Subsurface information from three wells in the Tonto Basin, Gila County, Arizona

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INTRODUCTION

Three wells drilled in the Tonto Basin have been studied to assist in the interpretation of subsurface geology of the basin. These are the Forest Service Windy Hill Test #1, drilled in 1991, the Sanchez-O'Brien Federal 1-4, drilled in 1983, and the Kerber 1 Federal, drilled in 1969. Locations and other information about the wells are included in Table 1.

GEOLOGIC SETTING

Mountain ranges surrounding the Tonto Basin consist of Early to Middle Proterozoic granitic and metamorphic rocks, overlain by Middle Proterozoic strata of the Apache Group and lower Paleozoic clastic and carbonate strata. Tertiary volcanic rocks overlie these units around the southeastern part of the basin. The physiographic Tonto basin consists of two geologic sub-basins, apparent on the depth-to-bedrock map for Arizona [Oppenheimer and Sumner, 1980]. A bedrock high between the area of Tonto National Monument and Windy Hill, then north from Windy Hill separates the sub-basins. The wells described in this report are from the southern part of the northern sub-basin and the transition zone between the sub-basins.

Paleozoic and Precambrian rocks

In the area of the bedrock high separating the two sub-basins of the Tonto Basin, Devonian and Mississippian sandstone, limestone and dolomite are preserved overlying the Apache Group. Cambrian(?) sandstone is locally preserved in paleovalleys beneath the Devonian strata [Spencer and Richard, in press]. Conodont color alteration indices from Mississippian limestone on Windy Hill and in the southern Sierra Ancha are 2 and 1, respectively [Wardlaw and Harris, 1984], indicating that they are potentially within the thermal maturation window for oil.

The Sierra Ancha, which lies on the north side of the subject area, consists mostly of sandstone, mudstone, quartzite, and limestone of the Apache Group and Troy Quartzite [Shride, 1967]. These strata are intruded by thick diabase sills that crop out over large parts of the mountain range. Northeast of the northern end of Theodore Roosevelt Lake, Middle or Early Proterozoic granitic rocks that underlie the Apache Group are exposed along the southwestern front of the Sierra Ancha [Bergquist et al., 1981].

The southern Mazatzal Mountains consist mostly of a variety of Early Proterozoic granitic rocks. Starting about 4 miles NW of Theodore Roosevelt Dam, and southward onto Two Bar Ridge, these granitic rocks are overlain by sandstone, mudstone, quartzite, and limestone of the Apache Group, and intruded by diabase sills. In the area immediately north and south of the Theodore Roosevelt Dam, Devonian and Mississippian sandstone, limestone and dolomite are preserved overlying the Apache Group.

Tertiary rocks

Tertiary basin fill strata consist of conglomerate, sandstone, and mudstone, with minor evaporite and carbonate beds. Nations [1987, 1988, 1990] identified two facies within this sequence, which he informally named the Tonto Basin formation. These are a basal and basin margin conglomerate facies and an upper and basin center fine-grained facies. The conglomerate facies consists of poorly stratified, very poorly sorted conglomerate. Clasts are locally derived and reflect the rock types present in nearby bedrock exposures. The conglomerate facies in the southern part of the basin contains abundant cobbles and boulders derived from Tertiary volcanic rocks, particularly the Apache Leap Tuff, which crop out around the south side of the Tonto Basin. The basin fill strata are younger than Apache Leap Tuff (18.6

Ma, McIntosh et al., 1998) in the southern part of the basin. The lower age limit is presently bracketed by the presence of a late Miocene or Pliocene vertebrate fossil in the mudstone member in the northern part of the basin. A K-Ar date of 18.6 Ma reported from a tuff interbedded near the top of the section in the northern part of the basin [Nations, 1987] suggests that much of the basin fill sequence in the Punkin Center area is older than the lower conglomerate in the southern part of the basin, and may in fact be correlative with strata referred to as Whitetail conglomerate in the southern part of the basin.

Lance et al. [1962] measured 3 stratigraphic sections in the area around Punkin Center and proposed a stratigraphic sequence as follows: 1) a sequence of red beds, consisting of sandstone and mudstone; 2) a zone up to 300 feet thick of red beds containing abundant gypsum; and 3) a few tens of feet of light colored beds of clay, silt, tuff, and marl, which contains the fossiliferous beds. The gypsiferous zone thins northward, and the red beds (units 1 and 2?) grade into conglomerate exposed around the northern end of the basin.

DISCUSSION OF WELLS

The Windy Hill Test was drilled as a possible water well to provide water for the Windy Hill Campground. At about 1600 feet the well hit limestone, and hydrogen sulfide gas was released from the formation. The well was completed at 1867 feet, and the maximum reported H_2S concentration at the surface was reported at 15-16 ppm [Arizona Geological Survey, Oil and Gas Commission files]. The hydrogen sulfide releases resulted in the evacuation of the Windy Hill campground [Likens, 1991]. A caliper survey, sonic log, and electric log were run in the hole from 130 to 1867 feet. The location of this well reported on the logs (NW1/4, SE1/4, NE1/4 sec. 25, T. 4N., R. 12E) is incorrect. The correct location, reported on the driller's report submitted to the Arizona Department of Water Resources, is SE1/4, NW1/4, NW1/4 Sec. 25, T. 4N, R. 12E (Reg@ 55-531851, File# A(4-12) 25 BBD).

Table 1. Wells included in this report

Name	Lat (N); Long (W)	Year Drilled	T.D. (feet)	Logs	Purpose	Notes
Windy Hill Test #1	33° 39.71', 111° 5.34'	1991	1867	Welenco, 128'-1867' • Caliper; • Sonic/Variable Density Waveform; • Electric Log	Water	H_2S released
Kerber 1 Federal	33° 43.17', 111° 3.04'	1969	485	Driller's log in well completion report	Oil and Gas	
Sanchez-O'Brien Federal 1-4	33° 43.21', 111° 8.19'	1983	3490	Mobilog Inc. mud log, 0-3500' Welex, 496-3490' • Caliper • Gamma ray • Dual induction guard log • Compensated density dual spaced neutron log	Oil and Gas	
Tonto Oil Co.	33° 42.38', 111° 8.02'	1914-1916	>120	None	Oil and Gas	Well was still open in 1983

Tonto Headlight Oil Co.	33° 43.57', 111° 8.46'	1915	1650	None	Oil and Gas	Sanchez-O'Brien Co. [1983] reports oil and gas shows at 400', 1150', 1310', 1500', and 1600'; source of this information unknown.

Interest in possible oil production in the Tonto Basin was sparked by early reports of dead oil in Devonian strata exposed at the present location of Theodore Roosevelt Dam [Botsford, 1913]. At least two wells were apparently drilled in 1914-1916 [Sanchez-O'Brien Oil and Gas Corporation, 1983]. These wells were located by surveyors locating the Sanchez-O'Brien Federal 1-4, and the locations are reported in Table 1. A newspaper article in the Oil and Gas Commission files [1915; source of article unknown] reports that petroleum was found in the Tonto Oil Co. well "in small quantities in a six inch bed of sand at a depth between 1100 and 1200 feet." Abandonment of these wells indicates that economic quantities of oil or gas were not proven in these wells.

INTERPRETATION OF LOGS

The Arizona Geological Survey has cuttings in its well cuttings repository from the Sanchez-O'Brien Federal 1-4 well. These were studied, and compared to the mud log and geophysical logs available. These data were taken together to interpret the lithology and stratigraphy of formations penetrated by this well. For the Windy Hill Test #1, no mud logs or cuttings are available. The caliper and density log from the Sanchez-O'Brien Federal 1-4 are surprisingly similar to the caliper and Sonic Density log from the Windy Hill test #1. Basin fill units apparently correlate well, suggesting surprisingly consistent stratigraphy within the basin. The bedrock intercept is clear in both wells, and correlation of bedrock units in the Sanchez-O'Brien Federal 1-4 can be done with some confidence based on examination of the cuttings. Correlation of bedrock units in the Windy Hill Test #1 is much more speculative, and is based largely on the interpretation that the H_2S release from this well was from the Martin Formation, consistent with the sketchy lithologic description available [AZGS, Oil and Gas Commission Files] and reports of dead oil and petroliferous odor in Martin limestone in the area. If the bedrock unit first penetrated was Martin Formation, the similarity of the log traces with the Sanchez-O'Brien Federal 1-4 well suggests the correlations reported in Table 3.

Table 4 summarizes lithologic information from a completion report for the Kerber 1-Federal. This well apparently penetrated mudstone, interbedded mudstone and sandstone, and intercepted Dripping Spring Quartzite at 360'.

Table 2. Data and interpretations for Sanchez-O'Brien Federal 1-4. Ground level 2190', kelly bushing 2195', Surface casing set to 500'. Caving of hole between bottom of casing at 500' and well bore stabilization at 612' suggests that much of the rock fragment and sand material mixed with mud from deeper in the well may be slough. Units of bulk density are grams/cc; units for gamma ray intensity are gamma ray units. Cuttings are stored in vials representing 10' depth intervals. The depth reported for cuttings are for the shallowest part of the interval for each vial. Where depths for lithologic transitions seen in cuttings do not agree with lithologic transitions recorded on geophysical logs, the geophysical logs are taken to be more accurate.

Depth in well (feet below ground level)	Elevation (feet above sea level)	Observations	Interpretations
500-612	1690-1578	Caliper indicates abundant caving of hole, rapid changes in hole diameter; diameter 13" to >18" Bulk density is <2.0, and highly variable, ranges 1.3-2.0 Cuttings: 600--first sample; contains white tuff grains with copper-colored biotite crystals; trace glassy quartz, black biotite flakes, possible hornblende, abundant mudstone/clay in tiny chips and dust.	Sandstone and conglomerate with interbedded tuff or clasts of tuffaceous rocks, not strongly indurated
612-1110	1578-1080	Caliper diameter stable, but less than drill bit diameter; diameter 6-7" to 1000' then diameter to about 8" average, but ranges 7-16", with ~5' thick wash out zones. Bulk density variable, averages 2.05, range 1.9-2.15 Gamma ray intensity avg. 105, range 100-110 Cuttings: 640--trace white tuff, rare angular quartz, no biotite or hornblende seen, much clay 1000--trace white tuff, glassy quartz, detrital biotite, some very fine-grained lithic sand, cuttings form clay balls. 1020--clay balls up to 1 cm diameter, some with medium-grained glassy quartz stuck to them; clay balls effervesce and disaggregate in hydrochloric acid 1090--trace rock fragments present, including some diabase	Abundant swelling clay in formation, probably mostly mudstone, with progressively more interbedded sandstone below 1000'. Tuff clasts or interbedded tuff present.
1110-1300	1080-890	Caliper stable, diameter 13.5±1"; diameter variations rapid. Bulk density averages 2.07, range 1.95-2.2, varies rapidly Gamma ray intensity avg. 98, range 90-107 Cuttings: 1110-1160--fine- to medium-grained lithic sandstone stuck to clay balls; rare light gray microcrystalline tuff?	Less clay in formation, non-swelling clay dominant, probably interbedded sandstone and mudstone; washing out of well bore suggests relatively poorly indurated material
1300-1350	890-840	Caliper 13.5-14.5", diameter increases down hole, rapid small variations Bulk density 2.07-2.17 Gamma ray intensity 100±7	Transition zone; mud log indicates mostly mudstone
1350-1485	840-705	Caliper 14.5"; diameter varies ±1" above 1390, then becomes relatively stable; hole narrows to 13" over bottom 30' of interval Bulk density average 2.17, range 2.1-2.25 Gamma ray intensity 100±7	Mud log indicates still mostly mudstone, but appears to become more homogeneous
1485-1630	705-560	Caliper 13.5-12", diameter decreases down hole Bulk density average increases from 2.15-2.27 down hole, varies ±0.07 Gamma ray intensity 90±10, generally decreases down hole Mud log reports significantly more "conglomerate" below about 1420. 1580--"mudstone, sample eludes 80 mesh screen"	Increasing induration of rock, progressively less clay, density and gamma ray variability suggested interbedded lithology or boulder conglomerate.
1630-1690	560-500	Caliper diameter decreases smoothly 12" to 9" down hole Bulk density average 2.15, range 2.0-2.25 Gamma ray intensity 85±5, generally decreases down hole Mud Log: 1640: reports "free quartz, clear to frosted" 1660: increasing dark minerals, 20% increase in free quartz	Conglomerate, derived from underlying volcanic rocks? Progressively more indurated.
1690-1810	500-380	Caliper diameter stable, 9" Bulk density, 2.65-2.7, drops to ~2.4 in 10' intervals at	Apache Leap tuff??, or conglomerate derived largely from tuff; low density zones may

Depth in well (feet below ground level)	Elevation (feet above sea level)	Observations	Interpretations
		1760 and bottom of interval Gamma ray intensity average 70, range 20-160; more stable in lower part Cuttings: 1710-1760, glassy quartz grains that look like quartz from phenocrysts in volcanic rock present 1750-very round, frosted quartz grains 1780-glassy quartz rare, spherical frosted quartz present, tiny biotite grains, cuttings have pinkish-tan color typical of Apache Leap tuff 1800-white calcite grains, and sparry, clear calcite cleavage rhombs, white tuff fragments, one with sanidine phenocryst Mud Log: 1740-1780--reports "chalky, in pit"	be non-welded intervals.
1810-1880	380-310	Caliper diameter stable, 9-10", diameter increases in middle of interval Bulk density average 2.4, range 2-2.55; lower density in middle part Gamma ray intensity: 30-200, monotonic increase down section. Cuttings: 1820--yellowish tan microcrystalline carbonate grains appear	Martin Formation or Mescal Limestone? Relative dense, low-clay carbonate unit at top, increasing clay or mica down section; apparent stabilization of well bore in lower part seems more consistent with relatively competent Beckers Butte sandstone at base of Martin than nodular silty carbonate unit and breccias seen at base of Mescal.
1880-1910	310-280	Caliper diameter decreases 9" to 8" downward Bulk density avg. 2.4 Gamma ray intensity 90±10 Cuttings: 1880--pyrite and limonite after pyrite, light greenish microcrystalline aggregates, reddish brown quartzite 1900--cuttings are coarser grained (mud density change?)	Bolsa Quartzite?, less clay than Martin, less K-spar than Dripping Spring
1910-2040	280-150	Caliper diameter stable, 8" to 2000' then increases to 10" at bottom of interval Bulk density 2.3-2.4 Gamma ray intensity 40-200, highly variable Cuttings: 1920--pinkish fine-grained arkose, silica cemented 1980--dark red brown fine-grained feldspathic(?) quartzite	Dripping Spring quartzite?, alternating quartz arenite and K-feldspar rich arkose
2040-3245	150-(-1055)	Caliper diameter stable 8-9" Bulk density stable 2.75-2.8, drops to ~2.5 in many 10' intervals Gamma ray intensity 20-30, very stable Cuttings: 2030--diabase appears 3220--rare K-feldspar fragments 3230--rare K-feldspar, rare red brown fine-grained quartzite	Diabase; lower density intervals may be crush zones
3245-3320	(-1055)-(-1130)	Caliper stable, 8" Bulk density 2.55±0.05 Gamma ray intensity 40-300, mostly around 100±20, with sharp peak to 300 at 3250. Cuttings: 3260--sparse red brown quartzite 3270--abundant medium to coarse grained red-brown arkose 3300--coarse- to very coarse-grained red brown arkose with glassy sub-rounded quartz grains	Pioneer Formation? Potassium or uranium concentration near diabase contact?

Depth in well (feet below ground level)	Elevation (feet above sea level)	Observations	Interpretations
3320-3365	(-1130)-(-1175)	Caliper stable, 8" Bulk density 2.55±0.05 Gamma ray intensity around 200±20, with sharp peak to 300 at 3355. Cuttings: 3320--1-2 mm diameter angular quartz grains 3340--very fine-grained granitic rock with tiny clots of opaque grains 3360--fine to very fine grained pink granitoid, diabase becomes more abundant	Granitic rock
3365-3490	(-1175)-(-1300)	Caliper stable, 8" Bulk density 2.9±0.1 Gamma ray intensity 50±5 Cuttings: 3400--about 70% diabase 3470--about 90% diabase	Diabase

Table 3. Data and interpretations for Windy Hill Test #1. Ground level 2200'. Interval transit times are in microseconds/foot. Descriptions are from notes taken during a telephone conversation by S. Rauzi [AZGS Oil and Gas Commission files]

Depth in well (feet below ground level)	Elevation (feet above sea level)	Observations	Interpretations
130-640	2070-1560	Caliper: much caving; diameter 10-15" (caliper pegs at 15") Interval transit time: 130-220, average ~180, highly variable Description: "a lot of clay, unconsolidated river gravels to 1600"'	Poorly indurated sand, mud and gravel?; transit time and caliper variations resemble density and caliper variations suggest correlation with 500-612 interval from Sanchez-O'Brien 1-4 Federal (SOB1-4).
640-1100	1560-1100	Caliper: highly variable, less caving than overlying interval; diameter 11-15", mostly stays on scale Interval transit time: 110-170, average ~135 Description: see above	Mostly mud, with sand and gravel layers?; logs suggest correlation with 612-1110 interval from SOB1-4.
1100-1150	1100-1050	Caliper: stable, diameter progressively decreases from 11.5 to 10.5" Interval transit time: 110-160, average 130	Transition zone
1150-1300	1050-900	Caliper: stable, diameter 10"; slight variations suggest beds about 10' thick Interval transit time: 135±5	Mudstone and sandstone; more indurated; logs suggest correlation with 1110-1300 interval from SOB1-4.
1300-1330	900-870	Caliper: diameter decreases to 9", thin wash-outs ±1" Interval transit time: decreases from 140 to 120, ±10	Transition zone
1330-1640	870-560	Caliper: diameter stable at 9" Interval transit time: decreases steadily from 115-90, ±10 in upper part, ±5 in lower part	Increasing induration, probably less clay and more conglomerate; logs suggest correlation with 1350-1690 intervals in SOB1-4.
1640-1685	560-515	Caliper: diameter 9-10", variations suggest 2-5' thick beds of slightly different competence Interval transit time: decreases from 80 to 60, ±10-20; rapid variations on 2-7' scale. Description: limestone bed at about 1600 feet, increasing H2S smell.	Martin Formation or Mescal Limestone; transit time and caliper variations resemble density and caliper variations in logs from SOB1-4, suggesting correlation.
1685-1720	515-480	Caliper: 9.25" diameter; slight variations on 2-5' scale suggest beds of slightly different competence. Interval transit time: 52 ±3, rapid variations on 2' scale in upper part.	Sandstone of Beckers Butte Member of Martin Formation, Bolsa Quartzite, or Dripping Spring Quartzite? Unit appears more homogeneous than underlying or overlying units

Depth in well (feet below ground level)	Elevation (feet above sea level)	Observations	Interpretations
1720-1850	480-350	Caliper: 9" diameter, very stable; caliper diameter drops to <0.5" at 1805, suggesting problem with tool. Interval transit time: 70±10, rapid variations on 2-10' scale	Dripping Spring Quartzite? Transit time and caliper variations resemble density and caliper variations in logs from SOB1-4, suggesting correlation.
1850-1867	350-333	Caliper: NA Interval transit time: 115±20, rapid variations on 5' scale	Diabase? Transit time variations resemble density variations seen in SOB1-4 at Dripping Spring-Diabase contact.

Table 4. Data and interpretations for Kerber 1-Federal. Ground level 2669'. Interval transit times are in microseconds/foot. Descriptions are verbatim from completion report for well [AZGS Oil and Gas Commission files]

Depth in well (feet below ground level)	Elevation (feet above sea level)	Description	Interpretations
0-50	2669-2619	Sand and gravel, with boulders, mixture of basalts andesite, quartzite, quartz.	Pediment veneer gravel
50-270	2619-2399	Clay Brown, buff, silty, and sand. About 20% quartz	Mudstone, some interbedded sand
270-360	2399-2309	Clay, as above, with about 40% silt and quartz sand	Mudstone, more interbedded sand
360-435	2309-2234	Quartzite, red-brown, fine grained, ¼ to ½ mm, iron stained. Thin streaks asphalt residue (colored the mud black) in middle and lower part. Slightly coarser ground at bottom.	Dripping Spring Quartzite. Black mud may indicate dark siltstone of middle Dripping Spring, or possibly diabase.
435-485	2234-2184	Quartzite, as above only slightly finer grained and somewhat harder, not as fine-grained in lower part. Fault with approximate 45° dip at 464'.	Dripping Spring Quartzite. Fine grained quartzite suggests middle or upper part of formation.

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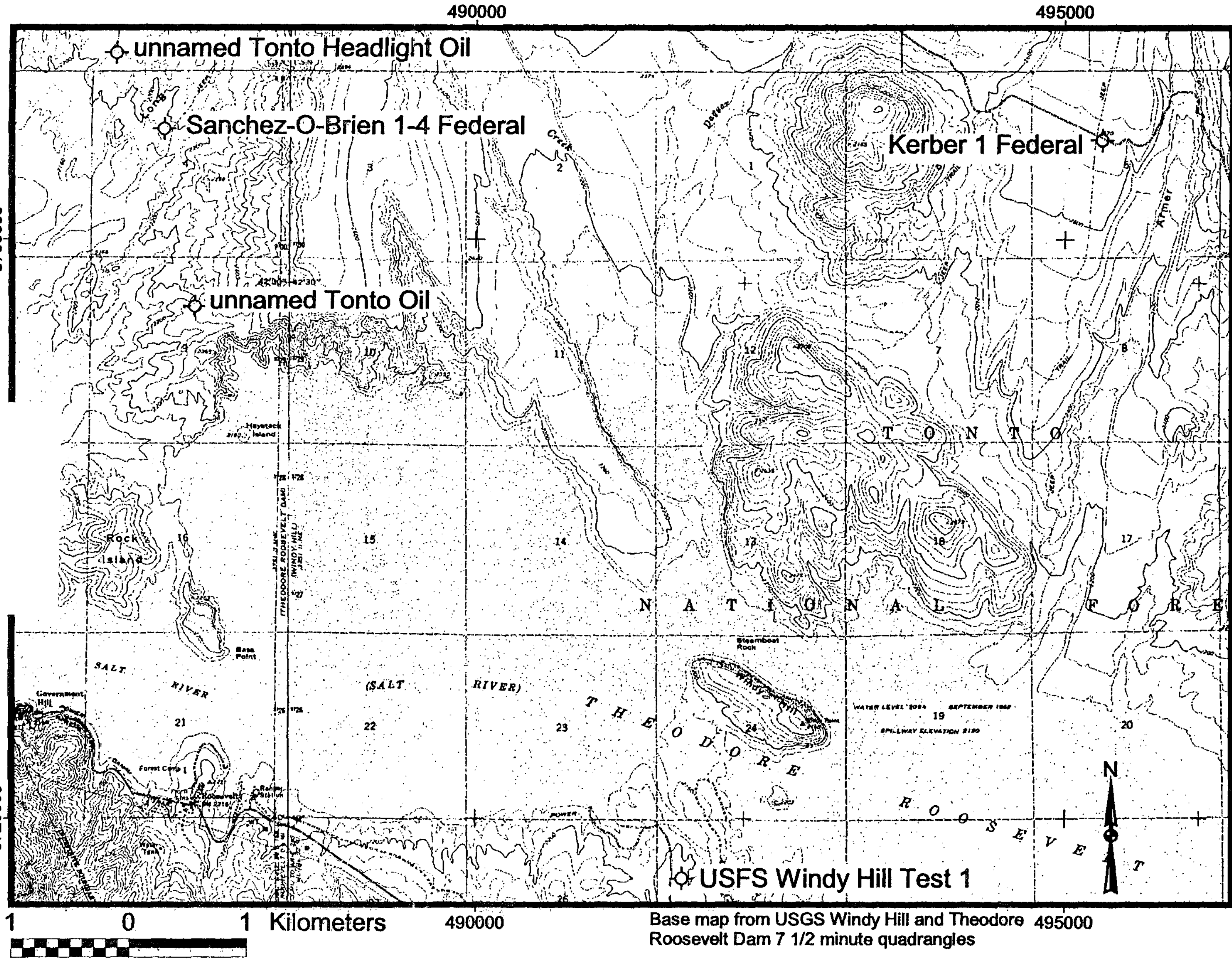

Location of Wells Discussed in this Report

Extract