OPEN-FILE REPORT OFR 08-07

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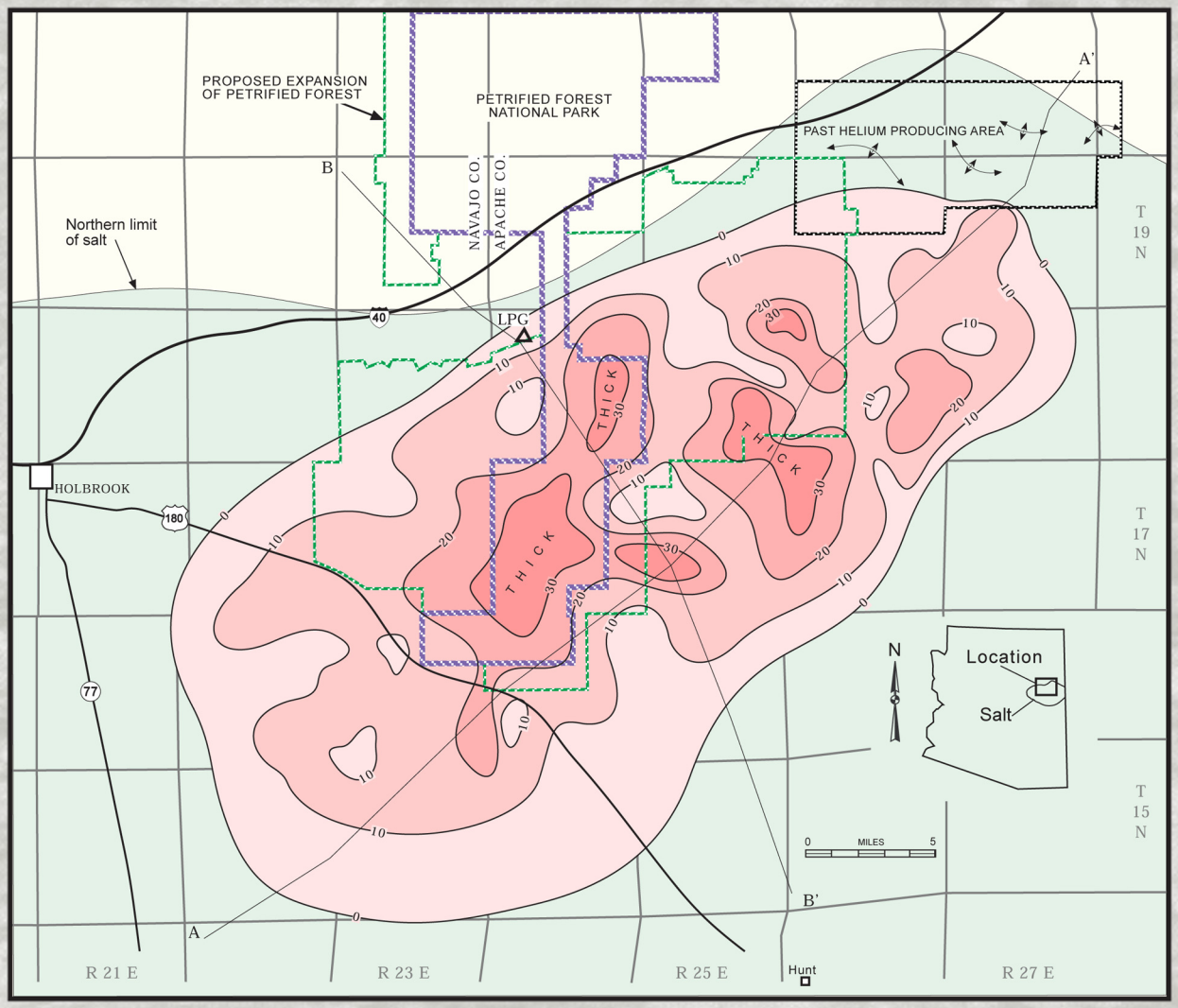

Potash and Related Resources of the Holbrook Basin, Arizona

August 2008

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Abstract

Recent analysis of subsurface data indicates a resource containing from 0.7 to 2.5 billion metric tons of potash in the Holbrook basin of east-central Arizona, some of which underlies Petrified Forest National Park (PFNP). The potash, located many hundreds of feet underground, is present near the top of extensive bedded salt deposits of Permian age. Caverns have been leached into the salt to store liquefied petroleum gas immediately west of the PFNP. Helium was produced northeast of PFNP in the 1960s and 1970s.

Solution mining would be expected to recover about 30% of the resource while conventional underground mining could recover about 70% because some parts of the deposit are not easily soluble. Total recoverable resources thus range from 210 million tons to 1.75 billion tons, assuming the entire deposit was available for development.

The potash deposit is deep enough that conventional underground or solution mining would have little or no effect on the surface except for the presence of the mining facilities themselves.

Potash (*'pät-,ash*) n:

(1) Potassium carbonate (K_2CO_3) especially the crude impure form obtained from a solution of wood ashes in iron pots.
(2) A term loosely used for any substance containing potassium whose potassium content is expressed in terms of K_2O.
(3) Used in fertilizers, ceramics, glass, and soap. [Source: Webster's Dictionary; AGI Dictionary of Geological terms]. Most potash is now obtained by mining.

Introduction

Potash prices have skyrocketed more than tenfold in recent years and recently reached about $1,000 per ton (Figure 1). Rapidly rising demand for fertilizer and limited expansion of production are leading causes of the increase (Sergeant, 2008). Good potash deposits are rare, there are few global producers, and growth in demand is great; the Arizona potash resource appears to be an economically attractive and viable target for development.

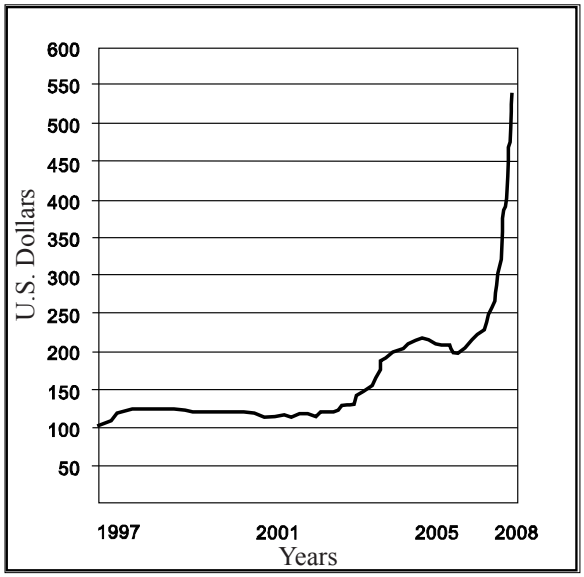

Figure 1. Price of Muriate (KCl) of potash in dollars per ton. Price is anticipated to reach $1000 per ton by the end of 2008. Source: Sergeant, Mineweb.com

Arizona Potash

Potash is present near the top of extensive salt (halite - NaCl) deposits in the Permian Supai formation (270-220 Ma) of east-central Arizona (Figures 2, 3, 4, and 5), where bedded salt underlies about 3,500 square miles and attains a maximum aggregate thickness of 655 ft (Rauzi, 2000). The extent of the salt defines the Holbrook salt basin. Potash underlies about 600 square miles within the upper part of the halite and ranges up to about 40 ft thick. Thickness of potash was estimated from the interval between initial to final inflections of high gamma ray readings in 117 wells (Figure 5). There is essentially one main potential potash "pay zone." Depth to the potash ranges from 700 to 2,000 ft but the depth in most holes is between 1,000 to 1,450 ft. Structural mapping of the top of a regionally persistent anhydrite bed about 100 ft above the potash zone

indicates that there are several small undulating structures across the extent of the potash deposit as depicted on Figure 2 (Rauzi, 2000, Plate 2).

Estimates of total potash in the potash zone of the Holbrook salt basin require an estimate of total volume and of potash grade. Total volume was estimated using the contour map of Figure 2 as follows: The contours were digitized using ESRI ArcGIS software, and the area of each enclosed contour area was then calculated. Most of these areas have a boundary representing the minimum thickness (for example 10 feet) and maximum thickness (for example 20 feet). The simplest approach to volume estimate for a particular contour interval is to use the intermediate thickness (in this example, 15 feet) and multiply it by the calculated area (Table 1A). However, for an approximately circular area, with a lower thickness on the outside of the circular area and a higher thickness on the inside, the average thickness is not the average of the minimum and maximum thicknesses, but rather is closer to the minimum. Specifically, the average thickness over a circular area with a cone-shaped sub-surface volume is one third the height of the apex (not one half). Accordingly, we made a second estimate of potash volume by using, as average thickness for each calculated area between contours, a value equal to the lower contour value plus one-third of the contour interval. This resulted in a lower estimate of total volume (Table 1B). Even though the lower volume estimate is our preferred value, we include the higher volume estimate because the number of data (well) points is still sparse for the area and there is considerable uncertainty in the calculations.

Two estimates of potash grade were used in calculations of total potash tonnage (Table 1). A high value of 20% average grade was reported by Carr (1966) based on analysis of drill data near the central and northern parts of Arkla Exploration Company's acreage block. A low value of 6% average grade is based on assays from five holes drilled by Duval (Figure 2; Table 2).

The total potential potash resource in the Holbrook basin thus ranges from 682 million metric tons (6% average grade, lower volume estimate) to 2.58 billion metric tons (20% average grade, higher volume estimate). With our preferred volume estimate (Table 1B), the upper resource value is still 2.27 billion metric tons.

Exploration drilling so far suggests that potash is confined to the northern part of the Holbrook salt basin where bedded salt reaches its maximum thickness (Rauzi, 2000). The salt appears to have formed by desiccation of saline mud flats and salt pans of an inner sabkha (supra-tidal environment in arid climates). The occurrence of potash near the top of the salt deposit may be due to the relative solubility of potash and salt during the evaporation of sea water across the sabkha. Repeated incursions of sea water appear to have preferentially dissolved and re-precipitated the potash thereby separating and concentrating the potassium from the halite.

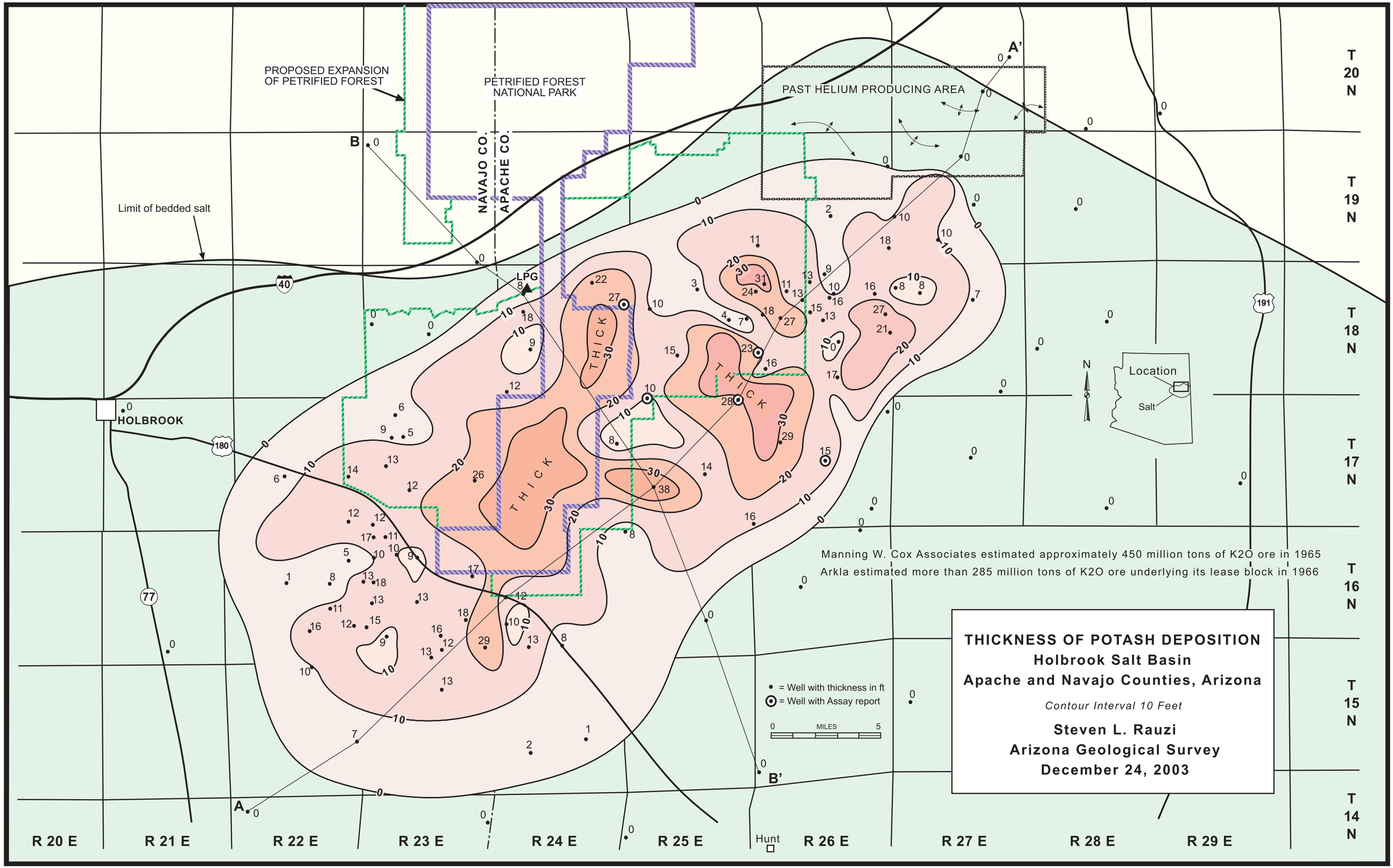

Figure 2. Map showing thickness in ft of potash in the Holbrook salt basin, Arizona. Note former helium producing area near northeastern extent of potash and LPG-storage facility near the northwestern extent.

In the 1960s and 1970s, a total of 135 holes were drilled to delineate the potash in the Holbrook salt basin. Arkla Exploration Company and Duval Corporation drilled 105 holes. Other potash holes were drilled by Kern County Land, National Potash, New Mexico and Arizona Land, St. Joe American, and U.S. Borax. Indications of potash in previously drilled oil tests started the potash play (Cox, 1965). Only five holes were drilled through the entire thickness of salt but 127 holes were drilled into the upper 100 to 300 ft of salt where potash is present (Figure 5). Most holes were cored through the upper 100 ft of salt to get direct information about the nature of the potash deposits. Arkla and Duval reported (Cox, 1965; Carr, 1966) the presence of potassium minerals sylvite (KCl), carnallite ($KMgCl_3$), and polyhalite ($K_2Ca_2Mg(SO_4)_4 \bullet 2H_2O$) in the main potash "pay zone." Cox further indicated that carnallite was only locally present in the ore and that none of Duval's holes encountered carnallite at the time of his report. Six holes drilled by Kern County Land and Arkla contained as much as 3% K_2O as carnallite and a section below the main potash "pay zone" contained as much as 6% K_2O as carnallite (Cox, 1965). Duval made a visual estimate of the K_2O content by dragging a sharp 4-H pencil across the surface of a core. The hardness of sylvite was such that the 4-H pencil gouged the sylvite but left a black mark on the halite. As a result, the geologist was able to estimate the K_2O content within 2% to 3% (Cox, 1965). Scattered blebs and traces of potash persist to about 30 ft below the main potash "pay zone." Well logs, samples, core descriptions, and six assay reports from the potash drilling are available in the well files of the Arizona Oil and Gas Conservation Commission at the Arizona Geological Survey in Tucson (Appendices 1 and 2, Fig 6 & 7).

To date, there has been no commercial production of potash in Arizona, either by conventional or solution mining, even though drilling by late 1965 indicated about 450 million tons of ore-grade K_2O covering an area of 80 square miles (Cox, 1965). Cox estimated that 100 million tons of at least 60% K_2O product were economically recoverable. By early 1966, Arkla estimated a potential of more than 285 million tons of nearly 20% average grade K_2O underlying its lease block, where about 92% of nearly 55,000 acres remained untested (Carr, 1966). Carr reported that the amount of potash under Arkla's prospective area exceeded the minimum economic requirement to justify installation of mining and ore-processing facilities by 540%. Overproduction of potash in Saskatchewan during a period of government subsidies and a global glut of potash in the late 1960s may have been the biggest factors in preventing development of Arizona potash at the time.

Another factor in the lack of exploitation of Arizona potash may be that the area underlain by potash in east-central Arizona is approximately centered under the PFNP. Isopach (thickness) mapping suggests that some of the thickest potash lies beneath the southern part of the PFNP (Figure 2).

Table 1A. Volume of potash deposit,[1] method A[2]

Upper bound contour (ft)	Lower bound contour (ft)	Contouring sequence	Area (m^2)*	Area (km^2)	Area (mi^2)	Average thickness (ft)	Average thickness (m)	volume (m^3)	volume (km^3)
20	10	17	615,570,211	615.6	237.6	15.0	4.57	2,815,107,674	2.8151
10	0	18	588,199,374	588.2	227.0	5.0	1.52	896,645,388	0.8966
30	20	14	144,765,553	144.8	55.9	25.0	7.62	1,103,395,984	1.1034
30	20	9	55,485,025	55.5	21.4	25.0	7.62	422,904,157	0.4229
35	30	5	41,179,683	41.2	15.9	32.5	9.91	408,030,398	0.4080
35	30	7	25,125,579	25.1	9.7	32.5	9.91	248,957,721	0.2490
30	20	12	21,288,058	21.3	8.2	25.0	7.62	162,256,543	0.1623
30	20	16	15,503,060	15.5	6.0	25.0	7.62	118,163,569	0.1182
10	0	6	14,301,907	14.3	5.5	5.0	1.52	21,801,687	0.0218
35	30	11	9,628,591	9.6	3.7	32.5	9.91	95,405,251	0.0954
35	30	4	8,890,614	8.9	3.4	32.5	9.91	88,092,978	0.0881
10	0	10	8,128,523	8.1	3.1	5.0	1.52	12,391,040	0.0124
10	0	1	6,845,637	6.8	2.6	5.0	1.52	10,435,422	0.0104
10	0	13	5,589,548	5.6	2.2	5.0	1.52	8,520,653	0.0085
10	0	2	3,771,564	3.8	1.5	5.0	1.52	5,749,335	0.0057
10	0	3	3,275,605	3.3	1.3	5.0	1.52	4,993,300	0.0050
32	30	15	3,247,554	3.2	1.3	31.0	9.45	30,693,347	0.0307
10	0	8	2,111,337	2.1	0.8	5.0	1.52	3,218,502	0.0032
							total	***6,456,762,950***	***6.4568***

[1]Thickness contours for potash deposit were drawn based on 117 drill intercepts and interpretation of geophysical logs.
[2]Average thickness used is average of upper and lower bound
*Contours were digitized and areas between contours were calculated using ESRI ArcMap software.

Assuming average grade of 20% potash, total resource is volume x grade x density =	2,582,705,180.01	metric tons (i.e., 2.58 billion metric tons)
Assuming average grade of 6% potash, total resource is volume x grade x density =	774,811,554.00	metric tons (i.e., 775 million metric tons)

Table 1B.Volume of potash deposit,[1] method B[2]

Upper bound contour (ft)	Lower bound contour (ft)	Contouring sequence	Area (m^2)*	Area (km^2)	Area (mi^2)	Average thickness (ft)	Average thickness (m)	volume (m^3)	volume (km^3)
20	10	17	615,570,211	615.6	237.6	13.3	4.07	2,502,317,933	2.5023
10	0	18	588,199,374	588.2	227.0	3.3	1.02	597,763,592	0.5978
30	20	14	144,765,553	144.8	55.9	23.3	7.11	1,029,836,252	1.0298
30	20	9	55,485,025	55.5	21.4	23.3	7.11	394,710,547	0.3947
35	30	5	41,179,683	41.2	15.9	31.7	9.65	397,568,080	0.3976
35	30	7	25,125,579	25.1	9.7	31.7	9.65	242,574,190	0.2426
30	20	12	21,288,058	21.3	8.2	23.3	7.11	151,439,440	0.1514
30	20	16	15,503,060	15.5	6.0	23.3	7.11	110,285,997	0.1103
10	0	6	14,301,907	14.3	5.5	3.3	1.02	14,534,458	0.0145
35	30	11	9,628,591	9.6	3.7	31.7	9.65	92,958,963	0.0930
35	30	4	8,890,614	8.9	3.4	31.7	9.65	85,834,184	0.0858
10	0	10	8,128,523	8.1	3.1	3.3	1.02	8,260,694	0.0083
10	0	1	6,845,637	6.8	2.6	3.3	1.02	6,956,948	0.0070
10	0	13	5,589,548	5.6	2.2	3.3	1.02	5,680,435	0.0057
10	0	2	3,771,564	3.8	1.5	3.3	1.02	3,832,890	0.0038
10	0	3	3,275,605	3.3	1.3	3.3	1.02	3,328,867	0.0033
32	30	15	3,247,554	3.2	1.3	30.7	9.35	30,363,311	0.0304
10	0	8	2,111,337	2.1	0.8	3.3	1.02	2,145,668	0.0021
							total	***5,680,392,448***	***5.6804***

[1]Thickness contours for potash deposit were drawn based on 117 drill intercepts and interpretation of geophysical logs.

[2]Average thickness used is weighted (2:1) toward lower bound

*Contours were digitized and areas between contours were calculated using ESRI ArcMap software.

Assuming average grade of 20% potash, total resource is volume x grade x density = 2,272,156,979.05 metric tons (i.e., 2.27 billion metric tons)

Assuming average grade of 6% potash, total resource is volume x grade x density = 681,647,094 metric tons (i.e., 682 million metric tons)

Table by Jon E. Spencer

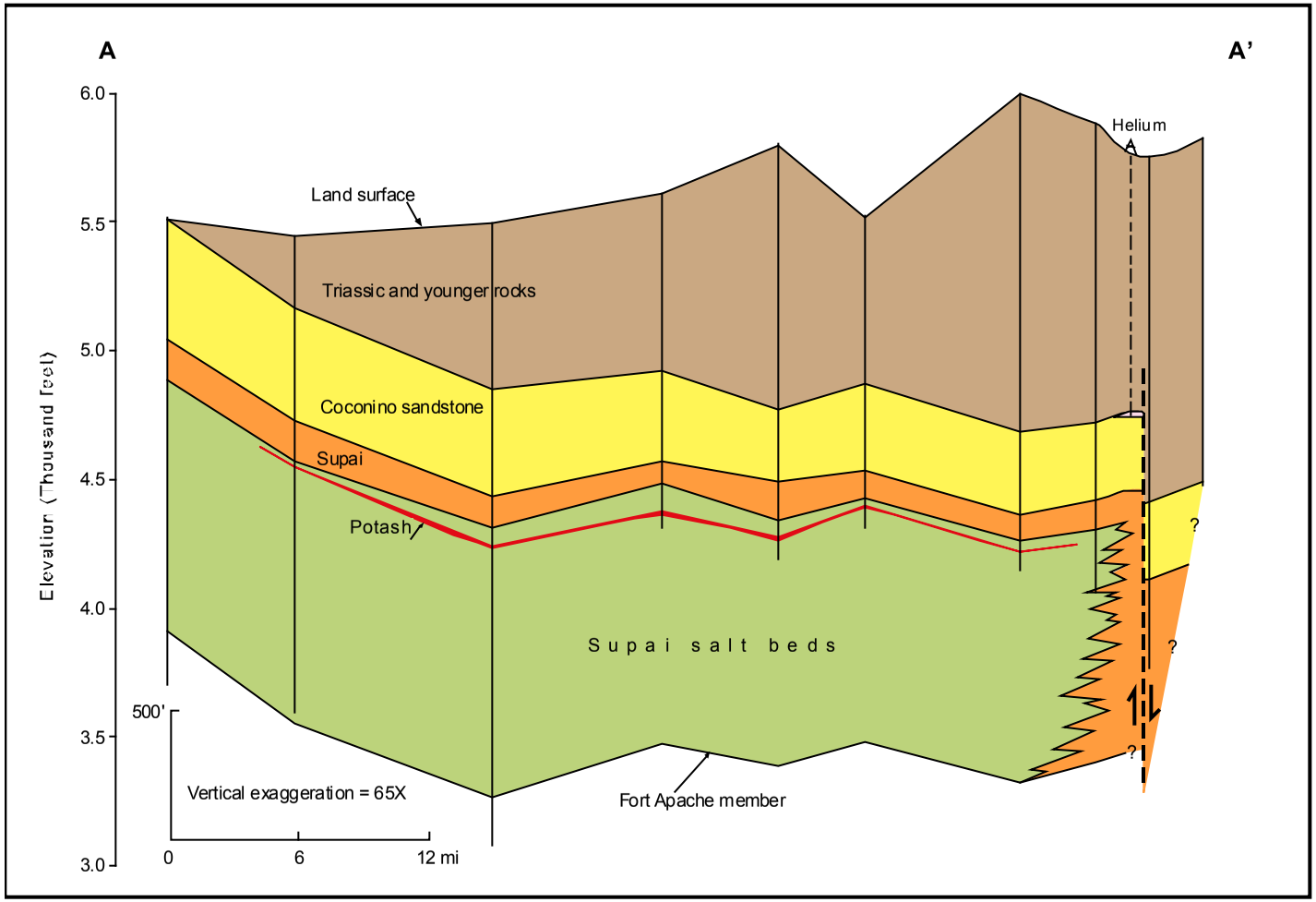

Figure 3. Diagrammatic structure section A-A' trending northeast-southwest showing northern edge of Supai salt, extent of potash deposits, and former helium producing area near the northeastern limit of the salt and potash deposits. Vertical scale is exaggerated 65 times.

The Petrified Forest Expansion Act of 2004 has the potential to substantially increase the area of the park if funds are eventually appropriated to buy the lands within the proposed expansion. The location of some of the potentially thickest potash under the PFNP expansion areas will require a creative approach to achieve access and development of Arizona's potash deposits. The federal government owns the minerals under the existing PFNP lands, which cover approximately 20% of the potash volume. The mineral rights within the proposed park expansion areas are owned by various entities and the intention of the National Park Service (NPS) is to acquire those rights if and when funds are appropriated to fund the expansion, which would cover an additional 28% of the potash volume. Regardless of mineral ownership, any resources under the park are withdrawn from mineral entry and this may be so for the expansion areas if the NPS is successful in acquiring mineral rights. The proposed expansion of the PFNP is depicted by the green line on Figure 2. A combination of State Trust, Indian, and public and private land is potentially available for development east and southwest of the PFNP and could remain so even if the PFNP expands as proposed, if the mineral rights are not acquired along with the surface lands.

Other Geologic Resource in the Holbrook salt basin

Helium: Helium was produced near the northeastern limit of the potash deposits from 1961 to 1976 (Figures 2 and 3). Wells in the Pinta Dome and Navajo Springs fields (Conley, 1974) produced nearly 700 million cubic feet of grade-A helium from the Permian Coconino Sandstone. Helium concentrations ranged up to 10% and averaged 8%, which is some of the richest helium-bearing gas ever produced. Spencer (1983) and Rauzi (2003) reviewed the geologic setting, production, and future potential of helium in Arizona.

Helium is vital to obtaining the extremely cold temperatures essential for cryogenic and superconducting technologies. Helium is also used for pressurizing and purging, welding cover gas, controlled atmospheres, leak detection, breathing mixtures, and filling blimps, weather balloons, and party balloons.

Hydrocarbon Storage: The bedded salt (halite) associated with the potash is used to form caverns to store liquefied petroleum gas (LPG). A cavern is formed by drilling a hole into the salt and pumping fresh water through steel pipe. The fresh water dissolves the salt and the resulting brine is pumped out of the hole. Some brine is stored at the surface for later use and some is pumped back into deep underground rock formations. The shape and size of the cavern is determined by controlling the amount and direction of fresh water pumped into the hole.

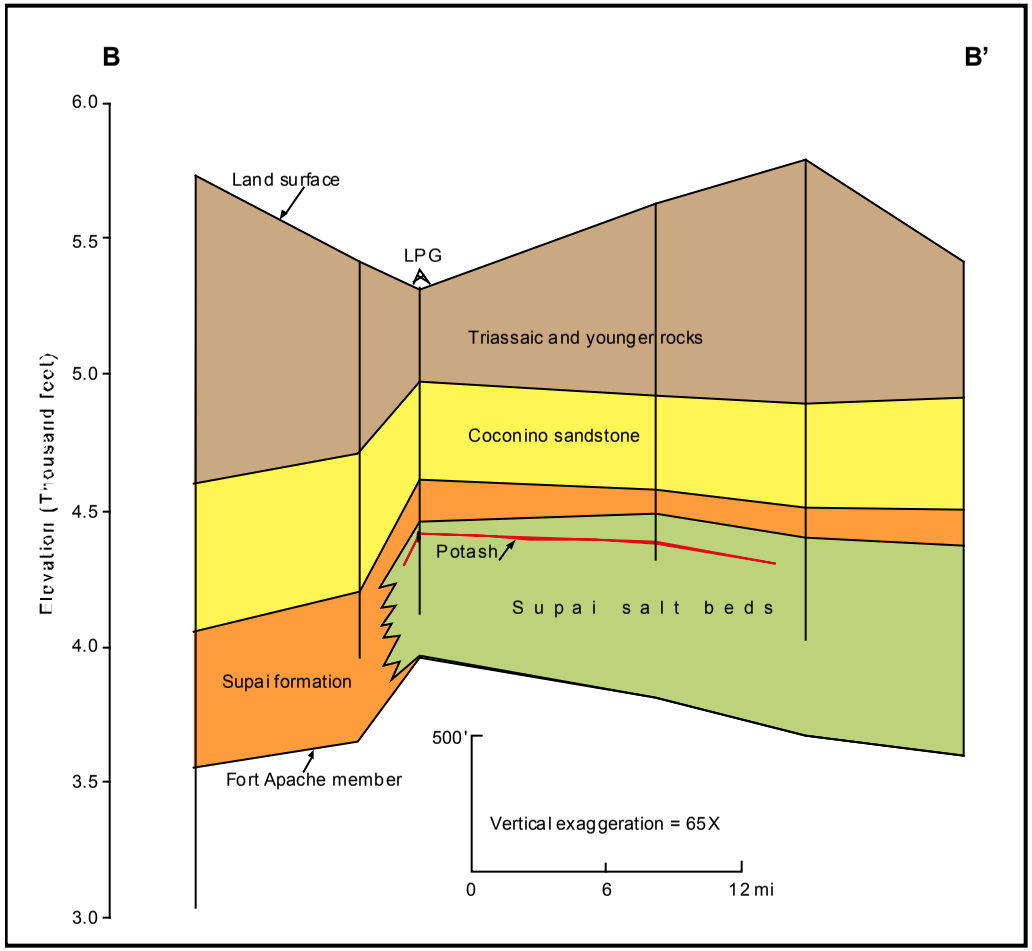

Figure 4. Diagrammatic structure section B-B' trending northwest-southeast showing northern edge of Supai salt, extent of potash deposits, and storage well for liquefied petroleum gas (LPG) with cavern leached near the top of the salt deposits. Vertical scale is exaggerated 65 times.

Enterprise Products operates the sole LPG-storage facility in the region, located about 20 miles east of Holbrook at Adamana (Figures 2 and 4). Propane and butane are the most common types of LPG. Most propane is used as fuel to heat homes in the winter whereas butane is commonly used to blend gasoline at refineries. The Adamana facility was first constructed in the early 1970s.

There are 11 storage wells at Adamana with a total capacity of about 90 million gallons. The top of the salt is about 900 ft below the ground surface. The caverns are leached about 75 ft below the top of the salt, have an average radius of 60 ft and height of 95 ft. Individual cavern volumes range from about 7 to 11 million gallons. The Adamana facility is served by the BNSF (Burlington Northern Santa Fe) railroad (Rauzi 2000, 2002).

Future

Growing global demand for potash for use in fertilizers makes Arizona's Holbrook basin deposit more economically viable and attractive than previously recognized. The size of the resource, as reported here, is based for the first time on a basin-wide assessment and is many times larger than fragmentary reports have indicated.

A creative approach will likely be necessary for exploitation of some of the potash resources in the Holbrook salt basin because of proximity of the PFNP and efforts to add adjacent potash-bearing lands to the PFNP. However, many square miles of land overlying potash deposits are outside the PFNP and its expansion area. There also remains good potential for additional storage of LPG along the BNSF railroad, and for future helium discoveries in the region. Many of the smaller geologic structures in the area have yet to be drilled for helium.

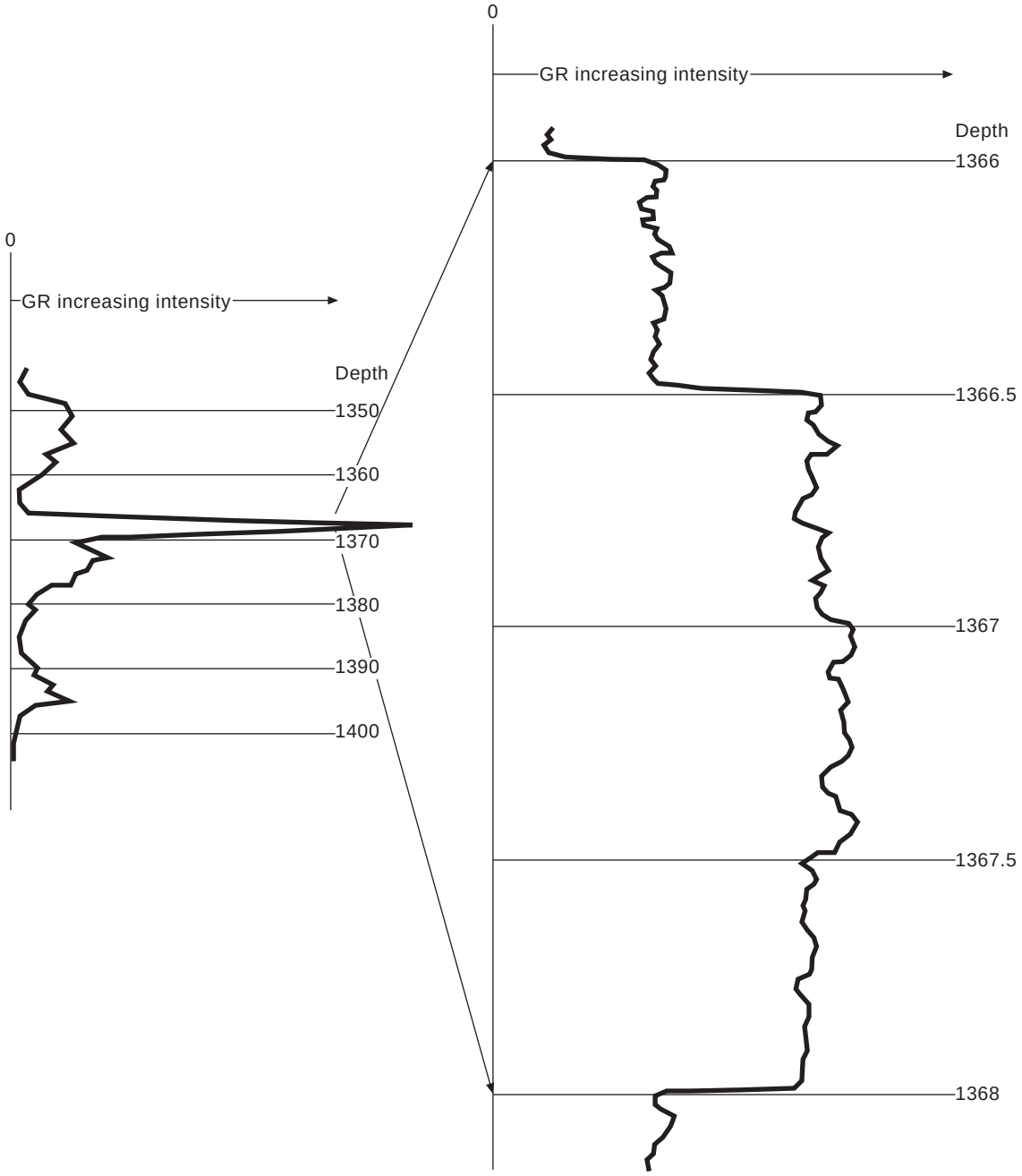

Figure 5. Typical gamma ray (GR) curve through a potash zone. Note the much higher intensity in the potash zone. The high GR in the potash zone is indicative of potassium. A very detailed and properly calibrated GR log as shown on the right can indicate the grade of ore or purity of particular potassium minerals.

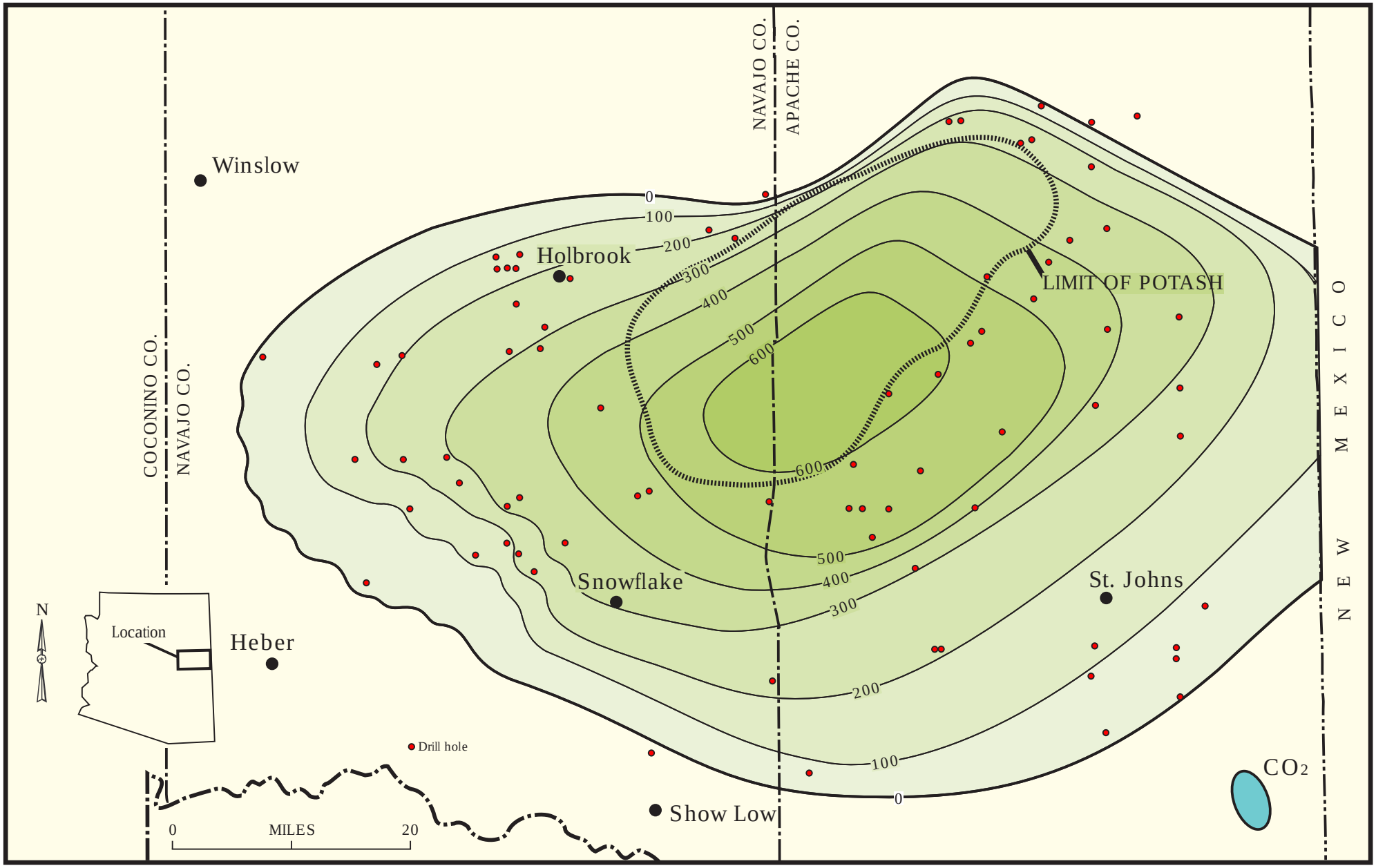

Figure 6. Map of Holbrook Salt Basin showing drill holes (red dots) outside of the known potash deposits and within the outer limits of Permian salt, aggregate thickness of salt in ft.

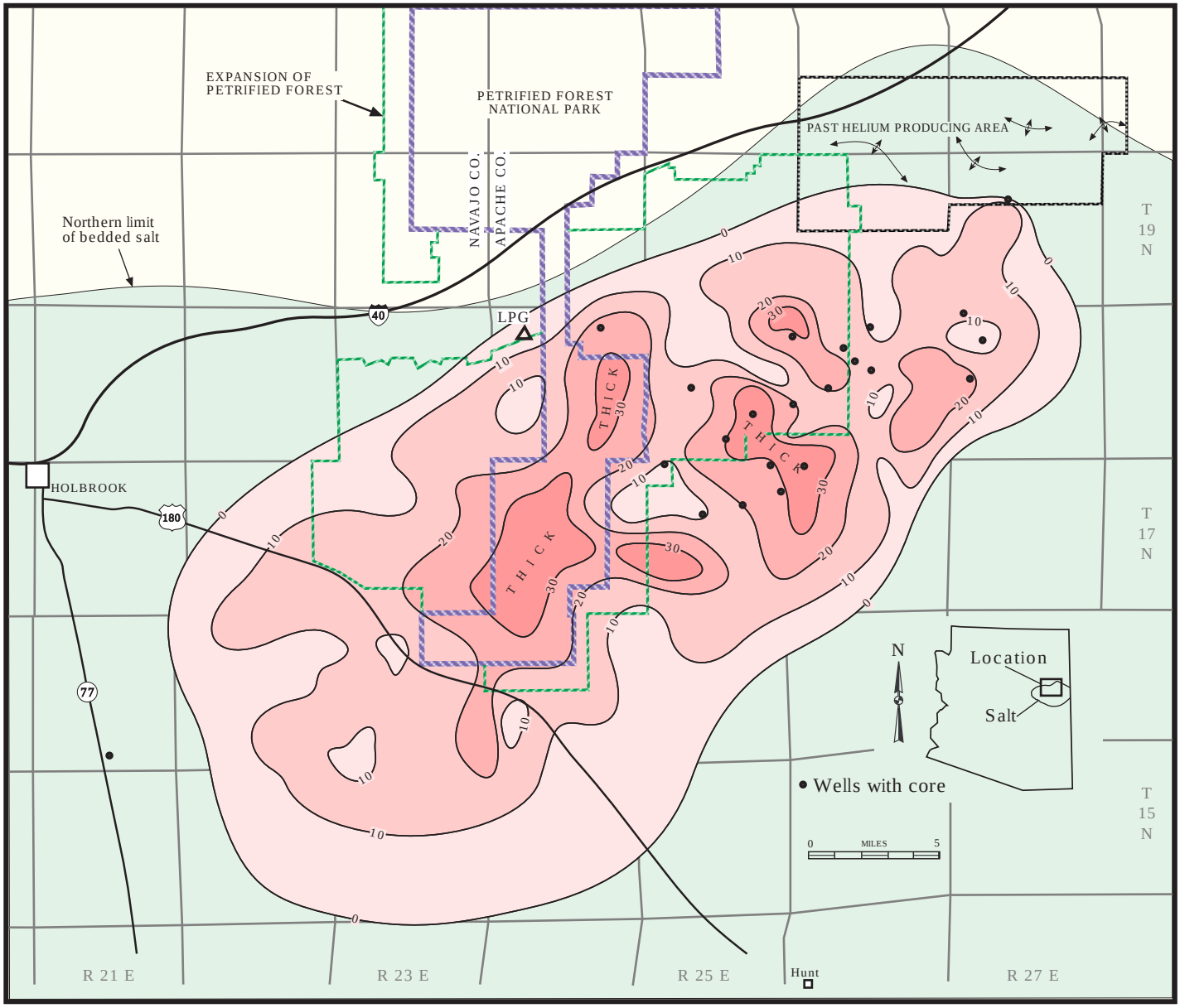

Figure 7. Map showing thickness in ft of potash in the Holbrook salt basin and the location of wells with skeletonized core listed in AZGS OFR 93-2. There are 24 wells listed in OFR 93-2. The skeletonized core for the 24 wells are contained in 70 boxes. Most boxes contain about 10 ft of core representing from 50 to 100 ft of hole. Two of the holes listed in OFR 93-2 are west of Holbrook and not shown on the map.

Table 2A. Weighted average %$K_2$0

Drill hole	K_2O (av %)	Thickness (ft)	% x ft
01-23	6.74	23.9	161.1845
01-24	8.16	8.3	67.691
01-29	7.62	10.4	79.249
01-36	3.67	27.3	100.128
01-44	4.76	19.16	91.2676
		89.06	499.5201

5.61 weighted average %K_2O

Table 2B. Weighted average %$K_2$0*

Drill hole	K_2O (av %)	Thickness (ft)	% x ft
01-23	6.74	23.9	161.1845
01-24	8.16	8.3	67.691
01-29*	8.19	9.5	77.773
01-36*	4.29	23.15	99.3185
01-44	4.76	19.16	91.2676
		84.01	497.2346

5.92 weighted average %K_2O

*More restricted interval with higher grades

Table by Jon E. Spencer

Acknowledgments

Ryan Clark performed the GIS analysis. Jon Spencer calculated potash volumes and prepared the tables. Jon Spencer, Lee Allison, and Mike Conway, AZGS, and Keith Long, USGS, reviewed the paper and provided helpful comments.

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Appendix 1. Well Logs used to estimate potash resources (Well ID is State Permit Number)

Well ID	Interval (ft)	Log type	Mining Company
0242GRN	300-1201	Gamma Ray-Neutron Log	New Mexico & Arizona Land Co
0242GRN1	600-940	Gamma Ray-Neutron Log	New Mexico & Arizona Land Co
0242SAMP	662-1200	Graphic Lithologic Log	New Mexico & Arizona Land Co
0243GRN	255-1842	Gamma Ray-Neutron Log	New Mexico & Arizona Land Co
0243GRN1	825-1168	Gamma Ray-Neutron Log	New Mexico & Arizona Land Co
0243SAMP	50-1820	Graphic Lithologic Log	New Mexico & Arizona Land Co
0244GRN	750-1050	Gamma Ray Radioactivity Log	New Mexico & Arizona Land Co
0244GRN1	816-1056	Gamma Ray-Neutron Log	New Mexico & Arizona Land Co
0244SAMP	812-1071	Graphic Lithologic Log	New Mexico & Arizona Land Co
0323GRN	0-1056	Gamma Ray-Neutron Log (4”/ft)	Arkla Exploration
0323GRN1	810-942	Gamma Ray-Neutron Log (Whipstock 1)	Arkla Exploration
0323GRN2	810-923	Gamma Ray-Neutron Log (Whipstock 2)	Arkla Exploration
0324GRN	0-1450	Gamma Ray-Neutron Log (5”/ft)	Arkla Exploration
0324GRN1	0-1046	Gamma Ray-Neutron Log (4”/ft)	Arkla Exploration
0324GRN2	1020-1187	Gamma Ray-Neutron Log (Whipstock 1)	Arkla Exploration
0324GRN3	1026-1171	Gamma Ray-Neutron Log (Whipstock 2)	Arkla Exploration
0326GRN	0-1170	Gamma Ray-Neutron Log (4”/ft)	Arkla Exploration
0326GRN1	800-915	Gamma Ray-Neutron Log (Whipstock 1)	Arkla Exploration
0326GRN2	800-919	Gamma Ray-Neutron Log (Whipstock 2)	Arkla Exploration
0328GRN	0-999	Gamma Ray-Neutron Log (3”/ft)	Arkla Exploration
0328GRN1	600-731	Gamma Ray-Neutron Log (Whipstock 1)	Arkla Exploration
0328GRN2	600-717	Gamma Ray-Neutron Log (Whipstock 2)	Arkla Exploration
0328GRN3	600-996	Gamma Ray-Neutron Log (3”/ft)	Arkla Exploration
0328GRN4	600-729	Gamma Ray-Neutron Log (Whipstock 2)	Arkla Exploration
0329GRN	0-3381	Gamma Ray-Neutron Log	Arkla Exploration
0329GRN1	570-741	Gamma Ray-Neutron Log (Whipstock 1)	Arkla Exploration
0329TL	100-3390	Temperature Log	Arkla Exploration
0331GRN	0-1143	Gamma Ray-Neutron Log (4”/ft)	Arkla Exploration
0331GRN1	790-879	Gamma Ray-Neutron Log (Whipstock 1)	Arkla Exploration
0333GRN	0-1330	Gamma Ray-Neutron Log (4”/ft)	Arkla Exploration
0333GRN1	970-1165	Gamma Ray-Neutron Log (Whipstock 1)	Arkla Exploration
0333GRN2	970-1082	Gamma Ray-Neutron Log (Whipstock 2)	Arkla Exploration
0334GRN	0-1278	Gamma Ray-Neutron Log (4”/ft)	Arkla Exploration
0334GRN1	880-1022	Gamma Ray-Neutron Log (Whipstock 1)	Arkla Exploration
0334GRN2	880-1016	Gamma Ray-Neutron Log (Whipstock 2)	Arkla Exploration
0335GRN	0-1463	Gamma Ray-Neutron Log (4”/ft)	Arkla Exploration
0335GRN1	1040-1213	Gamma Ray-Neutron Log (Whipstock 1)	Arkla Exploration
0335GRN2	1070-1190	Gamma Ray-Neutron Log (Whipstock 2)	Arkla Exploration
0337GRN	0-1626	Gamma Ray-Neutron Log (4”/ft)	Arkla Exploration
0337GRN1	1190-1392	Gamma Ray-Neutron Log (Whipstock 1)	Arkla Exploration
0337GRN2	1190-1388	Gamma Ray-Neutron Log (Whipstock 2)	Arkla Exploration
0340GRN	0-1560	Gamma Ray-Neutron Log	Arkla Exploration
0340GRN1	1050-1257	Gamma Ray-Neutron Log (Whipstock 1)	Arkla Exploration
0342GRN	0-1430	Gamma Ray-Neutron Log (4”/ft)	Arkla Exploration
0342GRN1	990-1160	Gamma Ray-Neutron Log (Whipstock 1)	Arkla Exploration
0342GRN2	1000-1172	Gamma Ray-Neutron Log (Whipstock 2)	Arkla Exploration
0343GRN	0-970	Gamma Ray-Neutron Log (4”/ft)	Arkla Exploration
0357GRN	0-1137	Gamma Ray-Neutron Log (4”/ft)	Arkla Exploration

Appendix 1 contd.. Well Logs used to estimate potash resources (Well ID is State Permit Number)

Well ID	Interval (ft)	Log type	Mining Company
0358GRN	0-1090	Gamma Ray-Neutron Log (4”/ft)	Arkla Exploration
0359CDL	879-1006	Compensated Formation Density Log	Arkla Exploration
0359GRN	0-1009	Gamma Ray-Neutron Log (4”/ft)	Arkla Exploration
0360GRN	0-1087	Gamma Ray-Neutron Log	Arkla Exploration
0361AMST	50-1260	Graphic Lithologic Log	Arkla Exploration
0361GRN	0-1323	Gamma Ray-Neutron Log	Arkla Exploration
0362GRN	0-945	Gamma Ray-Neutron Log (3”/ft)	Arkla Exploration
0363GRN	0-926	Gamma Ray-Neutron Log (3”/ft)	Arkla Exploration
0364GRN	0-1029	Gamma Ray-Neutron Log (3”/ft)	Arkla Exploration
0623GRN	0-1740	Radioactivity Log (Gamma Ray-Neutron)	Duval
0624GRN	0-1738	Gamma Ray-Neutron Log	Duval
0626GRN	0-2045	Radioactivity Log (Gamma Ray-Neutron)	Duval
0630GRN	0-2138	Gamma Ray-Neutron Log	Duval
0631GRN	0-1781	Radioactivity Log (Gamma Ray-Neutron)	Duval
0632GRN	0-1312	Gamma Ray-Neutron Log	Duval
0633GRN	100-1229	Gamma Ray-Neutron Log	St. Joe American
0634CAL	0-1243	Caliper Log	St. Joe American
0634GRN	30-1244	Gamma Ray-Neutron Log	St. Joe American
0635GRN	1200-1784	Gamma Ray-Neutron Log	St. Joe American
0636GRN	50-1451	Gamma Ray-Neutron Log	St. Joe American
0641GRN	250-1539	Gamma Ray-Neutron Log	St. Joe American
0642GRN	80-1601	Gamma Ray-Neutron Log	St. Joe American
0643GRN	0-908	Gamma Ray-Neutron Log	Duval
0644GRN	0-897	Gamma Ray-Neutron Log	Duval
0645GRN	0-1003	Gamma Ray-Neutron Log	St. Joe American
0649GRN	0-1016	Gamma Ray-Neutron Log	Duval
0650GRN	200-1431	Gamma Ray-Neutron Log	St. Joe American
0652GRN	150-1388	Gamma Ray-Neutron Log	St. Joe American
0664GRN	0-1265	Gamma Ray-Neutron Log	Duval
0665GRN	0-1451	Gamma Ray-Neutron Log	Duval
0673GRN	0-1251	Gamma Ray-Neutron Log	Duval
0675GRN	0-1839	Gamma Ray-Neutron Log	Duval
0679GRN	90-1382	Gamma Ray-Neutron Log	St. Joe American
0680GRN	50-1312	Gamma Ray-Neutron Log	St. Joe American
0681GRN	0-1246	Gamma Ray-Neutron Log	St. Joe American
0682GRN	10-1179	Gamma Ray-Neutron Log	St. Joe American
01-04GR_3E	0-246	Gamma Ray	Arkla Exploration
01-04GR_3N	0-266	Gamma Ray	Arkla Exploration
01-04GRN	0-2606	Gamma Ray-Neutron Log	Arkla Exploration
01-04GR-RES	0-267	Gamma Ray-Spontaneous Potential-Resistivity	Arkla Exploration
01-04IEL	67-906	Induction-Electrical Log	Arkla Exploration
01-04MUD	70-2610	Formation Analysis Daily Log	Arkla Exploration
01-04SL	50-902	Sonic Log-Gamma Ray with Caliper	Arkla Exploration
01-05GRN	0-2484	Gamma Ray–Neutron Log	Arkla Exploration
01-07GRN	0-2550	Gamma Ray–Neutron Log (5”/100’)	Arkla Exploration
01-07GRN1	0-2550	Gamma Ray–Neutron Log (2”/100’)	Arkla Exploration
01-07GRN2	1000-1450	Gamma Ray–Neutron Log (5”/100’)	Arkla Exploration
01-07GRN3	100-2567	Gamma Ray–Neutron Log	Arkla Exploration
01-07MUD	0-2570	Formation Analysis Daily Log	Arkla Exploration
01-07SL	1003-2567	Sonic Log with Caliper Log	Arkla Exploration

Appendix 1 contd.. Well Logs used to estimate potash resources (Well ID is State Permit Number)

Well ID	Interval (ft)	Log type	Mining Company
01-08GRN	0-1406	Gamma Ray–Neutron Log	Arkla Exploration
01-08GRN1	900-1400	Gamma Ray–Neutron Log (color annotated)	Arkla Exploration
01-08MUD	0-960	Formation Analysis Daily Log	Arkla Exploration
01-09GRN	20-1514	Gamma Ray–Neutron Log	Duval
01-10GRN	50-1838	Gamma Ray–Neutron Log	Duval
01-14GRN	0-2800	Gamma Ray-Neutron Log	Arkla Exploration
01-14GRN1	620-2800	Gamma Ray-Neutron Log (correlated)	Arkla Exploration
01-14MUD	0-2800	Formation Analysis Daily Log	Arkla Exploration
01-15GRN	0-1415	Gamma Ray-Neutron Log	Arkla Exploration
01-15GRN1	1000-1156	Gamma Ray-Neutron Log (4”/ft)	Arkla Exploration
01-15GRN2	1000-1156	Gamma Ray-Neutron Log (4”/ft)	Arkla Exploration
01-15GRN3	1000-1175	Gamma Ray-Neutron Log (5.5”/ft)	Arkla Exploration
01-16GRN	50-1812	Gamma Ray-Neutron Log	U.S. Borax
01-17GRN	0-1558	Gamma Ray-Neutron Log	Arkla Exploration
01-17A.IEL	25-780	Induction-Electrical Log	Arkla Exploration
01-17A.SL	25-779	Sonic Log-Gamma Ray with Caliper	Arkla Exploration
01-18GRN	0-1746	Gamma Ray-Neutron Log (annotated)	Arkla Exploration
01-18GRN1	0-1746	Gamma Ray-Neutron Log	Arkla Exploration
01-19GRN	0-1647	Gamma Ray-Neutron Log	Duval
01-19IEL	100-1368	Induction-Electrical Log	Duval
01-21GRN	100-1804	Gamma Ray-Neutron Log	Duval
01-21SAMP	0-1500	Graphic Lithologic Log	Duval
01-22GRN	0-1496	Gamma Ray-Neutron Log	Arkla Exploration
01-23GRN	0-1559	Gamma Ray-Neutron Log	Kern County Land
01-24GRN	0-1376	Gamma Ray-Neutron Log	Kern County Land
01-25GRN	0-1430	Gamma Ray-Neutron Log	Kern County Land
01-27GRN	0-1308	Gamma Ray-Neutron Log	U.S. Borax
01-28GRN	50-1914	Gamma Ray-Neutron Log	Duval
01-28GRN1	50-1914	Gamma Ray-Neutron Log	Duval
01-30GRN	0-1526	Gamma Ray-Neutron Log	Duval
01-32GRN	0-2346	Gamma Ray-Neutron Log	Duval
01-33GRN	80-2116	Gamma Ray-Neutron Log	Duval
01-34GRN	80-2541	Gamma Ray-Neutron Log	Duval
01-34IEL	1620-2172	Induction-Electrical Log	Duval
01-34SL	300-1614	Sonic Log	Duval
01-34SL1	1620-2173	Sonic Log-Gamma Ray with Caliper	Duval
01-35GRN	0-1083	Gamma Ray-Neutron Log	Kern County Land
01-36GRN	0-1011	Gamma Ray-Neutron Log	Kern County Land
01-37GRN	0-954	Gamma Ray-Neutron Log	Duval
01-37IEL	303-792	Induction-Electrical Log	Duval
01-37SL	308-788	Sonic Log	Duval
01-38GRN	50-952	Gamma Ray-Neutron Log	Duval
01-38IEL	90-792	Induction-Electrical Log	Duval
01-38SL	150-786	Sonic Log	Duval
01-39GRN	20-1062	Gamma Ray-Neutron Log	Duval
01-39GRN1	0-1031	Gamma Ray-Neutron Log	Duval
01-40GRN	0-1432	Gamma Ray-Neutron Log	Duval
01-41GRN	100-1144	Gamma Ray-Neutron Log	Duval
01-42GRN	0-430	Gamma Ray-Neutron Log	Duval
01-43GRN	100-1020	Gamma Ray-Neutron Log	Kern County Land

Appendix 1 contd.. Well Logs used to estimate potash resources (Well ID is State Permit Number)

Well ID	Interval (ft)	Log type	Mining Company
01-44GRN	100-1420	Gamma Ray-Neutron Log	Kern County Land
01-45GRN	100-1264	Gamma Ray-Neutron Log	Duval
01-46GRN	100-1560	Gamma Ray-Neutron Log	Duval
01-47GRN	0-1206	Gamma Ray-Neutron Log	Duval
01-48GRN	0-1414	Gamma Ray-Neutron Log	Duval
01-49GRN	50-1438	Gamma Ray-Neutron Log	Duval
01-50GRN	0-1225	Gamma Ray-Neutron Radioactivity Log	Duval
01-51GRN	100-1319	Gamma Ray-Neutron Log	Duval
01-52GRN	50-1804	Gamma Ray-Neutron Log	Duval
01-53GRN	100-1737	Gamma Ray-Neutron Log	Duval
01-54GRN	0-1494	Gamma Ray-Neutron Log	Duval
01-55GRN	0-1547	Gamma Ray-Neutron Log	Duval
01-56SL	1312-1670	Acoustic Velocity Log	Duval
01-56GRN	0-1875	Gamma Ray-Neutron Log	Duval
01-56IEL	100-1313	Induction-Electrical Log	Duval
01-56IEL1	1312-1674	Induction-Electrical Log	Duval
01-56SL	200-1307	Sonic Log	Duval
01-57GRN	50-2350	Gamma Ray-Neutron Log	Duval
01-58GRN	30-2444	Gamma Ray-Neutron Log	Duval
01-58IEL	20-1712	Induction-Electrical Log	Duval
01-59GRN	0-2787	Gamma Ray-Neutron Log	Duval
01-59IEL	40-2089	Induction-Electrical Log	Duval
01-59ML	40-2088	Micro Log with Caliper	Duval
01-59SL	2088-2425	Sonic Log	Duval
01-60GRN	90-2669	Gamma Ray-Neutron Log	Duval
01-60IEL	50-1864	Induction-Electrical Log	Duval
01-60IEL1	1862-2340	Induction-Electrical Log	Duval
01-63GRN	0-1238	Gamma Ray-Neutron Log	Duval
01-64GRN	0-1593	Gamma Ray-Neutron Log	Duval
01-64SAMP	0-1090	Graphic Lithologic Log	Duval
01-64SAMP1	0-1593	Graphic Cement Plug Log	Duval
01-65GRN	0-1582	Gamma Ray-Neutron Log	Duval
01-65SAMP	0-890	Graphic Lithologic Log	Duval
01-66GRN	200-2004	Gamma Ray-Neutron Log	Duval
01-67GRN	0-1905	Gamma Ray-Neutron Log	Duval
01-67IEL	1271-1588	Induction-Electrical Log	Duval
01-67SL	1211-1585	Sonic Log	Duval
01-68GRN	0-1883	Gamma Ray-Neutron Log	Duval
01-68SL	804-1730	Sonic Log	Duval
01-69GRN	0-1975	Gamma Ray-Neutron Log	Duval
01-69IEL	160-1481	Induction-Electrical Log	Duval
01-69IEL1	1484-1842	Induction-Electrical Log	Duval
01-69SL	160-1479	Sonic Log	Duval
01-70GRN	60-2001	Gamma Ray-Neutron Log	Duval
01-70IEL	649-1860	Induction-Electrical Log	Duval
01-70SL	649-1854	Sonic Log	Duval
01-71GRN	100-2126	Gamma Ray-Neutron Log	Duval
01-71IEL	782-2002	Induction-Electrical Log	Duval
01-71SL	782-1981	Sonic Log	Duval
01-73GRN	100-1977	Gamma Ray-Neutron Log	Duval

Appendix 1 contd.. Well Logs used to estimate potash resources (Well ID is State Permit Number)

Well ID	Interval (ft)	Log type	Mining Company
01-73IEL	100-633	Induction-Electrical Log	Duval
01-73SL	1102-1708	Sonic Log	Duval
01-74IEL	353-1895	Induction-Electrical Log	Duval
01-74SL	410-1890	Sonic Log	Duval
01-75GRN	100-1915	Gamma Ray-Neutron Log	Duval
09-04GRN	0-1348	Gamma Ray-Neutron Log	Arkla Exploration
09-10GRN_V	0-1245	Gamma Ray-Neutron Log	Arkla Exploration
09-10GRN_W1	890-1055	Gamma Ray-Neutron Log (Whipstock 1)	Arkla Exploration
09-10GRN_W2	890-1031	Gamma Ray-Neutron Log (Whipstock 2)	Arkla Exploration
09-11GRN_V	0-1194	Gamma Ray-Neutron Log (3”/ft)	Arkla Exploration
09-11GRN_W1	770-924	Gamma Ray-Neutron Log (Whipstock 1)	Arkla Exploration
09-11GRN_W2	800-914	Gamma Ray-Neutron Log (Whipstock 2)	Arkla Exploration
09-12GRN_V	0-1073	Gamma Ray-Neutron Log (4”/ft)	Arkla Exploration
09-12GRN_W1	670-816	Gamma Ray-Neutron Log (Whipstock 1)	Arkla Exploration
09-12GRN_W2	670-808	Gamma Ray-Neutron Log (Whipstock 2)	Arkla Exploration
09-13GRN_V	10-1318	Gamma Ray-Neutron Log (3”/ft)	Arkla Exploration
09-13GRN_W1	900-1058	Gamma Ray-Neutron Log (Whipstock 1)	Arkla Exploration
09-13GRN_W2	900-1048	Gamma Ray-Neutron Log (Whipstock 2)	Arkla Exploration
09-14GRN_V	3-1323	Gamma Ray-Neutron Log (3”/ft)	Arkla Exploration
09-14GRN_W1	910-1060	Gamma Ray-Neutron Log (Whipstock 1)	Arkla Exploration
09-14GRN_W2	910-1066	Gamma Ray-Neutron Log (Whipstock 2)	Arkla Exploration
09-15GRN_V	0-1400	Gamma Ray-Neutron Log (2”/ft)	Arkla Exploration
09-15GRN_W1	900-1148	Gamma Ray-Neutron Log (Whipstock 1)	Arkla Exploration
09-15GRN_W2	1020-1132	Gamma Ray-Neutron Log (Whipstock 2)	Arkla Exploration
09-16GRN_V	0-1253	Gamma Ray-Neutron Log (2”/ft)	Arkla Exploration
09-16GRN_W1	800-999	Gamma Ray-Neutron Log (Whipstock 1)	Arkla Exploration
09-16GRN_W2	850-1006	Gamma Ray-Neutron Log (Whipstock 2)	Arkla Exploration
09-17GR	0-823	Gamma Ray Log	Arkla Exploration
09-18GRN_V	0-1294	Gamma Ray-Neutron Log (2”/ft)	Arkla Exploration
09-18GRN_W1	880-1022	Gamma Ray-Neutron Log (Whipstock 1)	Arkla Exploration
09-19GRN	0-1299	Gamma Ray-Neutron Log	Arkla Exploration
09-20GRN_V	0-1258	Gamma Ray-Neutron Log (3”/ft)	Arkla Exploration
09-20GRN_W2	860-986	Gamma Ray-Neutron Log (Whipstock 2)	Arkla Exploration
09-20GRN_W1	860-997	Gamma Ray-Neutron Log (Whipstock 1)	Arkla Exploration
09-21GRN	0-940	Gamma Ray-Neutron Log (3.5”/ft)	Arkla Exploration
09-21GRN1	800-940	Gamma Ray-Neutron Log	Arkla Exploration
09-22GRN_V	0-1313	Gamma Ray-Neutron Log (4”/ft)	Arkla Exploration
09-22GRN_W1	910-1069	Gamma Ray-Neutron Log (Whipstock 1)	Arkla Exploration
09-22GRN_W2	900-1048	Gamma Ray-Neutron Log (Whipstock 2)	Arkla Exploration
09-25GRN	0-1172	Gamma Ray-Neutron Log	Arkla Exploration
09-25GRN1	0-1597	Gamma Ray-Neutron Log	Arkla Exploration
09-26GRN	0-1521	Gamma Ray-Neutron Log	Arkla Exploration
09-30GRN	0-1456	Gamma Ray-Neutron Log	Duval

Appendix 2. Well samples for potash holes available at the Arizona Geological Survey

O&GCC NUMBER	LOCATION			OPERATOR, No# & LEASE	SAMPLE No#	SAMPLE INTERVAL (ft) Cuttings Conv. core*(ft)	TOTAL DEPTH
343	15N-22E-03	NE	NE	Arkla Explr 55 New Mex & Ariz Land (strat)	1495	0-610	975
1-9	15N-27E-18	SE	SE	Duval 41 Federal (strat)	1302	0-1230	1514
1-10	15N-28E-04	NE	SE	Duval 40 Federal (strat)	1301	1100-1550	1839
323	15N-23E-10	SW	NE	Arkla Explr 7 State (strat)	1352	0-1060	1060
649	16N-18E-02	SE	SE	Duval 56 State (strat)	-----	0-000 c 918-1021	1017
643	16N-20E-02	NW	NW	Duval 54 State (strat)	-----	0-000 c 753-904	909
644	16N-21E-34	SE	NW	Duval 55 State (strat)	-----	0-000 c 665-907	898
329	16N-22E-16	SE	NE	Arkla Explr 64 State (strat)	1374	0-580	3380
362	-23	NE	SE	Arkla Explr 19 New Mex & Ariz Land (strat)	1796	40-890	945
328	-27	NE	SE	Arkla Explr 77 New Mex & Ariz Land (strat)	1363	0-600	1000
357	16N-23E-05	SW	NW	Arkla Explr 15 New Mex & Ariz Land (strat)	1510	40-975	1157
342	-13	NW	NW	Arkla Explr 16 New Mex & Ariz Land (strat)	1493	0-1010	1430
358	-18	SW	NW	Arkla Explr 25 State (strat)	1501	50-972	1100
359	-27	SW	SE	Arkla Explr 10 New Mex & Ariz Land (strat)	1509	70-820	1009
1-15	16N-24E-30	SW	NE	Arkla Expl 56 State (strat)	1477	0-1010	1420
324	-32	SW	NE	Arkla Expl 1 State (strat)	1350	0-1030	1450
1-19	16N-26E-02	NW	NE	Duval 4 State (strat)	1337	0-1364	1641
1-21	16N-29E-34	NE	NE	Duval 7 Federal (strat)	1334	0-1480	1802
331	17N-22E-21	NW	SW	Arkla Explr 33 New Mex & Ariz Land (strat)	1496	0-1140	1142
334	-24	NW	SW	Arkla Explr 7 New Mex & Ariz Land (strat)	1508	0-1270	1275
326	-36	NW	SW	Arkla Explr 3 State (strat)	1364	0-820	1170
337	17N-23E-05	SE	SW	Arkla Explr 6 New Mex & Ariz Land (strat)	1507	0-1330	1635
361	-08	SW	SE	Arkla Explr 44 New Mex & Ariz Land (strat)	1604	50-1260	1331
335	-19	NE	NE	Arkla Explr 36 New Mex & Ariz Land (strat)	1372	0-1090	1473
333	-29	SE	NE	Arkla Explr 39 New Mex & Ariz Land (strat)	1351	0-980	1340
364	-31	SW	SW	Arkla Explr 20 New Mex & Ariz Land (strat)	1492	100-970	1029
1-23	17N-25E-02	NE	NE	Kern County Land 7 State (strat)	-----	0-000 c 1402-1560	1600
636	-04	NW	NW	St. Joe American 4 State (strat)	1757	0-1449 c 1366-1404	1452
1-24	-06	NE	NE	Kern County Land 3 State (strat)	-----	0-000 c 1184-1388	1385
650	-10	SE	SE	St. Joe American 8 State (strat)	1761	0-1410 c 1288-1428	1428
641	-12	NW	NW	St. Joe American 5 State (strat)	1758	0-1530	1543
652	-16	NW	NW	St. Joe American 9 State (strat)	1762	0-1370 c 1216-1388	1388
1-28	17N-26E-01	NW	SE	Duval 5 Santa Fe (strat)	1336	0-1460	1905
642	-06	NW	NW	St. Joe American 6 State (strat)	1759	0-1590	1594
1-29	-16	SE	SE	National Potash Navajo 1 State (strat)	1347	0-1320	1507
1-30	-18	NE	NE	Duval 10 State (strat)	1331	10-1300	1528
1-31	-36	NW	NW	National Potash Navajo 2 State (strat)	1348	0-1000	1572
1-32	17N-27E-15	SW	SE	Duval 14 Santa Fe (strat)	1327	100-2000	2347
1-33	17N-28E-34	NE	NE	Duval 42 Federal (strat)	1300	0-1725	2107
1-34	17N-29E-27	NE	NE	Duval 38 Santa Fe (strat)	1303	100-1580 1610-2170	2529
340	18N-23E-18	NE	SW	Arkla Explr 24 New Mex & Ariz Land (strat)	1499	0-900	1560
360	-21	NE	NE	Arkla Explr 23 New Mex & Ariz Land (strat)	1500	0-1400	1919
1-35	18N-24E-02	S2	SW	Kern County Land 1 State (strat)	-----	0-000 c 905-1085	1134
1-37	-17	NW	NW	Duval 31 Santa Fe (strat)	1309	0-780	955
1-38	-20	SE	SW	Duval 36 Santa Fe (strat)	1306	0-800	955
1-39	-31	SE	SW	Duval 27 Federal (strat)	1315	0-780	1064
1-40	18N-25E-10	NW	NW	Duval 18 State (strat)	1323	0-1014	1433
682	-12	NE	NE	St. Joe American 13 State (strat)	1779	0-1080c and cc 1083-1182	1182
1-41	-14	C		Duval 35 State (strat)	1307	0-1040	1147
645	-16	SW	SW	St. Joe American 7 State (strat)	1760	0-1000 c 901-1003	100

Appendix 2 contd.

O&GCC NUMBER		LOCATION		OPERATOR, No# & LEASE	SAMPLE No#	SAMPLE INTERVAL (ft) Cuttings	Conv. core*(ft)	TOTAL DEPTH
1-42	-18	NE	NE	Duval 8 Federal (strat)	1333	0-775		923
1-43	-20	W2	W2	Kern County Land 6 State (strat)	-----	0-000 c 812-1021		1021
1-44	-20	SE	SE	Kern County Land 8 State (strat)	-----	0-000 c 1285-1420		1421
633	-24	NW	NW	St. Joe American 1 State (strat)	1754	0-1220		1228
634	-26	NW	NW	St. Joe American 2 State (strat)	1755	0-1240		1245
635	-34	NW	NW	St. Joe American 3 State (strat)	1756	0-1810 c 730-1818		1818
1-46	18N-26E-04	SE	NE	Duval 37 State (strat)	1305	100-1400		1564
679	-04	SE	SE	St. Joe American 10 State (strat)	1776	0-1250 c and cc 1260-1380		1380
1-47	-06	SW	SW	Duval 33 State (strat)	1311	0-1080		1206
673	-08	NW	NW	Duval 61State (strat)	1775	10-1250 cc 1140-50		1251
632	-08	NE	SE	Duval 52 State (strat)	1734	0-1160 c 1228-1268		1308
665	-10	NE	NW	Duval 57 State (strat)	1773	0-1450		1452
1-48	-10	W2	W2	Duval 16 State (strat)	1325	0-870		1414
624	-12	SW	NW	Duval 47 State (strat)	1729	0-1430		1735
1-49	-16	SE	NE	Duval 20 State (strat)	1321	0-1220		1440
680	-16	NW	NW	St. Joe American 11 State (strat)	1777	0-1160 c 1172-1312		1312
664	-18	SE	NE	Duval 53 State (strat)	1772	0-1265		1265
1-50	-18	W2	NW	Duval 24 State (strat)	1318	10-980		1224
1-51	-19	NW	NW	Duval 3 Fee (strat)	1338	100-1110		1321
681	-20	NW	NW	St. Joe American 12 State (strat)	1778	0-1130 c 1137-1252		1252
1-52	-22	E2	W2	Duval 32 State (strat)	1310	0-1700		1845
1-53	-24	NE	NE	Duval 11 State (strat)	1330	0-1260		1739
1-54	-30	NW	SW	Duval 26 State (strat)	1316	0-1260		1496
1-55	-34	NE	NW	Duval 13A State (strat)	1328	100-1300		1548
626	18N-27E-06	NW	NE	Duval 49 State (strat)	1731	0-1860 c 1870-1968		2046
1-56	-07	NW	NW	Duval 34 Santa Fe (strat)	1308	150-1570		1875
625	-08	SE	NW	Duval 48 State (strat)	1730	0-1740		1776
630	-08	SE	NW	Duval 50 State (strat)	1732	0-2000 c 2039-2099		2139
1-57	-10	NW	SE	Duval 9 State (strat)	1332	340-2200		2512
631	-18	SE	SE	Duval 51 State (strat)	1733	0-1670 c 1686-1786		1781
1-58	-35	SE	SE	Duval 43A Santa Fe (strat)	1354	0-2180		2445
1-59	18N-28E-15	SE	SE	Duval 25 Santa Fe (strat)	1317	110-1380	1410-2430	2789
1-60	-19	SW	SE	Duval 44 Santa Fe (strat)	1353	0-2360		2676
9-30	19N-23E-36	SW	SW	Duval 29 State (strat)	1313	0-700		1454
1-63	19N-25E-36	NE	NE	Duval 6 State (strat)	1335	0-1218		1342
1-64	19N-26E-12	NE	SE	Duval 2 State (strat)	1339	0-1400		1594
1-65	-22	SW	SW	Duval 12 State (strat)	1329	0-980		1583
1-66	-36	NE	NE	Duval 1A State (strat)	1340	200-1785		2005
623	19N-27E-09	SE	SW	Duval 46 Santa Fe (strat)	1728	0-1590 c 1601-1743		1743
1-67	-10	NW	NW	Duval 28A Santa Fe (strat)	1314	0-1590		1908
1-68	-19	SW	SW	Duval 30 Santa Fe (strat)	1312	0-1710		1890
1-69	-22	SW	NE	Duval 15 Santa Fe (strat)	1326	0-1840		1981
1-70	-28	SW	SW	Duval 39 Santa Fe (strat)	1304	0-1860		2001
1-71	19N-28E-21	NE	SW	Duval 19 Santa Fe (strat)	1322	130-2080		2127
1-73	20N-27E-26	NW	NW	Duval 21 Santa Fe (strat)	1320	0-1680		1978
1-74	20N-28E-33	SE	SE	Duval 23 Santa Fe (strat)	1319	0-2045		2068
1-75	20N-29E-31	NE	NW	Duval 17A Santa Fe (strat)	1324	0-1360		1916

* c = selected whole core; cc = core chips