HYDROGEOLOGY OF THE SANTA FE GROUP AQUIFER SYSTEM, SOUTHERN ESPANOLA BASIN, NEW MEXICO
RECENT DEEP TEST WELLS IN THE SANTA FE COMMUNITY COLLEGE DISTRICT

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ABSTRACT

Recent (2001-2002) sample and geophysical logging of a 1,500-ft exploration well in the "type" Santa Fe Group (SFG), and concurrent hydrogeologic studies throughout the Santa Fe embayment area are providing significant new insights on basin-fill aquifers of the southern Española Basin, New Mexico. Primary study sites include stratigraphic and production test-wells near the Santa Fe Community College and adjacent parts of the Rancho Viejo de Santa Fe, Inc. development. As in other Rio Grande rift basins (e.g. Hawley and Kernodle, 2000), our conceptual model of the area's hydrogeologic framework is here defined in terms of 1) *lithofacies assemblages* that are grouped into informal (lower, middle and upper) SFG *hydrostratigraphic units*, and 2) basin-boundary and intra-basin structural controls.

Our work confirms both the "type" SFG lithostratigraphic model (Ancha Fm/ Tesuque Fm) of Spiegel and Baldwin (1963) and recent revisions proposed by Koning and others (2002). Borehole logs of Community College District Exploratory Well #1 (CCDX1), however, provide a much clearer subsurface view of this previously unexplored part of the Santa Fe embayment. At the CCDX1 site, about 200 ft of the Pliocene Ancha Fm, with a veneer of arroyo deposits, are underlain by 1,300+ ft of the Miocene Tesuque Fm. The vadose zone is about 260 ft thick. The Upper Santa Fe Ancha Fm is composed of arkosic (Sangre de Cristo-derived) piedmont alluvium, but this facies is a subordinate Tesuque Fm component. The dominant *lithofacies assemblage* in the main body of the Tesuque (middle SFG *hydrostratigraphic unit*) is a basin-floor sequence of sandy channel and silty overbank deposits. Hydraulic testing is consistent with a heterogeneous system of stacked channel deposits. This unit is about 1,100 ft thick at the CCDX1 site and has significant groundwater-production potential.

Well logs, early geophysical surveys (Winkler *in* Spiegel and Baldwin, 1963), and recent interpretations of aeromagnetic data by Sweeney and others (2002) indicate that the southern Santa Fe embayment is a narrow rift subbasin that expands to the north and narrows southward toward the Laramide Galisteo basin. About 2 mi east of the test-well site, a shallowly buried (N-trending) linear feature is here interpreted as the principal boundary fault of the embayment. The southern subbasin termination, marked by an abrupt pinch out of the Tesuque Fm, is located about 4 mi SSE of the well site near the western edge of the Eldorado Community.

SETTING

The Community College District (CCD) of Santa Fe County, south of the City of Santa Fe, lies in the Santa Fe embayment of the Española Basin (Figure 1). The embayment formed in Oligocene time with emplacement of intrusives and concurrent uplift of the Cerrillos Hills and San Pedro and Ortiz Mountains (Grant, 1998). SFG deposits are up to 2000 feet thick in the embayment. A deep exploration well (CCDX1) was drilled, logged and tested in December 2001 to explore the aquifer production potential of the Tesuque Formation in the CCD. The wellsite was selected for aquifer thickness west of bedrock faulting apparent in aeromagnetic surveys (Figure 2). A second well (CCD Production Well 1 (CCDP1)) was drilled and tested at 300 gpm in 2002.

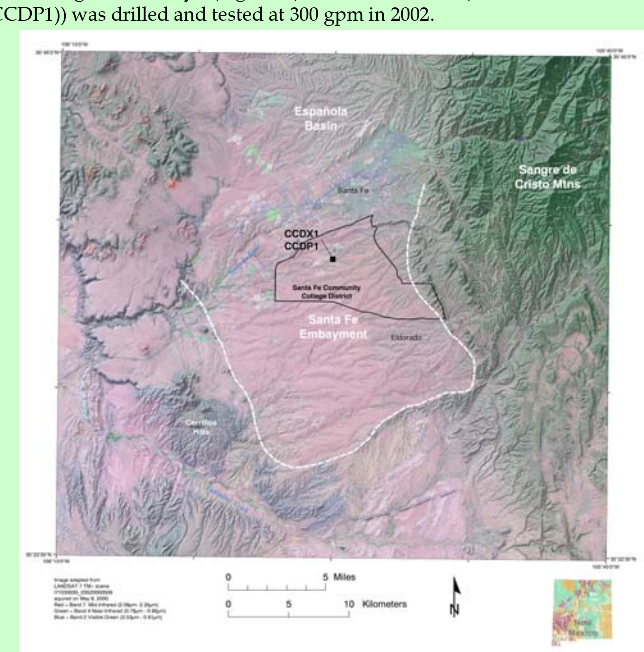


FIGURE 1. LOCATION MAP

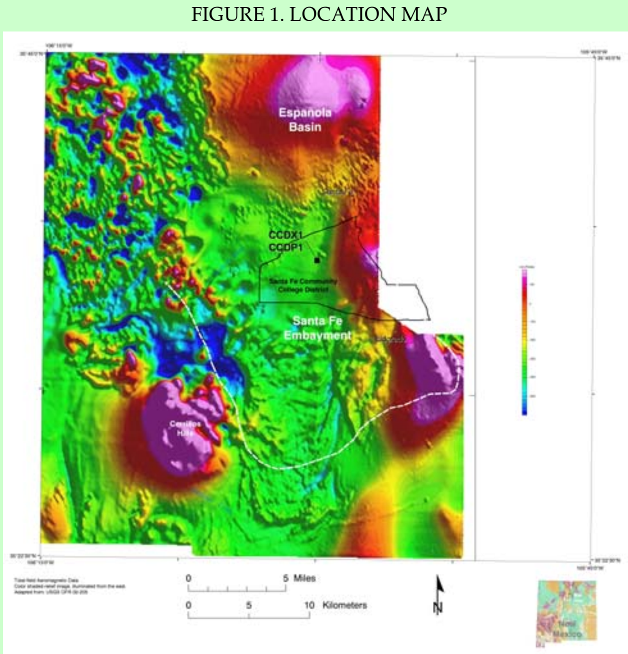


FIGURE 2. AEROMAGNETIC MAP

CCDX1 DRILLING AND LOGGING

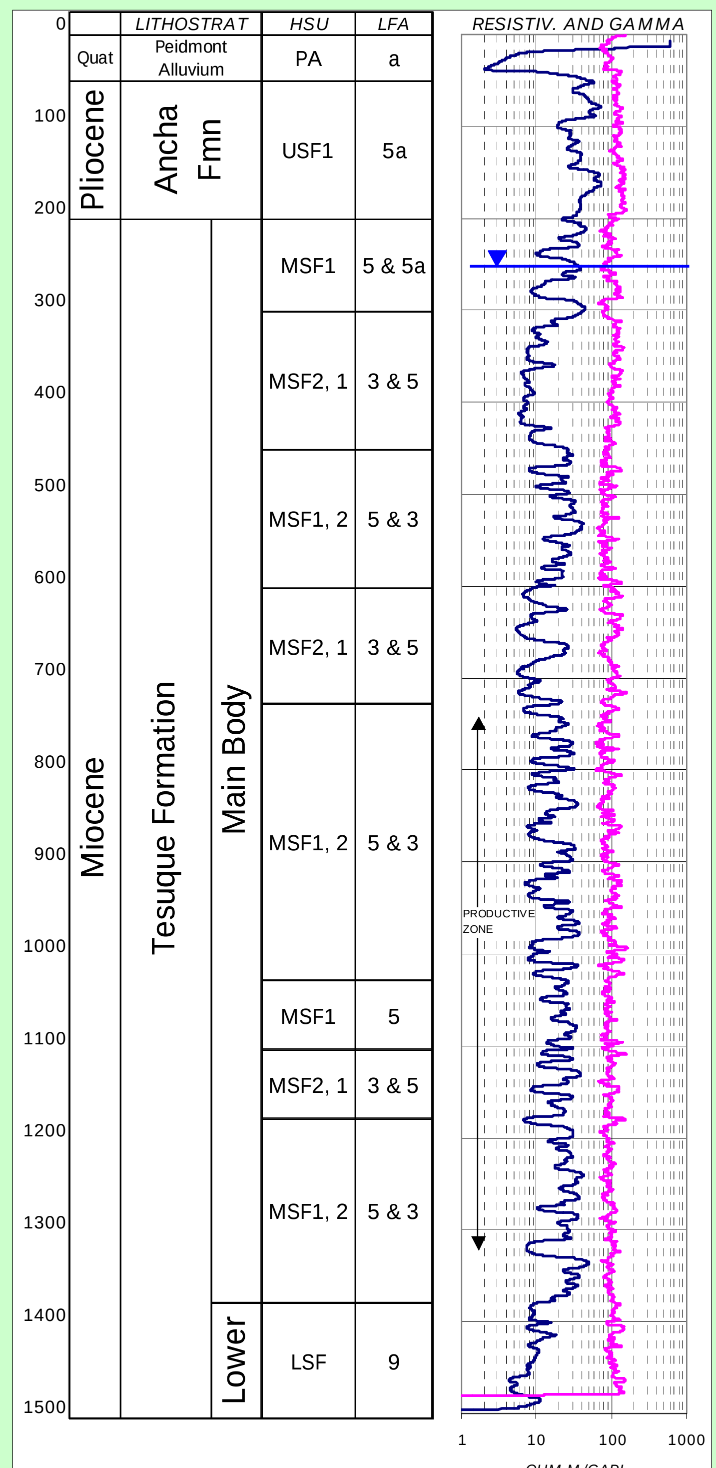


FIGURE 3. HYDROSTRATIGRAPHY AND GEOPHYSICS

LAYNE-WESTERN CHALLENGER
360-200 ROTARY DRILL RIG

CCDX1 was drilled by Layne-Western in December 2001 to 1500-foot depth using the reverse-rotary air-lift method. Drill cuttings were collected, bagged and analyzed at ten- to twenty-foot intervals from 40 to 1500 feet.

Borehole geophysical logging by Patterson Wireline included gamma ray, spontaneous potential, direct induction and short-normal resistivity. Short-normal resistivity and gamma are shown in Figure 3 above.

Sample logging involved use of standard field-identification procedures developed by the USDA-Natural Resource Conservation Service (NRCS) and other Federal agencies for their geological engineering and soil mapping programs (NRCS, 1996).

Except for Quaternary arroyo-valley fill in the uppermost part of the borehole (~60 feet), all deposits penetrated by the test well are correlated with the Miocene to Lower Pleistocene SFG Tesuque and Ancha Formations as defined by Brewster Baldwin (*in* Spiegel and Baldwin 1963, p. 38-64) (Figure 4, opposite panel). *Note that the "upper" Santa Fe-Ancha Formation has recently been redefined by Koning and others (2002), but at the CCDX1 Well site, the Ancha Fm conforms to both original and current lithostratigraphic concepts.* The bulk of SFG sediments in the CCDX1 Well area are interpreted as sandy, distal piedmont-slope lithofacies derived from the adjacent Sangre de Cristo uplift and lesser amounts of fine-grained basin-floor sediments (Figure 5, opposite panel). These deposits are here classified according to two systems of stratigraphic nomenclature: 1) Upper Neogene SFG lithostratigraphic units: Ancha Formation—upper zone, and Tesuque Formation—aquifer zone, and 2) informal hydrostratigraphic and lithofacies subdivisions of the SFG (Hawley and Kernodle, 2000) (Figure 5, Tables 1-3, opposite panel). Figure 3 shows the age and classification of CCDX1 cuttings alongside borehole geophysics.

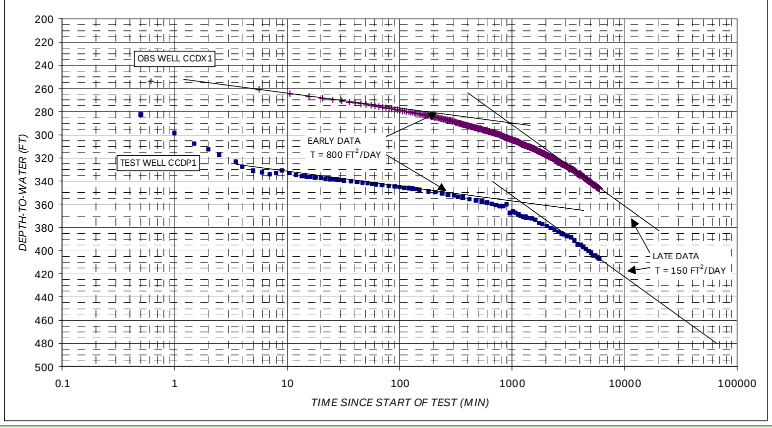
Hydraulic testing, sample logging and geophysical borehole data indicate high production potential between 740 and 1310 feet. A 12-inch production well (CCDP1) was drilled by Layne-Western to 1300 ft, completed in the productive zone, and tested at 300 gpm with 144 ft of drawdown in January 2002.

AQUIFER TESTING

During construction of exploratory well CCDX1, two zones were screened and tested: a temporary deep zone from 1090 to 1290 feet below ground and final shallow zone from 690 to 890 feet. Each zone was pumped for four hours and monitored for a half day during recovery. Theis (1935) analyses of recovery data give transmissivity (T) of about 400 feet^2/day (ft^2/d) in each tested zone, or hydraulic conductivity of 2.0 ft/d. CCDX1 test data, with geophysical logs and grain size analysis were used to specify drilling and completion of production well CCDP1.

CCDP1 was tested at 300 gpm for four days while water levels were observed in CCDX1 and several outlying wells. CCDP1 and CCDX1 drawdown are shown in Figure 6. Water levels in outlying wells did not respond to the test. Early and late drawdown data indicate T = 800 and 150 ft^2/d, respectively. Figure 7 shows time-distance drawdown. A Theis type-curve with T = 800 ft^2/ d and storativity (S) = 0.0004 fits early data. Figure 8 shows recovery in CCDP1 and CCDX1 for ten months after test shutdown. Drawdown and recovery data are interpreted to indicate high-T (800 ft^2/d) channel sediments in the screened zone, surrounded by lower-T (150 ft^2/d) material at intermediate distances. The diminishing slope of late-time recovery (Figure 8) as t/t' approaches 1.0 signals the expansion of the cone of depression into a higher-T regional aquifer near 500 ft^2/d. The three-step change in slope in the drawdown and recovery test trends indicates the varying response to pumping from heterogeneous stacked-channel deposits with differing permeability as the cone of influence expands. The trends during ten months of recovery data imply that the characteristic regional transmissivity in the more extensive flow field is an intermediate value between those of the channel sands and the enclosing sediments.

FIGURE 6
COMMUNITY COLLEGE DISTRICT PRODUCTION WELL #1 AQUIFER TEST
SEMILOG DRAWDOWN



CCDX1 TEST SETUP

CCDX1 AQUIFER TEST DISCHARGE

FIGURE 7
COMMUNITY COLLEGE DISTRICT PRODUCTION WELL #1 PUMP TEST
TIME-DISTANCE DRAWDOWN THEIS CURVE MATCH

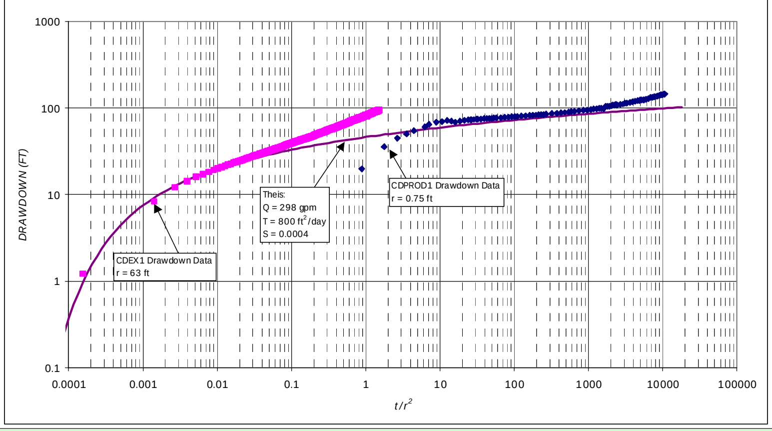
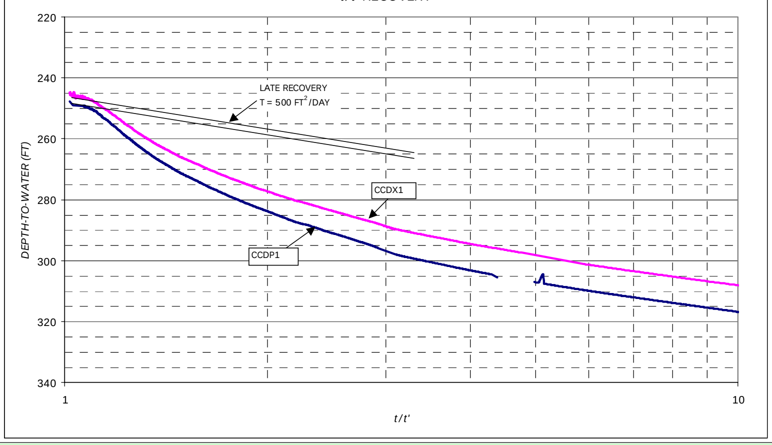


FIGURE 8
COMMUNITY COLLEGE DISTRICTPRODUCTION WELL #1 AQUIFER TEST
t/t' RECOVERY



SANTA FE GROUP NOMENCLATURE

Table 1. Summary of depositional settings and dominant textures of major lithofacies assemblages (***LFAs***) in basin and valley fills of the Rio Grande rift region: Santa Fe Group basin fill (***1-10***), and post-Santa Fe river-valley and basin fill (***a-c***). Modified from Hawley and Kernodle (2000)

Lithofacies		Dominant depositional settings and process	Dominant textural classes
1		Basin-floor fluvial plain	Sand and pebble gravel, lenses of silty clay
2		Basin-floor fluvial, locally eolian	Sand; lenses of pebble sand, and silty clay
3		Basin-floor, fluvial-overbank, fluvial-deltaic and playa-lake; eolian	Interbedded sand and silty clay; lenses of pebbly sand
4		Eolian, basin-floor alluvial	Sand and sandstone; lenses of silty sand to clay
5		Distal to medial piedmont-slope, alluvial fan	Gravel, sand, silt, and clay; common loamy (sand-silt-clay)
	5a	Distal to medial piedmont-slope, alluvial fan; associated with large watersheds; alluvial-fan distributary-channel primary, sheet-flood and debris-flow, secondary	Sand and gravel; lenses of gravelly, loamy sand to sandy loam
	5b	Distal to medial piedmont-slope, alluvial-fan; associated with small steep watersheds; debris-flow sheet-flood, and distributary-channel	Gravelly, loamy sand to sandy loam; lenses of sand, gravel, and silty clay
6		Proximal to medial piedmont-slope, alluvial-fan	Coarse gravelly, loamy sand and sandy loam; lenses of sand and cobble to boulder gravel
	6a	Like 5a	Sand and gravel; lenses of gravelly to non-gravelly, loamy sand to sandy loam
	6b	Like 5b	Gravelly, loamy sand to sandy loam; lenses of sand, gravel, and silty clay
7		Like 5	Partly indurated 5
8		Like 6	Partly indurated 6
9		Basin-floor—alluvial flat, playa, lake, and fluvial-lacustrine; distal-piedmont alluvial	Silty clay interbedded with sand, silty sand and clay
10		Like 9, with evaporite processes (paleophreatic)	Partly indurated 9, with gypsiferous and alkali-impregnated zones
a		River-valley, fluvial	Sand, gravel, silt and clay
	a1	Basal channel	Pebble to cobble gravel and sand (like 1)
	a2	Braided plain, channel	Sand and pebbly sand (like 2)
	a3	Overbank, meander- belt oxbow	Silty clay, clay, and sand (like 3)
b		Arroyo channel, and valley-border alluvial-fan	Sand, gravel, silt, and clay (like 5)
c		Basin floor, alluvial flat, cienega, playa, and fluvial-fan to lacustrine plain	Silty clay, clay and sand (like 3, 5, and 9)

Table 2. Summary of major sedimentary properties that influence the groundwater-production potential of Santa Fe Group lithofacies assemblages (***LFA's1-10***). Modified from Haase and Lozinsky (1992).

Lithofacies	Ratio of sand plus gravel to silt plus clay[1]	Bedding thickness (meters)	Bedding configuration[2]	Bedding continuity (meters)[3]	Bedding connectivity [4]	Hydraulic conductivity (K)[5]	Groundwater production potential
1	High	> 1.5	Elongate to planar	> 300	High	High	High
2	High to moderate	> 1.5	Elongate to planar	> 300	High to moderate	High to moderate	High to moderate
3	Moderate	> 1.5	Planar	150 to 300	Moderate to high	Moderate	Moderate
4	Moderate to low*	> 1.5	Planar to elongate	30 to 150	Moderate to high	Moderate	Moderate
5	Moderate to high	0.3 to 1.5	Elongate to lobate	30 to 150	Moderate	Moderate to low	Moderate to low
5a	High to moderate	0.3 to 1.5	Elongate to lobate	30 to 150	Moderate	Moderate	Moderate
5b	Moderate	0.3 to 1.5	Lobate	30 to 150	Moderate to low	Moderate to low	Moderate to low
6	Moderate to low	0.3 to 1.5	Lobate to elongate	30 to 150	Moderate to low	Moderate to low	Low to moderate
6a	Moderate	0.3 to 1.5	Lobate to elongate	30 to 150	Moderate	Moderate to low	Moderate to low
6b	Moderate to low	0.3 to 1.5	Lobate	< 30	Low to moderate	Low to moderate	Low
7	Moderate *	0.3 to 1.5	Elongate to lobate	30 to 150	Moderate	Low	Low
8	Moderate to low *	> 1.5	Lobate	< 30	Low to moderate	Low	Low
9	Low	> 3.0	Planar	> 150	Low	Very low	Very low
10	Low*	> 3.0	Planar	> 150	Low	Very low	Very low

[1] High >2; moderate 0.5-2; low < 0.5
[2] Elongate (length to width ratios > 5); planar (length to width ratios 1-5); lobate (asymmetrical or incomplete planar beds).
[3] Measure of the lateral extent of an individual bed of given thickness and configuration.
[4] Estimate of the ease with which groundwater can flow between individual beds within a particular lithofacies. Generally, high sand + gravel/silt – clay ratios, thick beds, and high bedding continuity favor high bedding connectivity. All other parameters being held equal, the greater the bedding connectivity, the greater the groundwater production potential of a sedimentary unit (Hawley and Haase 1992, VI).
[5] High 10 to 30 m/day; moderate, 1 to 10 m/day; low, < 1 m/day; very low, < 0.1 m/day.
* Significant amounts of cementation of coarse-grained beds (as much as 30%)

Table 3. Table 3. Summary of major sedimentary properties that influence the groundwater-production potential of post-Santa Fe river-valley and basin fill (***LFA's a-c***). Modified from Hawley and Kernodle (2000).

Lithofacies	Ratio of sand plus gravel to silt plus clay[1]	Bedding thickness (meters)[3]	Bedding configuration[2]	Bedding continuity (meters)[3]	Bedding connectivity [4]	Hydraulic conductivity (K)[5]	Groundwater production potential
a	High to moderate	> 1.5	Elongate to planar	> 300	High to moderate	High to moderate	High to moderate
a1	High	> 1.5	Elongate to planar	> 300	High	High	High
a2	High to moderate	> 1.5	Planar to elongate	150 to 300	Moderate to high	Moderate	Moderate
a3	Moderate to low	> 1.5	Planar to elongate	30 to 150	Moderate to high	Moderate to low	Moderate to low
b	Moderate to low	0.3 to 1.5	Elongate to lobate	<100	Moderate	Moderate to low	Moderate to low
c	Low to moderate	0.3 to 1.5	Elongate to lobate	30 to 150	Low	Low	Low

[1] High >2; moderate 0.5-2; low < 0.5
[2] Elongate (length to width ratios > 5); planar (length to width ratios 1-5); lobate (asymmetrical or incomplete planar beds).
[3] Measure of the lateral extent of an individual bed of given thickness and configuration.
[4] Estimate of the ease with which groundwater can flow between individual beds within a particular lithofacies. Generally, high sand – gravel/silt + clay ratios, thick beds, and high bedding continuity favor high bedding connectivity. All other parameters being held equal, the greater the bedding connectivity, the greater the groundwater production potential of a sedimentary unit (Hawley and Haase 1992, VI).
[5] High 10 to 30 m/day; moderate, 1 to 10 m/day; low, < 1 m/day; very low, < 0.1 m/day.

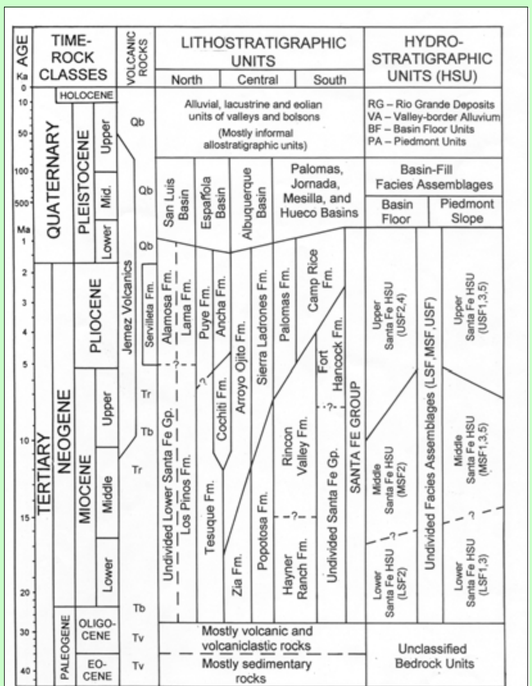


FIGURE 4. STRATIGRAPHIC CORRELATION CHART

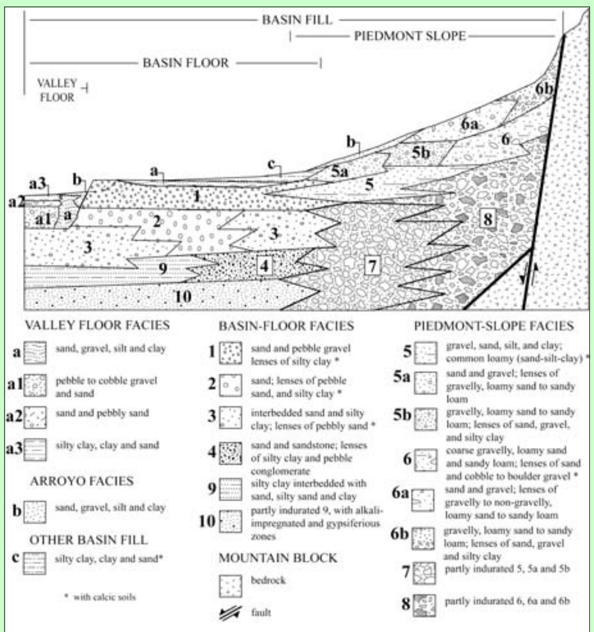


Figure 5. Schematic distribution pattern of major lithofacies assemblages (Tables 1 to 3) in Santa Fe Group basin fill and post-Santa Fe valley fills of the Rio Grande rift region. From Hawley and Kernodle (2000)

CCDX1 CUTTINGS

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