera/pre-Abo erosion. Gibson (1975, p. 13) reported that the Madera is 231.7 m (760 ft) thick near the western boundary of the Gallina 7.5' quadrangle and thickens to 472. m (1550 ft) near the Rio Gallina and Rio Capulin area. Nea the American Parks area (Plate 1) the Madera is approximate 120 m (400 ft) thick (Steve Hill, New Mexico Tech graduate student, personal communication, 1979).

Several springs issue from limestones in the Madera; these springs generally occur where limestone or sandstone rests on shale. Estimated yields of these springs vary fro $1.9 \times 10^{-3} - 0.11\ m^3$/minute (0.5 - 30 gpm). Several springs the study area issue from fractures in the Madera. Lime Spring (Plate 2), the largest spring of this type, yields a estimated 0.76 m /minute (200 gpm). Local residents report that a cave near the spring extends at least 120 m (400 ft) back from the surface. Many springs which issue from the Madera have been developed for stock or domestic purposes (fig. 11). Water which issues from the Madera is of good quality but does seem to have a large percentage of calcium (Table 7).

The only known outcrops of the Arroyo Penasco in the study area are in sec. 36, T23N, R1W. A section measured b Armstrong (1967, p. 35) reports the Arroyo Penasco to consi mainly of dolomitic limestone with thin conglomeratic sandstones near the base and top of the unit. The thicknes of the Arroyo Penasco in this area ranges from 0 - 40 m (0 - 130 ft; Armstrong, 1967, p. 35).

PRECAMBRIAN ROCKS

The Precambrian consists of various metamorphic and igneous rocks. The specific rock types present and their relationships have been discussed in detail by Woodward and others (1977, p. 92-99). For purposes of this study the Precambrian rocks were grouped into three categories: igneous rocks, metasedimentary rocks, and metavolcanic rock (Plate 1). Precambrian rocks crop out throughout the San Pedro Mountain province and are extensively fractured in th

Table 7. Chemical analyses of ground water from the Madera Foramtion, Cuba Quadrangle. Sample numbers correspond to those in Appendix B; see Plate 2 for locations. Under sample type Sp = Spring. Concentrations given as parts per million; nd = not detectable, -- = constituent not analyzed for, TDS = total dissolved solids. Additional chemical information given in Appendix E.

Sample Number	Sample Type	HCO_3	Cl	SO_4	Na	K	Mg	Ca	Fe	Si	TDS
SA-1	Sp	96	1.0	nd	1.6	0.6	0.7	30	--	5.3	88
SA-8	Sp	333	2.0	48	2.84	0.4	0.9	126	--	3.8	308
SA-9	Sp	340	6.0	44	9.0	1.6	0.86	120	--	5.3	352
SA-33	Sp	145	9.2	25	7.8	21.0	7.7	60	--	--	200

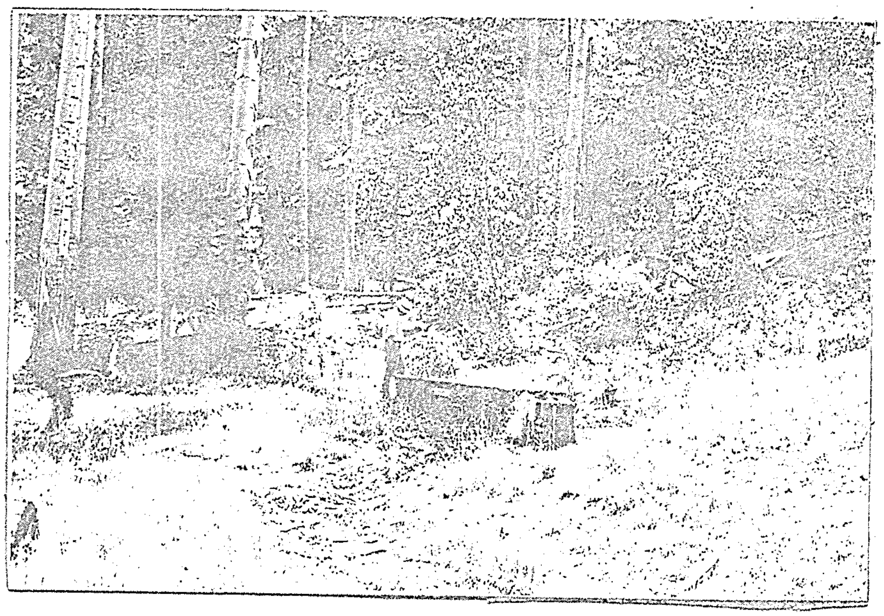


Figure 11. Lion Spring (SW 1/4, sec. 31, T23N, R1E); stock tank filled by overflow pipe which comes from fenced area; view southeast.

area. Measurement of 41 joint orientations yielded major trends of approximately N70° E, N35° E, N10° W, and N75° W.

Several small seeps are present in the San Pedro Mountain area where the Precambrian rocks crop out. These seeps are generally found in stream valleys and are seasonally dry. Most of the water in the Precambrian is confined to fractures. Any wells completed in the Precambrian rocks would not be expected to yield significant quantities of water.

HYDROGEOLOGY

The three provinces defined under "Physiography" above (fig. 2) are hydrogeologically distinct. The Hogback Belt and Chama Slope have completely separate ground-water systems. The crystalline-rock terrain of the San Pedro Mountain province permits very little storage and ground water is contributed to either the Hogback Belt, the Chama Slope, or areas to the south and east.

These provinces form a useful basis for discussion of the geologic controls of ground-water occurrence, movement, and quality in the area. Although the controls of occurrence and movement may be more or less generalized for all aquifers in a given province, the controls of water quality cannot and thus each aquifer is examined individually.

Geologic controls are difficult to assess for the bedrock aquifers because of the small size of the area as compared to the size of the depositional systems which produced them. Although geologic controls are easier to recognize for the unconsolidated aquifers, extensive dissection of the terraces and the scarcity of data on the characterisics of the alluvium hinder detailed interpretations.

HOGBACK BELT

Occurrence

Ground water in the Hogback Belt occurs in both unconsolidated sediments and major sandstone units. Principal aquifers include alluvium, terrace gravels, Cuba Mesa Member of the San Jose Formation, Ojo Alamo Sandstone, Cliff House Sandstone, Point Lookout Sandstone, and Dakota Sandstone. Although other rock units may contain suitable quantities and qualities of water little is known of their water-bearing characteristics and the steep westerly dips place them too deep for economic development in most of this province.

The alluvium and terrace gravels generally contain more water near the mountain front because they are coarser-grained and are characterized by higher porosity and permeability in this area. The terrace gravels would be expected to be thicker near the mountain front and in areas where they overlie shales which were deeply eroded prior to deposition of the gravels. The alluvium seems to generally be thicker away from the mountain front. Near Cuba, where the Rio Puerco and several of its tributaries join, the alluvium would also be expected to be quite thick. In these areas alluvium and terrace gravels would also be expected to yield significant quantities of water. The Cuba Mesa Member of the San Jose Formation and the Ojo Alamo Sandstone are the most developed aquifers in the Hogback Belt. The transmissivity of the Ojo Alamo is approximately 9 m^2/day (100 ft^2/day). The Cuba Mesa would be expected to have transmissivities equal to or greater than those of the Ojo Alamo because the Cuba Mesa is generally coarser-grained and better sorted than the Ojo Alamo. The Cliff House Sandstone, Point Lookout Sandstone, and the upper Dakota Sandstone all share a marine-shorezone origin (Fassett, 1977, p. 197; Owen, 1963) and thus have similar lithologic characteristics. This results in similar water-bearing characteristics for these units as well. Based on the limited exposures of these sandstones in the province, their lithologic characteristics do not seem to vary significantly from place to place and thus their water-bearing characteristics are expected to be more or less uniform throughout the area. The Point Lookout has a porosity of approximately 30 percent (Renick, 1931, p. 35); the Cliff House would be expected to have a similar porosity. The lower Dakota which was deposited in a fluvial environment (Grant and Owen, 1974) would be expected to have a higher porosity than either of the above units because of the very coarse-grained nature of the deposit.

Movement

Many streams that flow through this area have their headwaters in the San Pedro Mountain province. Very near the mountain front several of these streams are perennial, but as they flow westward across the gravel terraces and/or in the alluviated valleys they lose more water than they gain. As a result of this condition many of the streams are dry except during the snow-melt runoff period in the spring and for short periods in the late summer when heavy rains fall in the area. The water that is lost from these streams in their upper reaches would be expected to travel underground in the gravel terraces and alluvium until reaching a permeable unit among the beveled steeply dipping older deposits. In these areas much of the water traveling through the terrace gravels and/or alluvium would percolate into these permeable rock units. It would be expected that this process could make a significant contribution to the recharge of many of the area's aquifers.

West of the mountain front and near Cuba the dip of the strata is nearly horizontal and the strata have large outcrop areas. Many of the aquifers are recharged by infiltration of precipitation and snow melt over these large outcrop areas.

A good example of this is Mesa de Cuba west of the study are and between La Placita and La Jara where the Cuba Mesa Membe of the San Jose crops out (Plate 1).

The lack of data prevented constructing water-table map for all but one of the aquifers and this map only covers a small area (fig. 12). The water-table map constructed does show that the water moves westward from the mountain front (i.e. the outcrop area). This westward movement of ground-water would be expected for all aquifers in the Hogback Belt.

In some cases, the aquifers are confined between shale units and are therefore artesian west of the recharge areas.

Several seeps and springs are found along the margins c the terraces. Where the terraces are underlain by shales, water is perched and moves down gradient until reaching the terrace margin, when it discharges as springs and seeps. Most ground water moving through the Hogback Belt does not discharge in the study area but continues to flow west.

Quality

The main factor controlling the amount of dissolved solids in the water seems to be distance from the mountain front. Sample SA-34, collected 0.4 km (0.25 miles) from the mountain front contained 87 ppm total dissolved solids, Sample SA-11, taken 3.2 km (2 miles) from the mountain front contained 287 ppm total dissolved solids, and BZ-88, from 5.

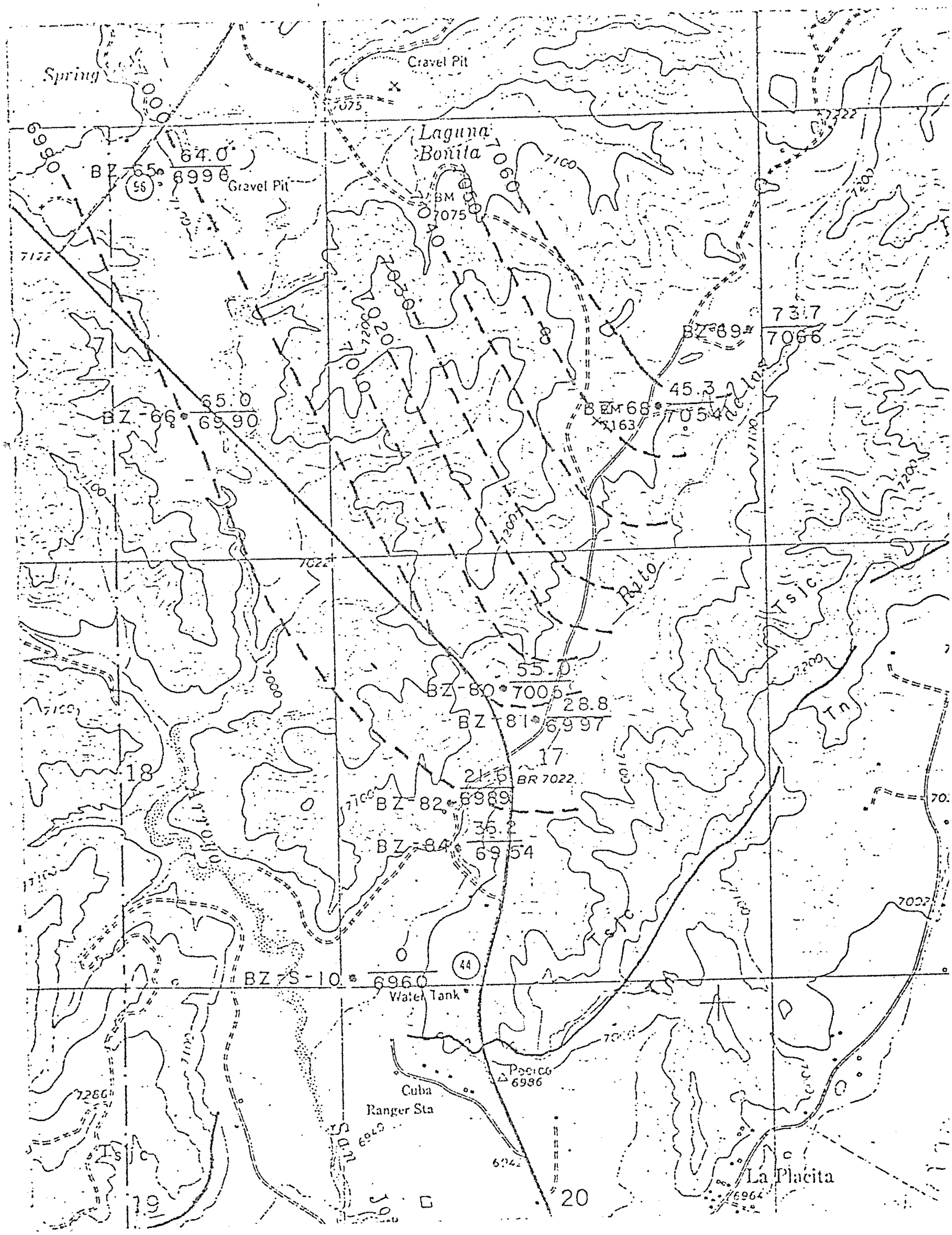


Figure 12. Water-table map for Cuba Mesa Member of the San Jose Formation, T21N, R1W; sample numbers correspond to those in Appendix B; depth to water (ft) / elevation of water level (ft); — = contact between Cuba Mesa and Nacimieto Formations; base from USGS Cuba 7.5' Quadrangle; water levels from Baltz and West (1967).

km (3.5 miles) west of the mountain front, contained 568 ppm total dissolved solids (Appendix E). Well depth may be an additional factor. The well from which SA-34 was collected is 9.1 m (30 ft) deep, that from which SA-11 was taken is 10 m (33 ft) deep, and that for BZ-88 is 25.9 m (85 ft) deep (Appendix B). From these analyses it seems that any wells completed in alluvium would yield potable water with quality deteriorating with distance from the mountain front and well depth.

Water obtained from alluvium in the Hogback Belt is generally high in dissolved calcium and bicarbonate. This may be due to the water in the alluvium leaching calcium and bicarbonate from weathered Precambrian rocks in the alluvium.

Water obtained from the terrace gravels is of very good quality (< 400 ppm total dissovled solids; Appendix E) which is probably due to very short residence times. The amount of dissolved solids in water in terrace gravels seems to increase away from the mountain front much like it does in the alluvium. Sample SA-10 contained the highest concentration of dissolved material (355 ppm total dissovled solids; Appendix E). This sample was collected from a well located at the very edge of a terrace, approximately 5.6 km (3.5 miles) from the mountain front.

The classification of water obtained from terrace gravels varies from one area to another. This is probably due to the variation in type of rock in the various gravels and the residence time of the water.

Water obtained from the the Cuba Mesa Member of the Sa Jose Formation generally contains between 3ØØ-6ØØ ppm total dissovled solids (Appendix E). The generally high amount o dissolved solids in the water so near the recharge areas is probably due to the solution of clays and weathered feldspars.

The percentages of specific consituents in water from the Cuba Mesa vary considerably and show no definite trends. This may be explained by the extremely variable lithologic nature of the Cuba Mesa, by differences in well constructio by differences in well depth, and by the distance from the recharge area. One interesting point that can be seen on t trilinear plot is that water which is high in sulfate also has a very high iron content (samples SA-16, SA-22, and SA-24, Appendix E; fig.13). The dissolved-sulfate content these samples is above the recommended limit of 25Ø ppm (He 197Ø, p. 321).

The wide range of iron concentrations in the samples a the large change in iron concentration in samples SA-13 and BZ-66 may be due to iron bacteria which live in the well casing and in the formation near the well screen. Such bacteria are generally introduced to the well during drilli or well completion. The bacteria oxidize iron compounds in the formation, the well screen, and the casing.

The problem might be solved by chlorinating the well t kill the bacteria and then pumping the well extensively to completely flush the well of the chlorinating agent.

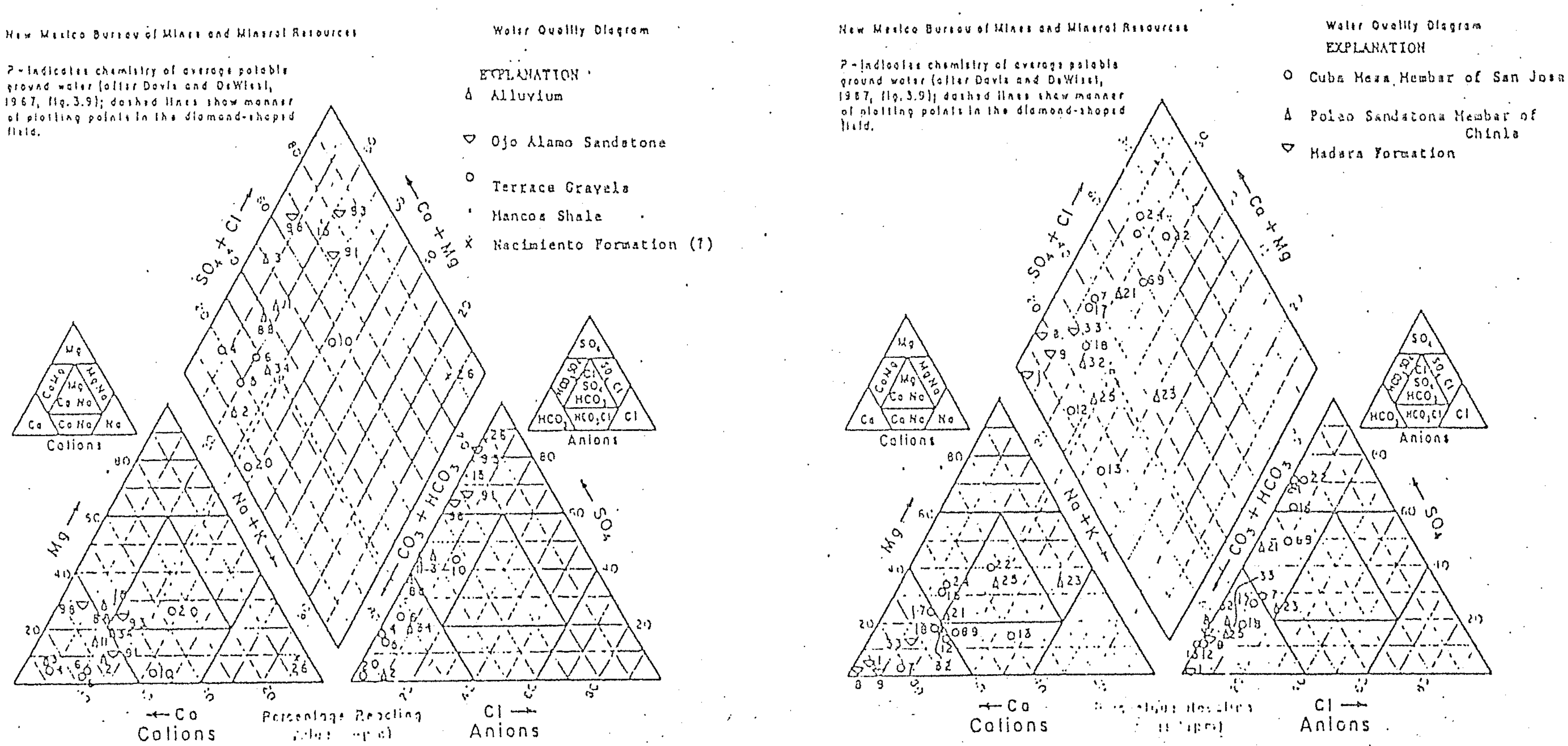


Figure 13. Piper diagram plots of water from several aquifers in the study area; see Appendix I for data used in plots.

The iron problem may also be due to the interaction of oxygenated recharge water and reduced iron minerals to yiel ferrous iron and sulfate. Such water will become depleted oxygen with time but considerable amounts of iron and sulfa may be dissolved by then. The iron compounds will complete dissolve with time and thus the water may tend to have less dissolved iron the longer the well is used.

The quality of water obtained from the Ojo Alamo Sandstone is poor in comparision to that of water from othe aquifers in the area (Appendix E).

In general water obtained from the Ojo Alamo contains large amounts of sulfate and considerable amounts of calciu (fig. 13; Appendix E). In all samples reported the sulfate concentration is above the recommended limit of 250 ppm. T water also seems to have a high concentation of iron. This high iron content may be due to the dissolution of pyrite i the Ojo Alamo. The generally poor quality of water near th recharge areas may be the result of leakage of poor quality water from the overlying Nacimiento Formation. The middle shale unit of the Ojo Alamo and the large clay content of t sandstones in some areas may also contribute to the poor water quality observed. The quality of the water seems to improve rather than deteriorate with distance from the outcrop. A change in the water from an oxidized state near the outcrop area to a reduced state farther away may explai this condition.

CHAMA SLOPE

Occurrence

Ground water in the Chama Slope occurs in unconsolidated sediments, the Poleo Sandstone Member of the Chinle, and the Madera Formation.

The gravel terraces in this area are not as extensive as the terraces in the Hogback Belt. Generally these terraces would contain water because they are coarse-grained and would be expecter to be quite permeable. The Poleo Sandstone Member of the Chinle is the major aquifer in the Chama Slope. The degree of sorting and cementation in the Poleo varies considerably; this is due partly to the fluvial origin of the unit (Gibson, 1975, p. 56). In areas where the Poleo is well sorted and/or poorly cemented it would be expected to yield the most water. Conglomeratic lenses in the Poleo would also be expected to yield significant quantities of water.

The Abo Formation would be expected to yield minor amounts of water in the area and the Madera, although very deep in the Chama Slope (Plate 1), would be expected to yield significant quantites of water. This water in the Madera would be confined to sandstone horizons and zones of secondary porosity.

Movement

The major aquifers of this province are recharged directly through infiltration of precipitation and snow-melt runoff and, to a lesser extent, by bed loss from several of the streams in the area. The headwaters of these streams are i the San Pedro Mountain province. The outcrop belts of the major aquifers of the area are quite extensive. The Poleo Sandstone Member of the Chinle Formation is the major aquif in the Chama Slope. Because the outcrop belt of this aquif is much higher in elevation than Gallina (Plate 1) and the aquifer is confined, most wells in the Gallina area complet in the Poleo are artesian and some are flowing. The region ground-water flow in this area would be expected to be northerly with a high gradient.

Quality

The low total-dissolved-solids content of water obtained from the Poleo Sandstone Member of the Chinle (Appendix E) is probably due to short residence time.

The percentage of the different dissolved constituents varies in the samples tested, but generally th water contains a large percentage of bicarbonate. This may be due to the carbonate cement of the Poleo dissolving in t ground water.

The well associated with sample SA-21 is probably completed in either the Upper Shale or Salitral Shale Membe of the Chinle in addition to the Poleo in view of the red nature of the water issuing from the well. Water in either the Upper Shale or the Salitral Shale would be expected to be of poor chemical quality because of the fine-grained nature of these units. The large difference between the total-dissolved-solids content in this sample and that of other samples from the Poleo supports the possibility of poor well construction (sample SA-21, Appendix E). Local residents have experienced problems with iron in the water; this is probably also due to poor well construction.

SAN PEDRO MOUNTAIN

Occurrence

The major water-bearing units in the San Pedro Mountain province are alluvium, the Madera Formation, and fractured Precambrian rock.

The alluvium in this area is derived from weathering of the Precambrian rocks and the Madera Formation This alluvium is generally coarse-grained and would be expected to have a high permeability.

The large cave near Lime Spring on the northern side of the San Pedro Mountian is evidence of the significar amount of secondary porosity that may be present in the limestones of the Madera Formation. This cave is located very near a fault (Plate 1) which was probably responsible for the initial fractures in which solution took place.

In most parts of this province the Precambrian is extensively fractured and may contain minor amounts of ground water. Areas near faults seem to be the most extensively fractured and may generally contain more water than other areas. However, the Precambrian would not be expected to contain much water.

Movement

Recharge to the alluvium and fractured bedrock occurs as the result of infiltration of precipitation and snow melt. Considerable amounts of water may be moving off the north, east, and south sides of the San Pedro Mountian area through fractures and solution cavities in the Madera Formation. The fracture orientations of N 70° E, N 35° E, N 10° W, and N75° W probably control the direction of water movement. Although much of the ground-water in the alluvium and fractured Precambrian rocks is discharged into the many streams of the area before moving any great distance. The streams that flow west and north off the San Pedro Mountian Area contribute to the recharge of aquifers in the Hogback Belt provinces and Chama Slope provinces.

Water in the Madera would be expected to travel down dip and out of the San Pedro Mountain province. This water would be expected to move quite fast as a result of th large amount of secondary porosity and moderate dip of the Madera.

Springs which issue from the Madera seem to be found in areas where faults have fractured the Madera or where the water is perched on shales

Quality

Water in the alluvium and fractured Precambrian rock would be expected to have low total-dissolved-solids concentrations based on analyses of surface water. The expected low total-dissolved-solids content would be expectec to be due to very short residence times.

Water issuing from springs in the Madera Formation is of very good quality; one such spring is used for the Regina public water supply (sample SA-33, Appendix E). The generally low total-dissolved-solids concentrations of water in the Madera is probably due to relatively short residence times. From the trilinear plot (fig. 13) it can be seen tha the water from the Madera is of a calcium-bicarbonate type. This is what would be expected for waters which travel through limestones. Water obtained from the Madera in the Gallina area would be expected to contain a higher concentration of dissolved constituents than the samples reported here because of a longer residence time. The water would, nonetheless, be expected to be of good quality.

WATER USE AND SUPPLY

MUNICIPALITIES

Presently community water systems supply the wate needs of most residents in the study area. The Cuba community water wells are located on Mesa de Cuba and tap t Cuba Mesa Member of the San Jose Formation. Many local residents do not use the water from the community system fo cooking and drinking, but instead use water from a spring i section 6, T2ØN, R1W. A chemical analysis of water obtaine from the Cuba water system (sample SA-3Ø, Appendix E) showe that the water was high in sulfate, calcium, iron, manganes and especially magnesium. A chemical compound of magnesium and sulfate (epsom salt) is known to have a bitter taste an this may be the reason that people of the Cuba area do not drink the water. Calcium and magnesium also make water har To solve this problem, water of the Cuba system could be softened or run through an ion exchange process to replace the calcium and magnesium ions with sodium ions. In 1977 a group from the Chemical Engineering Department at New Mexic State University set up portable reverse-osmosis and electrodialysis units to try to reduce the iron and mangane concentrations. While in operation the system lowered the iron and manganese levels significantly (Floster and Wilson 1979).

If the problem of high amounts of calcium and magnesium is solved the system is capable of producing larg amounts of water. Several new wells may have to be drilled in the future to meet demands, but significant quantities of water could be produced from the area of the present wells. If the problem cannot be solved economically wells should be drilled near the mountain front to tap the Point Lookout Sandstone or Dakota Sandstone.

The La Jara water system obtains water from alluvium near La Jara Creek in sec. 23, T22N, R1W (Plate 2). The water is of very good quality (sample SA-34, Appendix E) and this supply meets the present demands. In the future more wells may have to be drilled to meet the supply. The alluvium in this area will not be able to supply large amounts of water. To meet the demands for more water, wells drilled near the present well that would tap the Dakota or Point Lookout would be suggested.

The Regina Mutual Water Association is the largest system in the study area. This system runs from approximately 4.8 km (3 miles) south of Regina to Llaves approximately 22.5 km (14 miles) north of Regina. The water for this system is obtained from two springs located in sec. 36, T23N, R1W. The supply just meets the demands presently. In the future wells drilled near the mountain front which ta the Dakota or Point Lookout would be expected to yield significant quanties of water.

The Gallina Plaza community water system obtains water from a flowing well in section 9, T23N, R1E (Plate 2). This well produces sufficient quantities of water presently; in the future other wells may be necessay to meet the demands. Any wells drilled in the Gallina Plaza area that tap the Poleo Sandstone Member of the Chinle would yield significant quanities of potable water.

The Gallina community water system obtains water from a well in section 15, T23N, R1E (Plate 2). This well is not reliable and produces water which is very red in color. For the present needs of Gallina it seems a new well should be drilled. If a new well is drilled care should be taken so the well is screened only in the Poleo. If this well was drilled approximately 0.8 km (0.5 miles) south of Gallina and a large storage tank erected, a gravity pressure system would probably work well. Future water needs could be met by more wells in the area mentioned above.

SUMMARY AND CONCLUSIONS

1. Ground-water potential is good in the Cuba 15' Quadrangle and in the future will have to be developed to meet the increasing needs for water.
2. In the Chama Slope area the Poleo Sandstone Member of the Chinle Formation is presently being used as an aquifer and the Poleo has very good potential for future development.
3. Proper well construction is very important in obtaining good quality water from the Poleo. Care must be taken so that no well screen is set in the Upper Shale or the Salitral Shale Members of the Chinle Formation.

4. The Madera Formation would be expected to yield significant quanities of potable water in the Chama Slope area, although the Poleo presently meets the water demands of the area.

5. There are many potential aquifers in the Hogback Belt area which are not presently being used because of their great depth.

6. The terrace gravels and alluvium are important aquifers in the Hogback Belt area, although the quanity of water which may be produced from them is limited because of their limited thickness and extent.

7. The Cuba Mesa Member of the San Jose Formation is an important aquifer in the Hogback Belt area. Proper well sanitation and construction are very important to insure that the best quality water is produced from this aquifer.

8. The Ojo Alamo Sandstone yields significant quanities of water in the Hogback Belt area, but this water is of poor quality. All samples collected exceded the recommended limit for sulfate concentration.

9. The transmissivity of the Ojo Alamo in the study area is very similar to that reported for this aquifer elsewhere in the San Juan Basin.

10. In the San Pedro Mountain area the alluvium and Madera Fromation have the best potential as aquifers, although some water would be encountered in fractured Precambrian rocks.

11. The major aquifers are recharged as a result of bed loss from the many streams in the area and infiltration of precipitation and snow-melt.

12. In the Chama Slope area the ground water would be expected to move in a northerly or notheasterly direction with high gradients near San Pedro Mountain.

13. In the Hogback Belt area regional flow in the aquifers would be expected to be in a westerly direction.

14. Near Cuba the general quality of water in the terrace gravels and Cuba Mesa Member of the San Jose Formation has not changed significantly in the last 20 years based on comparision of recent analyses and those of Baltz and West (1967).

APPENDIX A

Measured Sections

Descriptions for the five sections measured for this study are presented below. The sections were measured with a metric tape, Jacob's staff graduated in metric units, and Abney level. Four of the sections measured are located in the study area; the other section (SA-5) was measured just east of the study area.

The sections were described using a reference shee compiled by Dr. William Stone (Feb., 1976), and the descriptions of all the parameters which follow except colo: sorting, and degree of roundness are taken directly from th sheet.

Color

Rock colors follow those of GSA Rock Color Chart (Goddard and others, 1975)

Bedding Size (McKee and Weir, 1953 as modified by Ingram, (1954; Campbell, 1967)

Very thick beds	> 100.0 cm
Thick beds	30.0 - 100.0 cm
Medium beds	10.0 - 30.0 cm
Thin beds	1.0 - 10.0 cm
Very thin beds	< 1.0 cm

Bedding Uniformity (Dunbar and Rogers, 1963)

Regularity	Regular - beds do not vary in thickness laterally
	Irregular - beds do vary in thickness laterally
Eveness	Even - all beds in vertical seccession similar in size
	Uneven - vertically adjacent beds not similar in size

Internal Structure of Beds (McKee and Weir, 1953; Campbell, 1967)

Very thick laminae	> 30.0 mm
Thick laminae	10.0 - 30 mm
Medium laminae	3.0 - 10.0 mm
Thin laminae	1.0 - 3.0 mm
Very thin laminae	< 1.0 mm
Massive	no laminae distinguishable

Bedding/Laminar Surface Shapes (modified from Campbell, 1967)

Planar - continuous/discontinuous; parallel/nonparallel

Wavy - continuous/discontinuous; parallel/nonparallel

Curved - continuous/discontinuous; parallel/nonparallel

Ripple Marks

Plan View

Continuous pattern

Straight - (rectilinear) parallel crests, normal to current

Caternary - parallel crests but not straight, nor everywhere normal to current, may grade into sinuous or lunate forms.

Sinuous - nonparallel crests, not everywhere normal to current

Discountinuous pattern

Lunate - crescentic, extremities point up current

Lingoid - crescentic, extremities point down current

Cross-Section View

Symmetrical/Asymmetrical

Climbing/"Normal"

Cross-Stratification

Magnitude (Jacob, 1973)

Small scale	< 0.05 m
Large scale	0.05 - 5.0 m
Very large scale	> 5.0 m

Relation With Lower Bounding Surface (Jacob, 1973)

- Concordant
- Discordant
- Tangential

Dip (Jacob, 1973)

Low angle	2.0 - 15.0
High angle	> 15.0

Grouping (Allen, 1963)

- Solitary
- Grouped

General Shape (modified from McKee and Weir, 1953)

- Planar
  - Tabular - sets bounded by parallel planar surfaces
  - Wedge - sets bounded by converging planar surfaces
- Nonplanar
  - Trough - sets bounded by curved surfaces

Grain Size (Wentworth, 1922)

Boulders	> 256.0 mm
Cobbles	64.0 - 256.0 mm
Pebbles	4.0 - 64.0 mm
Granules	2.0 - 4.0 mm
Very coarse sand	1.0 - 2.0 mm
Coarse sand	0.5 - 1.0 mm
Medium sand	0.25 - 0.5 mm
Fine sand	0.125 - 0.25 mm
Very fine sand	0.0625 - 0.125 mm
Silt	0.0039 - 0.0625 mm
Clay	< 0.0039 mm

Sorting (Compton, 1962)

Visual estimation using chart

Degree of Rounding (American Canadian Stratigraphic)

Visual estimation using chart

SECTION SA-1, HOGBACK (Regina 7.5' Quad.). Section measu along north side of roadcut; 8.9 km (5.5 miles) west of Gallina on NM 96; NW 1/4, SE1/4, NE 1/4, section 11, T23N, R1W, Rio Arriba County; section measured by Scott Anderhol

Unit	Lithology	Thickness m (ft)
CLIFF HOUSE SANDSTONE		
20	SANDSTONE--yellowish gray (5 Y 8/1) weathered and fresh; beds thick, regular, uneven, with medium, planar, continuous, parallel laminae; grains fine-medium, well-sorted, subrounded; contains carbonaceous material and marine trace fossils; upper portion of the unit eroded.	5.5 (18.
MENEFEE FORMATION		
19	SHALE AND COAL: SHALE--dusky yellowish brown (10 YR 2/2)- pale yellowish brown (10 YR 6/2) weathered and fresh; beds thick, irregular, uneven, with very thin, planar, discontinuous, laminae-massive; contains abundant carbonaceous material; contact with above sharp. COAL--black (N 1) weathered and fresh. Unit is largely shale but contains a few beds of coal; contact with above sharp.	31.9 (104.7
18	SANDSTONE AND SHALE: SANDSTONE--same as unit 2. SHALE--same as shale in unit 1.	3.6 (11

17	CLAYSTONE--black (N 1) weathered and fresh; beds thick, irregular, uneven, massive; contact with above sharp.	2.1 (6.9)
16	SANDSTONE--grayish brown (5 YR 3/2) weathered and fresh; beds medium, irregular, uneven, with thin, planar, continuous, nonparallel laminae; grains silt-medium, poorly sorted, subangular; contact with above sharp.	4.Ø (13.1)
15	CLAYSTONE--olive gray (5 Y 4/1) weathered and fresh; beds medium, irregular, uneven, with very thin, wavy, discontinuous, parallel laminae; contains ironstone concretions up to 3 m long and Ø.5 m thick; contact with above sharp.	2.7 (8.9)
14	SANDSTONE--yellowish gray (5 Y 8/1) weathered and fresh; beds thick, irregular, uneven, with very thin-very thick, planar, continuous, parallel laminae; grains fine-medium, moderaltely well-sorted, subangular; some thin interbedded shale layers; contact with above sharp.	9.4 (3Ø.8
13	SILTY CLAYSTONE--pale yellowish brown (1Ø YR 6/2)-dark gray (N 3) weathered and fresh; beds thick, irregular, uneven, with very thin, planar, continuous, parallel laminae; sone zones very carbonaceous; contact with above sharp.	5.9 (19.4)
12	SILTSTONE--dusky brown (5 YR 2/2) weathered and fresh; beds thick, irregular, uneven, massive; contact with above sharp.	1.Ø (3.3
11	CLAYSTONE--same as unit 3.	Ø.3 (1.Ø
1Ø	COAL--same as unit 8.	Ø.6 (2.Ø

9	SILTY CLAYSTONE--pale yellowish brown (10 YR 6/2) weathered and fresh; beds medium, irregular, uneven, with very thin, planar, discontinuous, parallel laminae; very silty zone near middle of unit; contact with above sharp.	1.6 (5.3)
8	COAL--black (N 1) weathered and fresh; contains plant impressions on bedding planes; contact with above sharp.	0.2 (0.7)
7	CLAYSTONE--pale yellowish brown (10 YR 6/2) weathered and fresh; beds very thick, regular, uneven, with very thin, planar, continuous, nonparallel laminae; contact with above sharp.	1.6 (5.3)
6	SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh; beds thick, irregular, uneven, with thin, planar, continuous, nonparallel laminae; large-scale, tangential, low-angle, solitary, tabular cross-beds; grains fine, moderately well sorted, subrounded; contact with above sharp.	0.4 (1.3)
5	CLAYSTONE--same as claystone in unit 1.	1.1 (3.6)
4	SANDSTONE--same as unit 2.	3.8 (12.5)
3	CLAYSTONE--dark gray (N 3) weathered and fresh; beds thick, irregular, uneven, with very thin, wavy, discontinuous, parallel laminae; contains two zones of which are very carbonaceous near the middle of the unit; contact with above sharp.	7.1 (23.3)
2	SANDSTONE--yellowish gray (5 Y 7/2) weathered and fresh; beds very thick, irregular, uneven, massive; grains silt-fine, moderately well sorted subrounded; some clay stringers interbedded with sandstone; contains carbonaceous material; contact with above sharp.	5.6 (18.4)

1	CLAYSTONE AND SANDSTONE:	6.2 (2Ø.3)

CLAYSTONE--light brownish gray (5 YR 6/1)-brownish black (5 YR 2/1) weathered and fresh; beds very thick-medium, regular-irregular, uneven, with very thin, planar, continuous, parallel laminae; contains large amount of carbonaceous material.

SANDSTONE--yellowish gray (5 Y 7/2) weathered and fresh; beds thick, irregular, uneven, with very thick laminae; grains fine-medium, moderately well sorted. Most of unit is claystone; contact with above sharp.

Total Section Thickness 94.6 (31Ø.4)

The base of the Menefee Formation is not exposed in this area, section was started at lowest portion of unit exposed at ground surface. strike N 2Ø° E, and dip 48° W.

SECTION SA-2, VALLECITO DEL RIO PUERCO, (Cuba 7.5' Quad.); south facing slopes on eastern end of small mesa; approximately 2.0 km (1.25 miles) northeast from Cuba High School; approximately 3.2 air km (2 miles) due east of La Placita; NE 1/4, section 22, T21N, R1W; Sandoval County; section measured by Scott Anderholm and Steve Craigg, July 1978.

Unit	Lithology	Thickness m (ft)
TERRACE GRAVEL		
14	BOULDER GRAVEL--pale reddish brown (10 Y 5/4) weathered and fresh; beds very thick, irregular, uneven, massive; grains boulder-clay, poorly sorted; upper portion eroded.	6.0 (19.7)
OJO ALAMO SANDSTONE		
13	SANDSTONE--yellowish gray (5 Y 7/2) weathered and fresh; beds very thick, irregular, uneven, with thick, curved, discontinuous, non-parallel, laminae-massive; large-scale, tangential, low-angle, solitary, trough cross-bedding; grains fine-coarse, moderately well sorted, subangular; composed mainly of quartz; contains concretions and iron staining; contact with above sharp.	12.6 (41.3
12	SHALE--olive gray (5 Y 3/2) weathered and fresh; beds very thick, massive; some zones contain silt; contact with above sharp.	7.2 (23.6
11	SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh; beds very thick, irregular, uneven, with thick laminae-massive; large-scale tangential, low-high-angle, solitary, trough cross-bedding; grains fine-medium, poorly sorted, subrounded; upper portion of unit very resistant; contact with above sharp.	11.6 (38.1

UNDIVIDED KIRTLAND SHALE-FRUITLAND FORMATION

10	SHALE--light olive gray (5Y 5/2) weathered and fresh; beds very thick, massive; non-calcareous; contact with above sharp.	8.7 (28
9	SANDSTONE--yellowish gray (5 Y 8/1) weathered and fresh; beds medium, irregular, uneven, with thick, planar continuous, parallel laminae; grains medium, well sorted, subrounded; unit not continuous laterally; contact with above sharp.	0.2 (0
8	SANDSTONE--yellowish gray (5 Y 7/2) weathered and fresh; beds very thick, regular, even, massive; grains fine-medium, poorly sorted, subrounded; composed mainly of quartz; unit contains some silt and clay; contact with above sharp.	3.7 (12.
7	SHALE--brownish gray (5 Y 4/1) weathered and fresh; beds thick, massive; contact with above sharp.	13.0 (42.
6	SANDSTONE AND SHALE:	8.5 (27.
	SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh; beds very thick, regular, even, with medium, planar, continuous parallel laminae; grains medium-coarse, well sorted, subangular-angular; contains trace fossils and carbonaceous plant fragments; iron staining present; contact with above sharp.	
	SHALE--brownish black (5 Y 2/1) weathered and fresh; beds medium, regular, even, massive; contains carbonaceous plant fragments; more shale near top of unit; contact with above sharp.	

5	SHALE--dark gray (N 3) weathered and fresh; beds very thick, with medium, planar, continuous parallel laminae; several beds contain silt; contains burrows filled with silt; contact with above sharp.	1.3 (4.3

PICTURED CLIFFS SANDSTONE

4	SANDSTONE--light olive gray (5 Y 5/2) weathered and fresh; beds very thick, massive; grains silt-fine, well sorted, subangular; contact with above sharp;	2.1 (6.9
3	SILTY SHALE--yellowish gray (5 Y 7/2) weathered and fresh; beds very thick, irregular, uneven, with very thick, wavy, discontinuous nonparallel, laminae; calcareous; contact with above sharp.	2.1 (6.9
2	SILTY SANDSTONE-SILTY LIMESTONE--yellowish gray (5 Y 7/2) weathered and fresh; beds very thick, massive; grains silt-fine moderately well sorted, subrounded; composed mainly of quartz with calcite cement; contact with above sharp.	3.2 (10.5

LEWIS SHALE

1	SHALE--olive gray (5 Y 3/2)-moderate brown (5 YR 4/4) weathered and fresh; beds very thick, massive; calcareous; contact with above gradational.	11.2+ (36.7+

Total Section Thickness 91.3 (299.5

Section started at break in slope in second small arroyo west of the road, offset at base of unit 11 to cliff approximately 1/4 mile west of original starting point.

SECTION SA-3, CERRO BLANCO (Gallina 7.5' Quad.) Section measured on east facing cliffs on east side of Cerro Blanco 2.4 km (1.5 miles) northeast of Gallina.

Unit	Lithology	Thickness m (ft)
LOWER MEMBER OF THE MORRISON FORMATION		
9	SILTY CLAYSTONE--grayish red (5 R 4/2) weathered and fresh; beds very thick, irregular, uneven, massive; very little of the unit exposed.	1.0+ (3.3+
TODILTO LIMESTONE		
8	GYPSUM--very light gray (N 8) (N 9) weathered and fresh; massive; contact with above sharp.	33.3 (109.3
7	LIMESTONE--yellowish gray (5 Y 7/2) weathered and fresh; beds medium-thick, irregular, uneven, with thin, wavy, discontinuous, non-parallel laminae; contact with above sharp.	2.1 (6.9
ENTRADA SANDSTONE		
6	SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh; beds very thick, irregular, uneven, massive; grains fine, well sorted, subrounded; composed mainly of quartz with calcite cement; some portions iron stained; contact with above sharp;	18.3 (60.0
5	SANDSTONE--very pale orange (10 YR 8/2) weathered and fresh; beds thick-very thick, regular, uneven, with medium-thick, continuous, parallel laminae; large-scale, discordant-concordant, low-high-angle, grouped, wedge cross-bedding; grains fine, well sorted, subrounded; composed mainly of quartz with calcite cement; contact with above sharp.	9.8 (32.2

4	SANDSTONE-- moderate reddish orange (1Ø R 6/6) weathered, light brown (5 YR 5/6) fresh; beds very thick, regular, uneven, with medium-thick, planar, continuous, parallel laminae; large-scale, discordant, high-angle, grouped-solitary, wedge cross-bedding; grains fine, well sorted, rounded-subrounded; composed mainly of quartz with some clay and calcite cement; contact with above sharp.	52.6 (172.
3	SANDSTONE--light greenish gray (5 GY 8/1) weathered and fresh; beds very thick, regular, uneven, with medium, planar, discontinuous, parallel laminae; small-scale, discordant, high-angle, grouped, tabular cross-bedding; grains fine, well sorted, subrounded; composed mainly of quartz with some clay and calcite cement; contact with above sharp.	1.5 (4.!
2	SILTY SANDSTONE--very pale green (1Ø G 8/2) weathered, greenish gray (5 G 6/1) fresh; beds very thick, regular, even, with medium, wavy, continuous, non-parallel laminae; grains silt-fine, moderatley -poorly sorted, subrounded; composed mainly of quartz with calcite cement; contact with above sharp;	2.5 (8.2)

UPPER SHALE MEMBER OF THE CHINLE FORMATION

1	SILTY CLAYSTONE--moderate reddish brown (1Ø R 4/6) weathered and fresh; beds very thick, regular, even, massive; highly calcareous; contact with above sharp.	3.2+ (1Ø.5+
	Total Section Thickness	124.3 (4Ø7.8

Measurement began in largest arroyo near middle of Cerro Blanco, offset at base of Todilto Limestone north approximately 1ØØ m (33Ø ft) to measure rest of section.

SECTION SA-4, BOX CANYON (Regina 7.5' Quad.). West facng slopes in canyon cut in Dakota dipslope; section started near Sandoval-Rio Arriba County line; 8 air km (5 miles) northeast of Regina; 4 air km (2.5 miles) southwest of Gallina Plaza; NE 1/4, NE 1/4, NW 1/4, section 24, T23N, R1W, Sandoval County; section measured by Scott Anderholm, July 1978.

Unit	Lithology	Thickness m (ft)
DAKOTA SANDSTONE		
12	SANDSTONE--pale yellowish orange (1Ø YR 8/6) weathered and fresh; beds medium, regular, uneven, with thin-thick, planar-wavy, continuous, parallel laminae; symmetrical straight ripple marks, crest height 1.3-2.5 cm (1/2-1 in), wave length 15-21 cm (6-9 in); grains silt-fine, moderately well sorted, subrounded; contains marine trace fossils; upper contact eroded.	1.4 (4.6)
11	SHALE AND SANDSTONE:	12.8 (42.Ø)
	SHALE--brownish black (5 YR 2/1) weathered and fresh; beds very thick, irregular, even, massive; contains some siltly zones.	
	SANDSTONE--very pale orange (1Ø YR 8/2) weathered and fresh; beds medium-thick, irregular, even, with thin, curved, discontinuous, nonparllel laminae; grains silt-medium, poorly sorted, subrounded.	
	Units contain cabonaceous material; sandstones near base of unit; contact with above sharp.	

10	SANDSTONE--pinkish gray (5 YR 8/1) weathered and fresh; beds medium-thick, irregular, uneven, with thin-medium, curved, continuous, parallel laminae; small-large- scale, discordant-concordant, high-angle, solitary-grouped, tabular-wedge-trough cross-bedding; grains medium-coarse, moderately well-poorly sorted, subrounded; unit contains some conglomeratic zones and some cross beds are outlined by thin pebble layers; contact with above sharp.	8.5 (27.9)
9	SANDSTONE--same as unit 7.	3.0 (9.8)
8	CONGLOMERATE--same as unit 6.	1.1 (3.6)
7	SANDSTONE--very light gray (N 8) weathered and fresh; beds medium, irregular, uneven, with thick, curved, continuous, parallel laminae; large-scale, discordant, low-high-angle, grouped, tabular-trough cross-bedding; grains medium-pebbles, moderately well-poorly sorted, subrounded; composed mainly of quartz with some feldspar and clay; contact with above sharp.	2.6 (8.5)
6	CONGLOMERATE--very light gray (N 8) weathered and fresh; beds very thick, irregular, uneven, massive; grains fine-pebbles, poorly sorted, subrounded; clay galls at base of unit; contact with above sharp.	1.0 (3.3)
5	SANDY SILTSTONE--yellowish gray (5 Y 7/2) weathered and fresh; beds medium, irregular, uneven, with thin-thick, planar, continuous, parallel laminae; grains clay-very fine, moderately well sorted; contains carbonaceous material; contact with above sharp.	0.9 (3.0)

4	SANDSTONE--very pale orange (10 YR 8/2) weathered and fresh; beds thin-thick, irregular, uneven, with thin-thick, curved, discontinuous, parallel laminae; large-scale, discordant-concordant, high-angle, grouped, trough-tabular cross-bedding; grains fine-pebbles, moderately well-poorly sorted, subrounded; some zones are conglomeratic and pebbles outline cross beds; contact with above sharp.	5.8 (19.0)
3	SANDSTONE--very pale orange (10 YR 8/2) weathered and fresh; beds thin-thick, irregular, uneven, with thin, planar, continuous, parallel laminae; large-scale, discordant-concordant, low-angle, grouped, trough cross-bedding; grains very fine-medium, well-poorly sorted, subrounded; contains several pebble rich zones; contact with above sharp.	6.7 (22.0)
2	SANDSTONE--yellowish gray (5 YR 8/1) weathered and fresh; beds thick, irregular, uneven, with thin laminae; grains fine-coarse, moderately well sorted, subrounded; contact with above sharp.	3.8 (12.5)

UPPER MEMBER OF THE MORRISON FORMATION

1	CLAYSTONE--olive green (5 Y 3/2) weathered and fr.	1.0+ (3.3+)
	Total Section Thickness	48.6 (159.4)

Section started approximately 0.4 km (0.25 miles) up major canyon in Dakota dipslope. Section measured near northern most exposure of upper member of the Morrison Formation in canyon.

SECTION SA-5, ARROYO CHIJUILLA (Arroyo Chijuilla 7.5' Quad.); measurement began on south facing slope on southern most cliff on border between sections 32 and 33, T21N, R2W; 4.1 air km (3 miles) north of N M 197; approximately 8.1 air km (6 miles) west of Cuba; sections 28, 32, and 33, T21N, R2W; Sandoval County; section measured by Scott Anderholm and Steve Craigg, June 1979.

Unit	Lithology	Thickness m (ft)
	CUBA MESA MEMBER OF SAN JOSE FORMATION	
20	SANDSTONE--dark yellowish orange (10 YR 6/6) weathered, very pale orange (10 YR 8/2) fresh; beds very thick-thick, irregular, uneven, with thick-medium, planar, continuous, parallel laminae; large-scale, tangential-discordant, high-low angle, grouped, tabular-trough cross-bedding; grains coarse-medium, moderately well sorted, subangular-subrounded; composed mainly of quartz; contains iron staining and carbonaceous material; top of unit eroded.	4.4 (14.4)
19	SILTSTONE AND SANDSTONE: SILTSTONE--yellowish gray (5 Y 8/1) weathered and fresh; beds very thick, irregular, uneven, massive. SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh; beds very thick-thick, irregular, uneven, with thick, planar, continuous, parallel laminae-massive; grains medium-fine, moderately sorted, subrounded; composed mainly of quartz with some mica; iron stained. Siltstone most common near the top of the unit; contact with above sharp.	9.8 (32.2)

REGINA MEMBER OF THE SAN JOSE FORMATION

18 CLAYSTONE--same as unit 16. 10.2 (33.

CUBA MESA MEMBER OF THE SAN JOSE FORMATION

17 SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh; beds very thick, irregular, uneven, with thick, planar, curved, continuous, parallel laminae; grains fine-medium, moderately sorted, subrounded; composed mainly of quartz with some mica; contains carbonaceous material; contact with above sharp. 5.2 (17.

REGINA MEMBER OF THE SAN JOSE FORMATION

16 SILTSTONE and CLAYSTONE: 21.8 (71.

SILTSTONE--very light gray (N 8) weathered, light olive gray (5 Y 6/1) fresh; beds very thick, irregular, massive.

CLAYSTONE-- grayish red (5 R 4/2) weathered and fresh; beds very thick, irregular, even, massive; Contact with above sharp.

CUBA MESA MEMBER OF THE SAN JOSE FORMATION

15 SANDSTONE--moderate yellowish brown (10 YR 5/4) weathered and fresh; beds medium, uneven, irregular, with thin, planar, continuous, parallel laminae; grains fine-medium, moderately sorted, subrounded; iron stained; unit partially covered; contact with above sharp. 19.2 (63.0

REGINA MEMBER OF THE SAN JOSE FORMATION

14 SILTY CLAYSTONE--pale brown (5 YR 5/2) weathered ,brownish gray (5 YR 4/1) fresh; beds very thick, irregular, uneven, massive; contact with above sharp. 9.Ø (29.5)

CUBA MESA MEMBER OF THE SAN JOSE FORMATION

13 SANDSTONE--very pale orange (1Ø YR 8/2) weathered and fresh; beds thick, irregular, uneven, with medium-thick, curved, continuous, parallel laminae; large-scale, tangential-discordant, low-angle, grouped-solitary, trough cross-bedding; grains medium-coarse, moderately well sorted, subangular; composed mainly of quartz, some feldspar; sand varies in thickness laterally; contact with above sharp. 21.1 (69.2)

NACIMIENTO FORMATION

12 SILTY CLAYSTONE AND SANDY SILTSTONE: same as unit 8. 7.Ø (23.Ø)

CUBA MESA MEMBER OF THE SAN JOSE FORMATION

11 SANDSTONE--dark yellowish orange (1Ø YR 6/6) weathered and fresh; beds thick-very thick, irregular, uneven, with thick, planar continuous, parallel laminae-massive; large-scale, discordant-tangential, low-high-angle, solitary-grouped, tabular-trough cross-bedding; grains coarse-very coarse, poorly sorted, subrounded-subangular; composed mainly of quartz with some feldspar; contact with above sharp. 15.1 (49.5)

NACIMIENTO FORMATION

10 SILTY CLAYSTONE AND SANDY SILTSTONE: 8.9 (29.2)
Same as unit 8.

CUBA MESA MEMBER OF THE SAN JOSE FORMATION

9 SANDSTONE--dusky yellow (5 Y 6/4) weathered and yellowish gray (5 Y 7/2) fresh; beds medium-thick, irregular, uneven, with thick, laminae; large-scale, discordant-tangential, high-angle, solitary, wedge-trough cross-bedding; grains fine-medium, moderately well sorted, subrounded; composed mainly of quartz with some mica; contact with above sharp. 1.3 (4.3)

NACIMIENTO FORMATION

8 SILTY CLAYSTONE AND SANDY SILTSTONE: 5.4 (17.7)

SILTY CLAYSTONE--olive gray (5 Y 4/1) weathered and dusky brown (5 YR 2/2) fresh; beds very thick, irregular, uneven, massive;

SANDY SILTSTONE--grayish red (10 R 4/2) weathered and fresh; beds thick, irregular, uneven, with thick, curved, discontinuous, parallel laminae; grains silt-very fine, poorly sorted, subrounded;

Both units contain carbonaceous material; contact with above sharp.

CUBA MESA MEMBER OF THE SAN JOSE FORMATION

7	SANDSTONE--grayish orange (10 YR 7/4) weathered and fresh; beds very thick, irregular, uneven, with medium-thick, planar, continuous, parallel laminae; large-scale, tangential-discontinuous, low-angle, solitary-grouped, trough-wedge cross-bedding; grains medium-coarse moderaely well sorted, subangular; composed mainly of quartz with feldspar and clay matrix; contains silicified wood and iron staining; contact with above gradational.	15.2 (49.9)
6	SANDY SHALE--light olive gray (5 Y 6/1) weathered and fresh; beds medium, irregular, uneven, with thin, curved, discontinuous, parallel laminae; unit not continous laterally; contact with above sharp.	0.5 (1.6)
5	SANDSTONE--yellowish gray (5 Y 7/2) weathered, yellowish gray (5 Y 8/1) fresh; beds medium-thick, irregular, uneven, with thick, planar, continuous parallel laminae; grains fine-medium, moderately well sorted, subrounded; composed mainly of quartz with clay matrix; contact with above sharp.	4.7 (15.4)

4 SANDY SILTSTONE AND CLAYSTONE: 1.6 (5.3)

SANDY SILTSTONE--light gray (N 7) weathered and fresh; beds thick, irregular, uneven, massive;

CLAYSTONE--light gray (N 7) weathered and fresh; beds thick, irregular, uneven, with medium, curved, continuous, parallel laminae.

Units contain sandstone clasts; contact with above sharp.

3 SANDSTONE--yellowish gray (5 Y 7/2) weathered and light gray (N 7) fresh; beds thick-very thick, irregular, uneven, with thick, curved, continuous parallel laminae; large-scale, tangential, low-angle solitary, trough-wedge cross-bedding; grains medium-very coarse, moderately well sorted, subrounded; contains silicified wood and liminitic wood; clay galls near base of unit; contact with above sharp. 11.1 (36.4)

NACIMIENTO FORMATION

2 SILTY CLAYSTONE--yellowish gray (5 Y 7/2) weathered, grayish black (N 2) fresh; beds thick, irregular, uneven, massive; contains carbonaceous material; contact with above sharp. 11.9 (39.0)

1 SANDY SILTSTONE, SANDSTONE, AND CLAYSTONE: 24.6 (80.7)

SANDY SILTSTONE-- weathered and fresh; beds medium-thick, irregular, uneven, massive; grains silt-very fine, poorly sorted.

SANDSTONE--yellowish gray (5 Y 7/2) weathered and fresh; beds thick, irregular, uneven, massive; grains very fine-fine, moderately-poorly sorted, subrounded.

CLAYSTONE-- light olive gray weathered, dark greenish gray (5 G 4/1) fresh; beds medium-very thick, irregular, uneven, massive.

Contains iron stone nodules; contact with above gradational.

Total Section Thickness 208 m (682.4 ft)

Measurement started at break in slope, near fence on section line between sections 32 and 33, measurement continued to top of cliff, offset at top unit 7 to NW 1/4, NE 1/4, SE 1/4, section 32 and measured northwest to top of south facing cliff on southwest side of arroyo, offset at base of unit 13 to base of south facing cliff on north side of arroyo and measured to highest point on mesa. Baltz (1967, Plate 1) mapped units 8, 10, and 12 as Regina Member of the San Jose Formation, the lithology of these units is very similar to the lithology of the Nacimiento Formation and it is the author's belief that the units are Nacimiento Formation and are a result of interfingering between the Nacimiento Formation and the San Jose Formation.

APPENDIX B

Well Inventory

Thirty wells, springs, and streams were inventoried in the study area. Whenever possible the depth of the well and depth to water was measured for each well. Table B-1 presents well inventory data.

The system of numbering the location of each well is that used by the New Mexico State Engineer and is based on the standard township, range, section, and quarter section. Each well has a set of numbers separated by periods which represents the wells location. The first numbers refers to township, the second set of numbers refers to the range, and the third set refers to the section the well is in. The last set of three numbers refers to the quarter sections the well is in. Each quarter section is divided into quarters and each quarter is assigned a number. The numbering is as follows: northwest quarter is 1, northeast quarter is 2, southwest quarter is 3, southeast quarter is 4. Each quarter of a section is divided into quarters with the same numbering scheme. The quarter-quarter sections are then divided into quarters again and the same nunbering system applied. If the location can not be determined to the quarter-quarter or quarter-quarter-quarter section a zero is used instead of one of the above numbers. In an area which is unsurveyed the locations were approximated using an extended township and range grid. A well in the SW 1/4, SE 1/4, NW 1/4, section 24, T23N, R1W would be designated 23N.1W.24.143 using this numbering scheme.

Table H-1

Well Inventory Data

Under sample number: SA = sampled by Scott Anderholm, SC = sampled by Steven Craigg, BZ = from Baltz and West (1967). Under aquifer: Qal = Alluvium, Qts = Terrace Gravels, TsJr = Regina Member of the San Jose Formation, TsJc = Cuba Mesa Member of the San Jose, Tn = Nacimiento Formation, Toa = Ojo Alamo Sandstone, Km = Mancos Shale, TRcp = Poleo Sandstone Member of the Chinle Formation, Pa = Abo Formation, Pm = Madera Formation. Under well type: Sp = Spring, St = Stream, Dug = Dug Well, Dr = Drilled. Under Well Use: N = No Use, D = Domesti S = Stock, PS = Public Service. For water quality data see Appendix E.

Owner	Sample Number	Location	Elevation	Well Depth	Water Level	Aquifer	Well Type	Well Use	An
U. S. Forest Service	SA-1	22.1E.9.410	9100	-	-	Pm	St	N	
U. S. Forest Service	SA-2	21.1E.3.100	10120	-	-	-	St	N	
U. S. Forest Service	SA-3	21.1E.21.100	9410	-	-	-	St	N	
Torbio Martinez	SA-4	21.1W.14.411	7440	15.6	1.0	Qts	Dug	D	
George Casaus	SA-5	21.1W.3.432	7430	-	-	Qts	Sp	D	
Unknown	SA-6	21.1W.14.332	7360	-	-	Qts	Sp	D	
Lupe Chavez	SA-7	21.1W.4.244	7390	282.0	230.0	TsJc	Dr	S	
U. S. Forest Service	SA-8	23.1E.31.332	8906	-	-	Pm	Sp	S	
U. S. Forest Service	SA-9	23.1W.25.431	8420	-	-	Pm	Sp	S	
Mark Camden	SA-10	23.1W.32.421	7440	59.0	14.2	Qts	Dr	S	
Fran Spratte	SA-11	23.1W.34.113	7580	33.0	1.0	Qal	Dr	D	
Dennis Vargo	SA-12	21.1W.9.214	7195	51.0	29.0	TsJc	Dr	D	
Bert's Trailer Park	SA-13	21.1W.7.414	7055	200.0	70.0	TsJc	Dr	D,PS	
Cosne Herrera	SA-14	20.1W.6.200	6880	220.0	87.0	Toa	Dr	S	
Lonnie Jacquez	SA-15	23.1W.12.411	7410	100	30	Km	Dr	D,S	
Carroll McLain	SA-16	21.1W.8.431	7160	159	-	TsJc	Dr	D	
L. A. McCracken	SA-17	21.1W.8.424	7100	87.0	76.0	TsJc	Dr	D	
Larry Senear	SA-18	21.1W.17.212	7060	-	-	TsJc	Dr	D	
Alice Wolf	SA-20	22.1W.34.433	7530	-	-	Tts	Sp	D,S	
Gallina Community	SA-21	23.1E.15.124	7590	-	-	TRcp	Dr	PS	
Alberto Herrera	SA-22	21.1W.7.234	6980	92.0	68.0	TsJc	Dr	S	
Willie Suazo	SA-23	23.1E.13.323	7710	45.0	8.0	TRcp	Dr	D	
Frank Garcia	SA-24	21.1W.8.331	7038	162	62.5	TsJc	Dr	D	
Jemez Mnt. School	SA-25	23.1E.15.123	7560	400.0	180.0	TRcp	Dr	PS	
John Shipley	SA-26	23.1W.15.233	7390	800	-	Tn(?)	Dr	S	
Cuba City Water	SA-30	21.2W.11.200	7280	800	-	TsJc	Dr	PS	
Jack Holley	SA-32	23.1E.9.341	7365	140.0	flows	TRcp	Dr	PS	
Regina Mun. Water	SA-33	23.1W.36.311	8490	-	-	Pm	Sp	PS	
La Jara Com. System	SA-34	22.1W.23.140	7980	30	-	Qal	Dr	PS	
U. S. Forest Service	SC-1	20.1E.6.234	7925	-	-	Pa	Sp	PS	
Juan Montoya	BZ-14	22.1W.20.134	7240	40.0	23.4	TsJr	-	N	
Genoveno Jaques	BZ-16	22.1W.30.232	7175	-	10.8	TsJr	-	D	
Genoveno Jaques	BZ-17	22.1W.30.232	7175	-	10.8	TsJr	-	N	
La Jara Store	BZ-31	22.1W.32.333	7150	192	160.0	TsJr	-	D	
H. B. Browning	BZ-34	23.1W.3.414	7320	734	456	TsJr	-	N	
Oribie Bridge	BZ-40	23.1W.19.244	7410	275	26.4	TsJr	-	D	
J. F. Herrera	BZ-65	21.1W.7.211	7060	125	64.0	TsJc	-	N	
Bert Herrera, Sr	BZ-66	21.1W.7.414	7055	155	65.0	TsJc	-	PS	
E. N. Maxey	BZ-68	21.1W.8.421	7100	106	45.3	TsJc	-	D	
R. D. Phillips	BZ-69	21.1W.8.422	7130	95	73.7	TsJc	-	D,S	
Girt Maxey	BZ-80	21.1W.17.142	7060	115	55	TsJc	-	D	
Ben Sawyer	BZ-81	21.1W.17.144	7025	46	28.8	TsJc	-	D	
Willian Eastlake	BZ-82	21.1W.17.321	7010	65	21.6	TsJc(?)	-	N	
William Eastlake	BZ-83	21.1W.17.323	6990	-	45	TsJc	-	D	
William Eastlake	BZ-84	21.1W.17.323	6990	76	36.2	TsJc	-	D	
Raphael Duran	BZ-88	21.1W.20.322	6920	85	41.8	Qal	-	D	
Cuba Schools 1	BZ-91	21.1W.28.143	6930	148	23.7	Toa	-	PS	
Cuba Schools 2	BZ-93	21.1W.28.211	6960	110	42.6	Toa	-	PS	
Standard Oil Co.	BZ-98	21.1W.29.240	6900	100	-	Toa	-	N	
William Eastlake	BZ-S-10	21.1W.17.333	6950	-	-	TsJc	Sp	S	
R. L. Reed	BZ-S-18	23.1W.22.333	7550	-	-	TsJr	Sp	S	

APPENDIX C

Thin-Section Analyses

Seven thin sections were described using a petrographic microscope. Most of the samples analyzed are from units that are aquifers or potential aquifers or potential aquifers in the area. Table C-1 summarizes the source of the samples.

Initially one hundred points were counted to determine relative abundance of framework, matrix, cement, and porosity. The matrix reported may be high because the samples were collected at the surface and thus were exposed to weathering processes. Porosity may also be inaccurate because of grain plucking during the cutting and grinding of the thin section.

Counting was resumed until 300 framework points had beei counted. The sandstones were then classified according to Folk's (1974) system by means of a computer program (William and Randazzo, 1976) which utilizes the point-count data to calculate percentages for each of Folk's end members and classify the rocks giving them a clan name and specific name It should be noted that although the version of the program used does not print out a framework percentage for granitic rock fragments, they are included in computing F-pole percentages and the group names are correct as shown. The computer print-outs for the samples analyzed follow Table C-1.

Abbreviations used in the print outs are: QTZ = quartz, KSP = potassium feldspar, PLAG = plagioclase, UNDF = undifferentiated feldspars, GR-RF = granitic rock fragments VRF = volcanic rock fragments, MRF = metamorphic rock fragments, CARF = carbonate rock fragments, SSRF = sandston rock fragments, SHRF = shale rock fragments, FECM = iron cement, CACM = carbonate cement, SICM = silica cement.

TABLE C-1. Source of samples studied in thin section. Where sample not from a measured section, legal description of sample site is given.

Number	Unit	Measured Section and Unit	
SA-II-12	Ojo Alamo	SA-2	11
SA-II-14	Ojo Alamo	SA-2	13
SA-III-4	Entrada	SA-3	4
SA-IV-4	Dakota	SA-4	4
SA-IV-7	Dakota	SA-4	7
SA-IV-12	Dakota	SA-4	12
SA-38	Poleo	NE 1/4, section 24, T23N, R1W	

```
SAMPLE NUMBER = SA-II-12     TOTAL POINTS COUNTED = 332     FRAMEWORK POINTS = 300

RAW DATA (INDIVIDUAL POINTS)
----------------------------

*QTZ*KSPAR*PLAG*UNDFS*GR-RF*VRF*MRF*CHERT*CARF*SSRF*SHRF*(FECM*CACM*SICM*CLAY*POROSITY
 136   97    13     1     16  15   0     0    0    6   16    20    1    0    1      10

FRAMEWORK PERCENTAGES
---------------------

Q-POLE**** 45.3

F-POLE**** 42.3
  KSPAR  87.4
  PLAG   11.7
  UNDFS   0.9

R-POLE**** 12.3
  VRF    40.5
  MRF     0.0
  SRF    59.5
    SED-RF POLE
     CHERT   0.0
     CARF    0.0
     SSRF   27.3
     SHRF   72.7

GROUP NAME IS **** ARKOSE

SPECIFIC NAME IS **** K-FELDSPAR-BEARING ARKOSE
```

SAMPLE NUMBER = SA-II-14 TOTAL POINTS COUNTED = 332 FRAMEWORK POINTS = 300

RAW DATA (INDIVIDUAL POINTS)

QTZ	KSPAR	PLAG	UNDFS	GR-RF	VRF	MRF	CHERT	CARF	SSRF	SHRF	(FECM	CACM	SICM	CLAY	POROSITY)
149	95	14	0	10	7	1	12	0	8	4	0	24	0	0	8

FRAMEWORK PERCENTAGES

Q-POLE**** 49.7

F-POLE**** 39.7
  KSPAR 87.2
  PLAG 12.8
  UNDFS 0.0

R-POLE**** 10.7
  VRF 21.9
  MRF 3.1
  SRF 75.0
    SED-RF POLE
      CHERT 50.0
      CARF 0.0
      SSRF 33.3
      SHRF 16.7

GROUP NAME IS **** ARKOSE

SPECIFIC NAME IS **** K-FELDSPAR-BEARING ARKOSE

SAMPLE NUMBER = SA-III-4 TOTAL POINTS COUNTED = 337 FRAMEWORK POINTS = 300

RAW DATA (INDIVIDUAL POINTS)

*QTZ	*KSPAR	*PLAG	*UNDFS	*GR-RF	*VRF	*MRF	*CHERT	*CARF	*SSRF	*SHRF	*(FECM	*CACM	*SICM	*CLAY	*POROSITY)
228	42	9	0	0	0	0	21	0	0	0	3	14	0	1	19

FRAMEWORK PERCENTAGES

Q-POLE**** 76.0

F-POLE**** 17.0
KSPAR 82.4
PLAG 17.6
UNDFS 0.0

R-POLE**** 7.0
VRF 0.0
MRF 0.0
SRF 100.0
SED-RF POLE
CHERT 100.0
CARF 0.0
SSRF 0.0
SHRF 0.0

GROUP NAME IS **** SUBARKOSE

SPECIFIC NAME IS **** K-FELDSPAR-BEARING SUBARKOSE

SAMPLE NUMBER = SA-IV-4 TOTAL POINTS COUNTED = 327 FRAMEWORK POINTS = 300

RAW DATA (INDIVIDUAL POINTS)

*QTZ	*KSPAR	*PLAG	*UNDFS	*GR-RF	*VRF	*MRF	*CHERT	*CARF	*SSRF	*SHRF	*(FECM	*CACM	*SICM	*CLAY	*POROSITY)
252	18	0	0	0	0	0	3	0	18	9	0	0	0	10	17

FRAMEWORK PERCENTAGES

Q-POLE**** 84.0

F-POLE**** 6.0
  KSPAR 100.0
  PLAG 0.0
  UNDFS 0.0

R-POLE**** 10.0
  VRF 0.0
  MRF 0.0
  SRF 100.0
    SED-RF POLE
      CHERT 10.0
      CARF 0.0
      SSRF 60.0
      SHRF 30.0

GROUP NAME IS **** SUBLITHARENITE

SPECIFIC NAME IS **** QUARTZOSE SEDARENITE ** OR **QUARTZOSE SANDSTONE ARENITE

SAMPLE NUMBER = SA-JV-7 . TOTAL POINTS COUNTED = 336 FRAMEWORK POINTS = 3

RAW DATA (INDIVIDUAL POINTS)

QTZ	KSPAR	PLAG	UNDFS	GR-RF	VRF	MRF	CHERT	CARF	SSRF	SHRF	(FECM	CACM	SICM	CLAY	PO
273	15	0	0	0	0	0	8	0	2	2	0	9	2	3	

FRAMEWORK PERCENTAGES

Q-POLE**** 91.0

F-POLE**** 5.0
- KSPAR 100.0
- PLAG 0.0
- UNDFS 0.0

R-POLE**** 4.0
- VRF 0.0
- MRF 0.0
- SRF 100.0
  - SED-RF POLE
    - CHERT 66.7
    - CARF 0.0
    - SSRF 16.7
    - SHRF 16.7

GROUP NAME IS **** SUBARKOSE

SPECIFIC NAME IS **** K-FELDSPAR-BEARING SUBARKOSE

SAMPLE NUMBER = SA-IV-12 TOTAL POINTS COUNTED = 311 FRAMEWORK POINTS = 300

RAW DATA (INDIVIDUAL POINTS)

QTZ	KSPAR	FLAG	UNDFS	GR-RF	VRF	MRF	CHERT	CARF	SSRF	SHRF	(FECM	CACM	SICM	CLAY	POROSITY)
223	73	0	0	0	0	0	2	0	0	2	0	0	6	1	4

FRAMEWORK PERCENTAGES

Q-POLE**** 74.3

F-POLE**** 24.3
  KSPAR 100.0
  FLAG 0.0
  UNDFS 0.0

R-POLE**** 1.3
  VRF 0.0
  MRF 0.0
  SRF 100.0
    SED-RF POLE
      CHERT 50.0
      CARF 0.0
      SSRF 0.0
      SHRF 50.0

GROUP NAME IS **** ARKOSE

SPECIFIC NAME IS **** K-FELDSPAR-BEARING ARKOSE

SAMPLE NUMBER = SA-38 TOTAL POINTS COUNTED = 326 FRAMEWORK POINTS = 300

RAW DATA (INDIVIDUAL POINTS)

*QTZ	*KSPAR	*PLAG	*UNDFS	*GR-RF	*VRF	*MRF	*CHERT	*CARF	*SSRF	*SHRF	*(FECM	*CACM	*SICM	*CLAY	*POROSITY)
234	49	3	2	0	0	0	12	0	0	0	0	22	3	1	0

FRAMEWORK PERCENTAGES

Q-POLE**** 78.0

F-POLE**** 18.0
KSPAR 90.7
PLAG 5.6
UNDFS 3.7

R-POLE**** 4.0
VRF 0.0
MRF 0.0
SRF 100.0
SED-RF POLE
CHERT 100.0
CARF 0.0
SSRF 0.0
SHRF 0.0

GROUP NAME IS **** SUBARKOSE

SPECIFIC NAME IS **** K-FELDSPAR-BEARING SUBARKOSE

Appendix D

Particle-Size Analyses

Particle-size analyses were completed on ten sandstone samples. Samples were selected so as to represent major aquifers or potential aquifers in the area. Table D-1 summarizes the source of samples analyzed.

The samples were disaggregated with 1Ø percent HCl. After decanting the samples several times and adding distilled water to wash the particles of all the acid, the samples were wet sieved with a 4.Ø phi sieve. The fractions of the samples larger than 4.Ø phi were then oven dried and sieved for 15 minutes with a Ro-Tap and a Ø.25 phi seive set Fractions of the sample smaller than 4.Ø phi were put into 1ØØØ ml cylinders along with approximately 1ØØ ml of dispersing agent and enough distilled water to bring the volume to 1ØØØ ml. The solution was then stirred until all particles were flocculated and distributed uniformly. The silt and clay fraction was then analyzed using a hydrometer. All grains smaller than 9.Ø phi were included in the 9.Ø phi size range.

A computer program was then used to evaluate the grain-size data. The program prints the raw data, calculate cummulative and weight percentages for each phi interval, an plots a cummulative curve and histogram for each sample. Th program scans the cummulative weight percents and prints the phi values which correspond to seven percentiles used in statistical calculations. The program calculates and prints the following statistical parameters (as defined by Folk, 1974): median, graphic mean, quartile deviation, graphic standard deviaton, inclusive graphic standard deviation, graphic skewness, inclusive graphic skewness and graphic kurtosis. The computer print-out for each sample analysis consists of three pages: the first page presents raw data and weight percentages, the second page presents a cummulative curve and histogram, and the third page presents the statistical parameters and the seven phi values used to calculate them. The remainder of this appendix presents the computer print-outs for the samples analyzed.

The classifications discussed in the text of this repor are based on Folk's (1974) graphic mean, inclusive graphic standard deviation, and inclusive graphic skewness.

Table D-1. Source of samples used in particle-size analyses Where sample not from a measured section, legal description of sample site is given.

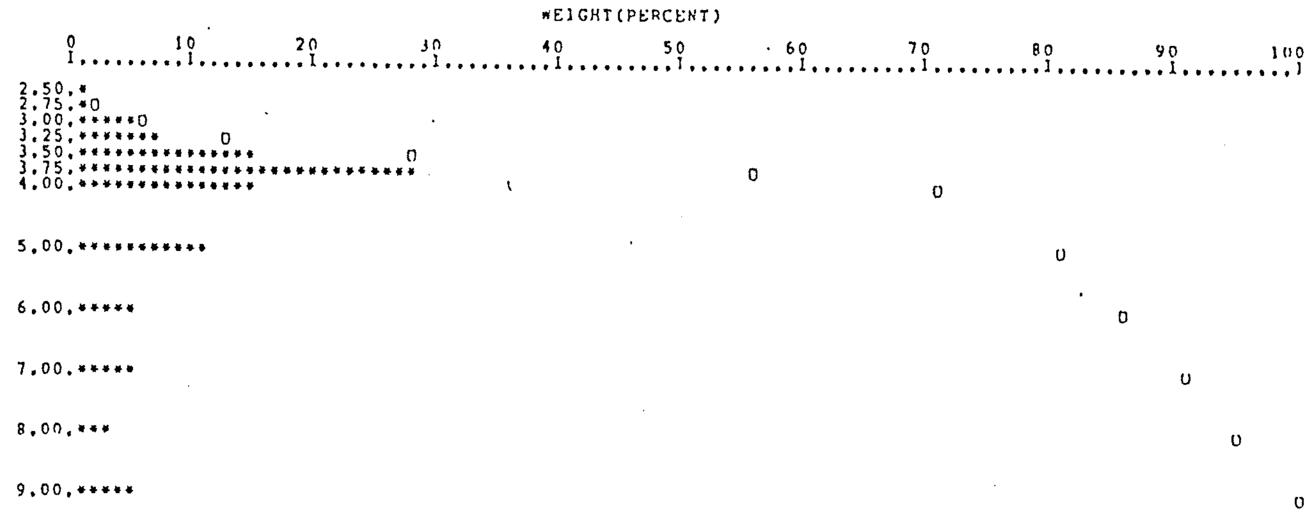
Number	Unit	Measured Section and Unit	
SA-II-4	Pictured Cliffs	SA-2	4
SA-II-6	Kirtland/Fruitland	SA-2	6
SA-II-8	Kirtland/Fruitland	SA-2	8
SA-II-11	Ojo Alamo	SA-2	11
SA-II-13	Ojo Alamo	SA-2	13
SA-III-4	Entrada	SA-3	4
SA-IV-4	Dakota	SA-4	4
SA-IV-7	Dakota	SA-4	7
SA-TSJCM-1	Cuba Mesa	NW 1/4, section 7,T21N, R1W	
SA-38	Poleo	NE 1/4, section 24, T23N, R1W	

SA-II-4

INITIAL SAMPLE WEIGHT= 57.92 GRMS
SUM OF SIZE FRACTION WEIGHTS= 47.91 GRMS
EXPERIMENTAL SAMPLE LOSS= 10.01 GRMS
CUMULATIVE PERCENTAGES CALCULATED USING SUM OF SIZE FRACTION WEIGHTS

PHI	DIAMETER (MM)	WEIGHT (GRMS)	WEIGHT PERC	CUM PERC
2.50	0.177	0.07	0.15	0.15
2.75	0.149	0.72	1.50	1.65
3.00	0.125	2.20	4.59	6.24
3.25	0.105	3.40	7.10	13.34
3.50	0.088	6.95	14.51	27.84
3.75	0.074	13.50	28.18	56.02
4.00	0.063	6.97	14.55	70.57
5.00	0.031	5.20	10.85	81.42
6.00	0.016	2.40	5.01	86.43
7.00	0.008	2.30	4.80	91.23
8.00	0.004	1.60	3.34	94.57
9.00	0.002	2.60	5.43	100.00

SA-II-4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2.75
3.00
3.25
3.50
3.75
4.00
5.00
6.00
7.00
8.00
9.00

SA-II-4

STATISTICS

PERCENTILES

CUMULATIVE PERCENT	PHI VALUE
5.	2.932
16.	3.296
25.	3.451
50.	3.697
75.	4.408
84.	5.514
95.	8.079

STATISTICAL PARAMETERS

MEDIAN = 3.697

GRAPHIC MEAN = 4.169

QUARTILE DEVIATION = 0.479

GRAPHIC STANDARD DEVIATION = 1.109

INCLUSIVE STANDARD DEVIATION = 1.334

GRAPHIC SKEWNESS = 0.639

INCLUSIVE GRAPHIC SKEWNESS = 0.671

GRAPHIC KURTOSIS = 2.203

SA-II-6

INITIAL SAMPLE WEIGHT= 66.00 GRMS

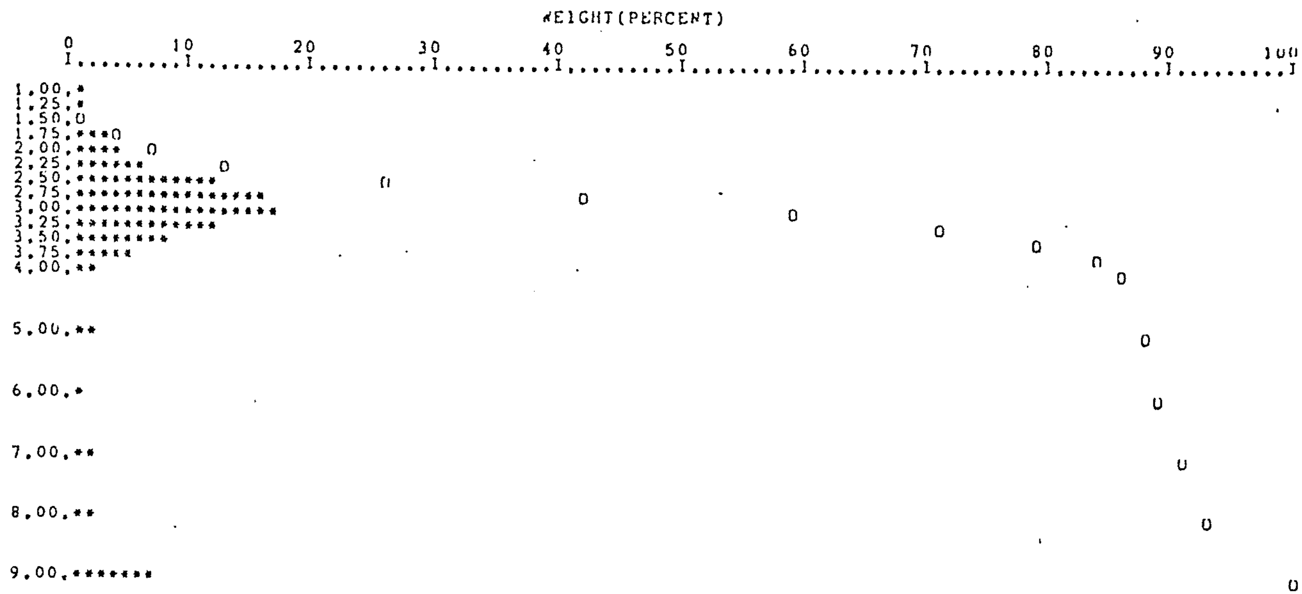
SUM OF SIZE FRACTION WEIGHTS= 64.64 GRMS

EXPERIMENTAL SAMPLE LOSS= 1.36 GRMS

CUMULATIVE PERCENTAGES CALCULATED USING SUM OF SIZE FRACTION WEIGHTS

PHI	DIAMETER (MM)	WEIGHT (GRMS)	WEIGHT PERC	CUM PERC
1.00	0.500	0.08	0.12	0.12
1.25	0.420	0.12	0.19	0.31
1.50	0.350	0.36	0.56	0.87
1.75	0.300	1.73	2.68	3.54
2.00	0.250	2.46	3.81	7.35
2.25	0.210	3.82	5.91	13.26
2.50	0.177	7.95	12.30	25.56
2.75	0.149	10.57	16.35	41.91
3.00	0.125	11.08	17.14	59.05
3.25	0.105	7.44	11.51	70.56
3.50	0.088	5.49	8.49	79.05
3.75	0.074	3.36	5.20	84.25
4.00	0.063	1.18	1.83	86.08
5.00	0.031	1.00	1.55	87.62
6.00	0.016	0.70	1.08	88.71
7.00	0.008	1.20	1.86	90.56
8.00	0.004	1.30	2.01	92.57
9.00	0.002	4.80	7.43	100.00

SA-II-6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1.25
1.50
1.75
2.00
2.25
2.50
2.75
3.00
3.25
3.50
3.75
4.00
5.00
6.00
7.00
8.00
9.00

SA-II-6

STATISTICS

PERCENTILES

CUMULATIVE PERCENT	PHI VALUE
5.	1.846
16.	2.306
25.	2.489
50.	2.868
75.	3.381
84.	3.738
95.	8.327

STATISTICAL PARAMETERS

MEDIAN = 2.868

GRAPHIC MEAN = 2.971

QUARTILE DEVIATION = 0.446

GRAPHIC STANDARD DEVIATION = 0.716

INCLUSIVE STANDARD DEVIATION = 1.340

GRAPHIC SKEWNESS = -0.215

INCLUSIVE GRAPHIC SKEWNESS = 0.450

GRAPHIC KURTOSIS = 2.978

SA-II-B

INITIAL SAMPLE WEIGHT= 55.90 GRMS

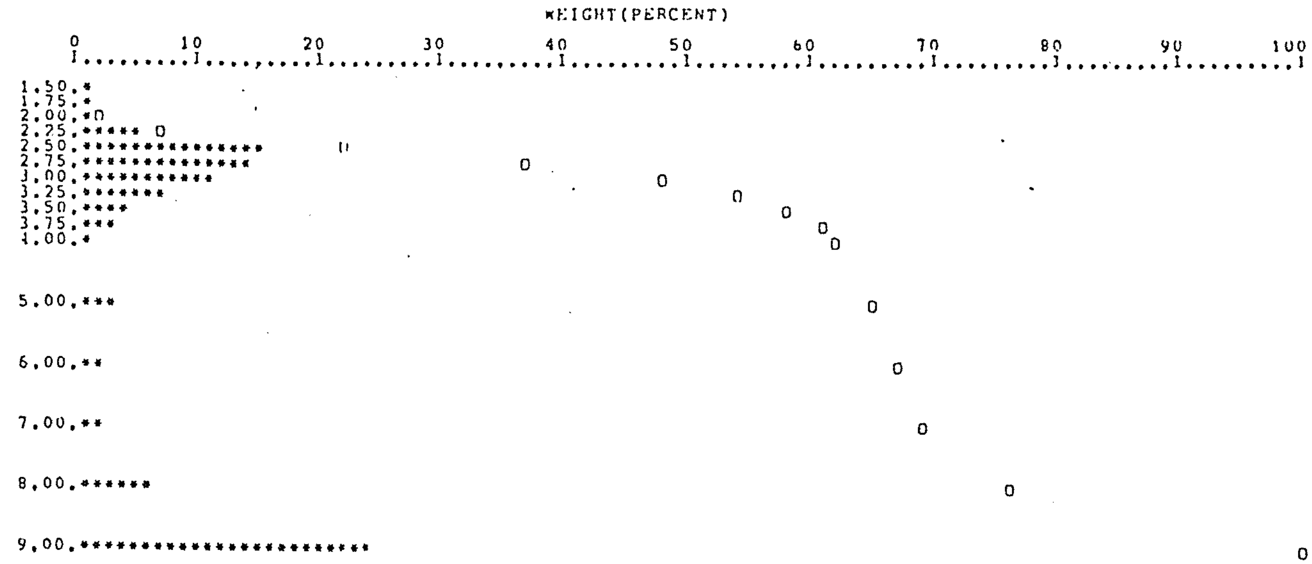
SUM OF SIZE FRACTION WEIGHTS= 49.32 GRMS

EXPERIMENTAL SAMPLE LOSS= 6.58 GRMS

CUMULATIVE PERCENTAGES CALCULATED USING SUM OF SIZE FRACTION WEIGHTS

PHI	DIAMETER (MM)	WEIGHT (GRMS)	WEIGHT PERC	CUM PERC
1.50	0.350	0.05	0.10	0.10
1.75	0.300	0.16	0.32	0.43
2.00	0.250	0.72	1.46	1.89
2.25	0.210	2.50	5.07	6.95
2.50	0.177	7.64	15.49	22.45
2.75	0.149	7.04	14.27	36.72
3.00	0.125	5.33	10.81	47.53
3.25	0.105	3.24	6.57	54.10
3.50	0.088	1.95	3.95	58.05
3.75	0.074	1.24	2.51	60.56
4.00	0.063	0.65	1.32	61.88
5.00	0.031	1.60	3.24	65.13
6.00	0.016	1.10	2.23	67.36
7.00	0.008	1.00	2.03	69.38
8.00	0.004	3.20	6.49	75.87
9.00	0.002	11.90	24.13	100.00

SA-II-8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1.75
2.00
2.25
2.50
2.75
3.00
3.25
3.50
3.75
4.00
5.00
6.00
7.00
8.00
9.00

SA-II-8

STATISTICS

PERCENTILES

CUMULATIVE PERCENT	PHI VALUE
5.	2.154
16.	2.396
25.	2.545
50.	3.094
75.	7.866
84.	8.337
95.	8.793

STATISTICAL PARAMETERS

MEDIAN = 3.094

GRAPHIC MEAN = 4.609

QUARTILE DEVIATION = 2.660

GRAPHIC STANDARD DEVIATION = 2.970

INCLUSIVE STANDARD DEVIATION = 2.491

GRAPHIC SKEWNESS = 0.765

INCLUSIVE GRAPHIC SKEWNESS = 0.741

GRAPHIC KURTOSIS = 0.511

L
SA-II-11

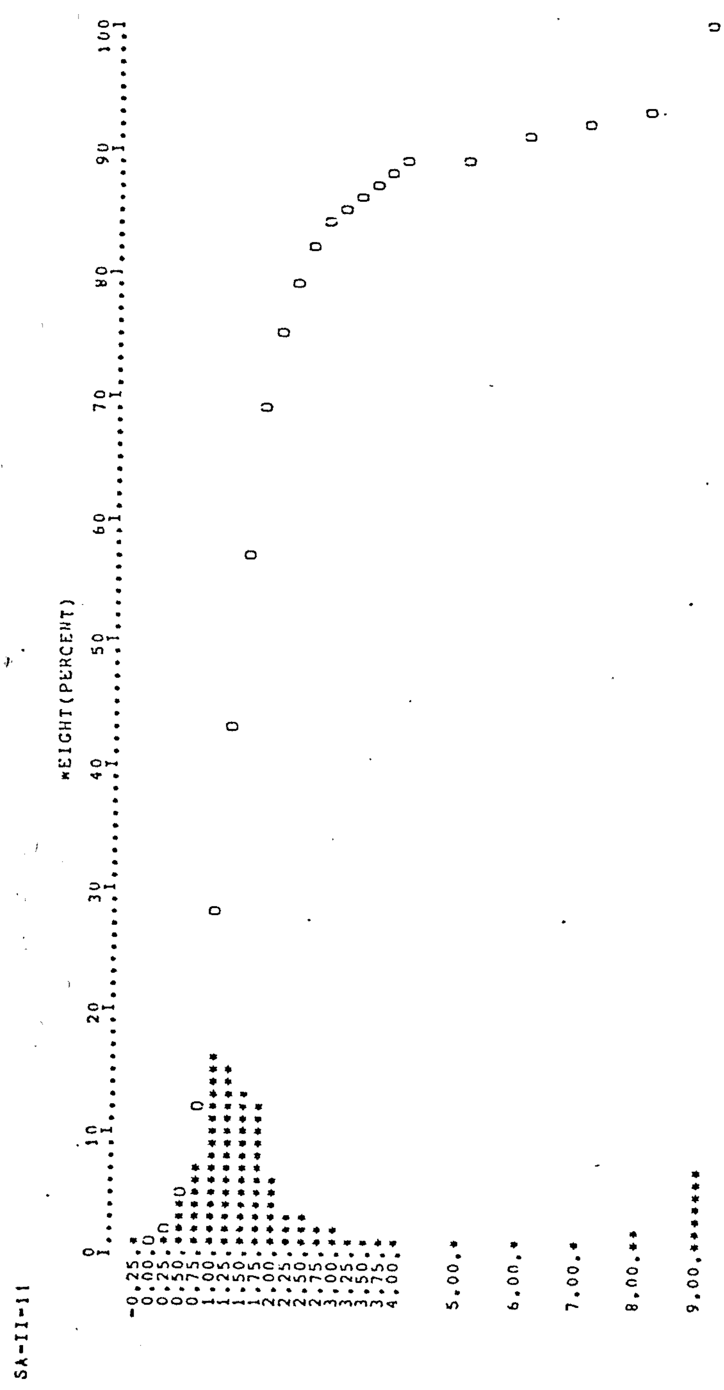
INITIAL SAMPLE WEIGHT= 64.63 GRMS

SUM OF SIZE FRACTION WEIGHTS= 64.63 GRMS

EXPERIMENTAL SAMPLE LOSS= 0.00 GRMS

CUMULATIVE PERCENTAGES CALCULATED USING SUM OF SIZE FRACTION WEIGHTS

PHI	DIAMETER (MM)	WEIGHT (GRMS)	WEIGHT PERC	CUM PERC
-0.25	1.190	0.10	0.15	0.15
0.00	1.000	0.25	0.39	0.54
0.25	0.840	0.66	1.02	1.56
0.50	0.710	2.45	3.79	5.35
0.75	0.590	4.27	6.61	11.96
1.00	0.500	10.58	16.37	28.33
1.25	0.420	9.78	15.13	43.46
1.50	0.350	8.68	13.43	56.89
1.75	0.300	7.95	12.30	69.19
2.00	0.250	4.00	6.19	75.38
2.25	0.210	2.24	3.47	78.85
2.50	0.177	1.91	2.96	81.80
2.75	0.149	1.26	1.95	83.75
3.00	0.125	1.00	1.55	85.30
3.25	0.105	0.70	1.08	86.38
3.50	0.088	0.64	0.99	87.37
3.75	0.074	0.50	0.77	88.15
4.00	0.063	0.26	0.40	88.55
5.00	0.031	0.50	0.77	89.32
6.00	0.016	0.90	1.39	90.72
7.00	0.008	0.70	1.08	91.80
8.00	0.004	1.00	1.55	93.35
9.00	0.002	4.30	6.65	100.00


SA-II-11
WEIGHT(PERCENT)
0
10
20
30
40
50
60
70
80
90
100
-0.25
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
2.75
3.00
3.25
3.50
3.75
4.00
5.00
6.00
7.00
8.00
9.00

SA-II-11

STATISTICS

PERCENTILES

CUMULATIVE PERCENT	PHI VALUE
5.	0.477
16.	0.812
25.	0.949
50.	1.372
75.	1.985
84.	2.790
95.	8.248

STATISTICAL PARAMETERS

MEDIAN = 1.372

GRAPHIC MEAN = 1.658

QUARTILE DEVIATION = 0.518

GRAPHIC STANDARD DEVIATION = 0.989

INCLUSIVE STANDARD DEVIATION = 1.672

GRAPHIC SKEWNESS = 0.434

INCLUSIVE GRAPHIC SKEWNESS = 0.602

GRAPHIC KURTOSIS = 3.076

SA-II-13

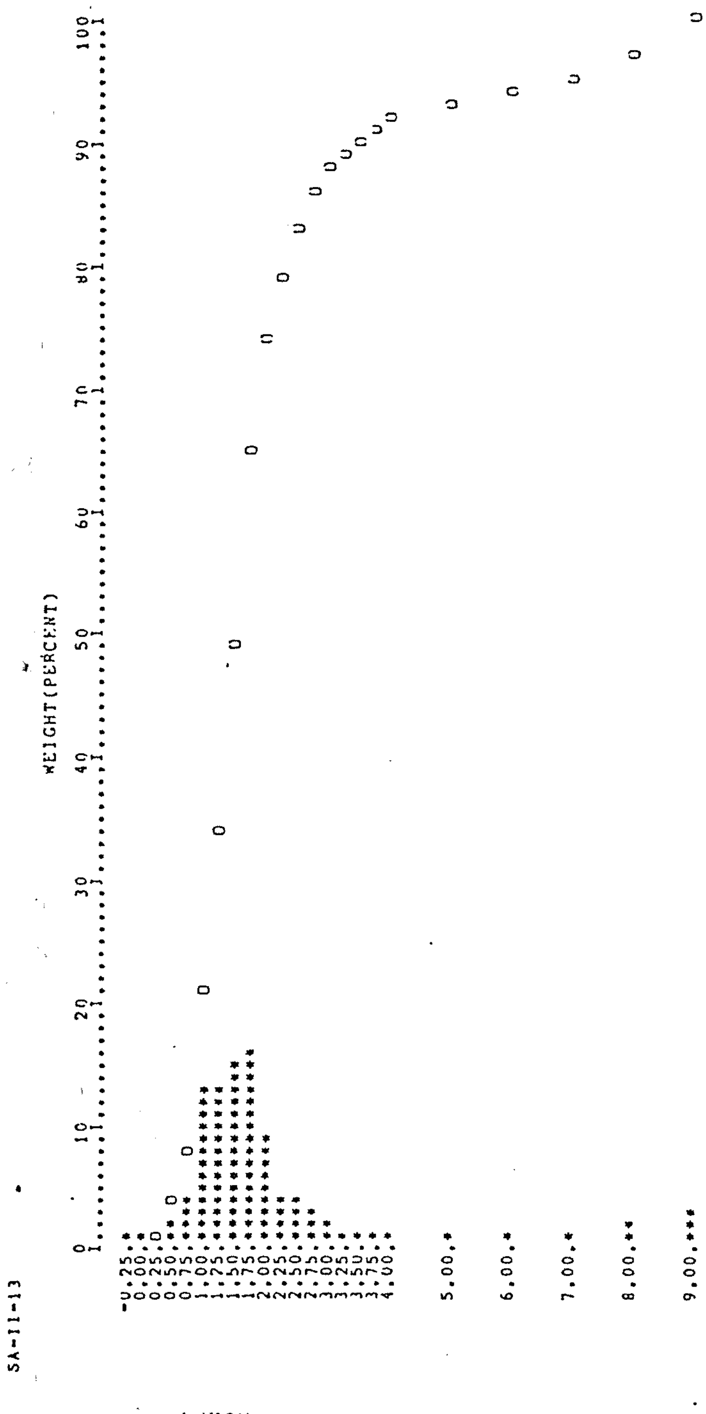
INITIAL SAMPLE WEIGHT= 67.49 GRMS

SUM OF SIZE FRACTION WEIGHTS= 64.45 GRMS

EXPERIMENTAL SAMPLE LOSS= 3.04 GRMS

CUMULATIVE PERCENTAGES CALCULATED USING SUM OF SIZE FRACTION WEIGHTS

PHI	DIAMETER (MM)	WEIGHT (GRMS)	WEIGHT PERC	CUM PERC
-0.25	1.190	0.11	0.17	0.17
0.00	1.000	0.18	0.28	0.45
0.25	0.840	0.53	0.82	1.27
0.50	0.710	1.59	2.47	3.74
0.75	0.590	2.84	4.41	8.15
1.00	0.500	8.10	12.57	20.71
1.25	0.420	8.46	13.13	33.84
1.50	0.350	9.55	14.82	48.66
1.75	0.300	10.37	16.09	64.75
2.00	0.250	6.04	9.37	74.12
2.25	0.210	2.86	4.44	78.56
2.50	0.177	2.77	4.30	82.85
2.75	0.149	1.80	2.79	85.65
3.00	0.125	1.42	2.20	87.85
3.25	0.105	0.87	1.35	89.20
3.50	0.088	0.75	1.16	90.36
3.75	0.074	0.56	0.87	91.23
4.00	0.063	0.35	0.54	91.78
5.00	0.031	0.90	1.40	93.17
6.00	0.016	0.50	0.78	93.95
7.00	0.008	0.90	1.40	95.35
8.00	0.004	1.10	1.71	97.05
9.00	0.002	1.90	2.95	100.00


SA-11-13
WEIGHT(PERCENT)
0 10 20 30 40 50 60 70 80 90 100
-0.25 0.00 0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00 2.25 2.50 2.75 3.00 3.25 3.50 3.75 4.00
5.00
6.00
7.00
8.00
9.00

SA-II-13

STATISTICS

PERCENTILES

CUMULATIVE PERCENT	PHI VALUE
5.	0.572
16.	0.906
25.	1.082
50.	1.521
75.	2.050
84.	2.603
95.	6.753

STATISTICAL PARAMETERS

MEDIAN = 1.521

GRAPHIC MEAN = 1.677

QUARTILE DEVIATION = 0.484

GRAPHIC STANDARD DEVIATION = 0.848

INCLUSIVE STANDARD DEVIATION = 1.361

GRAPHIC SKEWNESS = 0.275

INCLUSIVE GRAPHIC SKEWNESS = 0.484

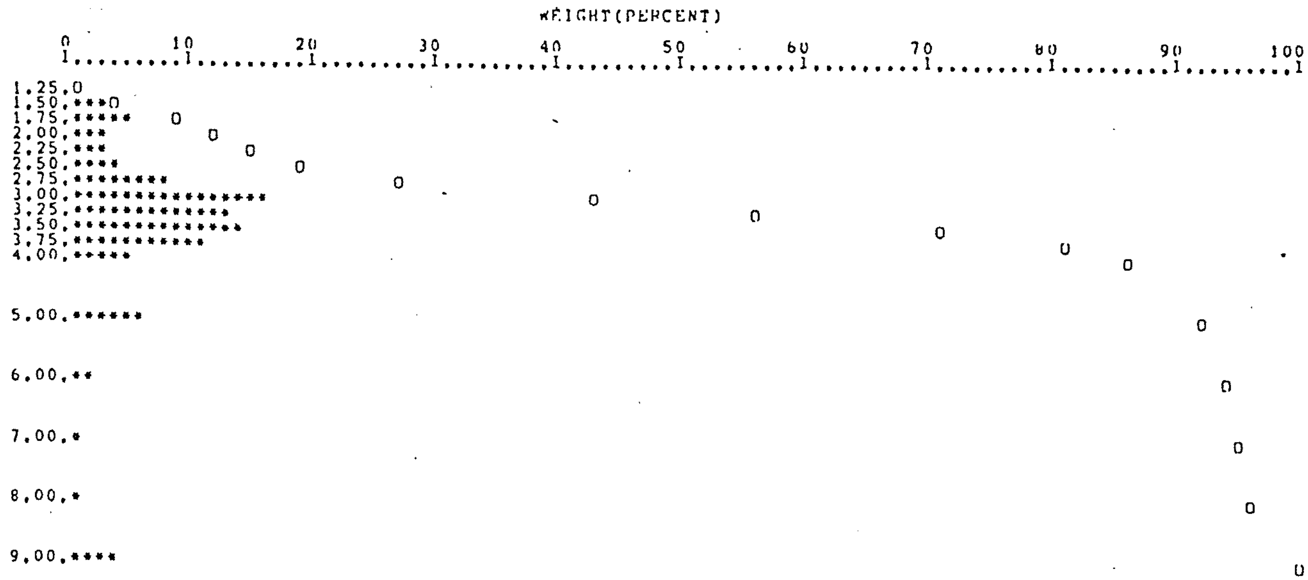
GRAPHIC KURTOSIS = 2.617

SA-III-4

INITIAL SAMPLE WEIGHT= 60.00 GRMS
SUM OF SIZE FRACTION WEIGHTS= 53.43 GRMS
EXPERIMENTAL SAMPLE LOSS= 6.57 GRMS
CUMULATIVE PERCENTAGES CALCULATED USING SUM OF SIZE FRACTION WEIGHTS

PHI	DIAMETER (MM)	WEIGHT (GRMS)	WEIGHT PERC	CUM PERC
1.25	0.420	0.40	0.75	0.75
1.50	0.350	1.92	3.59	4.34
1.75	0.300	2.50	4.68	9.02
2.00	0.250	1.65	3.09	12.11
2.25	0.210	1.34	2.51	14.62
2.50	0.177	2.16	4.04	18.66
2.75	0.149	4.54	8.50	27.16
3.00	0.125	8.38	15.68	42.84
3.25	0.105	7.15	13.38	56.22
3.50	0.088	7.66	14.34	70.56
3.75	0.074	5.82	10.89	81.45
4.00	0.063	2.51	4.70	86.15
5.00	0.031	3.00	5.61	91.76
6.00	0.016	1.00	1.87	93.64
7.00	0.008	0.60	1.12	94.76
8.00	0.004	0.40	0.75	95.51
9.00	0.002	2.40	4.49	100.00

SA-III-4


WEIGHT(PERCENT)
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1.25
1.50
1.75
2.00
2.25
2.50
2.75
3.00
3.25
3.50
3.75
4.00
5.00
6.00
7.00
8.00
9.00

SA-III-4

STATISTICS

PERCENTILES

CUMULATIVE PERCENT	PHI VALUE
5.	1.535
16.	2.336
25.	2.687
50.	3.134
75.	3.602
84.	3.886
95.	7.321

STATISTICAL PARAMETERS

MEDIAN = 3.134

GRAPHIC MEAN = 3.118

QUARTILE DEVIATION = 0.458

GRAPHIC STANDARD DEVIATION = 0.775

INCLUSIVE STANDARD DEVIATION = 1.264

GRAPHIC SKEWNESS = -0.030

INCLUSIVE GRAPHIC SKEWNESS = 0.209

GRAPHIC KURTOSIS = 2.591

SA-IV-4

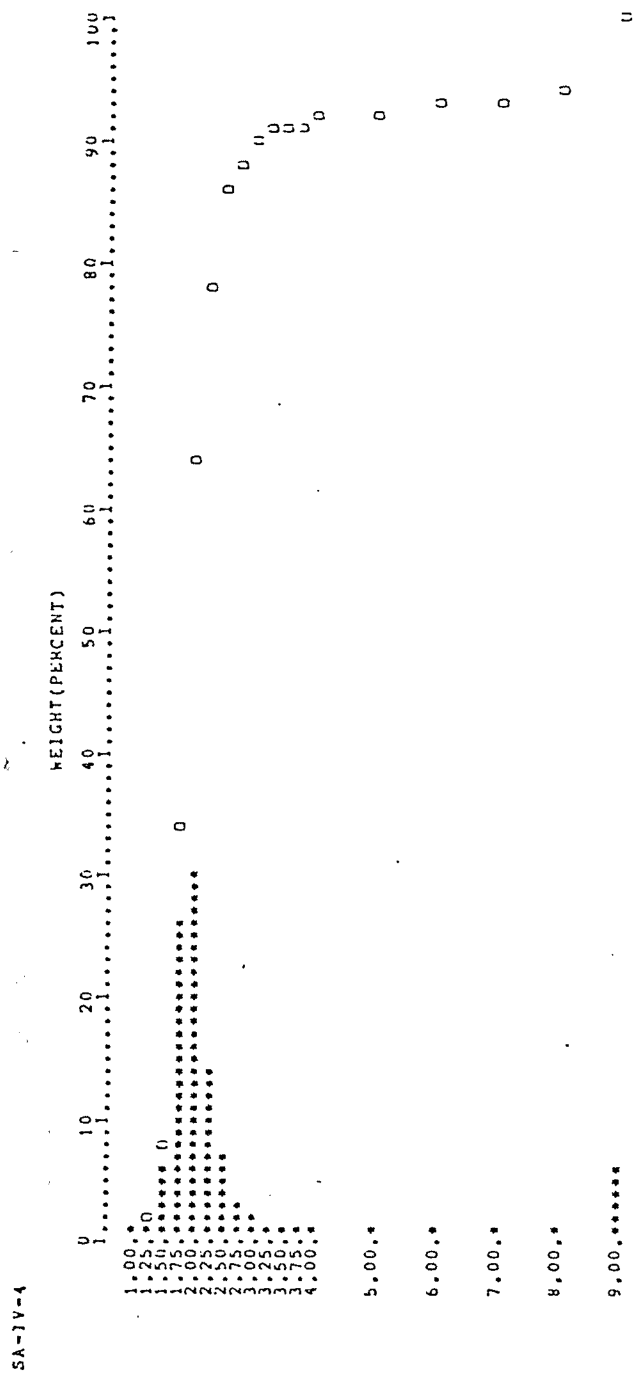
INITIAL SAMPLE WEIGHT= 84.02 GRMS

SUM OF SIZE FRACTION WEIGHTS= 83.59 GRMS

EXPERIMENTAL SAMPLE LOSS= 0.42 GRMS

CUMULATIVE PERCENTAGES CALCULATED USING SUM OF SIZE FRACTION WEIGHTS

PHI	DIAMETER (MM)	WEIGHT (GRMS)	WEIGHT PERC	CUM PERC
1.00	0.500	0.27	0.32	0.32
1.25	0.420	1.10	1.32	1.64
1.50	0.350	4.90	5.86	7.50
1.75	0.300	22.00	26.32	33.82
2.00	0.250	25.49	30.49	64.31
2.25	0.210	11.60	13.88	78.19
2.50	0.177	6.15	7.36	85.55
2.75	0.149	2.30	2.75	88.30
3.00	0.125	1.48	1.77	90.07
3.25	0.105	0.65	0.78	90.85
3.50	0.088	0.32	0.38	91.23
3.75	0.074	0.20	0.24	91.47
4.00	0.063	0.13	0.16	91.63
5.00	0.031	0.40	0.48	92.10
6.00	0.016	0.50	0.60	92.70
7.00	0.008	0.20	0.24	92.94
8.00	0.004	0.90	1.08	94.02
9.00	0.002	5.00	5.98	100.00


SA-IV-4
WEIGHT(PERCENT)
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20
30
40
50
60
70
80
90
100
1.00
1.25
1.50
1.75
2.00
2.25
2.50
2.75
3.00
3.25
3.50
3.75
4.00
5.00
6.00
7.00
8.00
9.00

SA-IV-4

STATISTICS

PERCENTILES

CUMULATIVE PERCENT	PHI VALUE
5.	1.393
16.	1.581
25.	1.666
50.	1.883
75.	2.193
84.	2.447
95.	8.164

STATISTICAL PARAMETERS

MEDIAN = 1.883

GRAPHIC MEAN = 1.970

QUARTILE DEVIATION = 0.263

GRAPHIC STANDARD DEVIATION = 0.433

INCLUSIVE STANDARD DEVIATION = 1.243

GRAPHIC SKEWNESS = 0.303

INCLUSIVE GRAPHIC SKEWNESS = 0.579

GRAPHIC KURTOSIS = 5.273

SA-IV-7

INITIAL SAMPLE WEIGHT= 68.52 GRMS

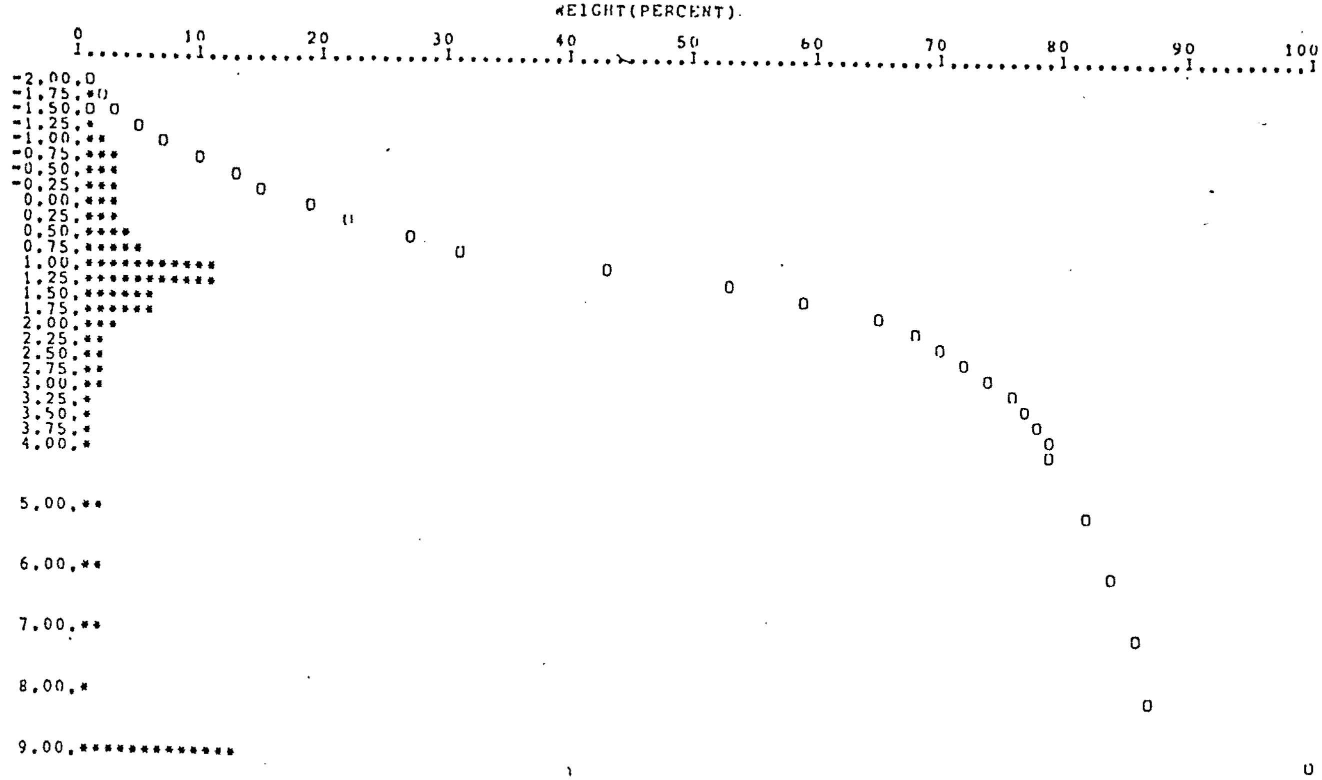
SUM OF SIZE FRACTION WEIGHTS= 67.23 GRMS

EXPERIMENTAL SAMPLE LOSS= 1.29 GRMS

CUMULATIVE PERCENTAGES CALCULATED USING SUM OF SIZE FRACTION WEIGHTS

PHI	DIAMETER (MM)	WEIGHT (GRMS)	WEIGHT PERC	CUM PERC
-2.00	4.000	0.82	1.22	1.22
-1.75	3.360	0.62	0.92	2.14
-1.50	2.830	0.74	1.10	3.24
-1.25	2.380	1.00	1.49	4.73
-1.00	2.000	1.65	2.45	7.18
-0.75	1.680	1.87	2.78	9.97
-0.50	1.410	1.81	2.69	12.66
-0.25	1.190	1.89	2.81	15.47
0.00	1.000	2.32	3.45	18.92
0.25	0.840	2.35	3.50	22.42
0.50	0.710	2.94	4.37	26.79
0.75	0.590	3.08	4.58	31.37
1.00	0.500	7.54	11.22	42.59
1.25	0.420	7.09	10.55	53.13
1.50	0.350	4.22	6.28	59.41
1.75	0.300	3.93	5.85	65.25
2.00	0.250	1.95	2.90	68.15
2.25	0.210	1.31	1.95	70.10
2.50	0.177	1.40	2.08	72.19
2.75	0.149	1.18	1.76	73.94
3.00	0.125	1.16	1.73	75.67
3.25	0.105	0.75	1.12	76.78
3.50	0.088	0.75	1.12	77.90
3.75	0.074	0.70	1.04	78.94
4.00	0.063	0.36	0.54	79.47
5.00	0.031	1.40	2.08	81.56
6.00	0.016	1.50	2.23	83.79
7.00	0.008	1.50	2.23	86.02
8.00	0.004	0.80	1.19	87.21
9.00	0.002	8.60	12.79	100.00

SA-IV-7


WEIGHT(PERCENT)
0 10 20 30 40 50 60 70 80 90 100
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-1.75
-1.50
-1.25
-1.00
-0.75
-0.50
-0.25
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
2.75
3.00
3.25
3.50
3.75
4.00
5.00
6.00
7.00
8.00
9.00

SA-IV-7

STATISTICS

PERCENTILES

CUMULATIVE PERCENT	PHI VALUE
5.	-1.223
16.	-0.212
25.	0.398
50.	1.176
75.	2.904
84.	6.095
95.	8.609

STATISTICAL PARAMETERS

MEDIAN = 1.176

GRAPHIC MEAN = 2.353

QUARTILE DEVIATION = 1.253

GRAPHIC STANDARD DEVIATION = 3.154

INCLUSIVE STANDARD DEVIATION = 3.066

GRAPHIC SKEWNESS = 0.560

INCLUSIVE GRAPHIC SKEWNESS = 0.536

GRAPHIC KURTOSIS = 1.608

SA-TSJCM-1

INITIAL SAMPLE WEIGHT= 62.58 GRMS

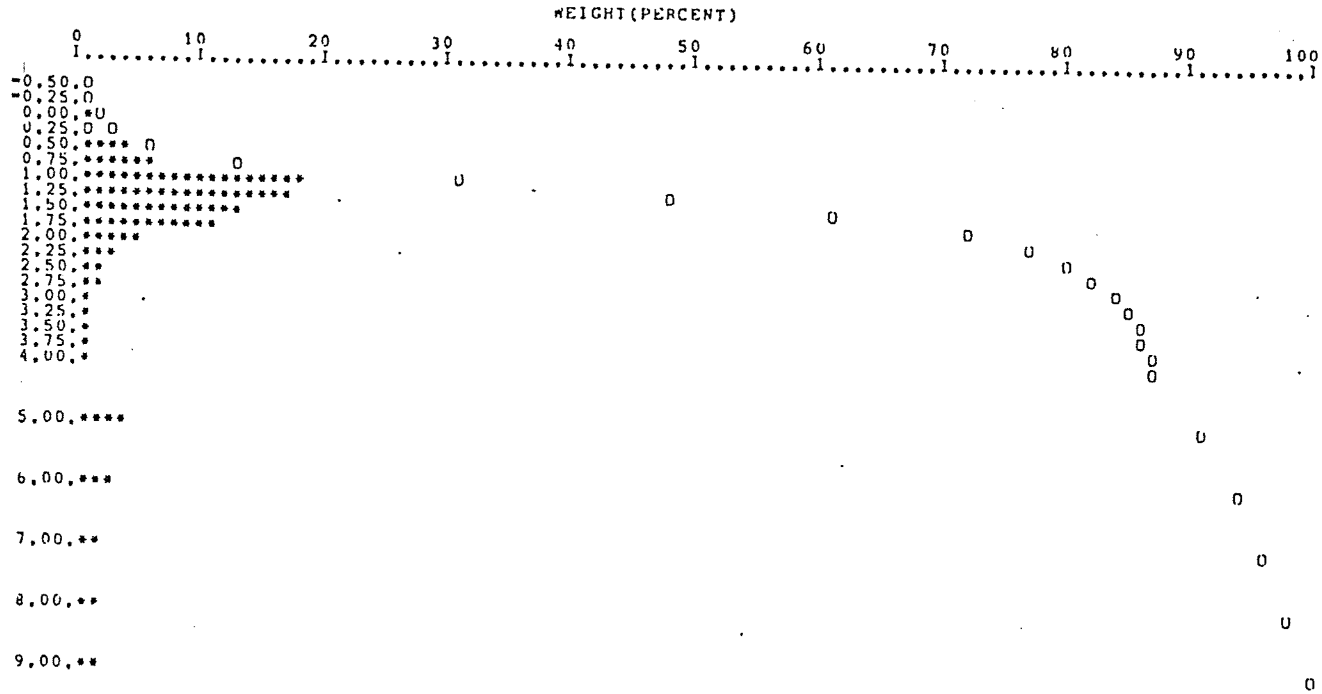
SUM OF SIZE FRACTION WEIGHTS= 68.87 GRMS

EXPERIMENTAL SAMPLE LOSS= -6.29 GRMS

CUMULATIVE PERCENTAGES CALCULATED USING SUM OF SIZE FRACTION WEIGHTS

PHI	DIAMETER (MM)	WEIGHT (GRMS)	WEIGHT PERC	CUM PERC
-0.50	1.410	0.70	1.02	1.02
-0.25	1.190	0.18	0.26	1.28
0.00	1.000	0.30	0.44	1.71
0.25	0.840	0.67	0.97	2.69
0.50	0.710	2.58	3.75	6.43
0.75	0.590	4.27	6.20	12.63
1.00	0.500	12.43	18.05	30.68
1.25	0.420	11.92	17.31	47.99
1.50	0.350	9.14	13.27	61.26
1.75	0.300	7.62	11.06	72.32
2.00	0.250	3.43	4.98	77.31
2.25	0.210	1.87	2.72	80.02
2.50	0.177	1.56	2.27	82.29
2.75	0.149	1.10	1.60	83.88
3.00	0.125	0.87	1.26	85.15
3.25	0.105	0.50	0.73	85.87
3.50	0.088	0.43	0.62	86.50
3.75	0.074	0.32	0.46	86.96
4.00	0.063	0.18	0.26	87.22
5.00	0.031	2.50	3.63	90.85
6.00	0.016	2.10	3.05	93.90
7.00	0.008	1.60	2.32	96.22
8.00	0.004	1.40	2.03	98.26
9.00	0.002	1.20	1.74	100.00

SA-TSJCM-1


WEIGHT(PERCENT)
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10
20
30
40
50
60
70
80
90
100
-0.50
-0.25
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
2.75
3.00
3.25
3.50
3.75
4.00
5.00
6.00
7.00
8.00
9.00

SA-TSJCM-1

STATISTICS

PERCENTILES

CUMULATIVE PERCENT	PHI VALUE
5.	0.404
16.	0.797
25.	0.921
50.	1.288
75.	1.884
84.	2.773
95.	6.473

STATISTICAL PARAMETERS

MEDIAN = 1.288
GRAPHIC MEAN = 1.619
QUARTILE DEVIATION = 0.481
GRAPHIC STANDARD DEVIATION = 0.988
INCLUSIVE STANDARD DEVIATION = 1.414
GRAPHIC SKEWNESS = 0.503
INCLUSIVE GRAPHIC SKEWNESS = 0.606
GRAPHIC KURTOSIS = 2.583

SA-38

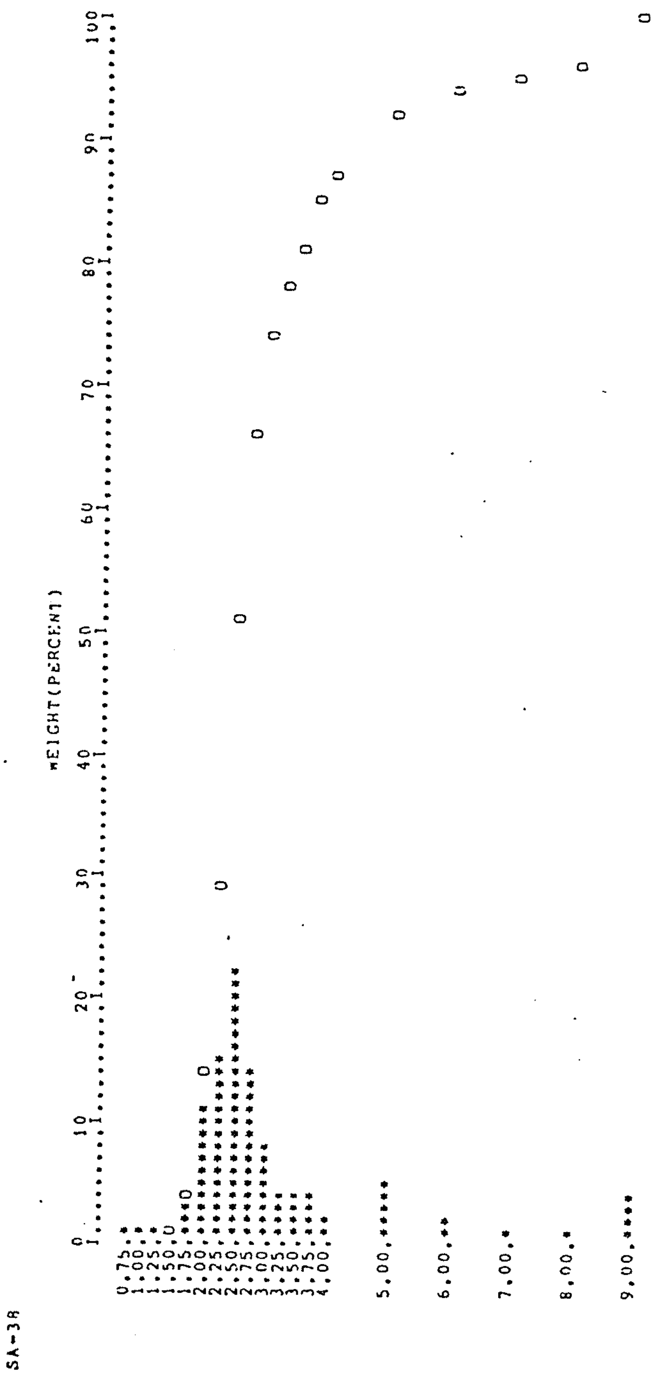
INITIAL SAMPLE WEIGHT= 58.73 GRMS

SUM OF SIZE FRACTION WEIGHTS= 46.27 GRMS

EXPERIMENTAL SAMPLE LOSS= 12.46 GRMS

CUMULATIVE PERCENTAGES CALCULATED USING SUM OF SIZE FRACTION WEIGHTS

PHI	DIAMETER (MM)	WEIGHT (GRMS)	WEIGHT PERC	CUM PERC
0.75	0.590	0.03	0.06	0.06
1.00	0.500	0.04	0.09	0.15
1.25	0.420	0.04	0.09	0.24
1.50	0.350	0.17	0.37	0.61
1.75	0.300	1.35	2.92	3.52
2.00	0.250	5.05	10.91	14.44
2.25	0.210	6.92	14.96	29.39
2.50	0.177	10.13	21.89	51.29
2.75	0.149	6.70	14.48	65.77
3.00	0.125	3.61	7.80	73.57
3.25	0.105	1.93	4.17	77.74
3.50	0.088	1.62	3.50	81.24
3.75	0.074	1.66	3.59	84.83
4.00	0.063	1.12	2.42	87.25
5.00	0.031	2.10	4.54	91.79
6.00	0.016	1.00	2.16	93.95
7.00	0.008	0.40	0.86	94.81
8.00	0.004	0.60	1.30	96.11
9.00	0.002	1.80	3.89	100.00


SA-3B
WEIGHT(PERCENT)
0
10
20
30
40
50
60
70
80
90
100
0.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
2.75
3.00
3.25
3.50
3.75
4.00
5.00
6.00
7.00
8.00
9.00

SA-38

STATISTICS

PERCENTILES

CUMULATIVE PERCENT	PHI VALUE
5.	1.784
16.	2.026
25.	2.177
50.	2.485
75.	3.086
84.	3.692
95.	7.144

STATISTICAL PARAMETERS

MEDIAN = 2.485

GRAPHIC MEAN = 2.735

QUARTILE DEVIATION = 0.455

GRAPHIC STANDARD DEVIATION = 0.833

INCLUSIVE STANDARD DEVIATION = 1.229

GRAPHIC SKEWNESS = 0.449

INCLUSIVE GRAPHIC SKEWNESS = 0.594

GRAPHIC KURTOSIS = 2.416

APPENDIX E

Water Quality Data

The chemical analyses in this Appendix for which sample numbers start with SA or SC were analyzed by the New Mexico Bureau of Mines and Mineral Resources Chemistry Laboratory (Table E-1). Precision of all analyses is as reported by th laboratory or published source used.

Table E-1

Chemical Analysis Data

Sample numbers correspond to sample numbers used in Appendix B and Appendix I. For well inventory data see Appendix B. HCO3 = Bicarbonate, Cl = Chloride, SO4 = Sulfate, NO3 = Nitrate, Fl = Fluiride, Na = Sodium, K = Potassium, Mg = Magnesium, Ca = Calcium, Mn = Manganese, TDS = Total Dissolved Solids; Specific Conductivity given in micromhos; nd = not detectable, - = constituent not analyzed for.

Sample Number	HCO3	Cl	SO4	NO3	Fl	Silica	Na	K	Mg	Ca	Iron	Mn	TDS	Specific Conductivity
SA-1	96	60	nd	< 0.1	0.16	5.3	1.6	0.6	0.7	30	-	-	88	142
SA-2	25	1.91	nd	< 0.1	0.42	5.3	2.03	0.35	0.46	6.0	-	-	38	37
SA-3	30	1.9	21	< 0.1	0.83	1.7	1.3	0.4	0.54	16	-	-	67	52
SA-4	117	1.0	20	< 0.1	0.49	10.0	4.0	0.14	0.85	41	0.21	< 0.01	141	178
SA-5	76	2	10	< 0.1	0.27	0.04	5.6	1.5	0.24	24	2.1	< 0.01	80	150
SA-6	213	12	50	< 0.1	0.51	5.0	22.4	0.2	1.37	75	0.05	< 0.01	253	444
SA-7	222	24	86	< 0.1	0.51	5.5	17.8	1.35	1.83	96	2.0	0.73	314	600
SA-8	333	2	48	< 0.1	0.38	3.8	2.84	0.4	0.9	126	-	-	308	541
SA-9	340	6	44	< 0.1	0.26	5.3	9.0	1.6	0.86	120	-	-	352	474
SA-10	160	30.6	131	0.21	0.51	2.5	26.5	1.5	0.66	32	9.0	0.3	355	493
SA-11	168	2.8	99	0.17	0.71	1.25	18	0.6	7.8	64	1.75	< 0.01	287	382
SA-12	410	18	37	0.66	0.24	5.2	42.5	1.2	11.8	100	1.6	< 0.01	430	515
SA-13	497	6	48	< 0.1	0.36	3.15	99	3.75	16	78	1.33	1.25	496	842
SA-14	497	4.3	370	-	-	-	324	5.6	6.9	24	< 0.01	< 0.01	983	1200
SA-15	277	7.7	632	1.58	0.41	0.75	67	5.8	63	204	0.24	< 0.01	960	1500
SA-16	161	21	253	< 0.1	0.56	7.5	22.5	3.2	27.5	79	22	2.4	446	720
SA-17	215	23	70	< 0.1	-	0.4	15	1.7	14.5	62	3.4	0.47	319	475
SA-18	168	15	33	< 0.1	-	0.5	12.2	6.5	8.6	49	1.7	0.55	217	380
SA-20	155	3.8	nd	0.4	-	6.2	15	1.5	7.4	7	0.05	< 0.01	122	246
SA-21	334	15	242	< 0.1	0.09	0.5	48.4	44.	29	130	1.0	< 0.01	672	900
SA-22	207	23	466	< 0.1	-	6.8	73	1.3	59	85	27	3.4	812	1165
SA-23	207	42	66	4.25	-	4.7	73.5	1.4	26.3	18	0.06	< 0.01	335	528
SA-24	122	5.7	254	< 0.1	-	6.4	18.6	2.6	29.5	78	15	0.95	466	569
SA-25	345	16.3	43	< 0.1	-	2.3	58.2	3.8	25.0	46	1.05	< 0.01	367	736
SA-26	216	10.5	1222	< 0.1	-	7.5	600	4.4	30.5	25	5.0	0.31	2000	2425
SA-30	362	1.0	199	-	-	33	49	3.3	36.5	96	< 1.0	0.08	566	740
SA-32	244	11.2	50	< 0.1	-	5.0	27.0	1.8	13.0	80	-	0.16	307	449
SA-33	145	9.2	25	< 0.1	-	7.6	7.8	< 1.0	7.7	60	-	< 0.01	172	302
SA-34	92	5.1	18	0.48	-	8.8	10.5	< 1.0	4.5	26	-	< 0.01	87	170
BZ-S-18	539	30	302	2.8	0.7	19	248		21	72	-	-	960	1430
BZ-44	475	20	384	1.5	0.2	17	470		6.7	45	-	-	1510	2160
BZ-66	474	4.0	97	0.0	0.5	15	104	3.6	19	77	14	-	569	894
BZ-69	154	14	93	11	0.3	0.11	29	0.4	9.7	62	0.11	-	194	514
BZ-88	373	7	174	0.1	0.4	14	63		28	98	0.86	-	568	888
BZ-91	254	38	521	0.0	0.5	22	92	4.4	20	208	2.1	-	1030	1410
BZ-93	608	31	2430	0.2	0.5	21	624		126	480	0.36	-	4010	4490
BZ-98	405	26	631	0.1	0.5	17	74		65	240	-	-	1250	1790

APPENDIX F

Subsurface Data

Well logs used to obtain thicknesses of units and to aid in drawing cross-sections are listed below. All logs ar on file at the New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico.

Continental Oil Company, 1-San Pedro Estates; section 28, T23N, R1W; ground elevation, 2321 m (7615 ft); total depth, 610 m (2000 ft).

Franks, Greathouse #2; section 10, T23N, R1W; ground elevation, 2240 m (7352 ft); total depth, 992 m (3253 ft).

Magnolia Petroleum Company, Evans Federal #1; section 18, T23N, R1W; ground elevation, 2239 m (7345 ft); total depth, 938 m (3078 ft).

Morris R. Antwiell, Skelly Federal # 1; section 1, T23N, R1W ground elevation, 2250 m (7383 ft); total depth, 271 m (890 ft).

Sun Oil Company, # 1 McElvain Government; NW 1/4, SW 1/4, NW 1/4, section 23, T21N, R2W; ground elevation, 2151 m (7058 ft); total depth,2195 m (7200 ft).

IBEX Parnership, # 1 Chorney 20 Federal, NW 1/4, section 20, T18N, R4W; ground elevation, 1982 m (6502 ft); total depth, 530 m (1741 ft).

APPENDIX G

Conversion Factors

Metric units have been stressed in this report. The conversions and abbreviations used are presented below. To calculate English units multiply the metric unit by the conversion factor.

Metric Unit X	Conversion Factor=	English Unit
centimeters (cm)	Ø.3937	inches (in)
meters (m)	3.28	feet (ft)
kilometers (km)	Ø.6214	miles (not abbreviated)
meters squared per day (m^2/day)	1Ø.764	feet squared per day (ft^2/day)
cubic meters per minute (m^3/min)	$1.3 \times 1Ø^{-3}$	gallons per minut (gpm)

Appendix H

Aquifer Test Data

An aquifer test was performed on a well in section 6, T2ØN, R1W in June, 1979. The test consisted of pumping th well for 8 hours at a constant discharge of 17 gpm. An attempt was made to measure drawdown as the well was pumpe but accurate readings could not be taken. After the pump w shut off recovery was measured using an electric water-leve indicator. The data from this test are presented in Table H-1.

Data from an aquifer test performed in 1957 by Roy Foster and F. X. Bushman are presented in Tables H-2 and H- For this test a well diameter of Ø.25 ft and a constant discharge of 13.9 gpm were assumed. All data were analyzed using the Jacob Straight Line Method (Lohman, 1972).

Table H-1. Aquifer test data from well in section 6, T20N, R1W.

Minutes after pumping stopped	Water level below ground surface (ft)	t/t-t2	drawdown
1	142.69	481	59.02
2	124.33	241	40.67
3	117.98	161	34.31
4	112.48	121	28.81
5	108.63	97	24.96
6	105.85	81	22.19
7	103.71	69.6	20.04
8	101.54	61	17.87
9	100.00	54.3	16.33
10	98.98	49	15.31
15	95.58	33	11.91
20	94.04	25	10.38
25	93.21	20.2	9.54
30	92.63	17	8.96
35	92.04	14.7	8.38
40	91.71	13	8.04
45	91.29	11.6	7.62
51	91.04	10.4	7.37
58	90.48	9.3	6.81
60	90.31	9	6.64
65	90.17	8.4	6.50
70	90.00	7.9	6.33
75	89.81	7.4	6.15
90	89.60	6.3	5.94
105	89.25	5.6	5.58
120	88.96	5	5.29
135	88.75	4.6	5.08
150	88.48	4.2	4.81
165	88.31	3.9	4.65
180	88.08	3.7	4.42
195	87.94	3.5	4.27
210	87.85	3.3	4.19
240	87.54	3	3.87
270	87.27	2.8	3.60
300	87.02	2.6	3.35
330	86.90	2.5	3.23
360	86.63	2.3	2.96

Table H-2. Aquifer test data from Foster and Bushman

Minutes after start of pumping	Water level in feet below top of casing	drawdown
0	17.8	0.0
2	24.4	6.6
5	28.5	10.7
11	31.2	13.4
12	31.2	13.4
27	32.7	14.9
65	33.8	16.0
100	34.6	16.8
122	34.2	16.4

Minutes after pumping stopped	Water level below ground surface (ft)	t/t-t2	dra
2	27.4	62.0	9
4	24.0	31.5	6
8	21.4	16.3	3
16	19.9	8.6	2
32	19.2	4.8	1
66	18.7	2.8	0

APPENDIX I

Piper Diagram Data

A computer program was used to calculate individual constituent percentages from raw epm (equivalents per million) data. Table I-1 presents the raw data and calculated percentages used on the Piper diagram (fig. 13, p. 67).

Table I-1.

DATA REDUCTION FOR PIPER DIAGRAM

WL	CATION FIELD RAW DATA (EPM) CA	MG	NA + K	TOTAL-C	PERCENTAGES CA	MG	NA+K	ANION FIELD RAW DATA (EPM) CO3+HCO3	SO4	CL	TOTAL-A	PERCENTAGES CO3+HCO3	SO4	CL
SW-1	1.310	0.054	0.049	1.413	92.374	3.348	4.278	1.580	0.000	0.027	1.607	98.320	0.000	1.680
SW-2	0.300	0.038	0.097	0.435	68.966	8.736	22.299	0.420	0.000	0.050	0.470	89.362	0.000	10.638
SW-3	0.840	0.044	0.066	0.950	88.421	4.632	6.947	0.497	0.430	0.053	0.980	50.714	43.878	5.408
SW-4	2.050	0.070	0.184	2.304	88.976	3.038	7.986	1.910	0.420	0.027	2.357	81.035	17.819	1.146
SW-5	1.200	0.020	0.290	1.510	79.470	1.325	19.205	1.250	0.220	0.050	1.520	82.237	14.474	3.289
SW-6	3.740	0.113	0.979	4.832	77.401	2.339	20.261	3.490	1.040	0.324	4.854	71.899	21.426	6.675
SW-7	4.800	0.151	0.808	5.759	83.348	2.622	14.030	3.640	1.780	0.670	6.090	59.770	29.228	11.002
SW-8	6.290	0.074	0.134	6.498	96.799	1.139	2.062	5.460	0.990	0.050	6.500	84.000	15.231	0.769
SW-9	5.990	0.071	0.433	6.494	92.239	1.093	6.668	5.570	0.920	0.160	6.650	83.759	13.835	2.406
SW-10	1.600	0.054	1.176	2.830	56.537	1.908	41.555	2.620	2.730	0.863	6.213	42.170	43.940	13.890
SW-11	3.190	0.640	0.798	4.628	68.928	13.829	17.243	2.750	2.060	0.080	4.890	56.237	42.127	1.636
SW-12	4.990	0.970	1.881	7.841	63.640	12.371	23.989	6.700	0.780	0.150	7.630	87.811	10.223	1.966
SW-13	3.890	1.320	4.410	9.620	40.437	13.721	45.842	8.140	1.010	0.160	9.310	87.433	10.849	1.719
SW-14	1.200	0.570	14.230	16.000	7.500	3.563	88.938	8.150	7.710	0.120	15.980	51.001	48.248	0.751
SW-15	10.200	5.200	3.100	18.500	55.135	28.108	16.757	4.500	13.300	0.200	18.000	25.000	73.889	1.111
SW-16	3.920	2.260	1.060	7.240	54.144	31.215	14.641	2.640	5.270	0.590	8.500	31.059	62.000	6.941
SW-17	3.100	1.200	0.740	5.040	61.508	23.810	14.683	3.520	1.500	0.600	5.620	62.633	26.690	10.676
SW-18	2.500	0.700	0.730	3.930	63.613	17.812	18.575	2.700	0.700	0.420	3.820	70.681	18.325	10.995
SW-20	0.900	0.600	0.900	2.400	37.500	25.000	37.500	2.540	0.000	0.100	2.640	96.212	0.000	3.788
SW-21	6.400	2.300	2.200	10.900	58.716	21.101	20.183	5.480	5.100	0.420	11.000	49.818	46.364	3.818
SW-22	4.250	4.850	3.210	12.310	34.525	39.399	26.076	3.400	9.700	0.650	13.750	24.727	70.545	4.727
SW-23	0.900	2.200	3.240	6.340	14.196	34.700	51.104	3.400	1.400	1.200	6.000	56.667	23.333	20.000
SW-24	3.890	2.400	0.900	7.190	54.103	33.380	12.517	2.000	5.300	0.200	7.500	26.667	70.667	2.667
SW-25	3.100	3.000	2.700	8.800	35.227	34.091	30.682	5.500	0.900	0.500	6.900	79.710	13.043	7.246
SW-26	1.300	2.500	26.500	30.300	4.290	8.251	87.459	3.500	25.700	0.300	29.500	11.864	87.119	1.017
SW-30	4.760	3.000	2.210	9.970	47.743	30.090	22.166	5.930	4.150	0.030	10.110	58.655	41.048	0.297
SW-32	3.990	1.070	1.220	6.280	63.535	17.038	19.427	3.990	1.040	0.320	5.350	74.579	19.439	5.981
SW-33	2.990	0.630	0.370	3.990	74.937	15.789	9.273	2.380	0.520	0.240	3.140	75.318	16.456	8.228
SW-34	1.310	0.370	0.490	2.170	60.369	17.051	22.581	1.510	0.380	0.140	2.030	74.384	18.719	6.897
SC-1	2.500	1.100	2.900	6.500	38.462	16.923	44.615	4.140	1.870	0.220	6.230	66.453	30.016	3.531
SC-44	2.450	0.550	7.580	10.580	23.157	5.198	71.645	7.910	14.880	0.560	23.350	33.876	63.726	2.398
SC-46	3.840	1.560	4.620	10.020	38.323	15.569	46.108	7.900	2.020	0.110	10.030	78.764	20.140	1.097
SC-49	3.090	0.800	1.270	5.160	59.884	15.504	24.612	1.570	1.940	0.390	3.900	40.256	49.744	10.000
SC-58	4.900	2.300	1.020	8.220	59.611	27.981	12.409	6.220	3.430	0.400	10.050	61.891	34.129	3.980
SC-91	10.380	1.640	4.110	16.130	64.352	10.167	25.480	4.230	10.850	1.070	16.150	26.192	67.183	6.625
SC-93	23.950	10.340	10.050	44.340	53.990	23.354	22.656	10.130	50.430	0.870	61.430	16.437	82.152	1.412
SC-98	11.980	5.350	1.200	18.530	64.652	28.872	6.476	6.750	13.150	0.730	20.630	32.719	63.742	3.539
SC 1-18	3.590	1.720	4.000	9.310	38.561	18.475	42.965	8.980	4.290	0.850	14.120	55.707	39.070	5.274

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