Potash Bed Mapping in the Paradox Basin, Northern San Juan County, Utah

Andrew Rupke and Taylor Boden

Arizona Geological Survey
Special Paper 9
Chapter #
For information on the mission, objectives or geologic products of the Arizona Geological Survey visit www.azgs.az.gov.

Manuscript approved for publication in 2014. Printed by the Arizona Geological Survey. All rights reserved.

**Officers and Organizers of the 48th Annual Forum on the Geology of Industrial Minerals**

**Board of Directors**

President – Mark Wolf
Vice President – Thomas Newman
Secretary – Stan Krukowski
Treasurer – Vanessa Santos

**Members**

Lynne Carpenter
Nelson Shaffer
Dale Scott

**Forum Steering Committee**

Lynne Carpenter
Dale Scott
Dave Crouse
Greta Orris

**Bates Scholarship Trustees - RLBMSF**

George Edwards
Roger Sharpe
Peter Harben
Vanessa Santos
Gretchen Hoffman
Marion Wiggins
Tom Newman

---

# TABLE of CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>2</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>2</td>
</tr>
<tr>
<td>Purpose and scope</td>
<td>2</td>
</tr>
<tr>
<td>Study area</td>
<td>3</td>
</tr>
<tr>
<td>Methods</td>
<td>5</td>
</tr>
<tr>
<td>REGIONAL GEOLOGY AND STRUCTURE</td>
<td>5</td>
</tr>
<tr>
<td>POTASH RESOURCES</td>
<td>7</td>
</tr>
<tr>
<td>General</td>
<td>7</td>
</tr>
<tr>
<td>Potash maps</td>
<td>7</td>
</tr>
<tr>
<td>Cycle 5 potash</td>
<td>8</td>
</tr>
<tr>
<td>Cycle 9 potash</td>
<td>12</td>
</tr>
<tr>
<td>Cycle 13 potash</td>
<td>14</td>
</tr>
<tr>
<td>Cycle 18 potash</td>
<td>15</td>
</tr>
<tr>
<td>CONCLUSIONS</td>
<td>20</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>20</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>22</td>
</tr>
</tbody>
</table>
Potash Bed Mapping in the Paradox Basin, Northern San Juan County, Utah

Andrew Rupke¹ and Taylor Boden
Utah Geological Survey, P.O. Box 146100, Salt Lake City, UT 84114-6100
¹andrewrupke@utah.gov

ABSTRACT

Strong international demand and high potash prices have prompted a number of companies to conduct or plan potash exploration in the already productive Paradox Basin of southeastern Utah. In response to potash interest in the area, the Utah School and Institutional Trust Lands Administration contracted the Utah Geological Survey to evaluate potash beds in the Pennsylvanian Paradox Formation in about 900 square miles of northern San Juan County, including the Hatch Point, Hart Point, and Lisbon Valley areas. The Paradox Formation is an evaporite sequence containing up to 29 recognized salt cycles that are numbered sequentially from top (1) to bottom (29), and the most significant potash beds in the study area are in salt cycles 5, 6, 9, 13, 16, 18, 19, 20, 21, and 24. Data on these beds were compiled from published and unpublished sources containing information on 132 potash exploration boreholes and oil and gas wells in and around the area. From the compiled data we created isopach, grade, overburden thickness, and structure contour maps of potash beds. For the maps, we interpolated the data using an inverse-distance-squared weighting, with an anisotropy applied to take the Paradox Basin’s northwest-trending geometry into account. Results suggest that multiple salt cycles in the study area may represent a potash resource; however, the resource comprises different beds in different areas. The primary potash-bearing mineral of most of the potential resources in the basin is sylvite, but carnallite is also present in some areas.

In the Lisbon Valley area, data suggest a potential resource in salt cycles 5 and 9. Analyses from both cycles show greater than 20% weight equivalent K₂O, and mapping suggests reasonably sized areas of above 15% K₂O. Potash thickness in high-grade areas is typically 10 ft. or less for cycle 5 and from about 5 to 15 ft. for cycle 9. Generally, data indicate that potash in cycle 9 would be a better target as it tends to be higher grade and more extensive than potash in cycle 5. Because Lisbon Valley represents a structural anticline, the potash deposits in that area have the advantage of being relatively shallow, although structural complexity at the anticline may present difficulties for extraction.

In the Hatch Point and Hart Point areas, potash in salt cycles 13 and 18 may represent potential resources. A few data points show potash grades of cycle 13 above 10% K₂O in the west-central part of the study area, and projected thicknesses are generally less than 10 ft. Mapping indicates that high-grade areas of cycle 18 potash (>15% K₂O) may be widespread in the southwestern part of the study area, including in the Hatch Point and Hart Point areas. Limited chemical analyses are available for cycle 18, but a number of boreholes show high gamma-ray signatures indicating high-grade potash. Projected thickness of high-grade potash in cycle 18 is variable, but ranges up to about 30 ft. In contrast to Lisbon Valley, topography is the primary control for overburden thickness where potential resource is present in cycles 13 and 18—overburden is thick at Hatch Point and Hart Point mesas, and is relatively thin in the valley to the west.

INTRODUCTION

Purpose and scope

The Utah School and Institutional Trust Lands Administration (SITLA) commissioned the Utah Geological Survey (UGS) to prepare a report on potash resources over a region that covers the Hatch Point, Hart Point, and Lisbon Valley areas of San Juan County, Utah. Due to recent increases in potash prices, the potash-bearing Paradox Formation of the Paradox Basin has drawn interest from a number of mining and exploration companies. These companies have leased and applied for rights to large tracts of SITLA and Bureau of Land Management (BLM) property. Two companies have recently drilled for potash within the study area: K2O Utah, LLC (90% owned by Potash Minerals Ltd., formerly known as Transit Holdings Ltd.) drilled in the Hatch Point area, and North American Potash Developments Incorporated (formerly known as Ringbolt Ventures Limited) drilled in the Lisbon Valley area.
This paper presents isopach, grade, overburden thickness, and structure contour maps of the potash beds in the study area that likely have the most economic potential. The maps were generated from compilation and analysis of existing potash data from wells drilled in and around the study area to provide a better picture of the potash resource. Limited potash drilling has occurred in the study area and few chemical analyses are available for most of the study area, so much of the potash data is interpreted from oil and gas well gamma-ray logs. While a reasonable amount of data are available, additional drill holes in key areas would provide a more complete and reliable picture of the potash resource within the study area.

**Study area**

The study area is situated in northern San Juan County and encompasses nearly 873 square miles (559,000 acres) (figure 1). The area includes primarily BLM and SITLA land with a small amount of private

---

*Figure 1. Study area. Blue dots represent locations of potash exploration boreholes and oil and gas wells used for potash bed mapping.*
Potash Bed Mapping in the Paradox Basin, Northern San Juan County, Utah

land that is concentrated on the east side of the area. Canyonlands National Park defines the western boundary of the study area. Manti-La Sal National Forest defines the southwestern boundary, and the flanks of the La Sal Mountains occur along much of the northeastern boundary. A short segment of the Colorado River is within the extreme northwestern part of the study area, and is near much of the western boundary. Some of the primary physical features in the study area are Hatch Point, which is a large, relatively flat mesa that extends from the central part of the area towards the northwest, and Lisbon Valley, which is an asymmetric, northwest-trending valley in the eastern part of the study area (figure 1). Elevations range from over 7000 ft. in the southwest on the flanks of the Abajo Mountains and the northeast on the flanks of the La Sal Mountains to about 4000 ft. at the Colorado River in the northwest.

Previous work and potash activity

Extensive work has been done on the geology and potash resources of the Paradox Basin, and this section highlights some of the more significant and relevant work. Some of the most important and early work on the Paradox Formation was conducted by Hite (1960a, b), who detailed and correlated 29 different salt cycles within that formation, providing a stratigraphic framework for potash exploration in the Paradox Basin. Shortly thereafter, Hite (1961) also produced a map estimating the extents of salt and potash within the Paradox Basin, and Elston and Shoemaker (1961) published a structure contour map of the top of the Paradox Formation salt that covers the Paradox Basin, including the study area. Ritzma and Doelling (1969) provided a good, general geological description of the potash resources in San Juan County. A number of geologists have mapped the surficial geology in and around the study area, but most recently Doelling (2004) compiled the geology of the La Sal 30’ by 60’ quadrangle, which covers nearly all of the study area. Surficial mapping of the southwestern part of the study area is covered by Witkind (1964; 2007 [digital]) and Lewis and others (2011). Case and Joestings (1972), Hildenbrand and Kucks (1983), and Bankey and others (1998), all from the U.S. Geological Survey, published gravity and magnetic surveys that cover the study area.

Extensive potash exploration has occurred in Lisbon Valley relative to other parts of the study area. From 1958 through 1961, Superior Oil Company drilled 17 potash exploration holes in the valley, with the primary targets being potash in salt cycles 5 and 9. Other companies, primarily the Pure Oil Company, drilled a number of oil and gas wells in Lisbon Valley during the early 1960s. Hodges and Banfield (1962) and Hite (1978) provided potash information from analytical data and gamma-ray log data that were gleaned from both the potash and oil-and-gas exploration and production wells. In response to the results of potash exploration, the BLM designated an area of Lisbon Valley as a Known Potash Leasing Area (KPLA) in 1960, which allowed the leasing of potash on BLM ground. Gwynn and Tripp (2009) prepared a potash resource evaluation of Lisbon Valley for the BLM and the BLM increased the area of the Lisbon Valley KPLA in response.

At Hatch Point and other parts of this study area, less potash exploration has occurred and less information is publicly available. However, Britt (1977) reviewed numerous gamma-ray logs from oil and gas wells and cataloged potential potash horizons for the Anaconda Company. The wells investigated by Britt (1977) cover much of the study area, including Hatch Point and Lisbon Valley. Some limited potash data are available for the northern Hatch Point area from a few unpublished Anaconda reports, including reports by Swinney (1962), Trimble (1962), Blanc (1963), and Trimble (1966). In 1981, Woodward-Clyde Consultants (1982b) completed a core hole near Gibson Dome (south of Hatch Point) as part of a U.S. Department of Energy (DOE) study examining the Paradox Basin for nuclear waste disposal. Some potash chemical analyses, as well as gamma-ray logs, are available from this study (Woodward-Clyde Consultants 1982b, Hite 1982, Hite 1983). Kohler (2009) prepared a report for the BLM suggesting that additional exploration was necessary in the Hatch Point area to define a KPLA. This report was solicited by the BLM in response to prospecting permit applications from K2O Utah, LLC in the area. Tripp and Tabet (2011) made a similar recommendation to BLM. Potash Minerals Ltd. has released information online from their evaluation of the Hatch Point area and recent drilling program in which three exploration holes were completed (Potash Minerals 2012).

Massoth and Tripp (2011) published a database that catalogs the tops and bottoms of Paradox Formation salt cycles in numerous wells throughout the Paradox Basin in Utah, primarily using publicly available gamma-ray logs. Massoth (2012) is currently expanding the database to include more detailed
information on potash-bearing horizons.

The only potash production from the Paradox Basin has come from the Cane Creek mine just north of the study area. Significant potash resource evaluation began in the Cane Creek area in 1956, and Texas Gulf Sulfur Inc. began underground room-and-pillar mining in 1964. In 1970, due to gas pockets, high temperatures, and ore zone complexity, solution mining began and underground mining was abandoned (Morgan and others 1991, Anderson 2008). In 1988, Moab Salt, Inc. purchased the operation, and the ownership transferred again in 2000 when Intrepid Oil and Gas bought the operation (Anderson 2008). The operator is currently known as Intrepid Potash, Inc. Sylvite was initially exploited from evaporite cycle 5 at Cane Creek, but currently sylvite from both cycles 5 and 9 is solution mined. Intrepid’s capacity for potassium chloride production at the Cane Creek mine is currently about 100,000 short tons per year (Intrepid Potash 2010).

**Methods**

Data used for potash evaluation and map creation were compiled from 132 potash exploration holes and interpreted gamma-ray logs from oil and gas wells. The well locations in and around the study area are shown in figure 1. Compiled information includes depth of potash beds, interpreted or measured thickness of potash beds, potash mineralogy (sylvite, carnallite, mixed, etc.), chemical analyses or inferred grade from gamma-ray, peak reading API units (the unit of radioactivity used for natural gamma-ray logs), and data sources for the information. We prepared a spreadsheet of the data, and recorded potash information from salt cycles 5, 6, 9, 13, 16, 18, 19, 20, 21, and 24. The spreadsheet borrowed extensively from Massoth (2012), but other important data sources include Hodges and Banfield (1962), Britt (1977), Hite (1978), Hite (1982), Kohler (2009), Massoth and Tripp (2011), and Transit Holdings Ltd. (2011). We also used the Utah Division of Oil, Gas, and Mining (2011) online oil and gas database extensively to review geophysical logs of relevant wells. Using published and unpublished information, previous interpretations, and peak gamma-ray API readings, we selected thicknesses and grades for each potash bed of each well for use in the preparation of interpolated maps presented in this study. Nelson’s (2007) published methodology for correlation of API to K₂O grade (percent K₂O is the typical format for reporting grade of a potash bed) was also used in determining appropriate grade values. Our interpreted potash grade values are also recorded in our spreadsheet. Tentative plans have been made to make the potash data spreadsheet publicly available in a future UGS open-file report.

Using the potash data spreadsheet, we created a GIS geodatabase, which allowed for interpolation and creation of isopach, grade, overburden thickness, and structure contour maps. We used a standard inverse-distance-squared interpolation technique, and applied a northwest-trending anisotropy to the interpolation to account for the shape of the Paradox Basin and the orientation of major geologic structures.

**REGIONAL GEOLOGY AND STRUCTURE**

The study area is in the Paradox Basin, a sedimentary basin in which extensive evaporites were deposited during the Pennsylvanian. The basin is elongate northwest, stretching from southwestern Colorado through east-central Utah (figure 2). The basin formed southwest of, and adjacent to, the Uncompahgre Uplift, which shed clastic material into the basin. A high-angle reverse fault that separates these two features created thousands of feet of vertical displacement from the Pennsylvanian to the Triassic (Hite and Cater 1972, Hintze and Kowallis 2009). The deepest portion of the basin is in the northeast, near the basin-bounding fault.

The rocks in the basin are a thick sequence of Pennsylvanian Paradox Formation evaporites and thinner shelf carbonates, known as the Pennsylvanian Pinkerton Trail and Honaker Trail Formations. Deposition occurred in a restricted marine basin, with the carbonates being more prevalent on the margins of the basin and the evaporites more prevalent in the central basin. Hite and Cater (1972) suggested that marine water entered the basin across a broad carbonate shelf in the southwest. The thick and widespread evaporite sequence that formed during the life of the restricted basin can be subdivided into 29 depositional cycles as catalogued by Hite (1960a, b). Figure 3 shows an example of the detailed saline and clastic stratigraphy of the Paradox Formation from a well drilled north of the study area. The cycles generally follow a pattern of organic-rich black shale at the base overlain by silty dolomite, anhydrite, and halite (with or without potash), such that each cycle
represents a regressive sea-level phase (Hite and Cater 1972). Hite and Cater (1972) noted that the tops of the cycles represent disconformities following a transgressive influx of fresher water into the basin. Many of the cycles are laterally continuous, but not all cycles are present across the whole basin due, in part, to a shifting depositional center in the basin. Hite and Cater (1972) estimated the original thickness of the evaporite section, prior to deformation, at 5000 to 6000 ft., but current, post-deformation thicknesses range from 0 to 14,000 ft. (Hintze and Kowallis 2009).

Following restricted-marine deposition in the Paradox Basin, mostly nonmarine, red-bed sediments were deposited in the area through the Jurassic (Ritzma and Doelling 1969). In the study area, a sequence of Permian through Jurassic rocks is exposed above the Pennsylvanian rocks, with limited exposures of Cretaceous beds in the southeast. No surface exposures of the Paradox Formation are present within the study area.

Perhaps during, but certainly shortly after deposition of the Paradox Formation, folding, likely genetically related to the Uncompahgre uplift, formed a series of northwest-trending anticlines in the Paradox Basin that were accentuated by the plasticity of salt. Development of the salt anticlines continued at least into Cretaceous time (Ritzma and Doelling 1969, Hite and Cater 1972). Presently, a number of the salt

Figure 2. The Paradox Basin as defined by potash and salt extents. The potash extent, salt extent, and anticline locations are from Hite and Cater (1972).
anticlines in the Paradox Basin form valleys due to salt dissolution. Most of the study area contains nearly flat-lying, relatively undeformed sedimentary rocks, but a few of the salt-anticline structures are also present in the area (figure 2). The most dramatic of these folded features in the study area is the Lisbon Valley anticline, which has a distinctive low-gravity signature on the Bouguer gravity map in figure 4. Lisbon Valley is a northwest-trending valley that exposes Pennsylvanian Honaker Trail Formation in its core and is cut on the northeast side by the Lisbon Valley fault. Hite (1978) and Woodward-Clyde Consultants (1982a) interpreted the fault as a normal fault that retains its northeast dip in the subsurface. Drilling results suggest complex folding of salt beds in the subsurface (Hite 1978).

**POTASH RESOURCES**

**General**

In the Paradox Formation, potash is known to occur in 18 of the 29 evaporite cycles (Hite 1960a, b). Within the study area, the primary potash-bearing salt cycles are 5, 6, 9, 13, 16, 18, 19, 20, 21, and 24. Historically, the shallower beds were considered to have the most economic potential, particularly beds 5, 9, 13, and 18. The primary potash minerals found in the Paradox Basin, and the study area are sylvite (KCl) and carnallite (KCl·MgCl2·6H2O), and these minerals are generally found in the central part of the basin (figure 2). Current interest in the area revolves around sylvite, as pure sylvite has an equivalent weight percent of 63.17 K₂O. Sylvite is the primary potash mineral at Intrepid’s mine, and their sylvite ore ranges in quality from above 10% to over 20% K₂O. Pure carnallite has an equivalent weight percent of just 16.95 K₂O, and can be more difficult to process for a potash product due to the soluble magnesium component (Prud’homme and Krukowski 2006). If carnallite were to become a significant target, magnesium compounds may be produced as a by-product.

**Potash maps**

The maps in the following sections present information on potash thickness, potash grade, overburden thickness, and structure contours for cycles 5, 9, 13, and 18 in the study area. Maps were also created for cycles 6, 16, and 19, but cycles 5, 9, 13, and 18 appear to represent the most economic potash horizons. Insufficient data were available to produce maps for cycles 20, 21, and 24. Thicknesses on the maps generally represent the entire thickness of the potash section. However, particularly where chemical analyses but no gamma-ray logs are available, the thicknesses may represent only a portion of the entire potash zone. Grade values should be considered estimates and generally represent a maximum grade within a potash zone, as only the maximum gamma-ray peak for a potash zone was recorded for this study—potash beds with multiple gamma-ray peaks were not catalogued and divided. In most cases, the maps should be interpreted as representing a maximum.
grade and maximum thickness for a given potash zone, so the grade posted on the map will not necessarily be representative of the entire thickness shown on the map.

Interpolated map data in portions of the study area with large data gaps should be used with caution. These areas are primarily in the central and southwest parts of the study area. Also, few data points exist northeast of the Lisbon Valley fault so changes that may occur across the fault are not well represented.

For this reason, overburden thickness and structure contour maps do not show information northeast of the Lisbon Valley fault.

**Cycle 5 potash**

Where present, potash in cycle 5 is generally reported to be sylvite, but in the western part of the study area there is essentially no potash (figure 5). In the eastern portion of the study area, some cycle 5 potash beds are present, and in one drill hole the thickness reaches 58 ft. However, most holes with
Figure 5. Potash isopach map of cycle 5. Note that color gradient is not linear. Wells outside study area used in interpolation are not shown. The northwest-trending potash zone, mostly in townships T. 30 S., R. 23 E. and T. 31 S., R. 24 E., is primarily a function of one hole on the border of T. 30 S. and T. 31 S. that has a very thick potash occurrence in cycle 5. The zone is likely much smaller than is represented on this map.
Potash show thicknesses of less than 20 ft., and where the highest grades are present, thicknesses are generally 10 ft. or less (figures 5 and 6). Hite (1978) noted that the highest grades of potash in cycle 5 are at the top of the potential ore zone, commonly underlain by a gradational zone that decreases in sylvite content with increasing depth. Seven chemical analyses are available for cycle 5, and they average 19.1% K$_2$O; the

Estimated Potash Grade Map - Cycle 5

*Figure 6. Estimated potash grade map of cycle 5. Wells outside study area used in interpolation are not shown.*
highest grade is 24.5% K₂O. The analyses are from Lisbon Valley and are reported by Hite (1978) and Hodges and Banfield (1962). The interpolated maps suggest that areas in Lisbon Valley contain potash with 10% or greater K₂O with thicknesses mostly ranging from 4 to 10 ft. In those same areas, overburden depth ranges from about 2400 to 4500 ft. (figure 7). These depths are relatively shallow, but structural

**Figure 7.** Overburden thickness and structure contours of the top of potash in cycle 5. Structure contours represent elevation above sea level of the top of the potash (or salt cycle where potash is absent). The contour interval is 500 ft. Information is not presented northeast of the Lisbon Valley fault due to insufficient data.
deformation in Lisbon Valley would likely add to extraction complexity.

**Cycle 9 potash**

In and near the study area, potash in cycle 9 is mostly sylvite, but some occurrences of carnallite are reported in drillholes. Cycle 9 potash is widespread, and where present, averages nearly 15 ft. thick (average was calculated from well occurrences, not aerial extent from mapping) (figure 8). Although present throughout much of the study area, the grade is quite low in most areas except for the eastern part of the study area (figure 9). In the Lisbon Valley area and to the south, a number of wells indicate

**Figure 8.** Potash isopach map of cycle 9. Note that color gradient is not linear. Wells outside study area used in interpolation are not shown.
potentially high grades of potash. Twelve chemical analyses are available for wells in Lisbon Valley that show K₂O contents up to 33%, and average 23.4% K₂O. Potash bed thicknesses in the areas of higher grade are variable, but typically range from about 5 to 15 ft. Significant gaps exist between data points in the northern and southern mapped extents that are interpolated as relatively high-grade potash, so additional drilling would be important to confirm the presence of high-grade potash in these elongate tail areas. Relatively thin overburden and high-grade potash coincide near Lisbon Valley, and in some of these areas overburden thickness is less than 3000 ft. (figure 10). However, where cycle 9 potash is mapped

Figure 9. Estimated potash grade map of cycle 9. Wells outside study area used in interpolation are not shown.
as high grade near the southeastern boundary of the study area, overburden thickness reaches over 7000 ft. Similar to cycle 5, structural complexity of potash in cycle 9 at Lisbon Valley would need to be considered in extraction scenarios.

**Cycle 13 potash**

Both sylvite and carnallite, often in combination, are found in cycle 13 in and around the study area. The thickness of cycle 13 potash generally increases from southwest to northeast across the study area (figure 11). Where present in the wells we examined, cycle 13
averages about 20 ft. thick. The thickest occurrence of potash 13 in the study area is 62 ft. in Lisbon Valley, and cycle 13 also thickens significantly in the northernmost part of the study area. A few areas of high-grade potash are indicated by the maps, but most are relatively small (figure 12). The largest high-grade area is in the west-central part of the study area, and is indicated by only a few wells. One of the wells is the DOE core hole drilled near Gibson Dome, where the 6.2 ft. of sylvite have an average grade of 16.5% K$_2$O (Hite 1982). The high-grade area is in the thinner portions of cycle 13 where the thickness ranges from about 4 to 10 ft. Overburden thickness over most of this area ranges from about 3500 to 4000 ft. (figure 13). A small number of wells define an area of moderate- to high-grade potash in cycle 13 in the central part of the study area, so additional drilling here could lead to expansion or contraction of the area with high-grade potash potential.

**Cycle 18 potash**

Published information reveals little data on the predominant potash mineral in cycle 18; however, carnallite has been encountered in some areas. In a few areas, salt cycle 18 has two distinct potash beds, but among the various data sources, less than 15 wells were identified as having two separate beds. The zone of little or no potash between the beds is generally between 30 and 50 ft. thick. Disagreement exists on the stratigraphic position of the upper and lower potash beds of cycle 18 among some of the sources, but for mapping in this
Potash Bed Mapping in the Paradox Basin, Northern San Juan County, Utah

Massoth (2012) included the lower bed as part of a net potash thickness for bed 18 where he identified it. Potash in salt cycle 18 is present throughout most of the study area, with the thickest known occurrences in Lisbon Valley and in the south-central portion of the study area (figure 14). Where present, the potash in cycle 18 averages about 16 ft. thick, and is 83 ft. at its thickest. Our mapping suggests large areas of potentially high-grade potash in the southwest half of the study area that range in thickness from about 6 to 30 ft. (figure 15). As noted previously, supporting well data in the central and far southwestern study area could provide a higher level of confidence to define the large, high-grade areas. A few isolated data points from Lisbon Valley also show elevated K₂O content. A chemical analysis of potash from cycle 18 is available from the Gibson Dome DOE core in the west-central part of the study area. The results of the analysis show 8.2 ft. of sylvite at 22.1% K₂O (Hite 1982).

Overburden thicknesses vary significantly in areas where high-grade potash is indicated in cycle 18 (figure 16). The thinnest overburden is in the western part of the study area, and the overburden thickens quickly approaching Hatch Point and Hart Point. Overburden thicknesses generally range from over 4000 to about 6500 ft. in the high-grade areas. The small, high-grade area in the

---

Figure 12. Estimated potash grade map of cycle 13. Wells outside study area used in interpolation are not shown.
**Figure 13.** Overburden thickness and structure contours of the top of potash in cycle 13. Structure contours represent elevation above sea level of the top of the potash (or salt cycle where potash is absent). The contour interval is 500 ft. Information is not presented northeast of the Lisbon Valley fault due to insufficient data.
northwest part of the study area has an overburden thicknesses of less than 4000 ft. Overburden is also very thin in Lisbon Valley, but little or no high-grade potash is known in the area.

**Figure 14.** Potash isopach map of cycle 18. Note that color gradient is not linear. Wells outside study area used in interpolation are not shown.
Estimated Potash Grade Map - Cycle 18

Figure 15. Estimated potash grade map of cycle 18. Wells outside study area used in interpolation are not shown.
CONCLUSIONS

Results from mapping potash thickness and grade suggest that potash resources do exist in the study area. In the eastern part of the study area, particularly in the Lisbon Valley area, high grades of potash are present in salt cycles 5 and 9; chemical analyses show grades for cycle 5 above 20% K₂O, and above 30% K₂O for cycle 9. Results indicate that high-grade potash in cycle 9 tends to be somewhat thicker and higher grade than in cycle 5. Cycle 9 potash is also much more extensive throughout the study area, but is only high grade in Lisbon Valley and nearby areas. Extraction of potash from the salt anticline in Lisbon Valley would have the benefit of shallower potash, but the added difficulty of more structural complexity. Some of the structural complexity can be seen in the abrupt thickness changes present in Lisbon Valley. However, some of the additional detail in Lisbon Valley is also likely a function of close well spacing relative to the rest of the study area.

In the southwest half of the study area, mapping indicates that high grades of potash with variable thickness (generally less than 30 ft.) may be present over large areas in cycle 18. One chemical analysis as well as more numerous gamma-ray data suggest sizable areas of better than 20% K₂O in cycle 18. A few wells also indicate that some high-grade potash is present in the west-central part of the study area in cycle 13, but it is much less extensive than cycle 18. The extent of higher-grade potash in cycles 13 and 18 needs to be better defined. Additional exploration in the central part of the study area could potentially expand (or reduce) the size of high-grade areas in these cycles. Additional information on the potash mineralogy would be important for these cycles to better understand the extent of carnallite in both horizons. For most of the study area, overburden is controlled by a combination of topography and the gentle northeast-dip of strata. Depths to cycles 13 and 18 are shallower in the west part of the area in the valley adjacent to the Colorado River, and increase significantly to the east once under the mesas that constitute Hatch Point and Hart Point.

Generally, the potash resource definition for the study area would benefit from additional coring and chemical analyses from potash horizons, particularly outside of Lisbon Valley. Such additional data would help to calibrate grades inferred from gamma-ray responses with actual analyses. Additional exploration wells in the central and southwestern parts of the study area would also help better define the true extent of potentially economic potash zones. Insufficient data are available in these areas to properly interpolate thicknesses and grades with much confidence. Additional work for the area could also include a more detailed evaluation of gamma-ray logs. This study only considered the highest gamma-ray API for a particular horizon, but many of the potential potash horizons included multiple smaller peaks. For smaller areas of interest, a valuable exercise could entail more detailed log analysis and estimate thickness and record peak API for subhorizons within the potash zones of interest.

ACKNOWLEDGEMENTS

We thank Thomas B. Faddies, assistant director of minerals, and the Utah School and Institutional Trust Lands Administration for providing funding for this study. Thanks to Christian Hardwick, UGS, for preparing a GIS gravity layer from the Pan American Center for Earth and Environmental Studies (2011) data.
Figure 16. Overburden thickness and structure contours of the top of potash in cycle 18. Structure contours represent elevation above sea level of the top of the potash (or salt cycle where potash is absent). The contour interval is 500 ft. Information is not presented northeast of the Lisbon Valley fault due to insufficient data.
REFERENCES


Blanc, R.P., 1963, Cane Creek area potash project: unpublished report prepared for the Richfield Oil Corporation Production Department – Research Division [copy obtained from Anaconda Collection, American Heritage Center, University of Wyoming].


Hodges, P.A., and Banfield, A.F., 1962, Potash resources of Lisbon Valley, San Juan County, Utah: unpublished Behre Dolbear & Company report to Superior Oil Company [copy obtained from Anaconda Collection, American Heritage Center, University of Wyoming].


Morgan, C.D., Yonkee, W.A., and Tripp, B.T., 1991, Geologic considerations for oil and gas drilling on state potash leases at Cane Creek anticline, Grand and
Swinney, C.M., 1962, Cane Creek area potash project: unpublished Anaconda Copper Company Inter-Office Communication to M.L. Natland, March 16, 1962, variously paginated [copy obtained from Anaconda Collection, American Heritage Center, University of Wyoming].
Trimble, R.B., 1966, Cane Springs potash core holes, San Juan County, Utah: Unpublished report prepared for Schwade, I.T. [copy obtained from Anaconda Collection, American Heritage Center, University of Wyoming].
Woodward-Clyde Consultants, 1982b, Gibson Dome No. 1 borehole, Gibson Dome study area of the Paradox Basin region, San Juan County, Utah: Completion Report by Woodward-Clyde Consultants for the Batelle Memorial Institute, Office of Nuclear Waste Isolation ONWI-388, 6 vol.