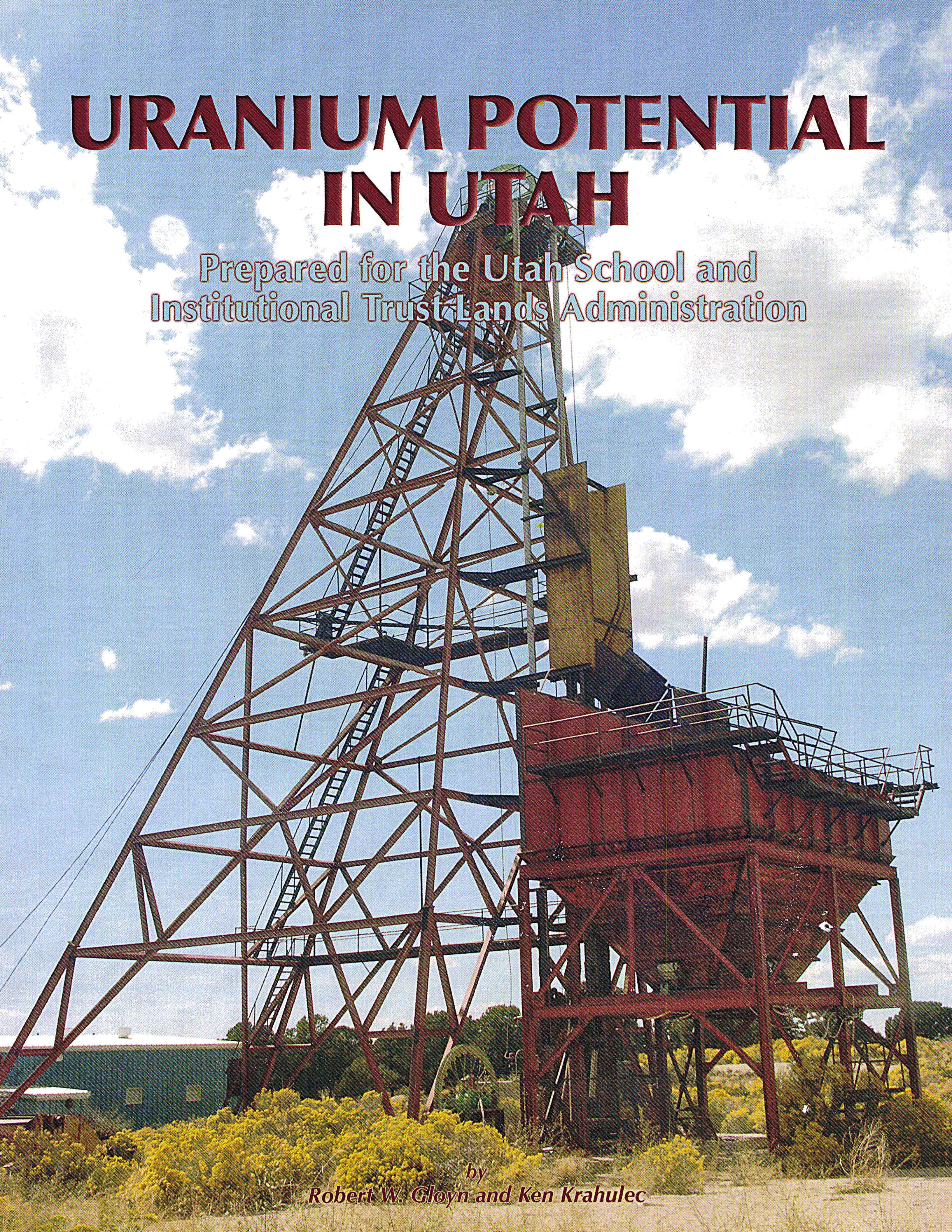
URANIUM POTENTIAL IN UTAH

Prepared for the Utah School and Institutional Trust Lands Administration



by

Robert W. Gloyn and Ken Krahulec

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PREFACE

A large portion of the text of this report, the prioritization of uranium potential, many of the figures, and accompanying map (plate 1) were completed in mid-2004 by the senior author, Robert (Bob) W. Gloyn. Sadly, Bob passed away in the fall of 2004. The "Uranium Potential in Utah" map with the high, moderate, low, and no potential designations and several district summaries were delivered to the School and Institutional Trust Lands Administration (SITLA) in 2004. The junior author took up the completion of the report in late February 2005. The text was reformatted to fit the structure and prioritization of the 2004 map, the figures were finalized, a few district descriptions were written to fill in gaps, and a summary and introduction were added to complete the report. The designation of the uranium potential and prioritization of the districts are solely the work of Bob Gloyn.

TABLE OF CONTENTS

FIGURES

PLATES

TABLE

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EXECUTIVE SUMMARY

Utah has been a moderate uranium producer, accounting for a total of about 130 million pounds of U_3O_8. The vast majority of its production has come from small, low- to moderate-grade sandstone-hosted uranium deposits of the Colorado Plateau, typically worked by underground methods. Four of the five areas listed as having high potential lie in the Paradox Basin of San Juan County: Lisbon Valley, La Sal, Dry Valley, and Ucolo. The Lisbon Valley – Big Indian mining district is Utah's only large uranium producer (53,636,121 pounds of U_3O_8).

The other high potential district is Shootaring-Del Monte district in the southern Henry Mountains of Garfield County. Utah's largest known remaining uranium resource, although moderate-grade (0.22% U_3O_8), is the Bullfrog-Tony M. deposits (23,822,000 pounds of U_3O_8) in the Shootaring-Del Monte district, near the Shootaring Canyon mill. Due to its existing infrastructure and defined resource, this deposit has the best opportunity to become a producer during the current upswing in the uranium market. An additional dozen uranium mining districts are judged to have moderate potential.

No sandstone-hosted deposits are currently (2005) being mined by underground methods in the U.S. U.S. primary uranium production comes dominantly from in-situ leaching (ISL) deposits. Utah may have some potential for ISL from the Tertiary sediments in the Spor Mountain district and the little reported uranium-copper occurrences of the Uinta Basin.

Utah has also produced minor amounts of by-product uranium and there may be some potential for additional production from the beryllium and phosphate producers in the state and possibly Bingham Canyon. Bingham Canyon recovered uranium temporarily from dump-leach water when the price was high in the 1980s. Similarly, Brush Wellman has recovered uranium, which is generally considered a contaminant along with fluorine and yttrium, from their Spor Mountain beryllium operations.

INTRODUCTION

History and Production

Utah's yellow carnotite ores were probably first exploited by Native Americans as a source of pigment (Cohenour, 1969). Uranium ores were initially recognized as such on the Colorado Plateau along Roc Creek and La Sal Creek near the Utah-Colorado border in the late 1890s and early 1900s. Uranium was first produced as a by-product of radium production from 1909 to 1923. R.P. Fischer has estimated that Utah produced between 12 and 15 grams of radium during this period (Chenoweth, 1990a). This early period saw the production of just a few thousand short tons (st) of selectively mined and hand-sorted ores reportedly averaging about 2 to 3% U_3O_8, which was still largely used as a pigment (Hilpert and Dasch, 1969).

From the mid-1930s to the early 1940s, uranium was largely a by-product of the state's vanadium production. Vanadium was used as a hardening agent in steel making. In the early 1940s, Vanadium Corporation of America built a vanadium mill for the U.S. Government in Monticello. Also during World War II, the Manhattan Project's uranium requirements resulted in the vanadium dumps and tailings being reprocessed for their uranium content. Southeastern Utah's mines produced an estimated 100,000 st of vanadium-uranium ore, containing 3,770,000 pounds of V_2O_5, and an unrecorded amount of uranium during this second period (Chenoweth, 1990a).

Utah's first real boom in uranium exploration began in 1948 when the U.S. Atomic Energy Commission (AEC) set a guaranteed price and bonus schedule for domestic uranium ore, driven by the requirements of nuclear weapons production. Subsequently, the AEC set up six uranium ore-buying stations (figure 1)

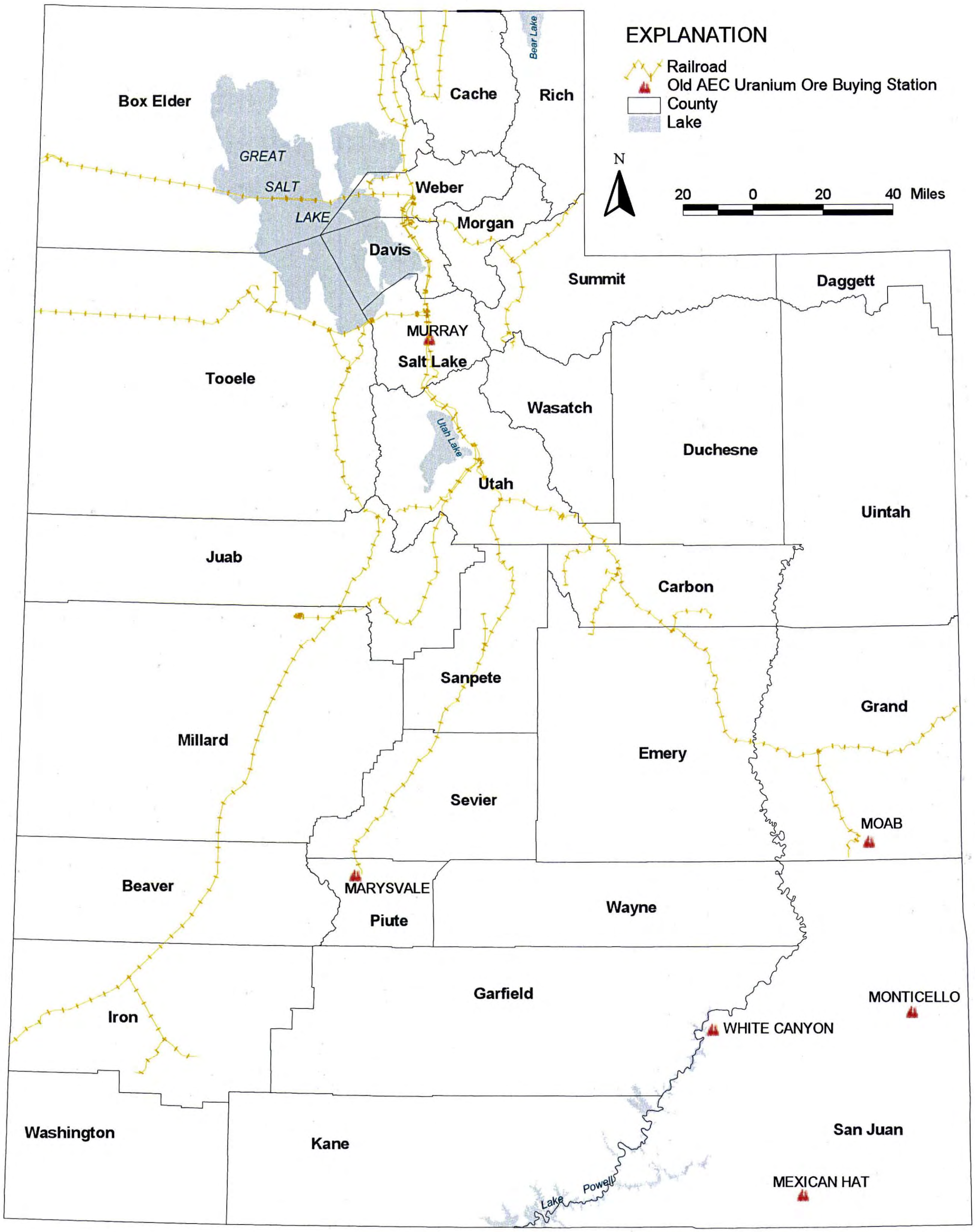

Figure 1. Location map of the U.S. Atomic Energy Commission's six Utah ore buying stations.

scattered across Utah. These facilities were opened (in chronological order) in Monticello, Marysvale, Murray, Moab, White Canyon, and Mexican Hat (Chenoweth, 1990a). Utah's uranium production grew rapidly during the late-1940s and on into the mid-1950s, peaking in 1958 with declining output into the 1960s (Hilpert and Dasch, 1969). By the late 1960s, all of Utah's uranium mines outside of the Colorado Plateau had closed (Chenoweth, 1990a). During this period, roughly 74 million pounds of U_3O_8 were extracted from about 11,000,000 st of ore produced by over 500 individual mines in Utah (Roger Bon, Utah Geological Survey unpublished data, 2005).

A second period of uranium exploration and development began in the early 1970s with the development of the nuclear power industry. This second phase of development resulted in peak production in 1981, but Utah's production during the second boom period only reached about a third of the 1958 peak. Since 1983, Utah's underground ores have had difficulty competing with other lower cost operations, resulting in rapidly declining production through the 1980s. This trend was exacerbated by the discovery of very large, high-grade, near-surface uranium ore bodies in Canada and Australia. By 1990, all of Utah's uranium production had ceased and within a few years there were no longer any underground uranium mines operating in the U.S. Utah has accounted for a total production of roughly 130 million pounds of U_3O_8, mostly from unoxidized ores (Roger Bon, Utah Geological Survey unpublished data, 2005).

The conversion of Russian, weapons-grade, highly enriched uranium (HEU) into low-enriched uranium (LEU) was agreed to by the U.S. and Russia in 1993. This program had converted 150 metric tons of HEU by 2002, and the agreement calls for an additional 350 metric tons to be converted by 2013 (Finch, 2003). Currently the U.S. produces 4% of the world's primary uranium supply while accounting for roughly a quarter of the world's consumption.

The price of U_3O_8 averaged roughly \$12/pound from early 1990 to early 2003 (figure 2). Since then, the price has nearly doubled with the current spot price (April 2005) at \$23.20/pound. In inflation adjusted dollar terms, this is the highest uranium price since the early 1990s. This price movement has encouraged some renewed uranium exploration and development. The most significant recent event in world uranium production is the beginning of construction at the Cigar Lake deposit in the Athabasca basin of Canada. This remarkable deposit hosts a proven reserve of 226.3 million pounds of U_3O_8 at an average grade of 20.67%.

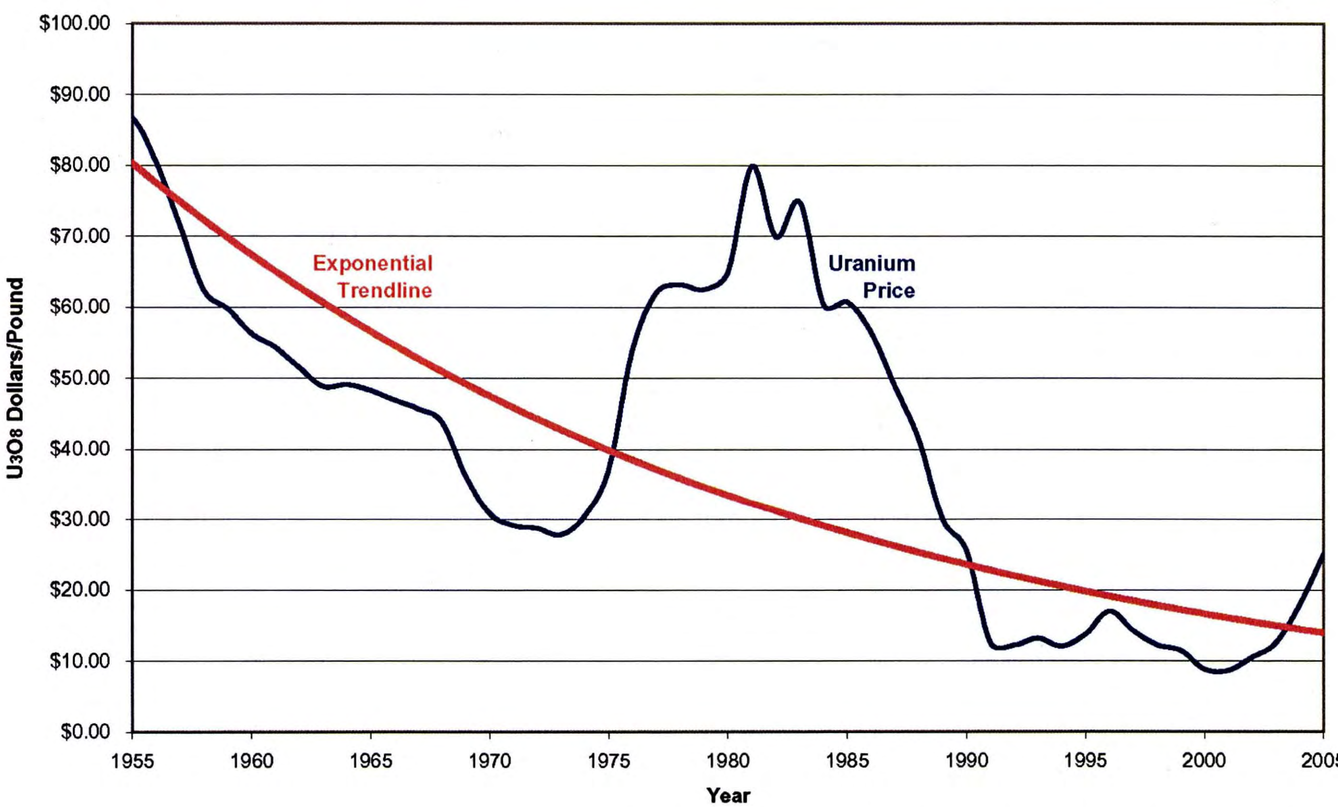

Figure 2. *Graph of the price of uranium oxide over the last half century, adjusted for inflation to 2005 dollars, with a best fit exponential trendline. Data for the years 1955 to 1973 from the U.S. Bureau of Mines yearbooks, 1974 to 1990 average uranium price as purchased by public utilities (W.L. Chenoweth, consulting geologist, written communication, 2005), and 1991 to 2005 the spot price of uranium oxide from the Ux Consulting Company, LLC, 2005, website http://www.uxc.com/review/uxc_g_price.html.*

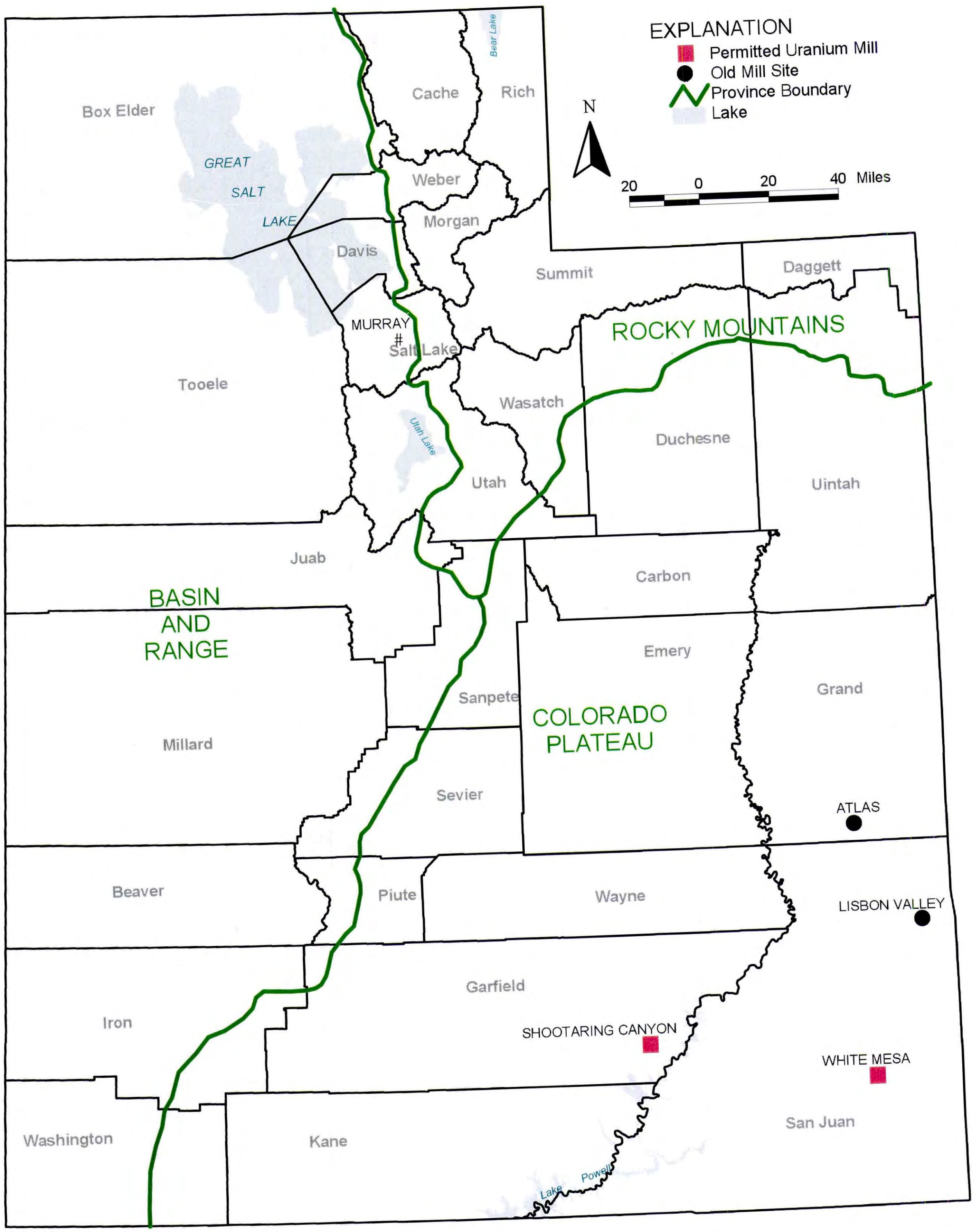

Figure 3. Uranium mills and mill sites with the three primary geological terranes in Utah (after Stokes, 1987).

Currently all Utah's uranium mines are closed and only one of its mills is still operating (figure 3). The Vitro mill site in Murray has been reclaimed. Rio Algom's Lisbon Valley uranium mill is being decommissioned. The Atlas mill and tailings in Moab has been transferred to the U.S. Department of Energy for reclamation. The Shootaring Canyon mill in Ticaboo, owned by U.S. Energy (formerly Plateau Resources), only operated briefly in the early 1980s and is currently on standby status, but is pursuing operating permits and licenses. Utah's lone, active uranium plant is International Uranium (USA) Corporation's White Mesa mill near Blanding, which is currently licensed by the U.S. Nuclear Regulatory Commission for the processing and permanent disposal of low-grade, alternate uranium-bearing feed materials obtained from a site in Maywood, New Jersey. To date, the White Mesa mill has produced 1.1 million pounds of U_3O_8 from these alternate feed materials (Utah Department of Environmental Quality, no date). Regionally, the other permitted uranium mills in the Intermountain West include Cotter Corporation's Canon City Mill in Colorado and Kennecott Uranium Company's Sweetwater mill in Wyoming.

Deposit Types and Mining Methods

Three types of primary uranium deposits account for 70% of the world's production: (1) unconformity-related, (2) quartz-pebble conglomerate, and (3) sandstone-hosted (Nash and others, 1981). The unconformity-related deposits are the largest and highest grade (0.3 to 26% U_3O_8) with the most prominent examples from Canada and Australia (Finch, 1996), for example Cigar Lake. Quartz-pebble conglomerate deposits are the next largest, but the lowest grade (0.04 to 0.2% U_3O_8) with important examples in South Africa and Canada. The sandstone-hosted uranium deposits are the smallest of the three types and the most common in the U.S. Sandstone-hosted deposits typically average 0.1 to 0.6% U_3O_8 (Finch, 1996).

In the last couple of decades, the iron oxide-copper-gold deposits (Olympic Dam) have become important uranium producers in Australia. A cursory literature review suggests that portions of the eastern Uinta Mountains may contain at least some of the characteristics of this class of deposit in Proterozoic-age rocks.

Uranium production in the U.S. during the 1990s shifted from underground mining to the development of (1) in-situ leaching (ISL) deposits in Tertiary sandstone basins in Wyoming, Nebraska, and Texas, (2) by-product production from phosphate operations, (3) milling of stockpiled ore and other alternate feed materials, and (4) mine water treatment operations (in decreasing order of importance). ISL has recently accounted for over half of the U.S. uranium production (Finch, 2003). Some of the sandstone-hosted deposits have been developed with low-cost ISL methods. The criteria for the use of this methodology are:

- The ore body needs to be below the water table.
- Mineralization has to be in a confined aquifer, preferably with pre-existing poor water quality so that it is not usable for drinking water purposes.
- The ore should have a low vanadium content because vanadium may act to tie-up the uranium in insoluble minerals.
- Copper-rich ores may also cause difficulties due to the solubility of copper in acidic solutions.

Most of the currently active ISL deposits are in Tertiary-age sediments, probably due to their high porosity and permeability. The leachate may be either dilute acid or alkali, depending on the local conditions (William L. Chenoweth, consulting geologist, oral communication, 2005).

There are currently no ISL uranium operations in the Colorado Plateau and the Utah deposits overall do not seem to lend themselves to this technology, as it exists today. However, Tertiary sedimentary rocks are known to host uranium-copper occurrences in the Uinta Basin (Castle Peak Draw district) and near Spor Mountain in west-central Utah.

Most of the uranium produced in the U.S. today is a by-product of Florida's phosphate industry. Syngenetic uranium occurring at low concentrations in the phosphate beds is not ore grade by itself, but uranium is recovered as a by-product of the fertilizer operation. In Utah, low-grade uranium has been reported in several phosphatic zones in the Meade Peak Phosphatic Shale member of the Phosphoria Formation of the upper Permian Park City Group (Dasch, 1967). The uranium content of the Meade Peak Member is reportedly directly proportional to the phosphate content and apparently substitutes for calcium in carbonate-fluorapatite (Gulbrandsen, 1960). By-product uranium has also been recovered from the dump leach solutions at the Bingham Canyon copper mine during a period of high uranium prices in the 1980s.

The vast majority of Utah's uranium production has come from sandstone-hosted uranium deposits of the Colorado Plateau. These deposits are typically peneconcordant, both tabular and roll front, vanadium- or copper-rich, and hosted by Permian, Triassic, or Jurassic fluvio-lacustrine channel sandstones developed in intracratonic basins (figure 4). The two most important host rocks are the Upper Triassic Chinle Formation and the Upper Jurassic Morrison Formation (table 1). Mineralization is believed to have formed from circulating, oxidizing, meteoric groundwater and

Table 1.

Generalized Stratigraphy of the Colorado Plateau

Age	Formation/Group	Member	Thickness
Cretaceous	Mancos Shale		+1000 feet
	Dakota Sandstone		100 feet
	Burro Canyon Formation		150 feet
Jurassic	Morrison Formation	Brushy Basin Member	320 feet
		Salt Wash Member*	250 feet
		Tidwell Member	60 feet
	San Rafael Group		500 feet
	Glen Canyon Group		750 feet
Triassic	Chinle Formation	Church Rock Member	300 feet
		Moss Back Member*	100 feet
		Temple Mountain Member	40 feet
		Shinarump Member*	100 feet
	Moenkopi Formation		350 feet
	Hoskinnini Sandstone		50 feet
Permian	Cutler Group		1800 feet
Pennsylvanian	Hermosa Group		3000 feet
	Molas Formation		60 feet

*Major uranium ore host.
Modified from Hintze (1988).

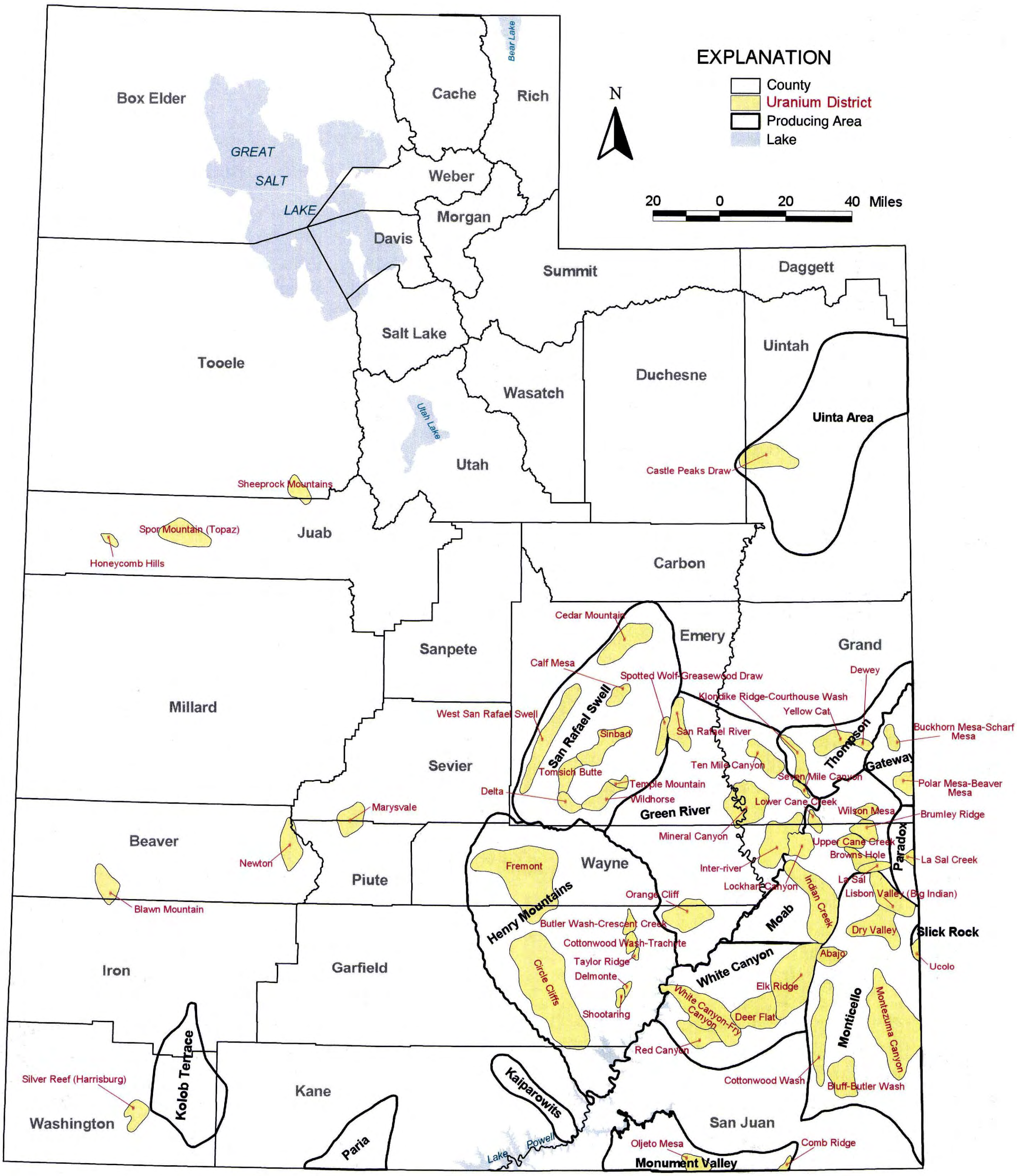

Figure 4. *Outline map of the broad uranium producing areas and uranium mining districts in Utah.*

locally derived diagenetic brines, which precipitate ore by reacting with organic reductants in porous and permeable aquifers. Uranium-vanadium was derived from within the basin soon after deposition of the host strata by leaching of rocks located up paleohydrologic gradient from the deposits (Finch, 1980; Nash and others, 1981; Wanty and others, 1990).

Curiously, the sediment-hosted, collapse breccia pipe uranium deposits found in the Arizona Strip of northern Arizona are apparently unknown in Utah. This is unfortunate because the breccia pipe deposits typically have better grade then the sandstone-hosted uranium deposits, for example 0.43 to 0.65% versus 0.2 to 0.35% U_3O_8, respectively (Finch and others, 1990). The collapse-breccia pipes also typically have over 1% copper. In Utah, there are unmineralized collapse-breccia pipes in the Paradox basin (Huntoon and Richter, 1979), Temple Mountain collapse structures in the San Rafael Swell with minor associated uranium (Gloyn and others, 2003), and the Apex Cu-Ga-Ge breccia pipe southwest of St. George. Although Finch and others (1990) indicate a portion of the southern Cedar City 1° by 2° quadrangle is prospective for undiscovered uraniferous breccia pipes, none are known.

The second most important style of uranium mineralization in Utah is vein-type deposits. The vein-type deposits are of hydrothermal origin, typically associated with felsic igneous activity, and the veins commonly contain fluorite. Examples of uranium veins are present in the Mt. Belknap caldera (Marysvale) area and Thomas Range (Spor Mountain) of western Juab County. Neither area has been an important producer. Other styles of uranium mineralization are present in Utah, such as sedimentary concentrations in phosphatic black shales, but are unimportant, very low-grade, and have not had any production (Hilpert and Dasch, 1969).

POTENTIAL URANIUM RESOURCE AREAS

The prioritization of the areas for the development of new uranium mines in this report was done solely by Robert W. Gloyn in 2004 (figure 5). The following sections were largely originally written by Robert W. Gloyn and the format has been modified to match the Uranium Potential of Utah map by Robert Gloyn and Sharon Wakefield, which accompanies this report as plate 1.

The use of the term "reserves" in this report is somewhat casual in that the Utah Geological Survey (UGS) has not investigated the many factors involved in a strict definition of a mineral reserve. The use of the term "reserves" herein is limited to reserves reported to the UGS by various sources or recorded in the literature and have not been given any additional review by the UGS of their geological, mining, metallurgical, legal, environmental, or economic characteristics which would be required for them to be strictly classified as mineral reserves. In all probability, the vast majority of these reported "reserves" would more accurately be defined as measured, indicated, and/or inferred mineral resources as defined by the Society for Mining, Metallurgy and Exploration, Inc. (1999).

High Potential Areas

Four of the five areas rated as having high resource potential for sandstone-hosted uranium mineralization are clustered together in northeastern San Juan County. Geologically, these four areas are underlain by 5000 feet or more of Pennsylvanian and Permian sedimentary rocks of the Paradox Basin, including thousands of feet of evaporites. Structurally, the sedimentary rocks in the Paradox Basin have been folded and faulted into northwest trending structures. The other area is the Shootaring-Del Monte area in the Henry Mountains structural basin. All of these areas have moderate to large known "reserves."

1. Lisbon Valley – Big Indian District, Monticello Area

Utah's single largest uranium producing area has been the sandstone-hosted deposits of the Lisbon Valley-Big Indian mining district (also known as the Big Indian district) in San Juan County (plate 1). This single district has accounted for roughly 60% of Utah's uranium production (Chenoweth, 1990b). In 1952, Charlie Steen discovered the Mi Vida uranium deposit, the first important mine in the Lisbon Valley-Big Indian district (Gloyn and others, 1995). Geologically, the Lisbon Valley district is dominated by a northwest-trending, doubly plunging anticline, which is faulted along its northeast flank. This fault is a normal fault, down-dropped to the northeast (figure 6). The Lisbon Valley district has copper-dominant ores to the northeast and uranium-dominant ores to the southwest.

The Lisbon Valley-Big Indian uranium deposits lie in an arcuate belt roughly 16 miles long and up to a mile wide along the south and west flanks of the Lisbon Valley anticline. The district extends southeastward from the Rio Algom (Lisbon) mine in the northwest to the unmined Uranez deposit in the southeast, covering parts of T. 29-31 S. and R. 24-26 E. Mineralization is strongest in the northern six miles and southern five miles of this belt. In between these two segments, the main host strata are either thin or missing. The northern and southern segments of the mineral belt have accounted for 43 million pounds and nearly 24 million pounds of the district's U_3O_8 production, respectively. All of the mining in the district has been

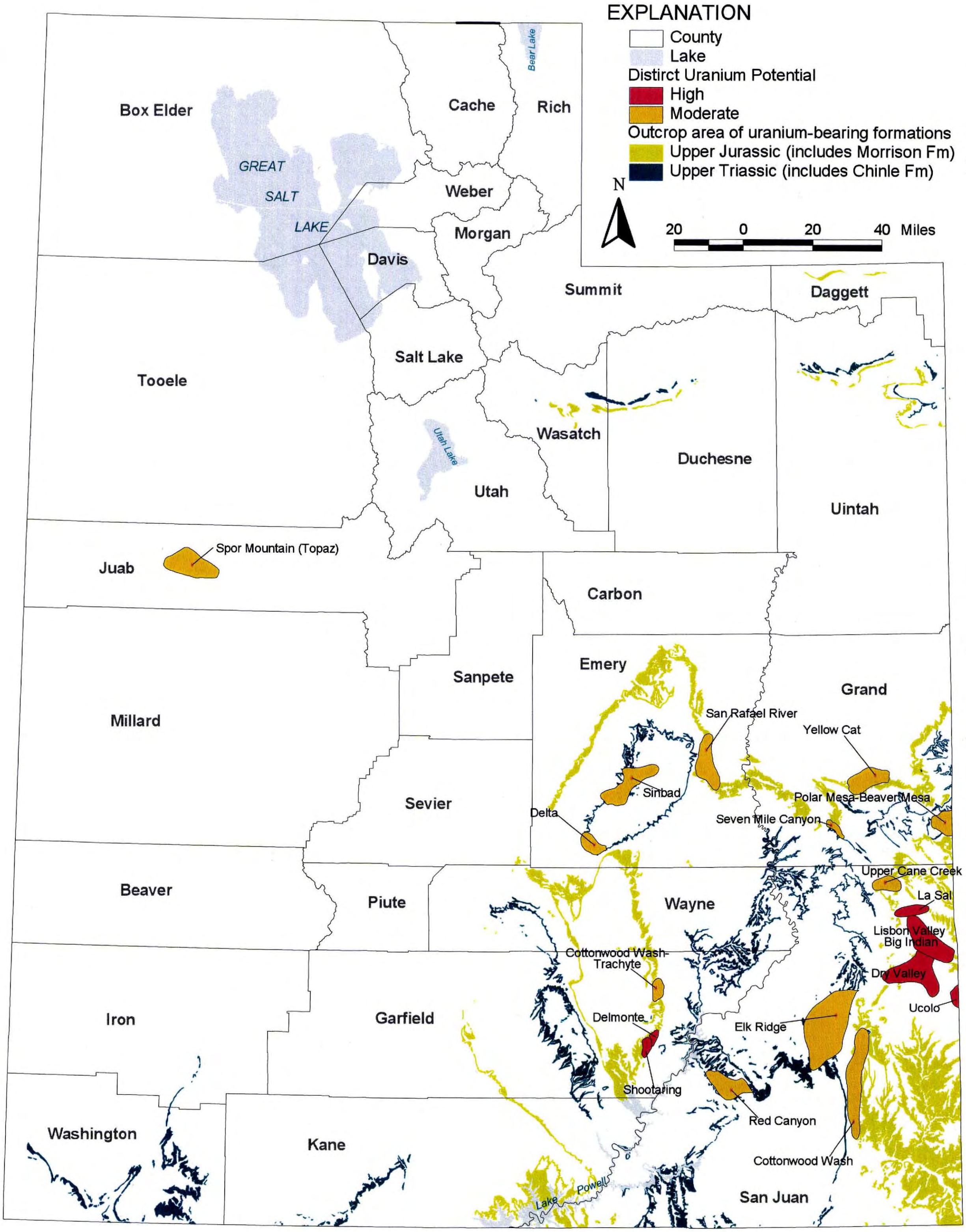

***Figure 5.** Mining districts with the best uranium potential (as defined by R.W. Gloyn in 2004). The generalized outcrop patterns of the major uranium host strata are shown for reference (Hintze and others, 2000).*

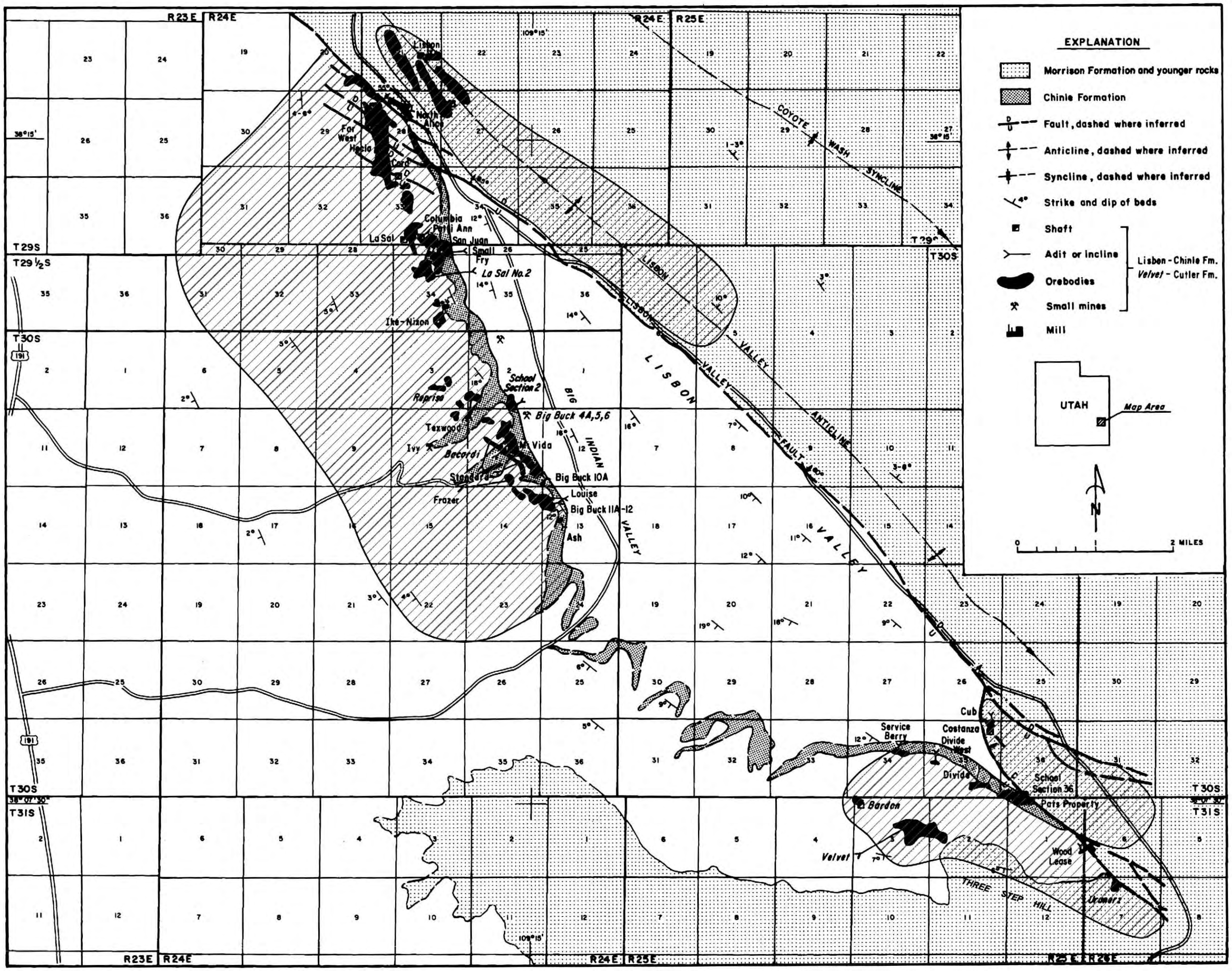

Figure 6. Lisbon Valley anticline showing the uranium mines, ore bodies, and prospective areas (hachured), San Juan County (modified from Wood, 1968).

by underground methods (Chenoweth, 1990b).

Individual ore deposits within the Lisbon Valley-Big Indian mining district range in size from 500 to 1,500,000 st of ore. The deposits are amoeba shaped in plan, a few inches to 45 feet thick (averaging 6 feet), sandstone hosted, and concordant with bedding (Chenoweth, 1990b). The deposits are typically hosted in the basal member of the Triassic Chinle Formation. This member is 13 to 80 feet thick and rests with slight (two to six degrees) unconformity upon the Permian Cutler Group sandstone. The host is a fluvial, cross-bedded, calcareous, arkosic sandstone containing woody trash material (Wood, 1968). The principal ore mineral is uraninite with lesser coffinite and a variety of vanadium-bearing minerals. The ore minerals typically occur intergranularly in the sandstone. The Lisbon Valley-Big Indian district deposits have averaged 0.3% U_3O_8 (Chenoweth, 1990b).

Production: The Lisbon Valley district is Utah's largest uranium district. Between 1948 and 1988 when the Lisbon mine and mill ceased operation, the district produced 77,913,500 pounds of U_3O_8 from approximately 12,778,500 st of ore (Chenoweth, in press). Peak production was in 1959 with approximately 6,690,000 pounds of U_3O_8 being produced from 640,000 st of ore. Annual production grades ranged from 0.15 to 0.47% U_3O_8 (Chenoweth, in press). Annual vanadium grades from 1948 to 1966, based on assays by the AEC, ranged from 0.10 to 1.10% V_2O_5 (Chenoweth, 1990b). However, only minor amounts of vanadium were recovered because the Moab mill did not add a vanadium circuit until 1967 and the Lisbon mill only began operating in 1972. Between 1978 and 1984, the Moab mill recovered about 5,760,000 pounds of V_2O_5 from Lisbon Valley ores. Most of the ore mined between 1955 and 1971 was processed at the Moab (Atlas) mill. Ore mined between 1972 and 1984 was processed at the Moab mill and at the Lisbon mill of Rio Algom, a mine-mouth mill. The Atlas mill shut down in March 1984, but the Lisbon mill continued operating until 1988.

Production has primarily been from the Triassic Chinle Formation (92%) with lesser production from the underlying Permian Cutler Formation (8%). Major Chinle-hosted uranium mines in the district are tabulated below along with their cumulative productions (in pounds of ore):

Lisbon (Rio Algom)	>13,000,000
Mi Vida	12,300,000
Hecla	>7,369,000
Far West	4,837,800
North Alice	4,500,000
San Juan-Small Fry	>3,117,000
Standard-Big Buck 9-9A	>3,046,300
Ike-Nixon	2,734,000
Louise-Big Buck 11A-12	1,942,000
Columbian-PattiAnn	>1,697,000
School Section 36-Pats Property (Continental)	688,000
La Sal	460,000
Divide-Yellow Jacket	339,400

Major Cutler-hosted mines or deposits and their cumulative productions (in pounds of ore) follow:

Velvet	4,200,000
Bacardi	1,153,000
School Section 2	380,000
Reprise	295,000
Bardon	275,000
La Sal No 2	45,000
Big Buck 4A, 5, and 6	7000

Various companies obtained federal and state mine permits for several Chinle-hosted mines; these permits have been relinquished. Mines permitted by Energy Fuels Nuclear include Patti Ann, Farr West, Wood, Standard II, Mi Vida, and Ivy. Mines permitted by Homestake Mining include North Alice, La Sal # 1, La Sal # 2. Mines permitted by W.K. Enterprises include Louise, Standard I, and Big Buck/Idle Day. Other past permitted mines include Cub (Kelmine Corporation), South Lisbon (Mineral Recovery Corporation), Small Fry (Molycorp Inc.), and Wood Complex (U.S. Energy Corp).

Reserves: The Lisbon Valley district has a large "reserve" base, although at a moderate average grade (0.21% U_3O_8). The following "reserves" are mostly from Atlas Minerals (Atlas Minerals, 1987). "Reserves" are circa 1987-1988 and most are probably still unmined. Where known, the reserve classification is shown. (top of next page)

Ore Deposits: Major uranium deposits in the Lisbon Valley district occur in two stratigraphic units: the "lower member" of the Upper Triassic Chinle Formation (originally thought to be equivalent to the Moss Back Sandstone Member but recently shown to be younger) and the lower Permian Cutler Formation. Over much of the district, the Triassic Moenkopi Formation is missing and the Chinle unconformably overlies the Cutler Formation.

The Chinle-hosted deposits are irregular, amoeba-shaped masses, generally concordant with bedding in gray, poorly sorted, calcareous, arkosic mudstone with interbedded mudstone, siltstone, and lime-pebble conglomerate. According to Chenoweth (in press), there is an abundance of mudstone pebbles and coalified wood-trash either directly in ore or overlying the ore-bearing host rock. Individual deposits range in size from 500 to 1,500,000 st and in thickness from a few inches to 45 feet with an average deposit thickness of six feet.

The Chinle deposits are confined to a narrow belt approximately one mile wide and are concentrated in a six-mile-long northwestern area with large coalesced

Cutler-hosted deposits:

Velvet mine: N½ section 2 and 3, T. 31 S, R. 25 E.	70,850 st @ 0.410% U_3O_8, 0.573% V_2O_5 Geologic-measured, indicated, and inferred
Bacardi mine: SW? section 11, T. 30 S., R. 24 E.	4800 st @ 0.120% U_3O_8, minimal V_2O_5 Geologic inferred
Reprise mine: SW? section 3, T. 30 S., R. 24 E.	29,950 st @ 0.087% U_3O_8, minimal V_2O_5 Geologic inferred
Uranerz deposit: NE? section 7, T. 31 S., R. 26 E.	2.5 million pounds U_3O_8 (Chenoweth, 1990b) Rumored grade 0.30% U_3O_8, 0.40% V_2O_5

Chinle-hosted deposits:

Ivy mine: section 10, T. 30 S., R. 24 E.	61,500 st @ 0.080% U_3O_8 Geologic inferred
Patti Ann mine: SE? section 32, T. 29 S., R. 24 E.	111,700 st @ 0.084% U_3O_8 Geologic inferred
Far West mine: section 28, T. 29 S., R. 24 E.	36,800 st @ 0.125% U_3O_8
Louise mine: section 13 and 14, T. 30 S., R. 24 E.	8000 st @ 0.26% U_3O_8
Lisbon: section 21 and 22, T. 29 S., R. 24 E.	Approximately 200,000 st @ 0.10-0.12% U_3O_8, Rio Algom deposit (Rio Algom, verbal communication, 2004)

Atlas subsequently made a later estimate lumping several of the above mines and including additional "reserves" (Jagoe, 1988):

- North Lisbon: 240,000 st at 0.09% U_3O_8, likely includes Farr West and Patti Ann "reserves" and possibly also "reserves" from Columbia, San Juan, La Sal, and Hecla mine, sold to Energy Fuels, and
- South Lisbon: 4800 st at 0.12% U_3O_8, likely includes "reserves" from Louise, Standard, Big Buck and others, Sold to WK Enterprises.

deposits and a five-mile-long southeastern area of scattered deposits (figure 6). The favorable lower member of the Chinle has been eroded in a five-mile-long portion between the two areas. The northern area contains a northern and southern cluster of multiple deposits separated by a two-mile-long zone with scattered deposits. The northern cluster has produced over 40 million pounds of uranium and the southern cluster has produced over 23 million pounds of uranium. Only 4.5 million pounds was produced in the area between these two clusters (Chenoweth, in press).

Primary ore consists of uraninite with minor coffinite and the associated vanadium minerals montroseite, doloresite, and vanadium clay. Sulfides include pyrite with very minor galena, chalcopyrite, and greenockite. The ore minerals fill interstices between sand grains but also replace calcite and/or plant material and to a lesser extent detrital quartz and feldspar grains.

The Cutler-hosted deposits occur within fluvial sequences consisting of alternating beds and lenses of pink, orange, and buff mudstone, calcareous siltstone, and arkosic sandstone. The sandstone host units are well sorted, fine to medium grained and as much as 50 feet thick. The uranium-bearing sandstones contain less calcite, more clay, and are slightly coarser grained than the non-ore sandstone. Carbonaceous material does not seem to be important. The Cutler-hosted deposits are generally within 6 feet of the unconformity although some ore has been found 40 to 100 feet below the unconformity. Most of the ore-bearing Cutler is bleached, with the thickness of bleaching related to the thickness of permeable units. The proximity of ore to the unconformity and the bleaching below the unconformity suggests that the unconformity acted as a channel-way for ore fluids.

The Cutler-hosted deposits are apparently not confined to a narrow belt. Although some deposits do occur below Chinle deposits (Bacardi, School Section 2), many, particularly in the southern part of the district, are several miles from the Chinle deposits. Ore thicknesses range from 2 to 9 feet with grades of 0.10 to over 5.00% U_3O_8 with the thicker and better grade portions within sandstone channels.

Primary ore consists of uraninite and coffinite and much of the uranium is associated with iron oxides as coatings and within the matrix. The ores contain significant vanadium but the vanadium minerals, while not identified, are most likely montroseite and vanadium clays.

Potential: There is limited potential for Chinle-hosted uranium deposits in the district. The favorable belt on the southwest side of the Lisbon anticline has been extensively drilled to the north, south, and downdip to the southwest with discouraging results. The intensity of previous drilling precludes the discovery of new deposits in this area. In addition, the remaining "reserves" noted above are all relatively low grade with little associated co-product vanadium. It is unlikely that such deposits would be economic at current prices even if the workings needed no rehabilitation.

A slightly better, but still low, potential area for Chinle-hosted deposits is on the northeast side of the fault. Substantial drilling in the area failed to discover any additional deposits, but the drill density was likely less than on the southwest side and small deposits could be present. The remaining low-grade "reserves" at the Lisbon mine (200,000 st at 0.10% U_3O_8) are not accessible because the access shaft has been closed and reclaimed. Drilling depths would be about 2000 feet.

An additional potential Chinle area is southwest of the Cub mine between the two strands of the Lisbon fault in section 36, T. 30 S., R. 25 E., S½ section 31, T. 30 S., R. 26 E., NE¼ section 1, T. 31 S., R. 25 S. and section 6, T. 31 S., R. 26 E. Shallow Chinle mineralization is present south of the Cub mine and several deep, mineralized Chinle holes have been reported south and east of section 36, T. 30 S., R. 25 E. Better potential is found in the northern part of section 36 where the Chinle is shallower (1200 to 1700 feet).

Better potential exists for Cutler-hosted deposits; the known "reserves" are better grade and contain by-production vanadium, the deposits are not restricted to a narrow belt (creating a larger target area) and the potential areas are less thoroughly tested. Potential exists all along the southwestern side of the Lisbon anticline although the downdip potential could be limited geologically by the presence of the Moenkopi Formation between the Chinle and the Cutler Formations and economically by drilling and mining depth cutoffs. Most of the area south of the Chinle outcrop in the Velvet mine area has been well tested by drilling but areas to the east of the west strand of the Lisbon fault in section 36, T. 30 S., R. 25 E., NE¼ section 1, T. 31 S., R. 25 E. and section 6, T. 31 S., R. 26 E. may have some untested potential. Other areas with potential are along the northwest trending belt from section 31, T. 30 S., R. 25 E. to section 18, T. 29 S., R. 24 E. Particularly favorable areas are downdip from the northern "Chinle cluster" and the southern "Chinle cluster."

Some of the known deposits (Velvet, Uranez) may have sufficient "reserves" or grade to be considered minable under highly favorable conditions of increased price and demand, and could be considered for possible acquisition. Current ownership is not known but the latest record from the Utah Division of Oil, Gas and Mining (DOGM) showed that the Velvet was controlled by U.S. Energy Corporation of Riverton, Wyoming.

2. La Sal District, Moab Area

The La Sal district is located in northern San Juan County (Plate 1) north of the Lisbon Valley district and contains a number of significant, underground, past producers located along an east-trending channel trend in the Morrison Formation. The La Sal zone extends from just south of La Sal Junction to about 5 miles east of La Sal, a distance of about 12 miles, straddling the boundary between T. 28 S. and T. 29 S. Most of the mines were discovered by drilling and are at depths of 500 to 800 feet. The production has been from these trends and some workers designate it as a separate district, the La Sal-La Sal Creek district (Thamm and others, 1981). The La Sal district lines up with the La Sal Creek district of the Paradox area of Utah and Colorado. The two areas are separated by the collapse structure along the Pine Ridge salt anticline. Mineralized Salt Wash sandstone is present in this collapse zone but is highly fractured and disrupted with spotty and discontinuous ore. The La Sal district also includes a northeast-trending channel containing the Rattlesnake deposit in the western part of the belt, mostly in the northeastern part of T. 29 S., R. 23 E. Very little has been written about deposits in this area; a short article by Kovschak and Nylund (1981) is the best available reference.

Production: The La Sal district has been a significant uranium and vanadium producer with remaining "reserves" at many mines. Major production in the La Sal district began in 1954 and continued until the early 1990s. Early production (1954 to 1970) was from the Rattlesnake mine. Drilling in the late 1960s and early 1970s revealed a number of concealed ore bodies north and east of the Rattlesnake mine. Mining began on these deposits in 1973 and continued until 1989.

Thamm and others (1981) estimated production for the La Sal-La Sal Creek district through 1978 at 989,000 st of ore containing 6,426,000 pounds of uranium. If the estimated production from the La Sal Creek district for this period is subtracted from this total, then the production from the La Sal district through 1978 is about 590,000 st at an average grade of 0.32% U_3O_8 and 1.46% V_2O_5, equivalent to 3.78 million pounds U_3O_8 and 17.3 million pounds V_2O_5. Post-1978 production is difficult to estimate because few uranium or vanadium production records are available. Mine files at the DOGM indicate that the Pandora mine operated intermittently to 1991, the La Sal mine from 1979 to 1990, and the Hecla mine from 1979 to 1983. The files show the tonnage of material moved, but do not give uranium or vanadium grades and often combine both ore and waste. Between 1979 and 2004, the La Sal district produced an estimated

650,000 st of ore containing 2,706,000 pounds U_3O_8 and 15,209,000 pounds V_2O_5. These numbers were calculated using DOGM tonnages assuming that 40 percent of the combined ore and waste was ore, and estimated uranium and vanadium grades from the Atlas reserve numbers. The 1987 Minerals Yearbook (U.S. Geological Survey) reported that Umetco began mining at the La Sal mine in 1986 and produced 4.8 million pounds U_3O_8 and 2.8 million pounds V_2O_5 in 1986. These numbers are in error; not only is the production excessive but the uranium to vanadium ratio does not fit with La Sal district ores. Most likely, the number represents uranium and vanadium recovered from ore milled at the White Mesa mill, some of which came from the La Sal mine, but most of which came from operations in northern Arizona. Total production from the La Sal district to 2004 is estimated at 1.24 million st of ore containing nearly 6.5 million pounds U_3O_8 and 32.5 million pounds V_2O_5.

Major deposits in the La Sal district from west to east include the Sunset, Rattlesnake, U.C.C.-Hecla, Redd Block, Beaver (western part of La Sal deposit), La Sal, Mike, Snowball, Pandora, "East Pandora," and an unnamed prospect in sections 4 and 5, T. 29 S., R. 25 E. (figure 7). There has been only limited mining on the Hecla deposit. The Redd Block and "East Pandora" deposits are undeveloped. Adits have been driven into the unnamed deposit in sections 4 and 5, but apparently little mining has been done.

The following mines produced the bulk of the ore (estimated):

Rattlesnake	294,800 st ore; 1,652,200 pounds U_3O_8, 4,950,000 pounds V_2O_5
La Sal-Snowball-Beaver	425,500 st ore; 1,698,000 pounds U_3O_8, 10,188,000 pounds V_2O_5
Pandora	400,000 st ore; 1,760,000 pounds U_3O_8, 9,200,000 pounds V_2O_5
U.C.C.-Hecla	24,500 st ore; 122,500 pounds U_3O_8, 392,300 pounds V_2O_5

Permitted mines (now inactive) include Pandora, La Sal, Snowball, Hecla shaft, Redd Block Four, Sunset, Pine Ridge #1, and Red Rock. Most are currently held by International Uranium (USA), Inc.

Reserves: Significant "reserves" exist at several mines in the trend and additional ore bodies are known or inferred in the trend but have insufficient drilling data to calculate reserves. Several reserve estimates are available: an earlier Atlas Mining Company estimate (Jagoe, 1983) and a later one by International Uranium, Inc, (Terry Wetz, written communication, 2003). A fourth estimate based on data from Energy Fuels Nuclear indicated resources, circa 1994, just on SITLA land.

<u>Atlas Minerals:</u>

La Sal	750,000 st at 0.20% U_3O_8, 1.25% V_2O_5; Jagoe, 1983
Pandora	289,200 st at 0.218% U_3O_8, 1.10% V_2O_5; Atlas Minerals 1987 (Geologic 300,158 st at 0.227% U_3O_8)
Hecla	200,000 st at 0.22% U_3O_8, 0.75% V_2O_5; Jagoe, 1983

International Uranium:

Resource data compiled from Terry Wetz, International Uranium (letter dated June 16, 2004) for the Pandora, La Sal-Snowball, La Sal Trend (including Redd Block Four) and Hecla Joint Venture ore bodies is 980,000 st at 0.214% U_3O_8 and 1.06% V_2O_5.

<u>SITLA:</u>

Data from Energy Fuels Nuclear (1994) in SITLA files:

Lease 24092 (partial section 5, Hecla)	97,700 st at 0.25% U_3O_8, 0.81% V_2O_5
Lease 18301 (section 36, east La Sal)	75,200 st at 0.17% U_3O_8, 1.10% V_2O_5
Lease 23549 (partial section 36, Hecla)	58,500 st at 0.16% U_3O_8, 0.93% V_2O_5
Lease 27248 (W2 section 2, SW La Sal)	8,000 st at 0.26% U_3O_8, 1.08% V_2O_5
Lease 27247 (W2 section 35, NW La Sal)	7,000 st at 0.19% U_3O_8, 0.70% V_2O_5

Ore Deposits: Uranium-vanadium deposits in the La Sal district occur as both tabular and roll-type ore bodies. The tabular ore bodies occur throughout the belt, but abundant roll-type deposits apparently are concentrated in the central part of the belt around the La Sal-Snowball mines. Kovschak and Nylund (1981) noted that the deposits in the central part of the belt are "atypical in that they are composed of a high percentage of 'roll ore'" and that the locations of the rolls show no relationship to interbedded shales, a common feature in the Uravan mineral belt.

Deposit shapes are also atypical. Within the overall east-west belt, the deposits show a strong linear trend as compared to the more amoeboid-shaped ore

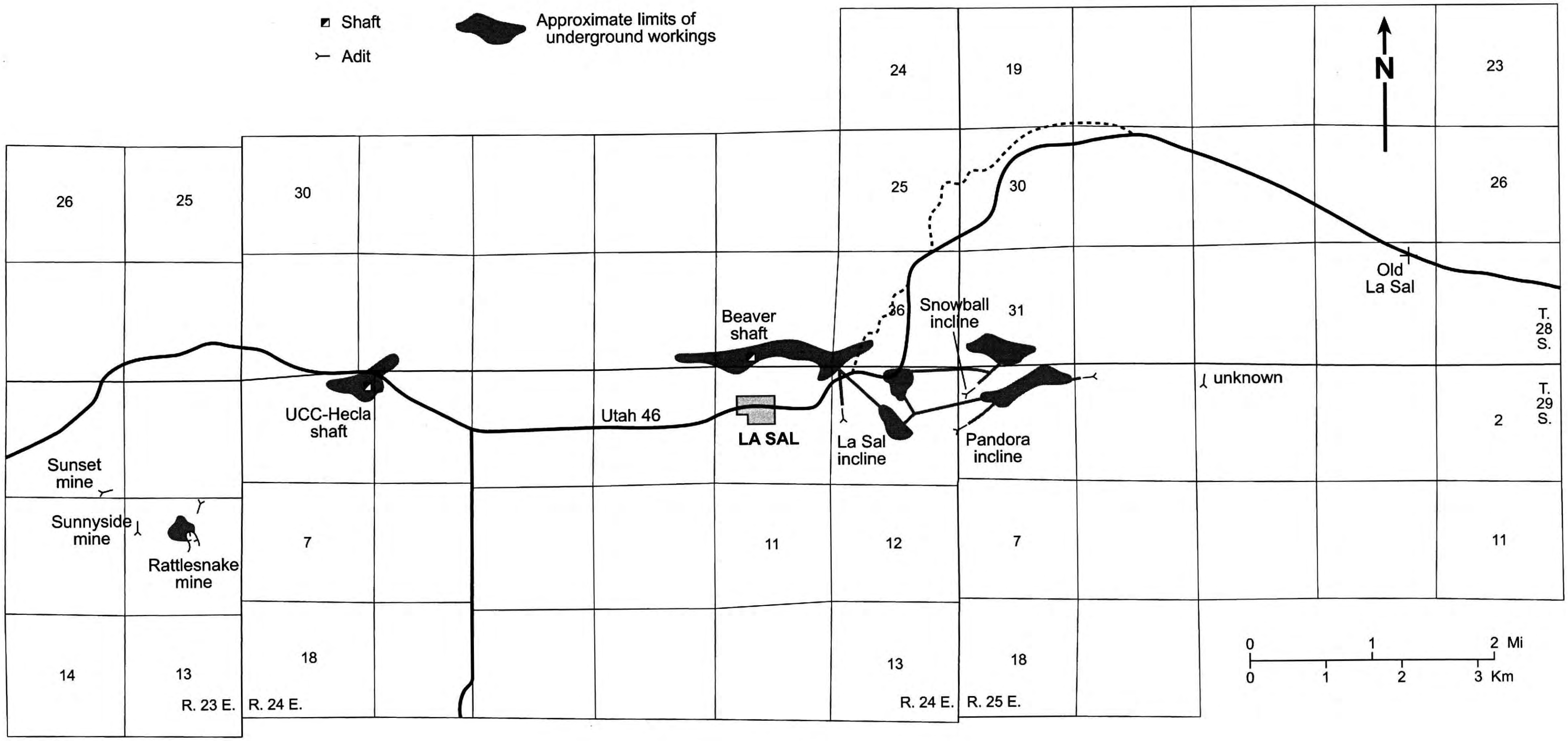

Figure 7. Major mines and the extent of mine workings, La Sal district, Moab district, San Juan County, Utah.

bodies of the Uravan mineral belt and Ucolo district. However, ore pods at the Rattlesnake mine are less linear and have more typical amoeboid shapes. In the main trend, the distribution of underground workings suggests that individual ore pods are 60 to 350 feet wide, 150 to 1200 feet long, and cluster into areas 1500 to 2000 feet wide and up to 5000 feet long (La Sal mine). Most ore pods are aligned N. 80° W. to N. 70° E., but several, including the Mike deposit, trend N. 30-50° W. and are thought to represent meander bends. In the Rattlesnake mine, average ore pods are 30 feet wide, 100 to 150 feet long, and cluster into areas 200 to 400 feet wide and 500 to 1000 feet long. "Rattlesnake ore pods" generally trend northeasterly, but a stoped area in the northern adit trends northwesterly.

The La Sal deposits are also atypical in that ore is present at several different horizons in the Salt Wash Member of the Morrison Formation. Cross sections in Kovschak and Nylund (1981) show up to five separate ore horizons in a single drill hole, with most drill holes having at least three separate ore intercepts. In the western part of the trend, near the Hecla mine, most ore intercepts are in the lower 25 to 30 feet of the channel, but to the east (Pandora, La Sal, Beaver mine areas), the ore zones are distributed throughout the entire Salt Wash section. At the Rattlesnake mine, two ore zones were mined; both were in the upper part of the Salt Wash Member and were separated by 20 feet of barren sandstone. In the main belt, the ore zones range from less than 2 to over 13 feet thick with most ore zones 3 to 5 feet thick. In the Rattlesnake mine, the ore is less than 1 to over 20 feet thick. Average grades for mineralized zones range from 0.02 to 1.12% U_3O_8. Initial reports on the Rattlesnake mine reported grades of 0.75 to 1.0% U_3O_8, but the average mine grade was significantly lower.

The La Sal deposits are confined to the Salt Wash Member and occur over a distance of nearly 12 miles within a 1.5- to over 2-mile-wide channel trend and in a shorter northeast-trending channel containing the Rattlesnake deposit (figure 8). Individual channel sandstones average 40 to 50 feet thick and are generally separated by thin mudstones or scour zones. However, in the central part of the main trend, near the town of La Sal, several channels coalesce to form thick sandstone bodies up to 120 feet thick, over 1 mile wide, and several miles long. These thicker sandstones host the La Sal, Snow, and Pandora ore bodies. Kovschak and Nylund (1981) also report that channel trends are more regular in the western end of the trend (Hecla area?) and bifurcate into multiple channels at the eastern end. Kovschak and Nylund believe the "La Sal channel" represents the junction of two main channels; a northeast-trending channel containing the Rattlesnake deposit and an east-trending channel extending eastward from La Sal Junction and containing most of the other deposits. They believe that the La Sal channel is a major trunk or distributary channel to the finer-grained, braided-stream deposits of the Uravan mineral belt to the east. The host sandstones in the La Sal district are similar to other Salt Wash sandstones, but are coarser grained (medium to coarse grained vs. typical fine to medium grained), are thicker, and have a more linear trend. The host sandstones are relatively homogeneous, reduced gray sandstones. Underlying mudstones are greenish-gray in contrast to the more normal red-brown color away from ore. Carbonaceous material is present, but apparently is of minor importance in localizing ore. Most of the known uranium deposits occur along the southern margin of the channel where gray channel sandstones interfinger with red and pink sandstones and mudstones. Kovschak and Nylund (1981) stated that only small isolated uranium intercepts were found by drilling in the northern and central part of the channel.

Nearly all of the deposits are primary, unoxidized ores and occur at depths of 500 to 800 feet or more; the only oxidized deposits are at the Rattlesnake pit and several miles to the east in the La Sal Creek district. Unoxidized ore consists of uraninite, coffinite, montroseite, and vanadium clays. Oxidized ore consists of carnotite, tyuyamunite, and vanadium clays with minor hewettite and corvusite. Unoxidized ore coats detrital grains and fills void spaces and replaces some detrital quartz and feldspar. Oxidized ore occurs as void fillings and grain coatings, but also as coatings along fractures and joints particularly in the southern part of the Rattlesnake pit. Some secondary ore is extremely rich with spots of almost pure carnotite. Carbonaceous material does not appear to be important in most deposits, although Weir and Puffett (1981) reported that at the Rattlesnake mine, uranium concentrated in and around plant remains and was associated with clay pebbles and galls. Although not previously noted in the literature, there appears to be a regional gradation in vanadium content with higher vanadium ore bodies in the eastern part of the main trend.

Potential: The La Sal district has potential for uranium and vanadium production and discovery of additional reserves. Known "reserves" for four areas in the belt total nearly 1 million st of ore at a low average grade of 0.22% U_3O_8 and 1.06% V_2O_5. Additional mineralized areas are known, but have not been assigned any reserves (figure 8). Several additional areas not shown on figure 8 have exploration potential; high potential areas are north and east of the Pandora deposit (section 32 and 33), east of the "Section 4-5 deposit" (north half of sections 3 and 4), north and east of the Rattlesnake mine (sections 1 and 6), and the western end of the trend (southern parts of sections 34, 35, and 36). These trends have undoubtedly been partially drilled in the past, but results are not known. Any "reserves" in these areas would not be included in the Atlas or International Uranium "reserves" (see above)

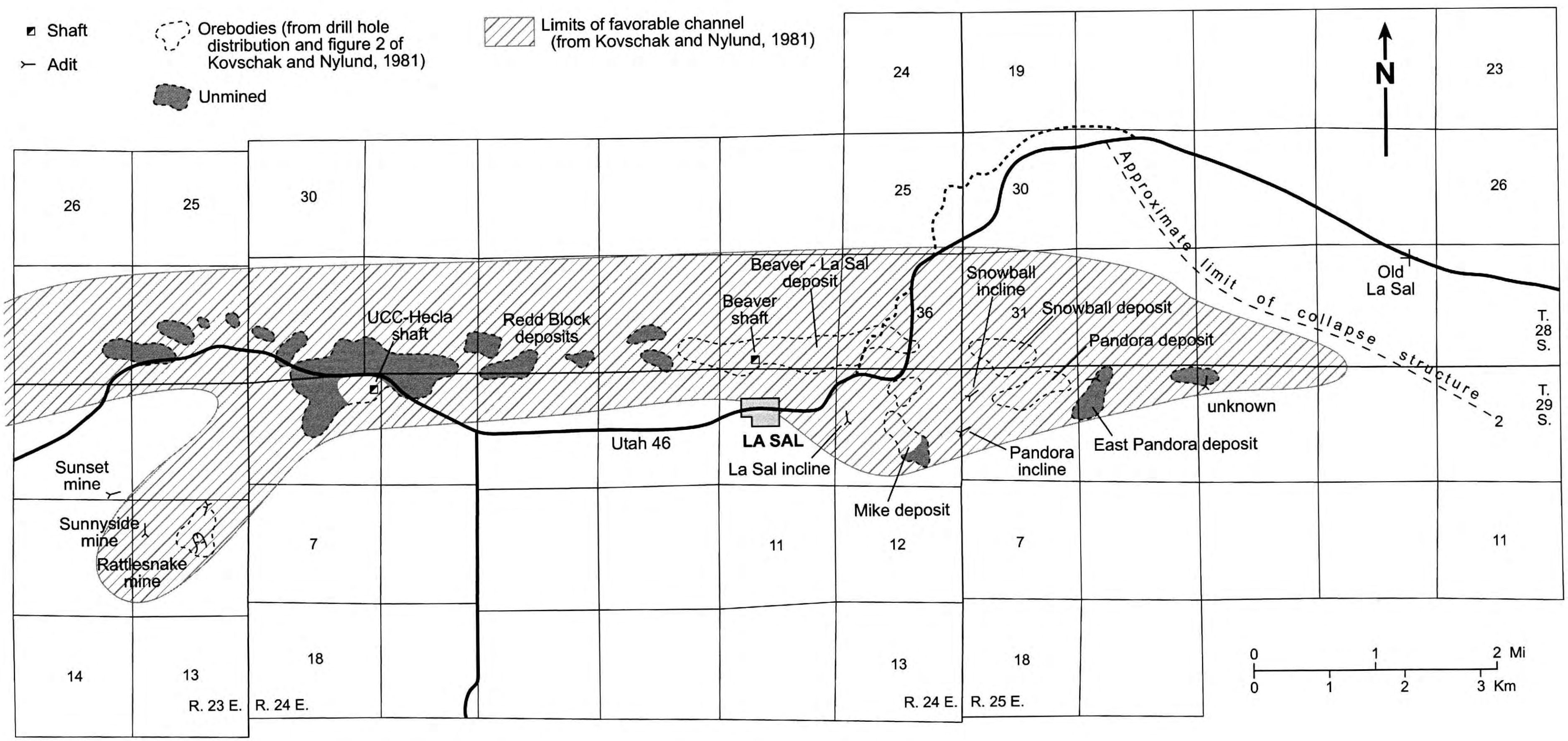

Figure 8. Major mined and unmined ore bodies and limits of favorable channel trend, La Sal district, Moab area, San Juan County, Utah.

because they did not control these areas. The northern part of the trend also has some potential for smaller, less continuous deposits; apparently some ore was found by drilling, but was not developed because it was lower grade and more scattered compared to the southern area.

The district has good potential for development with increased uranium and vanadium prices. It is logistically favorable; it is close to major roads with flat to gentle rolling topography and is less than 60 miles via good roads from the White Mesa mill. The deposits are at reasonable depths (600 to 900 feet), have moderate average grades, and contain continuous ore horizons. Most of the workings have been reclaimed and both the La Sal and Pandora inclines would require significant rehabilitation before they could be reopened. The mines are probably wet and would require pumping. In addition, there is a heavy clay zone in the overlying Brushy Basin that is prone to caving and apparently created serious problems in the declines.

DOGM Permitted Mines	Location	Operator
Pandora	section 1, T. 29 S., R. 24 E.	International Uranium
La Sal	section 31, T. 28 S., R. 24 E.	International Uranium
Snowball	section 31, T. 28 S., R. 24 E.	International Uranium
Hecla Shaft	section 5, T. 29 S., R. 24 E.	International Uranium
Redd Block Four	section 33, T. 28 S., R. 24 E.	International Uranium
Red Rock mine	section 27, T. 28 S., R. 23 E.	S & S Mining Co. (local)
Sunset mine	section 2, T. 29 S., R. 23 E.	Umetco
Pine Ridge #1	section 4, T. 29 S., R. 25 E.	WesternStates Resources
Pine Ridge #1-4	section 4, T. 29 S., R. 25 E.	Continental Minerals, Inc.

3. Shootaring-Del Monte Districts, Henry Mountains

The Shootaring (Shitamaring)-Del Monte districts lie in the Little Rockies section of the Henry Mountains in Garfield County (Plate 1). The uranium-vanadium deposits in the Henry Mountains occur in the Jurassic Salt Wash Member of the Morrison Formation. Mineralization is peneconcordant and associated with carbonaceous trash, fossil wood, and mudstone lenses in the fluvio-lacustrine sandstone host rocks (Wanty and others, 1990).

Production: During the 1950s, 1960s, and 1970s, some 130 mines in the Henry Mountains produced 79,500 st of ore averaging 0.3% U_3O_8 for a total production of about 474,500 pounds plus an additional 1,694,100 pounds of V_2O_5 through 1978 (Chenoweth, 1980). The majority of the deposits (98%) occur along a northerly trending exposure of the Morrison Formation on the east flank of the Henry structural basin, known as the Henry Mountains mineral belt.

Reserves: Some larger, lower-grade resources were discovered in the Little Rockies section of the mineral belt in the late 1970s and have been partially developed. The largest of these discoveries was the Tony M. deposit, which has 3 miles of underground workings. These newer, low-grade resources have seen only very limited production; about 43,300 st of ore, averaging 0.08% U_3O_8, was put through the 750-ton/day Shootaring Canyon mill (completed in 1980) at Ticaboo in the early 1980s (William L. Chenoweth, consulting geologist, oral communication, 2005). Gloyn (written communication, 2004) reports that the Tony M. produced 294,565 st of ore and 275,818 st of waste between 1979 and 1983, suggesting that the Tony M. stockpile holds 251,265 st of ore.

The International Uranium Company (IUC) acquired the Utah state section at the Tony M. mine for $1 million and acquired the unpatented claims over the deposit in the Henry Mountains in early 2005 (figure 9). IUC lists the following inferred mineral resources at the Tony M. and adjoining Bullfrog properties (http://www.intluranium.com/data/050307.pdf):

Deposit	Size (tons)	Grade (% U_3O_8)	Resource (pounds U_3O_8)
Tony M. mine[1]	3,549,000	0.15	10,898,000
Bullfrog			
Southwest	461,000	0.32	2,906,000
Copper Bench	1,009,000	0.31	6,184,000
Indian Bench	468,000	0.41	3,834,000
Subtotal	1,938,000	0.33	12,924,000
Total	5,487,000	0.22	23,822,000

[1]These numbers probably include the Frank M. resource and various other sources have suggested slightly higher grades and significantly fewer tons, for example, Kreidler (1984) suggest 6,000,000 pounds.

Ore Deposits: The Henry Mountain mineral belt has been divided variously, although typically into three

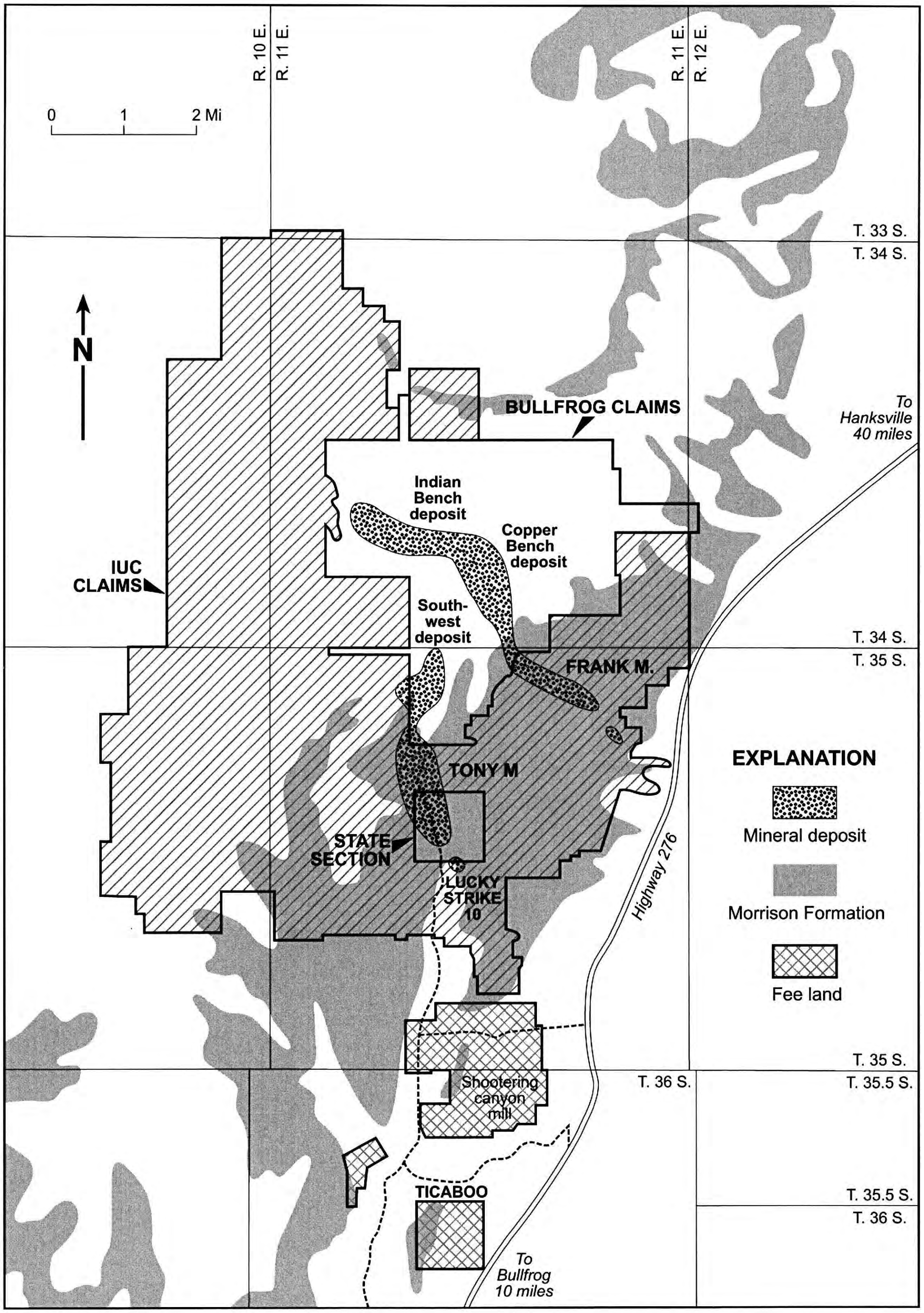

Figure 9. *Generalized map of the Bullfrog-Tony M. portion of the Shootaring-Del Monte mining districts in the southern Henry Mountains area, Garfield County. The map shows the approximate outline of the exposed Morrison Formation, which dips gently to the west, and the surface projection of the known uranium deposits (proprietary company data).*

sections, from north to south: North Wash (Butler Wash and North Wash), Trachyte (Woodruff Springs to North Wash-includes Woodruff, Taylor Ridge, Trachyte Creek, and Cottonwood Wash), and Little Rockies (Lost Spring, Shootaring Canyon, and Del Monte).

The mined-out uranium deposits of the Henry Mountains are typically small oxide bodies, the mean size of the deposits being 80 st of ore. Coffinite and tyuyamunite are the principal ore minerals with lesser autunite (Chenoweth, 1980; Northrop and others, 1986a).

The Shootaring-Del Monte district ores are typical tabular, uranium-vanadium deposits hosted in fluvial sandstones of the Salt Wash Member of the late Jurassic Morrison Formation. Host sandstone ranges from 30 to 40 feet thick and occurs 10 to 100 feet above the base of the Morrison Formation (Chenoweth, 1980). The mineralized zones are characteristically argillaceous and carbonaceous sandstones. These zones occur as multiple uraniferous horizons associated with and enclosed within a broader vanadium-rich interval and haloed by dolomite-cemented sandstone (Northrop and others, 1986a). The larger resource consists of close-spaced clusters of smaller deposits.

Potential: The Shootaring-Del Monte districts have development potential for renewed uranium-vanadium production. The combination of permitted mines, known large mineral resources, and a nearby permitted uranium mill suggest the possibility of additional production given a strong uranium price.

DOGM Permitted mines	Location	Operator
Farley Project	section 33, T. 34 S., R. 11 E.	Atlas Minerals
Lucky Strike	section 27, T. 35 S., R. 11 E.	Hydro-Jet Services, Gary Ekker
Jets 1-64	section 14, T. 35 S., R. 11 E.	Hydro-Jet Services, Gary Ekker
Ace 1-12	section 5, T. 36 S., R. 11 E.	Hydro-Jet Services, Gary Ekker
Tony M./Lucky Strike	section 21, T. 35 S., R. 11 E.	US Energy (Ore on section 16)
Frank M.	section 2, T. 35 S., R. 11 E.	US Energy

4. Dry Valley (East Canyon) District, Monticello Area

The Dry Valley district covers approximately 270 square miles in northern San Juan County (plate 1). It is separated from the Montezuma Creek district to the south by a drainage divide; streams in the Dry Valley district flow northward and those in the Montezuma Creek district flow to the south. The two districts are often discussed together, but are separated in this report because of the more extensive and larger deposits in the Dry Valley district. Most of the mines in the Dry Valley district are in a northeast-trending belt extending from the Lookout-Little Joe mines on the west side through the Jimbo Bob-Waterfall, Rim, and Frisco group mines in the center to the Bench Group-Liberty-Dunn mines on the east side. Most of the major mines are in a belt approximately 6 miles wide by about 15 miles long. Inclusion of the Dunn mine increases the width of the belt to 14 miles and adding the Bench Group and Liberty mines increases the length to 25 miles (figure 10). The southeastern part of the area (Dunn mine and others) may connect to the Ucolo district of the Slick Rock area.

Production: The Dry Valley district has historically been a moderate producer at low average uranium grades, but with significant vanadium production. According to Thamm and others (1981), the Dry Valley-East Canyon district produced 487,000 st of ore containing 1,525,000 pounds U_3O_8 and 12,662,000 pounds V_2O_5 at average grades of 0.15% U_3O_8 and 1.30% V_2O_5 through 1980. This recorded production is based on U.S. Department of Energy records and likely represents only a portion of the actual production. Some of the early vanadium production (pre-1945) may not have been included in the totals. Pre-1945 production is reported at 23,000 st averaging 0.10% U_3O_8 and 1.87% V_2O_5. Most of the contained uranium was likely recovered, but the amount of vanadium recovered is unknown because production was sent to mills with and without a vanadium circuit. However, because the district was initially (pre-1947) mined for vanadium, it is likely that most of the vanadium was recovered. The critical question is whether all of this recovered vanadium was included in the production estimate of Thamm and others (1981). Doelling (1969) reported that between 1956 and 1965, the Dry Valley district produced 105,000 st of ore at a low average grade of 0.18% U_3O_8 and 1.35% V_2O_5. From 1980 to 1998, there was intermittent production estimated at less than 60,000 st of ore. The last known production in the district was in 1998, when Jim Butt mined 7000 st at a very low average grade of 0.08% and >2.0% V_2O_5 from the Rim Shaft mine and approximately 1000 st of stockpiled ore was shipped from the Neighbor mine. The low-uranium grade from the Rim Shaft is not representative because most of the

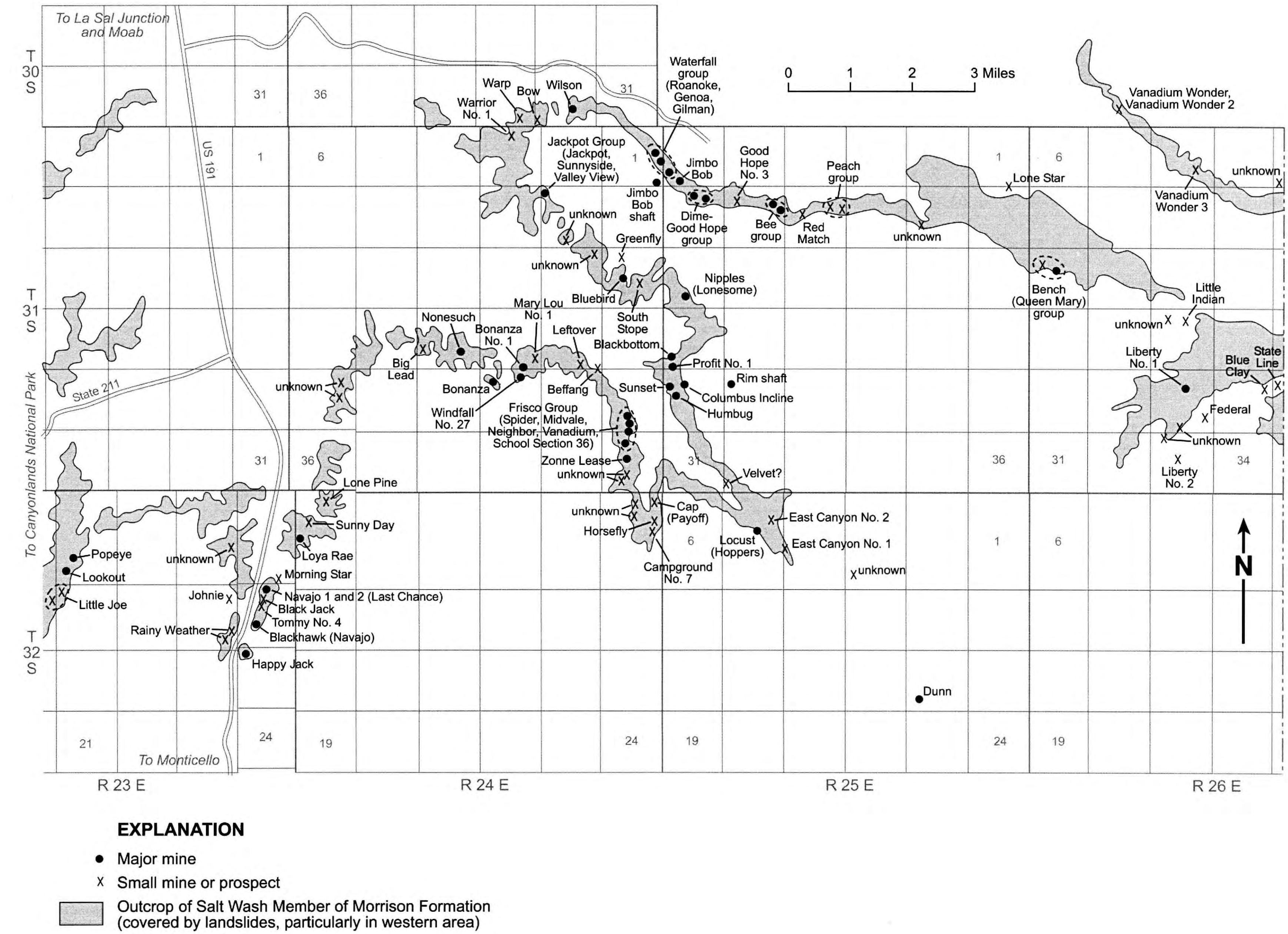

Figure 10. *The Dry Valley (East Canyon) mining district, Monticello area, San Juan County, showing exposures of the Salt Wash Member of the Morrison Formation and the uranium mines and prospects (after Williams, 1964, updated by R.W. Gloyn, 2004); dips are generally to the south.*

ore mined was from cleaning out old drifts and rehabilitating the mine.

Nearly all of the production has been from the Jurassic Morrison Formation with most of this production from the upper sandstone unit of the Salt Wash Member. Much less production has come from sandstones in the lower part of the Salt Wash Member or from sandstones in the Brushy Basin Member. Major mines/mine complexes include the following in decreasing order of production with recorded production through 1973:

Columbus Incline-Humbug-Rim	154,142 pounds U_3O_8, 374,977 pounds V_2O_5
Sunset (Bluebell)*	105,719 pounds U_3O_8, 690,000 pounds V_2O_5
Rim Shaft	74,019 pounds U_3O_8, 679,887 pounds V_2O_5
Jimbo Bob-Good Hope	62,565 pounds U_3O_8, 118,360 pounds V_2O_5
Waterfall Group (Roanoke-Gillman)*	57,240 pounds U_3O_8, 240,400 pounds V_2O_5
Sunnyside-Jackpot Group*	40,963 pounds U_3O_8, 250,000 pounds V_2O_5
Geneva*	25,500 pounds U_3O_8, 120,000 pounds V_2O_5
Frisco-Frisco South	23,368 pounds U_3O_8, 706,160 pounds V_2O_5
Bonanza Group*	19,300 pounds U_3O_8, 100,000 pounds V_2O_5
Dime	17,104 pounds U_3O_8, 274,327 pounds V_2O_5
Happy Jack*	5377 pounds U_3O_8, 350,000 pounds V_2O_5
Wilson	5686 pounds U_3O_8, 43,498 pounds V_2O_5
Nonesuch	3542 pounds U_3O_8, 21,257 pounds V_2O_5
Lookout*	3000 pounds U_3O_8, 15,000 pounds V_2O_5
Blackbottom*	unknown U_3O_8, 200,000 pounds V_2O_5

*Estimated production

Significant post-1973 (particularly in the period 1973 to 1985) production was from the Dunn, Rim-Columbus, Frisco, Jimbo-Bob complex, and Locust mine area, but details are not known.

Recent permitted mines (now archived or inactive) include the Neighbor and Frisco mines (section 25, T. 31 S., R. 24 E.), Geneva mine (section 1, T. 31 S., R. 24 E.), Dunn mine (section 14, T. 32 S., R. 25 E.), Jimbo-Bob complex (section 7, T. 31 S., R. 25 E.), Rim-Columbus (section 19 and 30, T. 31 S., R. 25 E.), Rim-Cresslar (section 29, T. 31 S., R. 25 E.), Locust-Spider (section 5, T. 32 S., R. 25 E.), and Windfall (section 27, R. 31 S., R. 24 E.).

Reserves: The Dry Valley district hosts moderate "reserves" at moderate to low average uranium grades. Butler and Fisher (1978) estimated that as of 1971, the Sage Plain area contained identified resources of 225,000 st at an average grade of 0.15% U_3O_8 and 1.5% V_2O_5 and undiscovered resources of 1,325,000 st at an average grade of 0.167% U_3O_8 and 1.5% V_2O_5. Most of the "identified resources" were probably mined between 1971 an 1984, but "reserves" do remain at several mines (see below). The "undiscovered resources" are probably still unmined, but because Butler and Fisher (1978) included an area all the way to the Colorado state line, some of the unmined resources may be in the Ucolo district of the Slick Rock area (see Ucolo section of this report).

In 1987-1988, Atlas minerals estimated the following "reserves" for their properties:

Dunn mine: 40,500 st at 0.204% U_3O_8, 1.64% V_2O_5; Atlas Minerals (1987). Note: Jagoe (1988) gives 65,456 st at 0.14% U_3O_8; likely represents diluted "reserves".

Rim-Columbus: 69,456 st at 0.220% U_3O_8, 1.80% V_2O_5 estimated.; Jagoe (1988). Note: More recent estimate (International Uranium Corporation, 2004) 103,000 st at 0.186% U_3O_8, 1.715% V_2O_5 (Proprietary).

Rim-Cresslar: 72,903 st at 0.212% U_3O_8, 2.20% V_2O_5; Atlas Minerals (1987). Note: Jim Butt (verbal communication, 1999) gives estimate of 187,730 pounds U_3O_8, 1,785,554 pounds V_2O_5 (probably represents measured mine reserve along with Atlas estimate of measured plus inferred).

More recent estimates from Jim Butt (written communication, July 2004) give the following "reserves":

- **Dunn:** Similar to Atlas estimate
- **Rim area:** 72,903 st at 0.22% U_3O_8 and 1.22% V_2O_5 (probably equivalent to Atlas Rim-Columbus)
- **Rim mine:** 124,000 st at 0.18% U_3O_8 and 1.75% V_2O_5
- **Jimbo:** 50,000 st at 0.15% U_3O_8 and 1.60% V_2O_5
- **Sunset:** 5000 st

Most of these "reserves" are still intact because little mining has occurred since the estimates were made, except for 7000 st mined from the Rim Columbus and less than 3000 st from the Dunn mine. No mining has occurred at the Rim Cresslar. Additional "reserves" remain at several of the other mines in the area, particularly the Jimbo-Bob, Dime (?), Frisco group (Neighbor, School Section 36, and others) and Locust areas, but no estimates are currently available.

Ore Deposits: Uranium-vanadium ore deposits in the Dry Valley area occur predominately as thin, tabular to lenticular layers of dark gray-green to gray sandstone with disseminated vanadium or uranium minerals or more rarely as irregular, elongate rolls. According to Doelling (1969), the tabular ore bodies, on average, measure 3 feet thick by 30 feet wide by 200 feet long with the long dimension generally parallel to the channel trend. Descriptions by Weir and Puffett (1981) for individual deposits in the belt suggest that the average deposit size is somewhat smaller, closer to 1-2 feet thick by 20-50 feet long except in the major mine areas (Windfall-Jimbo Bob; Frisco group, Sunset-Columbus-Rim, Happy Jack). In the major ore areas, the lenticular deposits are from 3 to 10 feet thick, 50 to 150 feet wide, and 100 to possibly as much as 500 feet long. The roll-type ore bodies are up to 6 feet thick and from 30 to 100 feet long. Descriptions suggest that the roll-type deposits are confined to the major mine areas. "Ore bodies, both tabular and roll type can occur at any level within the host lens, but generally hug the bottom or sides" (Doelling, 1969). In general, the ore minerals fill voids, impregnate the host sandstone, and locally replace carbonaceous material. Within the 1- to 4-foot-thick ore zone, mineralization often consists of a series of irregular, thin, wispy zones of more concentrated ore. According to Jim Butt (verbal communication, 2004), the rolls in the Rim-Columbus/Frisco area occur at the margin of the channels and contain both uranium and vanadium, but the major lenticular bodies are at the base of the channel and contain mostly vanadium. He believes that the uranium was leached from the tabular deposits and was deposited elsewhere, perhaps in the rolls. This proposed leaching would only occur in unoxidized ore with flushing by oxidizing fluids. In the oxidized zone, most of the uranium would be in immobile vanadates.

Most of the deposits are in the upper sandy unit of the Salt Wash Member of the Morrison Formation, most commonly in the lower part of the upper sandstone, but some are in sandstones and conglomerates in the lower part of the Brushy Basin Member of the Morrison Formation. Most of the Brushy Basin occurrences are in the easternmost part of the belt and produced only minor amounts of uranium and vanadium. Some uranium, generally low grade and sporadic, also occurs in sandstones below the upper Salt Wash channel system. The Salt Wash Member averages about 300 feet thick in the East Canyon district and consists of a lower, generally continuous sandstone unit about 30 feet thick, a middle unit with several thin (10 to 25 feet thick) discontinuous sandstone lenses, and an upper, generally continuous sandstone unit 15 to over 80 feet thick with occasional 10- to 20-foot-thick shale interbeds. The larger and more concentrated groupings of deposits occur where this upper sandstone is thicker, generally in the range of 40 to 80 feet thick. The host sandstone is generally tan to brownish gray in contrast to the more reddish hues away from the ore and the underlying shale is often altered to greenish-gray from the original red-brown below the major ore deposits. Cross-bedded sandstone appears to be a more favorable host although deposits are also known in thin-bedded to laminated sandstone. Carbonaceous material and fossil logs are generally sparse, but are locally conspicuous and favorable sites for uranium-vanadium mineralization. The Brushy Basin-hosted deposits occur in relatively thin (10 to 15 feet thick), generally coarse-grained sandstones and pebbly sandstone in the lower part of the Brushy Basin Member, usually 30 to 80 feet above the base of the formation.

Most of the mined deposits were oxidized and consisted of vanadium mica/vanadium clays, carnotite, tyuyamunite, corvusite, and occasionally volborthite. The copper carbonates, azurite and malachite, are reported for some deposits but are rare. Some unoxidized ore was probably mined from the Rim shaft, Rim Columbus, Rim Cresslar, Frisco, and Jimbo-Bob area. The unoxidized ore consists of uraninite, coffinite, montroseite, and vanadium micas. Several types of vanadium micas are present, but are usually not distinguished. The most common phase is roscoelite, a vanadium muscovite; however, other phases include a vanadium chlorite and a hydrous vanadium clay. Associated sulfides are mostly pyrite, but minor chalcocite and chalcopyrite are probably present in some deposits.

The major ore bodies appear to be concentrated in three to possibly five channel trends with individual trends having widths of 2000 to possibly as much 5000 feet. Johnson and Thordarson (1966) show three zones trending N. 45-60° E. Gloyn's re-interpretation of the data, based in part on channel trends reported by Weir and Puffett (1981), suggests five to possibly as many as 12 trends with a more easterly trend changing to a southeasterly trend to the east (figure 11). The easternmost parts of these trends could connect with the northwest trends in the Ucolo district of the Slick Rock district (see Slick Rock section). Johnson and Thordarson (1966) postulated that this change in channel orientation could be due to Salt Wash streams being deflected southeastward by the ancestral Lisbon Valley salt anticline.

In addition to the northeast to east to southeast channel trends, most of the major deposits in the Dry Valley-Sage Plain area occur within a 4-mile-wide zone trending approximately N. 30-35° W. The explanation for this distribution is unknown, but could represent a cross-channel change in fluvial regime similar to the better-known Uravan mineral belt to the east.

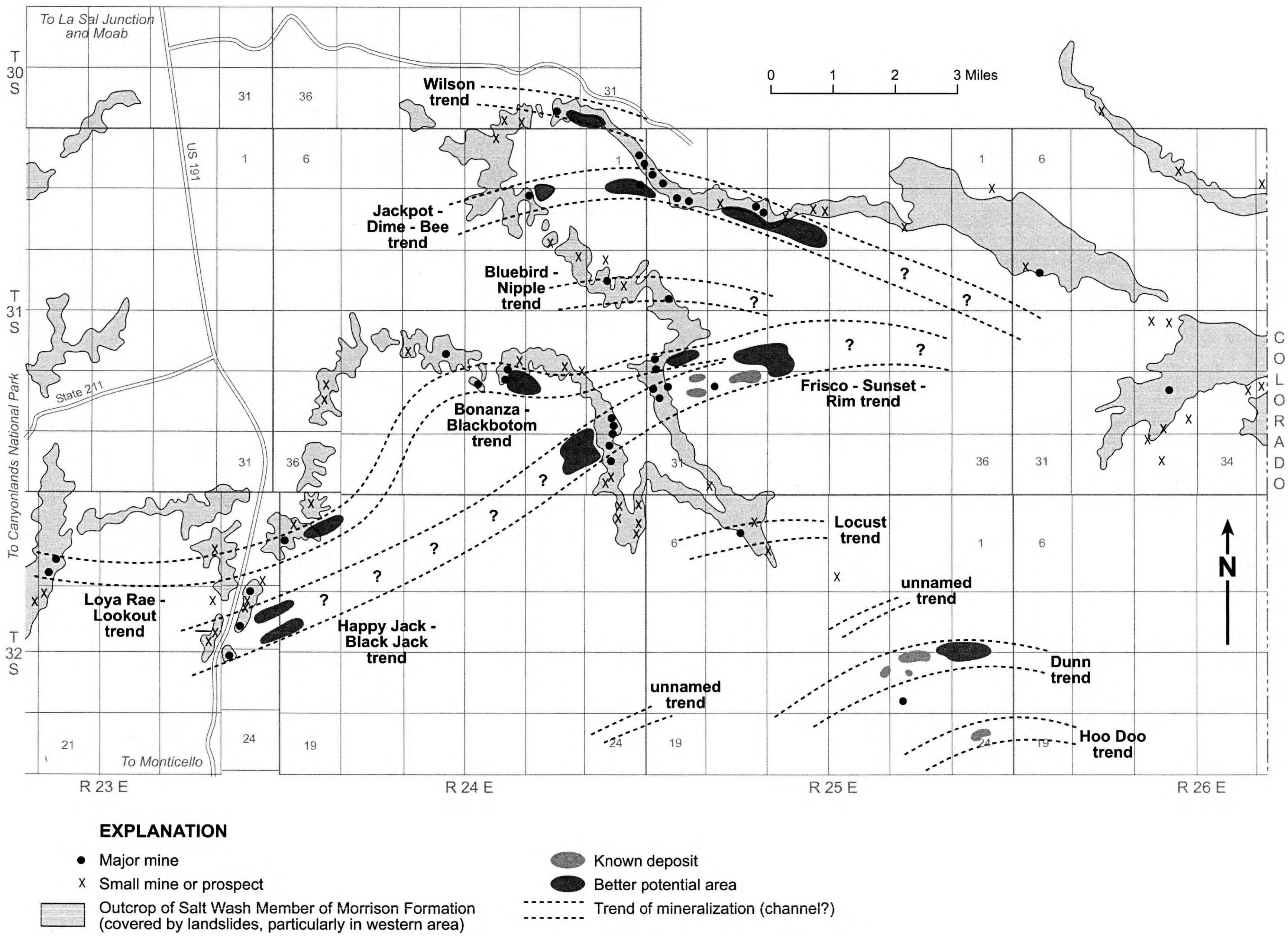

Figure 11. Speculative trends of mineralization/stream channels in the Dry Valley mining district, San Juan County, including approximate outlines of the known deposits and potential target areas (modified from Weir and Puffett, 1981).

Potential: The most obvious potential is on trend from existing mines particularly in areas of known "reserves." These areas include the west-central part of the Jackpot-Windfall-Dime-Bee trend (Jimbo-Bob shaft area), the Frisco and Rim Cresslar areas of the Frisco-Sunset-Rim trend and the Dunn mine area of the Dunn trend. In addition to these areas, potential also exists in other areas along these trends and several other recognized trends (figure 11). Potential by trend is discussed below. In general, the less speculative, but not necessarily better potential, is closer to established mines. For most of the areas, the deposits would be at depths of 400 to 600 feet.

<u>Wilson Trend:</u> The Wilson trend is in the northernmost part of the Dry Valley-East Canyon district. The channel trend at the Wilson mine is slightly south of east with potential areas to the east (south half of sections 35 and 36, T. 30 S., R. 24 E.) of the Wilson mine for a distance of less than 1 mile before the favorable Upper Salt Wash host unit is lost due to erosion. Potential to the west is much lower because the area with un-eroded, favorable Salt Wash host is likely south of the main mineralized trend. Prospects in this southern area are small, low grade, and mostly undeveloped.

<u>Jackpot-Windfall-Dime-Bee Trend:</u> This trend contains the prolific Windfall Group-Dime-Jimbo Bob and Bee Group mines. Previous work postulated a northeast trend with most of the northern part of the trend area eroded. A review of individual mine descriptions suggests that the central part of the trend (Dime-Bee) extends southeast with good potential south of the Dime-Bee areas and to the southwest of the Bee Group (central and southern part of section 7 to 9 and possibly northern parts of sections 14 and 15, T. 31 S., R. 25 E.). Potential also exists to the west of the Jimbo-Bob shaft. This trend may also continue further to the southwest and connect with the Jackpot Group workings. Descriptions by Weir and Puffett (1981) indicate that in the Windfall Group (Roanoke, Geneva, Gilman) the uranium lenses become smaller and lower grade to the northwest. "Reserves" probably exist at the Jimbo-Bob mine, but most other areas would require testing by drilling.

<u>Bluebird-Nipple Trend:</u> A possible east-west arcuate trend exists between the Bluebird and Nipple occurrences, but is likely of only minor importance because the known mines in the trend were only minor producers.

<u>Bonanza-Blackbottom Trend:</u> Mineralization in the Bonanza-Nonesuch mines trends S. 65-70° E. and extends to the Blackbottom and Profit mines. The location of the mines suggests a possible 2000- to 3000-foot-wide channel between the two areas. In the western area, the main channel would be south of most of the rim cuts and adits, mostly in the northern halves of sections 26 to 28 (T. 31 S., R. 24 E.), with the best potential southeast of the Bonanza and Windfall workings. In the eastern area, the best potential would be northeast of the Blackbottom adits in the southeastern part of section 19 (T. 31 S., R 25 E.). Further to the east, the channel probably curves to a more easterly trend and may merge with the Frisco-Sunset-Rim trend (see below).

<u>Frisco-Sunset-Rim Trend:</u> This area contains the best-mineralized trend in the Dry Valley district. More than half of the production of the East Canyon district has come from this trend and the trend contains the largest known reserves/resources in area at the Rim-Columbus and Rim Cresslar deposits (150,000 st at 0.220% U_3O_8, 2.00% V_2O_5). "Reserves" also likely exist in the Frisco-Neighbor area, but resource numbers are not known. In the Sunset to Rim Shaft area, the distribution of workings and drill holes suggests a 2000- to 2400-foot-wide mineralized area trending N. 60° E. The trend continues through the Cresslar ore body and likely across section 21 (T. 31 S., R 25 E.). Drilling along the south boundary of section 16 (T. 31 S., R 25 E.) intersected mineralized intervals of 1.5 to 4.5 feet containing 0.030 to 0.625% U_3O_8 probably close to the northern margin of the mineralized trend. To the east, the channel probably trends more easterly, but its extent is unknown. Southwest of the Sunset area, the ore trend continues through the Frisco Group and beyond. The ore trends within the individual mines in the Frisco Group are not known, but the zone is 2200 to 3000 feet wide based on the distribution of the mines and workings. A continuation of the trend to the southwest would connect to the Happy Jack-Blackhawk mines, but drilling would be needed to confirm that a postulated channel actually continues to these mines.

<u>Loya Rae-Lookout Trend:</u> This is a minor trend between the Loya Rae and Lookout mines based mainly on the distribution of workings, but had no supporting evidence from the mines as to mineralization or channel trends. The better potential along this trend would be northeast of the Loya Rae mine or northeast of the Lookout/Popeye area. A low priority is given to this trend because of the very limited production of its mines and the absence of significant prospects in the area between the Lookout and the Loya Rae mines.

<u>Locust Trend:</u> An east to slightly northeast ore trend is proposed for the Locust area, but drilling would be needed to confirm the orientation and extent. Although only minor production is reported for the Locust mine, the area is given higher priority because, until recently, it was an active permit held by Atlas Minerals and some "reserves" are likely present at the mine. The most obvious exploration area would be southwest of the existing workings. The area to the northeast is thought to be less favorable because of the absence of significant workings on the east side of the canyon.

Unnamed Trends: Drilling in the area between the Locust and Dunn trends has discovered spotty, but occasionally near ore-grade, uranium mineralization and several N. 45 to 60° E.-trending thicker sandstone zones in the upper part of the Salt Wash Member. Insufficient information is available to make any judgment on the grade and continuity of mineralization.

Dunn Trend: The Dunn trend includes the Dunn ore body and several smaller zones of mineralization to the southwest in section 15 which were discovered by drilling in the early 1980s. Southwest of the Dunn mine the zone trends southwest but bends more easterly in the Dunn mine itself. Over 40,000 st of "reserves" at a low grade of at 0.204% U_3O_8 are present at the Dunn mine. The area around the Dunn mine has likely been extensively drilled but the area to the southwest and east have potential for additional discoveries.

Hoo-Doo Trend: The Hoo-Doo trend is only known from drilling. A mineralized area is present in NW? section 24 (T. 32 S., R 25 E.) and several mineralized drill holes show an east to northeast trend. A drill hole in section 23 (T. 32 S., R 25 E.) intersected 2.0 feet of 0.18% U_3O_8.

Between 1982 and 1985, Atlas Minerals extensively explored in the East Canyon-Sage Plain-Ucolo districts. Based on incomplete record at the UGS, an estimated 75 to 80 holes were drilled during this period, but apparently no major ore deposits were discovered. Some of the holes were drilled along postulated trends, but a number of others were drilled south of the main mineralized zones on available land or leases.

5. Ucolo District, Slick Rock Area

The Slick Rock area is at the southern end of the Uravan mineral belt, an arcuate belt extending from the Polar Mesa area in the north through the Gateway, Uravan, Gypsum Valley, and Slick Rock areas. This mineral belt is approximately 70 miles long and 2 to 10 or more miles wide with indistinct boundaries depending on personal interpretation (Motica, 1968). Within the belt the Salt Wash Member-hosted uranium deposits have a closer spacing, larger size, and possibly higher grade than in adjacent areas. Most of the Slick Rock area is in San Miguel County, Colorado, but the southwest end extends into Utah in the easternmost part of San Juan County. In Utah, the area covers 14 to possibly 25 square miles in the southeastern part of T. 32 S., R. 26 E. and the northeastern part of T. 33 S., R. 26 E. (figure 12). In Colorado, the Slick Rock area covers 570 square miles in western San Miguel and Dolores Counties (Shawe and others, 1968).

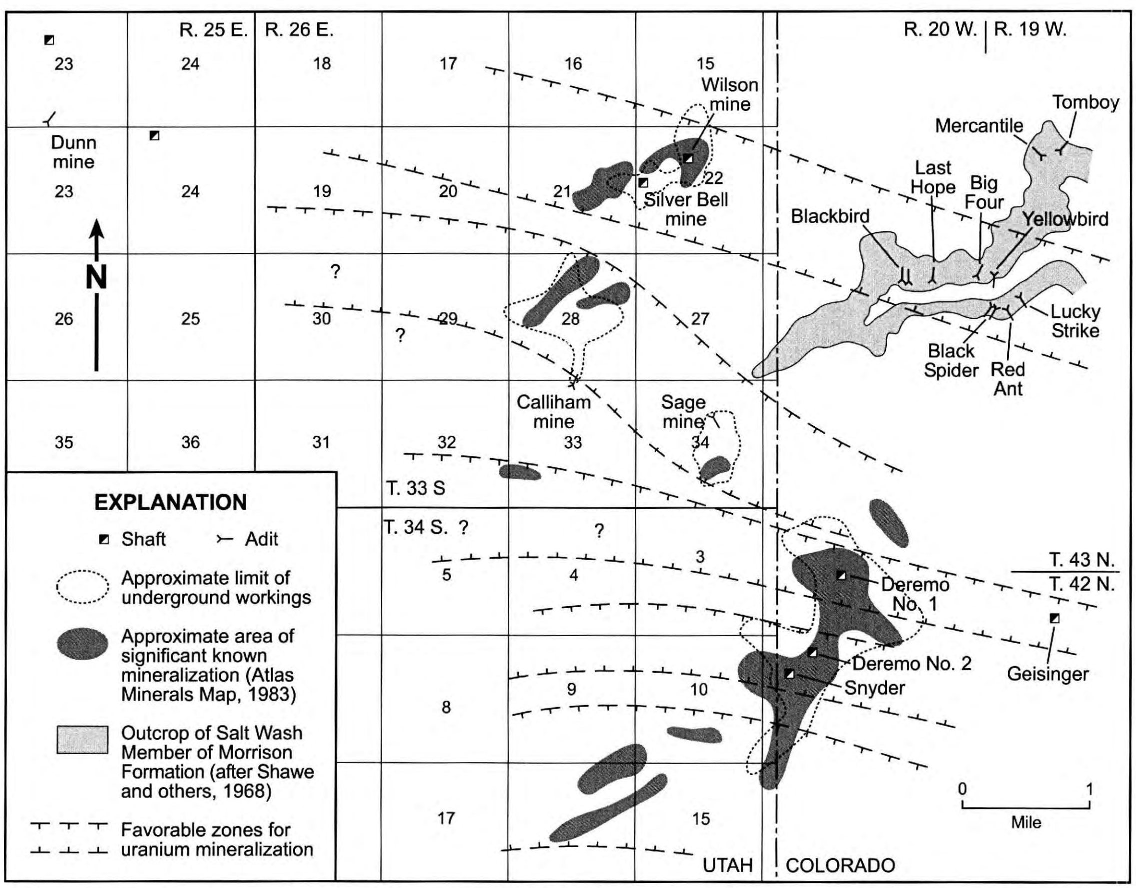

Figure 12. Major mines and prospects, Ucolo district, western Slick Rock area, San Juan County, Utah, and San Miguel County, Colorado. Significant known mineralized uranium areas and favorable trends are shown.

Production: The Utah portion of the Slick Rock area has produced a moderate amount of uranium ore at moderate grades with important associated vanadium production. The Slick Rock area has intermittently produced uranium and vanadium since the early 1900s; pre-1944 production was mostly for radium and vanadium and post-1948 production has been for both uranium and vanadium. Most production summaries include the Slick Rock area in the Uravan belt and do not separate production from individual districts. For the Slick Rock area, Chenoweth (1981) estimated the pre-1946 production at 98,700 st at a grade of 2.38% V_2O_5. Doelling (1969) reported that the area produced 1,506,119 st containing 5,291,289 pounds of U_3O_8 and 37,708,517 pounds V_2O_5 between 1956 and 1962. Nelson-Moore and others (1978) reported that San Miguel County produced 3,722,900 st of ore containing 15,889,200 pounds U_3O_8 and 177,416,000 pounds of V_2O_5 between 1948 and 1978, mostly from the Slick Rock area. Production has continued intermittently to the present. The Utah portion of the production is much less, estimated at approximately 1.25 million pounds U_3O_8.

Limited production statistics are available for the Utah mines in the Slick Rock area. The Wilson-Silver Bell mine produced 392,636 pounds U_3O_8 through 1973. Between 1962 and 1972, the mine produced 279,701 pounds U_3O_8 and approximately 2,019,400 pounds V_2O_5 from 61,467 st of ore. Post-1973 production is not known. Based on known production and the size of the workings, Gloyn estimates the following production for the major Utah mines:

Deremo-Snyder-Peterson	500,000 pounds U_3O_8 and 5,000,000 pounds V_2O_5, Utah portion
Wilson-Silver Bell	450,000 pounds U_3O_8, 3,245,500 pounds V_2O_5
Calliham	200,000 pounds U_3O_8, 1,200,000 pounds V_2O_5
Sage-Denny	100,000 pounds U_3O_8, 750,000 pounds V_2O_5

Most of the Colorado production came from mines 4 to 5 miles from the Utah border, but several of the mines shown on figure 12 had significant production. Estimated production for several of the larger mines is listed below (Nelson-Moore and others, 1978):

Deremo-Snyder-Peterson*	794,810 st, 3,218,079 pounds U_3O_8, 31,240,735 pounds V_2O_5
Tomboy-Mercantile (to 1977)	137,598 st, 811,680 pounds U_3O_8, 4,083,025 pounds V_2O_5
Black Spider	4054 st, 18,398 pounds U_3O_8, 57,960 pounds V_2O_5

*Most of Deremo production came from Colorado, but based on stope maps, 20% may have come from the Utah side of the border.

Both Atlas Minerals and Umetco (Union Carbide) were active in the district; Atlas subsequently sold its properties to either Umetco or J.M. Butt in the late 1980s. Current ownership of the Calliham, section 9-10, Wilson-Silver Bell, and Deremo-Peterson mines is not known; the latest mine permits list Umetco as the operator. J.M. Butt controls the Sage mine, a number of unpatented claims, and state leases in the area. Permitted operations (all inactive or archived) include Wilson-Silverbell, Calliham, Sage, and Deremo-Peterson. The last mining in the district was in 1991 by Umetco; the UGS files do not record any significant later work.

Reserves: "Reserves" at the Ucolo district are moderate with a low average uranium grade (0.16%), but with good by-product vanadium credits. Atlas Minerals' estimated "reserves" (Atlas Minerals, 1987), most classified as "potential geologic," but the Calliham classified as measured, indicated, and inferred, as follows:

Section 9-10, T. 33 S., R. 26 E.	251,222 st ore at 0.125% U_3O_8; 1.00% V_2O_5
Silver Bell	200,000 st ore at 0.170% U_3O_8; 1.20% V_2O_5
Calliham	52,385 st ore at 0.188% U_3O_8; 1.22% V_2O_5
Dulaney	42,250 st ore at 0.242% U_3O_8; 1.45% V_2O_5
Sage-Denny	6032 st ore at 0.276% U_3O_8; 2.20% V_2O_5

Note: The Dulaney is reportedly in Colorado, but the exact location is not known.

Jagoe (1988) updated the above reserve numbers in August 1988. His "reserves" for the Sage-Denny, and section 9-10 are identical with those given above, but the Calliham/Skidmore "reserves" increased dramatically to 390,650 st ore at 0.15% U_3O_8, no V grade given (1.2% estimated). This revised reserve probably represents the northern and eastern continuations of the Calliham mine onto property leased from J. Skidmore. It is not known how much of these "reserves" remain unmined, but the lack of significant post-1987 production suggests that most are still in place.

Ore Deposits: The uranium-vanadium deposits occur mainly as tabular to pod-like bodies generally parallel to sedimentary structures, particularly bedding or, more rarely, as crescent-shaped roll fronts cross-cutting bedding. The tabular ore bodies are a few inches to over 20 feet thick with an average thickness of 3 to 4 feet and are up to 200 feet long. Tabular ore bodies are often elongate along channel trends. Ore bodies are generally more abundant in areas of average or greater sandstone thickness (20-40 feet thick), but can occur anywhere within the channel. In detail, most of the ore bodies are oval to irregular in plan and have somewhat lenticular cross sections. Doelling (1969) states that the deposits are more irregular where the host unit is irregular with abundant shale interbeds or carbonaceous material. Typically, a mine will consist of one or more clusters of individual ore bodies, which may or may not be connected by lower grade material. Tabular ore bodies contain from a few to tens of thousands of st of ore.

The crosscutting rolls are generally C- or S-shaped in cross section and may be elongate or sinuous for several hundred feet along the channel trend. Roll-type ore bodies can be up to 5 feet thick, 15 feet high, and 300 or more feet long, but are generally much smaller, averaging only 5 feet high. Roll-type ore bodies often occur near the impermeable boundaries at the edges of the elongate sandstone lenses. Roll-type deposits account for only a small part of the uranium/vanadium production and roll-type ore bodies are typically limited to a few thousand standard tons. Roll-type deposits are present in both oxidized and unoxidized portions of the host sandstone.

Most of the deposits are in the upper part of the Salt Wash Member of the Jurassic Morrison Formation, but ore deposits are also found in the lower part of the overlying Brushy Basin Member and in the underlying, middle part of the Salt Wash Member. Most of the uranium ore bodies are in a relatively continuous sandstone horizon formed by numerous, juxtaposed, fluvial-channel sandstone lenses, locally separated by mudstone splits or lenses. The sandstone shows abundant cross-bedding and scour-and-fill features and carbonaceous material is common, but not ubiquitous. Relatively coarse-grained, yellowish-brown sandstone with limonite staining is more favorable for uranium deposits than reddish-brown, fine-grained sandstone. Near the uranium deposits, the underlying red mudstone has been altered to gray to greenish-gray. The favorable ore host is 15 to 100 feet thick in the Slick Rock area.

Ore minerals fill voids and coat grains, or more rarely replace detrital grains or carbonaceous material. Primary minerals include uraninite, coffinite, montroseite, corvusite, pyrite (up to 7%), and various base metal sulfides. Oxide minerals include carnotite, V-mica, tyuyamunite, and a number of oxidized vanadate minerals. Average mined grades are 0.20-0.25% U_3O_8 and 1.7-2.0% V_2O_5. Some ore contains up to 0.3% copper, 0.018% lead, 0.22% zinc, 0.044% molybdenum, and 0.021% arsenic.

The better deposits occur at a facies change in the Salt Wash Member from a floodplain environment with few distributary channels on the west to a floodplain environment with numerous distributary channels on the east. Farther to the east, the Salt Wash appears to have been deposited in standing water. This facies change defines the "Uravan mineral belt." Within the belt, deposits are generally concentrated along several cross-trends, up 3 miles wide, generally perpendicular to the trend of the mineral belt. Chenoweth (1978) identified two trends, the Burro Canyon trend in the north (Slick Rock area) and the Deremo trend in the south (with nearly all the Utah deposits in the Deremo trend). Within these cross-trends, underground mine maps suggest even more restricted trends. For the area shown in figure 12, eight to ten zones can be identified that trend S. 65-70° E. and are 600 to 2000 feet wide. The better areas of significant mineralization within these trends appear to be oriented almost perpendicular to the channel trend.

Potential: The district has potential for the development of existing deposits, particularly with high vanadium prices, because most of the deposits have a uranium:vanadium ratio of 1:6 to 1:10. Approximately 900,000 st of "reserves" are identified in existing mines, and there is good potential to extend these "reserves" to the northwest along the N. 65-70° W. trends. Sections 4, 5, 8, 9 and W½ of section 3, T. 33 S., R. 26 E. and section 32 and S½ of section 33, T. 32 S., R. 26 E. are prospective for a continuation of the Deremo and section 9-10 mineralization. Section 28 and 34, S½ of section 20, and N½ of section 29, T. 32 S., R. 26 E. are prospective for a continuation of the Calliham mine trend to the west and between the Calliham and Sage mines to the east. Section 16, 17, and the NE¼ of section 21, T. 32 S., R. 26 E. are prospective for the continuation of the Wilson-Silver Bell trend. Many of these area were drilled by Atlas Minerals in 1980-1983 with closer spaced drilling in the W½ section 29, SE¼ section 34, and S½ section 35, SW¼ section 33, and N½ section 17, T. 32 S., R. 26 E. Results are not known.

Although the mines are underground, the favorable horizon is only at depths of 600 to 800 feet and there should be no logistical problems for testing; access is good and drilling should be easy. However, drilling on 100- to 200-foot centers would probably be required to block out the ore. It is not known how much of the prospective areas has been previously drilled; these areas are obvious targets and on-trend with several major mines. The potential areas may be close to the western margin of the Uravan mineral belt, but the location of the Silver Bell and Wilson mines suggests that there is still a 1- to 2-mile-wide, or more, favorable area west of the major mines that is still in the mineral belt.

The Slick Rock area is given a high potential ranking because of its significant "reserves," the presence of fairly good sized, relatively continuous ore clusters, the high vanadium content, and the proximity to the White Mesa mill (less than 50 miles). Negative factors are the relatively low uranium grade, water, reported heavy ground, and possible metallurgical problems with the locally high base-metal sulfide content. Most of the mines have been reclaimed and the condition of the underground workings is not known.

Moderate Potential Areas

The following twelve areas have been rated as having moderate potential for uranium largely on the basis of their past production records, perceived exploration potential along recognized mineral trend, and/or geological similarities to other deposits. All of the moderate potential areas, except Spor Mountain, are in the sandstone-hosted uranium terrane of the Colorado Plateau.

6. Cottonwood Wash District, Monticello Area

The Cottonwood Wash district of the Monticello mining area is located in central San Juan County (plate 1). The uranium deposits of the district are hosted in the Jurassic Morrison Formation, which is exposed in a north-south band between the Pennsylvanian-cored Monument Uplift to the west and the Blanding Basin to the east. The 210- to 245-foot-thick Salt Wash Member host sandstones are mineralized where permeable sandstone is interbedded with carbonaceous trash and mudstone lenses (Doelling, 1969). The ore deposits are unoxidized below the water table and are dominantly composed of intergranular uraninite and montroseite with an average lime content of 6% (Doelling, 1969).

The uranium deposits in the Cottonwood Wash district average 2 feet thick by 50 feet wide by 100 feet long (Doelling, 1969). The uranium:vanadium ratio averages 1:10 and the uranium grade runs a low 0.16% (Doelling, 1969). Gloyn and others (1995) list production for the Cottonwood Wash district as 896,000 pounds U_3O_8 and 5,664,000 V_2O_5 from about 295,000 st of ore.

The Cottonwood Wash district is near the White Mesa mill. Despite the small size and low-grade of the worked deposits, the area presents a well-defined trend that is open to the east where it was drilled by the AEC and Minatome with unknown results.

DOGM Permitted mine	Location	Operator
Cottonwood # 1	section 4, T. 37 S., R. 21 E.	Dave Kimmrle
Cottonwood-Floodwater-Springwater	section 3, T. 37 S., R. 21 E.	Minatome
Imagination	section 9, T. 37 S., R. 21 E.	Dale Shumway
Basin	section 10, T. 37 S., R. 21 E.	Shumway Brothers
Imagination #2	section 10, T. 37 S., R. 21 E.	Unknown
Yellowstone	section 3, T. 37 S., R. 21 E.	Unknown
Yellow Jacket	section 4, T. 37 S., R 21 E.	Kevin Shumway
Snake Mine	section 4, T. 37 S., R. 21 E.	Unknown

Reserves:

Peg Area (Peg and Lucky Boy claims east end of trend in section 11 or 14): Jim Butt reports 38,953 st at 0.22 U_3O_8 and 1.73 V_2O_5.

Minatome Area: Drilled in 1978-80, ore in zone 1.5 to 2.0 miles long goes to bottom of adjacent canyon; fairly continuous ore, but drilling was wide-spaced.

Potential: The Cottonwood Wash district lies near the White Mesa uranium mill in Blanding. Exploration potential may exist at shallow depths (less than 500 feet), along a well-established trend to both the east and west, and associated with strong vanadium values.

7. Red Canyon District, White Canyon Area

The Red Canyon district is located in remote southwestern San Juan County (plate 1). The White Canyon area as a whole is credited as Utah's second largest uranium producer. Chenoweth (1993) reports a total production for the White Canyon area for the period 1949 to 1987 as 2,259,822 st of ore containing 11,069,032 pounds of U_3O_8 (0.24% U_3O_8). The Red Canyon district is the southwestern portion of the White Canyon area. The area is part of the deeply incised Red Rock Plateau/White Canyon Slope, sandwiched between the Colorado River on the west and the Monument Uplift to the east.

The uranium ores of the Red Canyon district are hosted in the basal Shinarump Member of the Triassic Chinle Formation (Chenoweth, 1993). Mineralization is associated with channel scours and sandstone pinchouts against mudstone with the grade directly proportional to amount of carbonaceous material available (Doelling, 1969). The generally unoxidized ore bodies average 3.5 feet thick and range from 10 to 500 feet wide and 50 to 1000 feet long (Doelling, 1969). The low-lime ore is primarily uraninite with low vanadium, but commonly over 1% copper values, primarily as chalcopyrite (Doelling, 1969). Butler and others (1920) report cobalt oxide is locally associated with the copper.

According to Chenoweth (1993), from 1949 to 1970 the 26 mines of the Red Canyon district produced 520,000 st of ore averaging 0.26% U_3O_8 for a total of 2,744,000 pounds of U_3O_8. The largest producers in the Red Canyon mining district include the Radium King, Markey, and Maybe mines. Between 1949 and 1970, the Radium King and Markey operations, in conjunction with some smaller nearby mines, are credited with 268,000 st of ore averaging 0.26% U_3O_8 and 1.30% Cu (Chenoweth, 1993).

DOGM Permitted Mine	Location	Operator
Radium King	section 11, T. 37 S., R. 15 E.	B&W Construction

Hillside Complex	section 11, T. 37 S., R. 16 E.	Unknown
Daneros 1, 2, 3, and 4	section 6, T. 37 S., R. 16 E.	Lark Mining and Mike Shumway

Reserves:

Radium King - 23,500 st at 0.199% U_3O_8 for 93,530 pounds U_3O_8, Strathmore resources acquired in 1998 and gave resource at 2,500,000 pounds.

Lark-Royale (Cove) - approximately 2,000,000 pounds at 0.20 to 0.25%, section 6, covers area of ? mile south and ? mile east of Cove adit (Utah Power and Light-Shumways).

Potential: Chenoweth (1993) notes that a Department of Energy (DOE) study, as part of the National Uranium Resource Evaluation (NURE) program, suggested that projections of the Radium King channel have not been explored to the north under the towering cliffs of the Wingate Sandstone. Drilling depths there exceed 1,000 feet.

8. Elk Ridge District, White Canyon Area

The Elk Ridge district of the White Canyon mining area is located in central San Juan County (Plate 1), west of the Abajo Mountains. Geologically, the district is dominated by the north-trending Comb Ridge monocline, which dips up to 30° and defines the eastern margin of the Monument Uplift.

The primary host to uranium mineralization is the lower section of the Triassic Chinle Formation with lesser ore produced from the Moenkopi Formation (Doelling, 1969). The ore is fine grained, occupies the interstices between sand grains, and is associated with carbonaceous matter and mudstones of the Moenkopi (Doelling, 1969). The primary uranium mineral is uraninite, locally associated with chalcopyrite, bornite, domeykite, tennantite, and pyrite with traces of galena and sphalerite; however, vanadium is uncommon (Doelling, 1969). Chenoweth (1993) estimates that from 1949 to 1970 the Elk Ridge district produced roughly 226,000 st of ore, 1,226,000 pounds of U_3O_8 (0.27% U_3O_8) and 23,900 pounds V_2O_5 (0.15% V_2O_5) with minor copper locally.

DOGM Permitted Mine	Location	Operator
Glade Pit	section 33, T. 33 S., R. 20 E.	Energy Fuels Nuclear
Betty mine	section 27, T. 33 S., R. 20 E.	Energy Fuels Nuclear
Avalanche 13	section 27, T. 34 S., R. 20 E.	Unknown
Shumway Unpermitted	section 6, T. 35 S., R. 20 E.	Ken Shumway

Production (to 1973):

Betty	277,625 pounds U_3O_8
Glade	255,544 pounds U_3O_8, 956 pounds V
Abe	213,107 pounds U_3O_8, 277,688 pounds Cu
Avalanche Group	129,838 pounds U_3O_8
King James	50,761 pounds U_3O^8
Horseshoe	4771 pounds U_3O_8

Potential: The Elk Ridge district has moderate potential based on its relatively continuous, some moderate-grade, good-sized deposits, and the likely presence of "reserves" to the northwest based on drilling in 1970s. The Glade deposit lies at a moderate depth of 50-100 feet. Some thick ore lenses of 10-12 feet may represent multiples zones. Problems include the low V and high Cu, complex ore, as well as the relatively remote location, not near a mill, and on U.S. Forest Service land.

9. Cottonwood Wash-Trachyte District, Henry Mountain Area

The Cottonwood Wash-Trachyte mining district of the Henry Mountain area is located in eastern Garfield County (Plate 1). The Cottonwood Wash-Trachyte district is the central section of the Henry Mountain mineral belt, discussed above under high priority area 3 - Shootaring (Shitamaring)-Del Monte district (Chenoweth, 1980). All of the ore is hosted in the Salt Wash Member of the Morrison Formation, which dips gently west into the Henry Mountains syncline. The Cottonwood Wash-Trachyte ore occurs 100 to 150 feet above the base of the Salt Wash Member, at a higher stratigraphic horizon than at Shootaring or Del Monte, but it is still associated with a thick, favorable mudstone. Paleo-streams meandered considerably, but channels in the Salt Wash Member generally trend east-west (Utah Geological and Mineralogical Survey, 1974).

Typical ore bodies average 50 feet long by 20 feet wide by 2 feet thick and are associated with trash-pocket type accumulations of carbonaceous material. The ore minerals occur interstitially to sand grains (Utah Geological and Mineralogical Survey, 1974).

Past production from this section of the mineral belt has mainly come from the Woodruff, Taylor Ridge, Trachyte Creek, and Cottonwood Wash mines. Uranium production through 1978 is estimated at 26,600 st averaging 0.33% U_3O_8 and 1.48% V_2O_5 for a total of 175,560 pounds U_3O_8 and 787,380 pounds V_2O_5 (Gloyn, 2004).

DOGM Permitted Mine	Location	Operator
Copper Creek	section 1, T. 32 S., R. 11 E.	Hydro-Jet Services, Gary Ekker
Straight Creek	section 1, T. 32 S., R. 11 E.	Energy Fuels Nuclear

Potential: The uranium potential is considered moderate based on the proximity to a mill and occurrence of numerous moderate-grade uranium-vanadium lenses similar to the pre-discovery drilling at Shootaring Canyon to the south.

10. Upper Kane Creek/Browns Hole District, Moab Area

Seven districts are present within the Moab mining area (plate 1). The historical Upper Kane Creek (Upper Kane Canyon)/Browns Hole district of the Moab area covers an area of about 40 square miles in the southern part of T. 27 S., R. 22-23 E. and the western part of T. 28 S., R. 23 E. in northern San Juan County. Most workings were rim cuts and inclines in the Salt Wash Member of the Morrison Formation which is exposed around three sides of Black Ridge. Little has been written on the deposits in the Upper Kane Creek/Browns Hole district.

The Moab area as a whole includes deposits in the Morrison, Chinle, Cutler, and Rico formations. Deposits in the Morrison Formation occur in the Upper Kane Creek/Browns Hole, Wilson Mesa, and Brumley Ridge districts. Most of the Morrison uranium production has been from the Upper Kane Creek subdistrict and from deposits near La Sal in the southernmost part of the Browns Hole subdistrict. The Browns Hole and Upper Kane Creek subdistricts are separated from the Brumley Ridge and Wilson Mesa areas by the Spanish Valley collapsed salt anticline. The Moab area (excluding the La Sal Creek district) has not been a large producer of uranium.

Production records for the districts are somewhat difficult to compile because most production summaries combine production from several subdistricts or areas. The Upper Kane Creek/Browns Hole district likely produced 85-90% of the Morrison production from the entire Moab area with nearly 60% of the production from one mine group, the Yellow Circle group. Using these estimates, the district produced approximately 74,000 st of ore containing 415,000 pounds U_3O_8 and 2,250,000 pounds V_2O_5 at an average grade of 0.28% U_3O_8 and 1.52% V_2O_5.

Potential: The Upper Kane Creek/Browns Hole is rated as moderate uranium potential despite the lack of any known reserves and the past production from small, low-grade deposits. However, the deposits do tend to cluster, the geologic setting is similar to the moderate-sized deposits of the La Sal district, and the distance to a mill is moderate.

11. Seven Mile Canyon District, Green River Area

The Seven Mile Canyon district is located approximately 10 miles northwest of Moab in Grand County (Plate 1), Utah. The district is about 7 miles long extending from Little Canyon to just north of Corral Canyon and about 2 miles wide (figure 13). Workings consist of numerous adits driven into the lower part of a prominent escarpment on the west side of the Moab fault. Workings extend from the Bicentennial mine in the north to the Klondike mine in the south and may extend several thousand feet downdip from the outcrop. The district is mostly in the northeast part of T. 25 S., R. 20 E., but also extends into T. 24 S., R. 20 E.

Uranium was discovered in the district in 1948; the major mines were operated by the Thornburg Mining Company from the early 1950s to the mid-1970s, and by the Cotter Corporation until 1985. Between 1985 and 1988, Western States Resources (Michael Shumway) operated the Bicentennial mine. Through 1973, the Seven Mile Canyon district produced nearly 750,000 pounds of U_3O_8 with over 65% from the Thornburg and Bicentennial mines. Most of the remaining production was from the Shinarump No. 1, 3, and 4 mines. The Shinarump No. 1, 3, and 4 are rim-cut adits on the south side of Corral Canyon; the Thornburg/Memorial mine complex is the downdip extension of the mineralization in the Shinarump mines. The Bicentennial mine complex on the north side of Corral Canyon is the northern extension of the mineralization in the Thornburg/Memorial mine complex. The Thornburg and Bicentennial were usually operated together and production was not reported separately.

Production: Production from 1974 to 1985 was probably 600,000 to 650,000 pounds U_3O_8 almost entirely from the northern mines (Thornburg/Memorial, Bicentennial, Shinarump No. 1, 3, and 4 mines). Between 1977 and 1985, the Cotter Corporation mined 123,831 st of ore with an average grade of 0.202% U_3O_8 and recovered 500,895 pounds U_3O_8. Production was from both the Thornburg and Bicentennial mines. Between 1985 and October 1988, Western States Resources mined 15,943 st of ore and recovered 59,155 pounds U_3O_8. Mining apparently stopped because of the closure of the Lisbon mill of Rio Algom located south of Moab. Total production for the district from 1950 to 2000 was approximately 1.4 to 1.5 million pounds of U_3O_8. Major mines (figure 13) include the Bicentennial and Thornburg (1,233,000 pounds U_3O_8) and Shinarump No. 1, 2, and 4 (283,064 pounds U_3O_8). The Nicholas J. Murphy mine is credited with production of 10,193 pounds of U_3O_8, but this amount is suspect considering the location of the mine; more likely this production should be assigned to the Shinarump mines that Mr. Murphy leased in the early 1950s.

Reserves: Significant resources probably remain in the Bicentennial and Thornburg mines particularly downdip to the west of the current workings. Doelling (verbal communication, 2004) estimates that 400,000 to 500,000 st at a grade of 0.40 to 0.50% U_3O_8 is present downdip from the two mines. Apparently the area

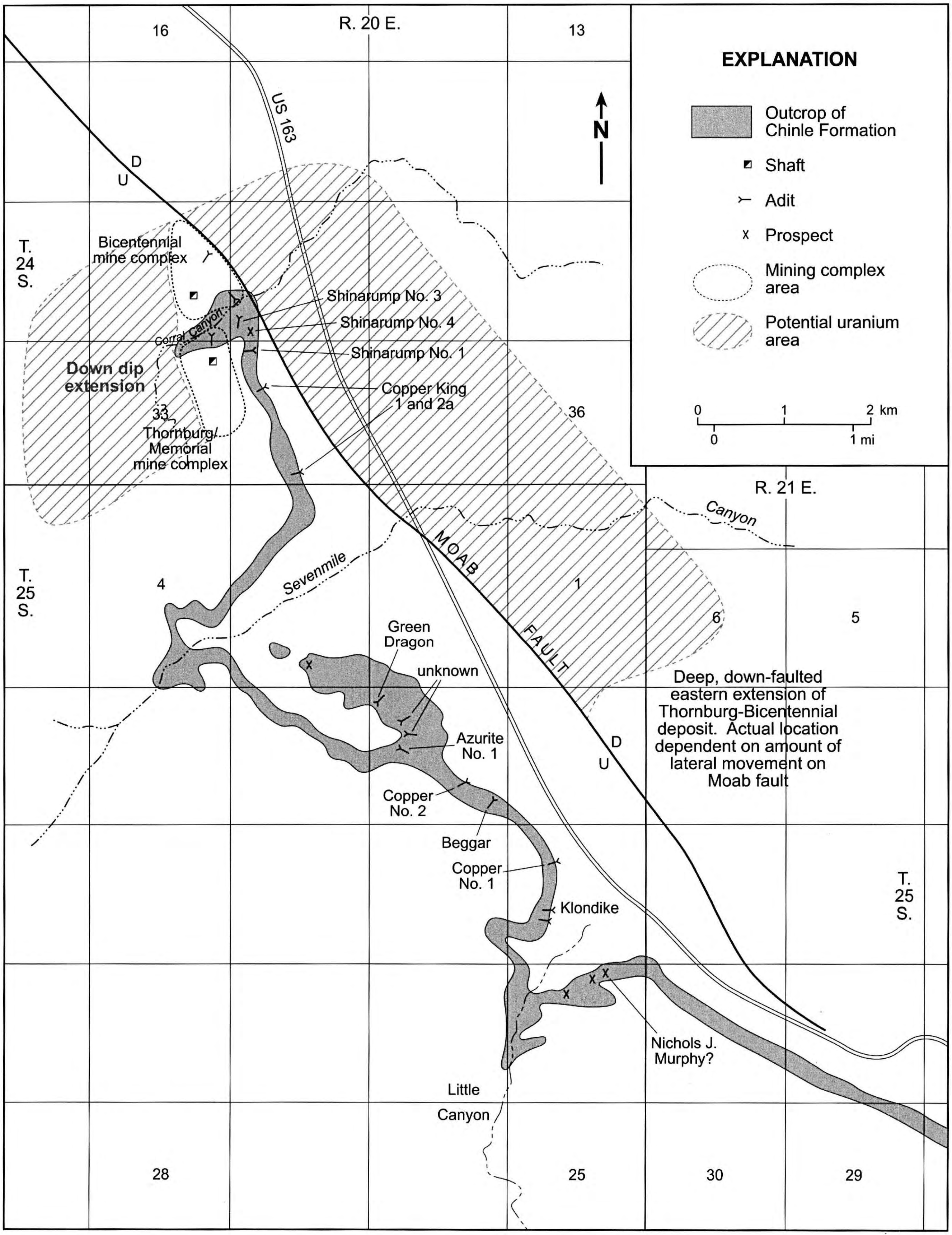

Figure 13. Location of major uranium mines and potential uranium areas, Seven Mile Canyon district, Green River area, Grand County, Utah (after Utah Geological and Mineralogical Survey, 1974).

was extensively drilled, but drilling results are unavailable. Additional information might be available from the last operator-Michael Shumway of Moab.

Ore Deposits: The ore occurs as discontinuous, single or multiple, quasi-tabular lenses or saucer-shaped zones of disseminated uranium mineralization in the lower 25 to 30 feet of the Chinle Formation. Three mineralized horizons are present in the Shinarump No. 1 mine: (1) a basal siltstone with interbedded shale, sandstone, and conglomerate 1 to 10 feet thick; (2) the upper part of an overlying gray-brown, 2- to 10-foot-thick limestone pebble conglomerate; and (3) within a carbonaceous siltstone 5 to10 feet stratigraphically above the pebble conglomerate (Finch, 1954). Droullard and Jones (1955) reported that the basal ore zone was deposited in channels scoured into the underlying Moenkopi and that the uranium minerals are seldom visible. They also reported that the pebble conglomerate ore zone was commonly high-grade (>1.0% U_3O_8) and was characterized by massive uraninite and its alteration products. Most of the production from the Shinarump No. 1 was from the basal siltstone zone whereas most of the production from the Shinarump No. 3 was from the upper siltstone unit. Little has been written about the Thornburg-Memorial and Bicentennial mines, but most of the ore at these mines appears to have been in the same horizon as the Shinarump No. 3.

The mineralized zones are quasi-horizontal, but cross lithologic boundaries and apparently have little relationship to rock permeability. In fact, most of the ore in the Thornburg and Bicentennial mines was in silty to clayey, fine-grained sandstone. Ore zones can be up to 18 feet thick, but most are much thinner. Ore zones are generally bleached. Hemme (verbal communication, 1998) noted that sandstones and clays below the ore were red, but away from the ore were gray. He believed this relationship was due to oxidation accompanying the uranium mineralization. Other workers report that the beds below the ore are bleached to green or gray from the original red.

Ore minerals consist mostly of uraninite, chalcocite, and pyrite with subordinate chalcopyrite and bornite. Secondary uranium minerals include gummite, schroeckingerite, and becquerelite (Finch, 1954). Secondary copper minerals include malachite, azurite, and possibly chalcocite. The ore minerals occur as impregnations, replacements of carbonaceous material and as coatings on limestone clasts. The ore is reportedly high in carbonate and low in vanadium. The ratios of V_2O_5 to U_3O_8 range from 3:1 to 1:500. Few vanadium-bearing minerals are recognized and most of the vanadium is probably associated with clays (Droullard and Jones, 1955). Reported grades ranged from 0.18% to over 0.40% U_3O_8 and up to 0.13% V_2O_5. Although copper minerals are reported for most mines south of the Shinarump No. 3, Hemme (verbal communication, 1998) reported no copper in the Thornburg or Bicentennial mines immediately to the north.

Potential: The geology of the Seven Mile district is similar to the Lisbon Valley district. Uranium ore deposits occur within the lower members of the Chinle Formation on the western and southwestern side of a faulted salt anticline. Using this analogy, Butler and Fisher (1978) estimated a resource of approximately 500,000 st of ore containing 3,046,400 pounds of U_3O_8, mostly on the southwest side of the Moab anticline, but no specific locations were identified. The area north of the Thornburg/Memorial mine seemingly has the most obvious potential, but Cotter Corporation, Uranex, and Minerals Recovery Corporation have all tested the area by drilling. Apparently only low-grade mineralization was found, and according to Hemme (personal communication, 1998), the mineralization in the Bicentennial mines drops off rapidly to the north beyond the mine workings. Other areas of potential include the downdip extension of the basal Chinle not only west and southwest of the major workings (see reserves section above), but also as far to the south as Little Canyon. The southern area has lower potential because of the absence of significant mines or prospect in the exposed Chinle Formation. However, blind ore bodies could be present along favorable, as yet unknown, trends in the subsurface. The major constraint for these areas, particularly the southernmost area is the depth to the favorable horizon, both for drill testing and mining.

There is also potential for a continuation of the Thornburg and Bicentennial mineralization in the eastern, down-dropped block of the Moab fault in a situation geologically similar to Rio Algom's deep Lisbon deposit east of the Lisbon fault in the Lisbon Valley district. The favorable zone would be at depths of 2000 feet or more and would probably require drilling on less than 1000-foot spacing to discover a Thornberg-Bicentennial-size deposit. A number of companies including Anaconda and Cotter Corporation contemplated such a drilling program in the late 1970s, but apparently decided it was too risky and expensive for the target sought. A potential area is shown on figure 13. Depending on the amount of lateral displacement on the fault, the potential area could be anywhere within the marked area.

The Seven Mile Canyon district is considered to have moderate potential. Positive factors include reported moderate grades (with careful mining); moderate-sized, fairly continuous ore bodies; and proximity to well-established roads and infrastructure. Negative features include the low vanadium content of the ore, possible milling problems due to complex ore and associated sulfides, extreme depth to ore with attendant water problems, distance from existing mills, and proximity to Arches National Park.

12. San Rafael River District (Tidwell Bottoms), Green River Area

The San Rafael River district of the Green River area is located in eastern Emery County approximately 13 miles west of Green River (plate 1). It is also known as Tidwell Bottoms or the San Rafael River mining district. It covers an area of approximately 70 square miles, mostly in T. 21-22 S., R. 14 E. The district is divided into a northern Tidwell belt and a southern Acerson belt (figure 14). Interstate 70 goes through the district just north of the boundary between the Tidwell and Acerson belts. The Tidwell belt is further divided into northern and southern areas with most of the larger and better grade mines in the northern area (figure 15).

Production: Gloyn and others (2003) compiled various production estimates for the mining district. The estimate of Union Carbide for the period 1948 to 1988 is thought to be the most accurate: 950,000 st ore averaging 0.20% U_3O_8 and 0.19% V_2O_5 for a total of 3,800,000 pounds of U_3O_8 and 3,610,000 pounds of V_2O_5.

The low average production grade of 0.20% U_3O_8 is more a reflection of the lowest grade of ore that could be shipped free to the AEC buying stations and mills between 1948 and 1966. Because the AEC would pay the shipping costs, most operators blended their better grade ore with lower grade or waste rock to reach the "optimum grade."

Major mines and their cumulative production in the San Rafael River district follow:

Tidwell belt	
No. 7 Incline Group	631,566 pounds U_3O_8
Inclines No. 4, 5, 6, and 4C-6	556,101 pounds U_3O_8
Newell shaft	295,044 pounds U_3O_8
Incline No. 9	145,518 pounds U_3O_8
Incline No. 8	135,426 pounds U_3O_8
Snow	81,854 pounds U_3O_8
Welsh shaft	69,776 pounds U_3O_8
United Prospectors	55,589 pounds U_3O_8
Incline No. 3	50,303 pounds U_3O_8
Incline No. 17	21,202 pounds U_3O_8
Incline No. 14	16,290 pounds U_3O_8
Black Panther	13,210 pounds U_3O_8
Wedding Bell*	9980 pounds U_3O_8
Acerson belt	
Sahara	6731 pounds U_3O_8
Fantastic	5748 pounds U_3O_8
School Section H2	3148 pounds U_3O_8

Production numbers are from unpublished AEC/ DOE records and generally are through 1973 (Gloyn and others, 2003). Production numbers marked with an asterisk are from Trimble and Doelling (1978). Mine locations are shown in figure 14.

Production data are incomplete for some mines that were operating after 1973, including the Snow, Incline No. 14, Black Panther, Probe, and Sahara. Vanadium production was not compiled for individual mines, but probably is similar to uranium production because grades were so similar. The last significant production in the district was by Atlas Minerals in 1981-83 at the Snow and Probe mines. Past mine permits in the district, now all archived, include the Snow, Sahara, Probe, and Four Corners mines.

Reserves: In 1974, the Utah Geological and Mineralogical Survey estimated "reserves" in the San Rafael mining area at 73,000 st at a low average grade of 0.20% U_3O_8 and 0.80% V_2O_5. Most of these "reserves" were probably mined during the period of high uranium prices between 1976 and 1980, but additional exploration, particularly in the Acerson belt, discovered new "reserves."

Atlas Minerals (1987) estimated the following "reserves" for four properties in the San Rafael mining area, all located in T. 21 S., R. 14 E.:

Four Corners area	NE¼ section 22	63,800 st at 0.146% U_3O_8 and 0.146% V_2O_5
Snow mine	E½SE¼ section 22	24,500 st at 0.269% U_3O_8 and 0.270% V_2O_5
Probe mine	NW¼ section 14	19,500 st at 0.282% U_3O_8 and 0.280% V_2O_5
Jupiter area	SE¼SE¼ section 10 NE¼NE¼ section 15	19,700 st at 0.148% U_3O_8 and 0.148% V_2O_5

These properties were subsequently acquired by San Rafael Energy, Inc. of Moab (Gary L. Jacobson). In addition to the Atlas mines, "reserves" probably also exist at the Sahara, Black Dragon, and possibly several other mines, but numbers are not currently available. Current status of these and other properties is not known.

Ore Deposits: The ore bodies are generally tabular, amoeboid to elongate bodies ranging in size from several square feet to bodies up to 10 feet thick and 200 feet long. "Individual ore bodies often occur in clusters that are as much as 1200 feet long and 200 to 300 feet wide. The clusters are commonly aligned parallel to channel trends" (Gloyn and others, 2003). Clusters are more common in the northern Tidwell belt and are much less common in the Acerson belt although clusters are likely present in the Sahara mine complex. Deposits range from 2000 to 20,000 st with clusters up to 100,000 st.

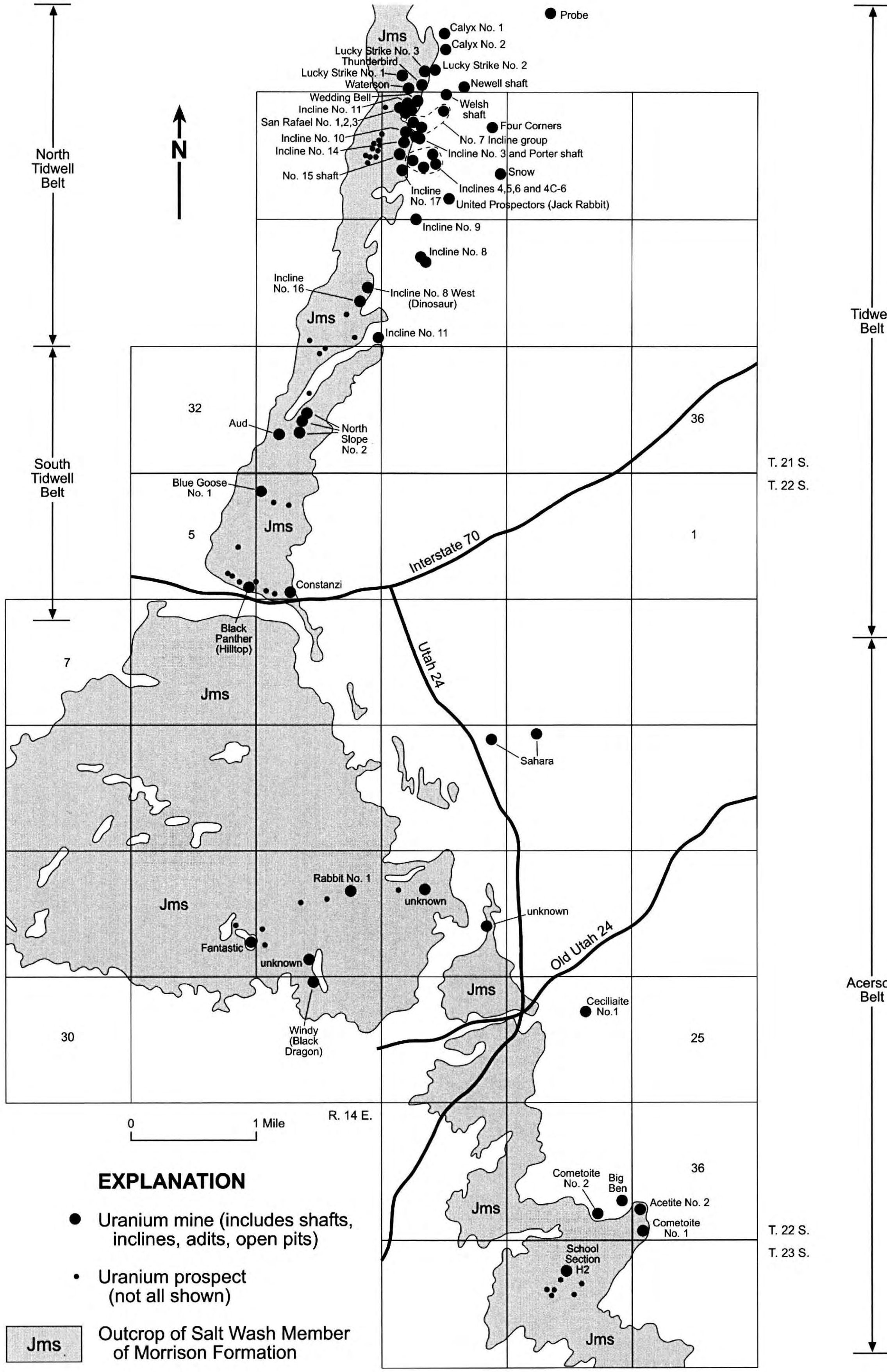

Figure 14. *Mine location map, San Rafael River district, Green River area, Emery County, Utah; the strata generally dipped to the east (after Trimble and Doelling, 1978).*

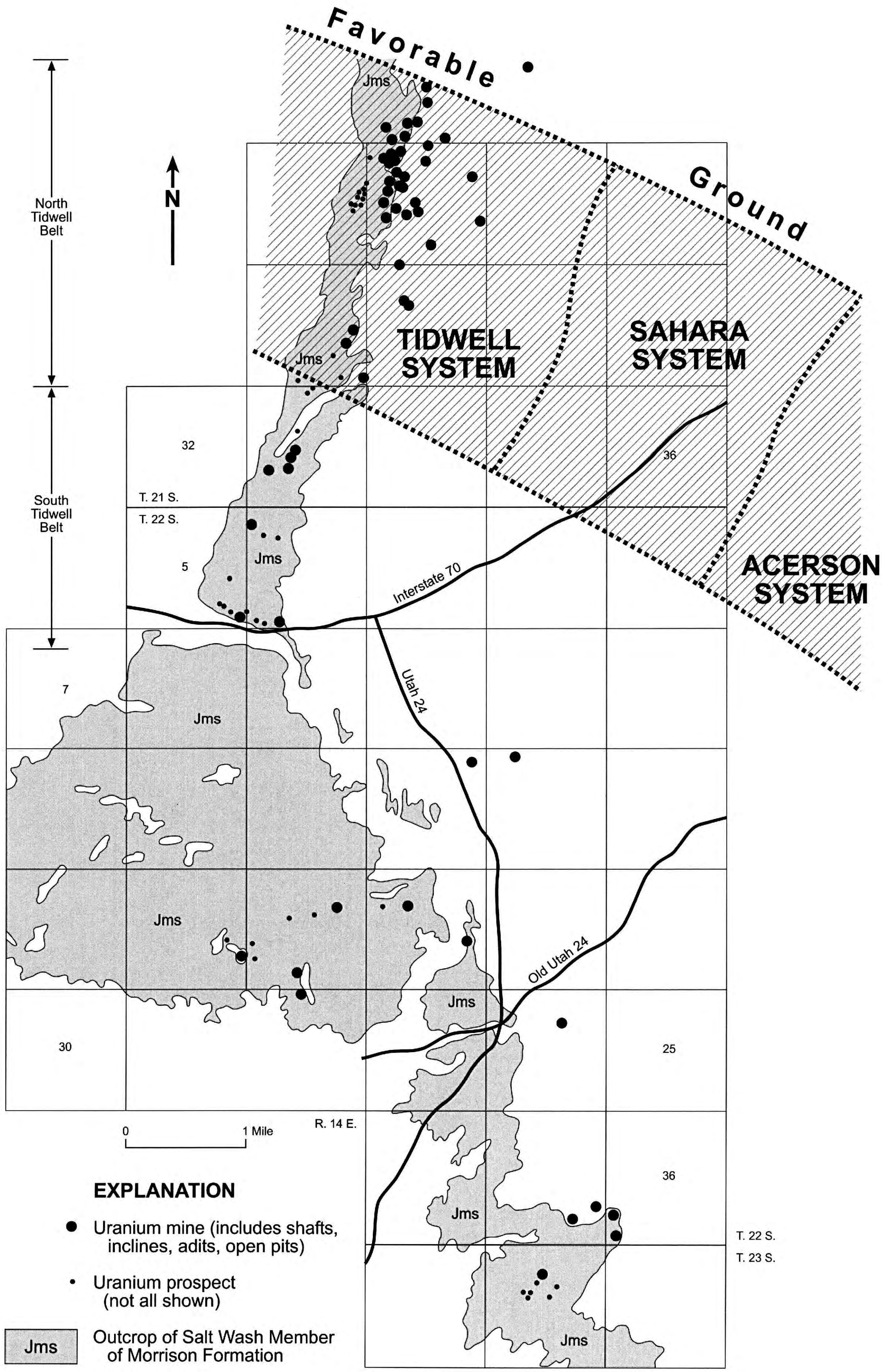

Figure 15. Major drainage systems and areas favorable for significant uranium-vanadium deposits, San Rafael River district, Emery County, Utah (after Trimble and Doelling, 1978).

"The ore is generally concentrated at the edges and base of individual channels, particularly in heterogeneous, poorly sorted zones containing abundant carbonaceous material, clay galls, pebble beds, and shale partings, or in highly carbonaceous sandstone " (Gloyn and others, 2003). Fossil logs are particularly favorable sites in the Acerson belt. According to Trimble and Doelling (1978), the deposits typically show a zonal arrangement with a higher-grade core surrounded by lower grade material. The ore zone consists of an upper, low-grade zone 2 to 4 feet thick containing 0.01-0.20% U_3O_8, a central, higher grade zone up to 1.5 feet thick containing 0.25 to 2.5% U_3O_8, and a lower, low-grade zone 1 to 4 feet thick containing 0.01 to 0.20% U_3O_8. Clark and Million (1956) suggested that better ore occurs on the flanks and noses of small longitudinal and transverse folds and at the intersection of longitudinal and transverse folds.

Most of the San Rafael River district uranium deposits are in the upper part of the Salt Wash Member of the Morrison Formation, but minor deposits are also present in the overlying Brushy Basin Member. The Salt Wash-hosted deposits are confined to thick, massive to cross-bedded, channel sandstones in the upper third of the member. Individual channel sandstones are from 5 to 35 feet thick and may coalesce to form thick aggregate units 80 to 90 feet thick. Channel sandstones are mostly aggradational and trend north-northeast. Three drainage systems have been recognized (from west to east): Tidwell drainage system, Sahara drainage system, and Acerson drainage system (figure 15). According to Trimble and Doelling (1978), in the Tidwell (westernmost) drainage system the mineralized sandstone appears to be a composite of two channel systems. The lower system trends northeast, persists throughout the entire belt and contains most of the ore. The upper system trends southeast, is relatively thin (2-15 feet), scours into the underlying lower system, and is only locally present. Brushy Basin-hosted mineralization is in thin (3-6 feet), fine-grained, commonly iron-stained sandstone in the basal part of the member and in fractured gray mudstone in the middle and upper parts of the member. Most mineralization in mudstone is secondary and occurs along joints and fractures or along carbonaceous partings.

The host units are white to dark gray, moderately reduced sandstone and gray to greenish gray mudstone. All units are relatively reduced. There is no relationship of ore to red brown oxidized sandstone as is seen in Salt Wash-hosted deposits in other districts and areas.

The ore minerals fill pore spaces and voids and replace interstitial clay, cementing material, organic debris, and fossil logs. Unoxidized ore consists of coffinite with subordinate uraninite and the vanadium minerals montroseite and paramontroseite. Associated sulfides are mostly pyrite and marcasite, but only minor base metal sulfides are present (sphalerite, chalcopyrite, clausthalite [PbSe]). Oxidized ore consists mostly of tyuyamunite, metatyuyamunite, and corvusite with rare schroeckingerite, uranopilite, hewettite, and liebigite. Ore grades range from less than 0.05 to over 2.5% U_3O_8 and average 0.15-0.20% U_3O_8 (Trimble and Doelling, 1978). Uranium:vanadium ratios range from 1:1 to 1:2, significantly less than for Morrison-hosted deposits farther to the east in Grand and San Juan Counties.

The deposits are concentrated along the three major drainage systems with most of the deposits in the North Tidwell and South Tidwell areas in the westernmost or Tidwell belt. The central belt (Sahara drainage system) contains the Sahara, Black Dragon, and Fantastic deposits. The eastern belt (Acerson drainage system) contains the Aceite, Cometite, Big Ben, and School Section H2 deposits. Additional Salt Wash channels could be present further to the east, but are covered by younger sedimentary units. The channel trends are from 3000 to 10,000 feet wide and become broader to the northwest. The better and more clustered deposits are present in the northern parts of the channels in a favorable belt perpendicular to the channel trends. This favorable belt corresponds to: (1) an increased percentage of interbedded siltstone and shale, (2) a more braided, less well defined channel system, and (3) finer grained, more dispersed carbonaceous material. Trimble and Doelling (1978) identified this favorable belt (figure 15) and believed it represented a transition from higher velocity, well-defined trunk streams to lower velocity, more braided streams in a floodplain environment.

DOGM Permitted Mine	**Location**	**Operator**
Sahara	section 15, T. 22 S., R. 14 E.	Energy Fuels Nuclear
Smiths Fee Ground	section 5, T. 22 S., R. 14 E.	Chinook Construction
Snow	section 22, T. 21 S., R. 14 E.	Unknown
Four Corners	section 22, T. 21 S., R. 14 E.	All San Rafael Energy
Probe	section 14, T. 21 S., R. 14 E.	Unknown

Potential: In addition to the known "reserves" at existing mines, there is excellent potential for discovery of additional uranium-vanadium discoveries in the San Rafael River mining district. Favorable areas exist where major trunk paleo-channels "break up into a complex of splays and meanders that provide lithologic heterogeneity and an abundance of preserved organic trash" (Mickel and others, 1977). Three major trunk channels are recognized in the San Rafael River mining district, but significant uranium has only been mined from the Tidwell drainage system in the North Tidwell area (figure 15). Each of the unmined San Rafael River channels could contain as much uranium as was mined in the North Tidwell area for an aggregate total of 7 to 10 million pounds each of uranium and vanadium. Doelling (verbal communication, June 2004) believes the area has potential for one or more ore bodies with an aggregate size of 9 million st of ore. Particularly favorable exploration areas include the northern and eastern extensions of the Tidwell drainage system (sections 14, 15, 23, 26, and 27, T. 21 S., R. 14 E.), the northern extension of the Sahara drainage system (sections 25, 35, and 36, T. 21 S., R. 14 E, and section 30, T. 21 S., R. 15 E.) and the northern extension of the Acerson drainage system (sections 29, 30, 31, and 32, and sections 5 and 6, T. 22 S., R. 15 E.). During the mid-1980s, Atlas minerals did widespread exploration drilling to determine the eastern limits of the Tidwell drainage system. In addition, there is potential for additional Salt Wash channel systems further to the east buried beneath younger units.

Any uranium deposits in these areas would be blind and at depths of 300 to as much as 1200 feet deep. Because deposits are typically spotty and discontinuous, a drill spacing of 500 to 600 feet would be required to discover "ore clusters" with even closer spacing (50 to 100 foot spacing or less) required to define "reserves." Four Corners Uranium Corporation used an initial 150-foot drill spacing during their exploration of the district in the early 1950s.

The San Rafael River district has moderate potential for development of significant uranium-vanadium deposits. Favorable features include: (1) known "reserves" (500,000 pounds U_3O_8) are present both in several existing mines and in unmined areas, (2) historically moderate-size ore clusters in broad 1.0- to 1.5-mile-wide channels, (3) excellent exploration potential for northern and eastern extensions of the Tidwell drainage system and in two untested channel trends to the east with potential for 7 to over 20 million pounds U_3O_8, and (4) relatively simple ores amenable to treatment. Negative features include: (1) depth to ore (400-1200 feet) and attendant water problems, (2) low vanadium content (0.25% V_2O_5) significantly lower than most Morrison deposits in San Juan and Grand Counties, and (3) distance from existing mills. Existing mills in southeastern Utah are more than 100 miles away from the district, and although a major paved road goes through the center of the mining area, transportation to either mill would cost $20.00 to 30.00/ton.

13. Sinbad District, San Rafael Swell Area

The Sinbad district is centrally located within the San Rafael Swell of Emery County (Plate 1). The San Rafael Swell is an asymmetric, doubly plunging anticline, with a very steeply dipping east limb. Mineralization in the Sinbad mining district is predominantly hosted in the Triassic Chinle Formation. The Chinle consists of three fining-upward, fluvial-lacustrine sandstone sequences. Sedimentalogical work on the Chinle suggests northwest-trending transport from a braided-stream environment in the southeast to floodplain and lacustrine environments progressively to the northwest (Lupe, 1977).

The Sinbad mine, the major producer in the district, is hosted in a north-northwest-trending sandstone channel in the Monitor Butte Member of the Chinle Formation. Mineralization in the district is principally uraninite interstitial to sand grains and may be associated with V, Cu, Zn, Pb, and Mo (Gloyn and others, 2003).

Production and Reserves: The production at the Sinbad mine prior to 1985 amounted to approximately 250,000 pounds U_3O_8. "Reserves" at the Sinbad mine are estimated at approximately 100,000 to 150,000 st at 0.20% U_3O_8 (Gloyn and others, 2003).

Potential: The potential for the Sinbad district is characterized as moderate based on the presence of known "reserves," fairly continuous deposits, shallow depth (200 to 250 feet), multiple mineralized horizons, potential for additional nodes to the northwest and southeast and the potential for similar mineralization elsewhere in the Monitor Butte Member northwest of the Hertz deposit (also good producer). The lack of important by-product vanadium, proximity to I-70, location in the San Rafael Swell, lack of a nearby mill, possible difficult ore with Cu, and other sulfides offset the positive factors. Plus, the area has been reclaimed and the property dropped.

14. Delta District, San Rafael Swell Area

The Delta mining district lies at the southwestern margin of the San Rafael Swell. The bulk of the uranium ore is hosted by the Monitor Butte Member of the Triassic Chinle Formation with weaker mineralization in the Moss Back Sandstone Member. Paleo-channels in the Moss Back Sandstone Member trend N. 60° W. and are generally in the basal part, not very productive, and thin. Monitor Butte channels trend northeast and contain the moderate-sized Delta deposit (section 9., T. 26 S., R. 9 E.). The Delta and Blue Bird mines both occur in the basal Monitor Butte Sandstone Member (Gloyn and others, 2003).

Production and Reserves: Past production from the Delta mine had accounted for 827,248 pounds of U_3O_8 by 1973 with an additional 1353 pounds of U_3O_8 from the Bluebird (Gloyn and others, 2003). Some "reserves" are listed at the Delta mine, 105,000 st at 0.13% U_3O_8 and about 0.16% V_2O_5, and an additional 10,000 st averaging 0.2% U_3O_8 and 0.2% V_2O_5 at the

Bluebird (Gloyn and others, 2003). The mine permit at the Delta mine has been archived.

Potential: The Delta district is given a moderate to low rating based on the known good deposits in the sub-Moss Back Sandstone Member and the presence of some "reserves" and exploration potential. On the negative side is the low V content, complex Cu-rich ores, deep targets, difficult access, and location between two Wilderness Study Areas.

15. Yellow Cat District, Thompson Area

The Yellow Cat district of the Thompson area is located on the northeast limb of the Salt Valley anticline in central Grand County approximately 24 miles north of Moab (plate 1). The district covers an area of approximately 20 square miles but with the most productive part of the district confined to a central area of about 5 square miles. The district is about 9 miles long and 2.5 to 4 miles wide and straddles the boundary between T. 22 N. and T. 23 N. and R. 22-23 E. The main part of the district extends from the Silver Moon prospect on the west to the Flat Top No. 1 mine on the east.

Production: The Yellow Cat district has been mined successively for radium (1911 to 1923), vanadium (1939 to 1944), and uranium-vanadium (post-1948) (Cannon, 1964). Production from 1911 to 1923 was probably low tonnage, but relatively high-grade; only 50,000 st was mined from the entire Colorado Plateau during this period, and probably less than 10% was from the Yellow Cat district. Two estimates are available for production during the period 1939 to 1946; Chenoweth (1981) estimates that 10,600 st at 2.79% V_2O_5 was produced prior to 1946 and Cannon (1964) estimates that 16,000 st at an unspecified grade was mined between 1939 and 1944. Very little, if any, of the contained uranium was recovered.

Various estimates have been made for uranium-vanadium production from the Thompson area and are given below. Over 95% of the Thompson area production was from the Yellow Cat district so the district production estimates are very close to production from the Yellow Cat district alone:

Tons Mined (st)	Period	U_3O_8 (%)	V_2O_5 (%)	U_3O_8 Pounds	V_2O_5 Pounds	Source
135,000	1911-1978	0.21	1.16	571,000	3,132,000	Thamm and others, 1981
106,000	1911-1973	0.249	0.708	527,000	1,500,000	UGS, 1974
106,177	1911-1967	0.25	–	526,683	–	Cohenour, 1969

The estimate of Thamm and others (1981) is thought to be the best estimate; the numbers for uranium production are consistent with the other estimates and the vanadium grades are reasonable considering the uranium to vanadium ratio of the deposits. The low vanadium estimate from the Utah Geological Survey is probably in error; most of the production was likely shipped to the Uravan mill, which recovered vanadium, but some may have gone to the Moab mill, which did not install a vanadium circuit until 1976. The post-1978 production is probably minor; only during 1980-81 was any production reported for Grand County.

Major mines include:

Parco mines	39,000 st, 156,000 pounds U_3O_8 est., 668,000 pounds V_2O_5 est.
Blackstone Incline	72,288 pounds U_3O_8, 173,490 pounds V_2O_5 est.
Cactus Rat-Mineral Treasure	57,842 poundsU_3O_8, 310,300 pounds V_2O_5 est.
McCoy (Red Vanadium)	30,861 pounds U_3O_8, 220,000 pounds V_2O_5 est.
Parco 23	Estimated at 6000 st, 25,000 pounds U_3O_8, 100,000 pounds V_2O_5 from "reserves" given in Cannon (1964)
School Section 2 (Nickerson State Lease)	19,385 pounds U_3O_8, 15,407 pounds V_2O_5, likely incomplete
Johns Incline	12,924 pounds U_3O_8, 77,500 pounds V_2O_5 est.
Telluride	1315 st, 5837 pounds U_3O_8, 32,759 pounds V_2O_5
Ringtail Shaft	5074 pounds U_3O_8, 47,258 pounds V_2O_5, likely incomplete
Black Ape	3939 pounds U_3O_8, 24,800 pounds V_2O_5 est.
Flat Top No. 1	3866 pounds U_3O_8 ,23,000 pounds V_2O_5 est.
Little Pittsburg No. 1	700 st, 3820 pounds U_3O_8, 12,300 pounds V_2O_5
Windy Point -Juniper	3149 pounds U_3O_8, 19,000 pounds V_2O_5 est.
Blackjack (Blackstone 5)	likely significant production, but no records; may have been included with Blackstone incline
Rube	likely moderate production but unknown
Allor 12	likely moderate production but no records
Parco 25	likely moderate production but no records
AEC (Group 2 Telluride 3)	likely moderate production but no records
Memphis mines	likely moderate production but no records

Many of the mines, particularly those in the southwest part of the area, consist of numerous short adits, inclines, shallow shafts, and small surface pits in a small area. It is not unusual to have 5 to 10 openings of various types and sizes assigned to a particular mine or mine area. For example, the Parco mine consists of approximately 18 adits, 4 shafts, 3 inclines, and numerous surface prospect pits in an area 1000 feet long by 500 feet wide. Because several mine areas may be present in a single claim group with each particular mine area consisting of a great number of openings, it is difficult to accurately assign production to a particular mine. Production from single claim groups were often reported together even though the production came from widely separated areas, and many individual mines reported production under many different names and companies. The production estimates given above are best estimates based on available data and should be considered as showing relative sizes of the mines rather than absolute production. Production records for many, particularly the older, near-surface mines, are not available (no records) or are incomplete.

Permitted mines (all currently archived) include the Cactus Rat (Atlas Minerals); Section 32 and Blackstone (Homer Davis), Blackjack (Parco North area) and DCMI mine (section 9, T. 23 S., R. 21 E.) (Day Mining Company), and Cougar No. 1 (Telluride area) (NBS Mining).

Reserves: No formal reserves are known in the area, but significant lower grade ore is probably present in many of the larger mines. Butler and Fisher (1978) estimated "reserves" in the Thompson area at 21,300 st containing 125,600 pounds U_3O_8 and 640,000 pounds V_2O_5 as of 1971 and the Utah Geological Survey estimated "reserves" remaining in existing mines in the Yellowcat district at 3575 st at 0.17% U_3O_8 and 1.21% V_2O_5 as of 1974. Some, but not all, of these "reserves" were mined between 1971 and 1978. Doelling (verbal communication, May 2004) believes that much ore remains in the old workings particularly in the Johns Incline mine. Other mines with remaining ore include School Section 2, Ringtail Shaft, Blackjack (Blackstone 5), and possibly also in the Allor 12, Juniper, and "Cactus West" areas.

Ore Deposits: Uranium-vanadium deposits in the Yellow Cat district occur as relatively continuous, tabular and roll-type ore bodies and as isolated mineralized logs surrounded by a halo or aureole of lower grade ore. Tabular bodies are most common, but roll-type deposits are relatively common. Stokes and Mobley (1954) reported that the roll-type bodies were larger and better grade than the tabular bodies, but their conclusion was based mostly on the oxidized deposits around the Parco mine before the moderate-sized, tabular deposits in the northwestern part of the district had been developed. Both tabular and roll-type ore bodies occur together with roll-type ore bodies grading into tabular bodies along bedding or unconformities. According to Stokes (1952), roll-type ore bodies have sharp contacts, but the boundaries of tabular bodies are more gradational with limits determined by assay cutoffs. The size of individual ore bodies ranges from a few to several thousand st, but often cluster with several "ore pods" within an area 400 to 800 feet long by 250 to 300 feet wide.

Roll-type ore bodies are typically C- or S-shaped (S-shaped apparently more common), but may be extremely irregular with multiple combinations of C- and S-shaped bodies (see cross sections in Stokes, 1952). Roll-type ore bodies are 3 to 15 feet high, 2 to greater than 6 feet wide, and up to 900 feet long. Rolls are often grouped with multiple rolls occurring together either adjacent to each other or "along strike." The rolls generally follow paleo-current directions or channel trends. Grade is highly variable along trend with better grade zones separated by lower grade areas.

Tabular ore bodies are generally parallel to bedding or unconformities, have highly irregular shapes, and exhibit a sporadic grade distribution with complex interfingering of high and low grade areas. Ore body margins are less well defined than in roll type deposits. Ore bodies are from several inches to over 16 feet thick with an average thickness of 3 feet and lateral dimensions ranging from small pods 5 by 15 feet, to larger bodies 200-250 feet wide by 1400 or more feet long (Stokes and Mobley, 1954).

The major deposits are confined to the Salt Wash Member of the Morrison Formation, but some very minor prospects are developed in sandstones in the lower part of the Brushy Basin Member. In the Yellow Cat district, the Salt Wash is approximately 260 feet thick and consists of interbedded mudstone and lenticular sandstone to conglomeratic sandstone. Overall the member contains almost equal amounts of sandstone and mudstone/siltstone. The sandstone and conglomerate beds are 10 to over 50 feet thick and are separated by layers of mudstone of variable thickness. The sandstones consist of numerous overlapping and coalescing sandstone lenses deposited by aggrading streams in a floodplain environment. Stokes (1952) believed that most sandstones were deposited by relatively straight, low-sinuosity streams, most likely a braided-stream environment. Although individual sandstone lenses can rarely be traced for more than a mile, the sandstone lenses are concentrated into "channels" characterized by (1) a higher percentage of sandstone lenses than in surrounding areas and (2) a relatively consistent paleocurrent direction (Stokes, 1952). None of the earlier geological reports gave any information on "channel widths," but based on the distribution of mines and prospects, favorable zones are 3000 to 7000 feet wide, similar to those in other Salt Wash areas.

Four major sandstone horizons are recognized: (1) a lower massive sandstone with a thin clay zone near the base (30 to 60 feet thick; 50 to 60 feet above base of Salt Wash Member); (2) a medium- to fine-grained impure sandstone (30 to 60 feet thick, occurs approximately 20 to 25 feet above lower sandstone); (3) an upper, cross-bedded conglomeratic sandstone with abundant gray pebbles (10 to 25 feet thick, occurs 6 to 15 feet above sandstone); and (4) an uppermost conglomerate sandstone with abundant red and green chert pebbles (5 to 15 feet thick, occurs at the top of Salt Wash Member). In addition, some thin, discontinuous sandstone beds interbedded with mudstone and siltstone are present in the basal 50 to 60 feet of the Salt Wash Member.

Many of the uranium deposits are in the lower sandstone horizon with many thin deposits occurring at the stratigraphic level of the clay zone. This lower horizon contains most of the deposits near Yellow Cat including the Parco mines, AEC 1 and 3, and Parko 23 deposits in the main part of the district, and the Black Ape and Memphis deposits in the graben to the south. Few deposits occur in the middle impure sandstone horizon. The upper conglomeratic sandstone horizon contains deposits in the Little Pittsburg 3 and 4, Telluride No. 3, and Flat Top No. 1 areas. The Johns Incline, Parko 23, and Blackstone Incline deposits may also be in this conglomerate horizon. The uppermost conglomerate horizon contains the Ringtail Shaft, Blackjack Incline, School Section 32, Cactus Rat, and McCoy-Red Vanadium deposits. The Little Pittsburg No. 1 and several small occurrences southwest of this mine are probably in discontinuous sandstones in the basal siltstone-mudstone unit.

Most deposits are in coarse- to medium-grained sandstone, but are also present in siliceous pebble conglomerate in the upper and uppermost sandstone-conglomerate horizons. Mudstone and siltstones are generally barren except where in contact with ore-bearing sandstone. According to Stokes and Mobley (1954), the deposits generally occur in the thicker, more continuous sandstones with the larger deposits usually within the center of the channels, usually within the lower third of the sandstone lens. However, a high percentage of deposits, including the deposits in the Red Vanadium, Telluride 3, and Flat Top No. 1 areas occur along the lateral margins of sandstone lenses adjacent to shale and mudstone. The host sandstones are white to gray. Shales and mudstones are predominately red, but are altered to blue-green near the ore deposits. Roll-type deposits generally follow paleocurrent directions and channel trends, but the tabular deposits are often at angles to these trends. Mineralization trends for deposits in the upper sandstone and uppermost sandstone-conglomerate are generally at angles of 20 to 40° to the channel trend. This feature is common for many Morrison-hosted deposits including those in the La Sal and La Sal Creek districts. The tabular bodies at the Ringtail shaft, School Section 32, Cactus Rat mines, and Flat Top No. 1 all show this feature and could possible represent cross-scours.

The Salt Wash channels generally trend east to northeast and reportedly are relatively straight with few meanders. Paleo-current direction based on numerous cross-bedding measurements showed two main trends, a strong trend at N. 55° E. and subsidiary trend at S. 85° E. However, the paleocurrent directions show much variability and change in orientation along trend and between different sandstone horizons. An evaluation of plate 2 of Stokes (1952) shows that each of the three major sandstone horizons has a slightly different "channel" trend. The uppermost sandstone and conglomerate unit trends N. 45° E. on the west, but gradually curves to due east further east. The lower, upper sandstone generally trends N. 15° E. in the south, but curves to N. 25° E. further north. The main sandstone trends N. 80° E., but with occasional meander bends west and south of the Yellow Cat camp site.

In oxidized deposits above the water table, the principal uranium-vanadium minerals are carnotite, tyuyamunite, roscoelite, corvusite, and vanadium hydromica. These minerals are associated with gypsum, selenates, and many secondary uranium-vanadium minerals such as hewettite, meta-hewettite, rossite, meta-rossite, and pascoite. Unoxidized deposits contain uraninite (pitchblende), coffinite, and montroseite associated with metallic sulfides and selenides. Several rare uranium minerals are present at the Cactus Rat deposit including rauvite, steigerite, and phosphuranylite. Some unoxidized ore was present at relatively shallow depth where the ore was protected from oxidation by impermeable shales (Juniper mine). Most of the mines in the central part of the area near the Yellow Cat camp site were oxidized, but the deeper ores accessed by shafts and inclines to the north (School Section 2, Blackstone Incline, Ringtail shaft, and others) mined unoxidized ore. The ore minerals occur as void fillings, as coatings on detrital grains, and as replacements of clay in thin seams, clay pebble conglomerates or galls, and as replacement of carbonaceous material. According to Stokes (1952), the vanadium minerals occur homogeneously distributed throughout the sandstone, concentrated along bedding or as irregular spots or blebs. Yellow or brown limonite staining is prominent around most of the oxidized deposits likely from oxidation of primary iron sulfide and selenides.

Ore grades range from 0.05 to 5% U_3O_8 with an average grade of 0.25% U_3O_8 and 0.10 to over 15% V_2O_5 with an average grade of 2.0% V_2O_5 (Stokes and Mobley, 1954 for range; Cannon, 1964 for average). The average uranium:vanadium ratio is estimated at 1:7 (Utah Geological and Mineralogical Survey, 1974). Replacements of carbonaceous material may assay as high as 10% U_3O_8. Stokes and Mobley (1954) reported that the smaller deposits are usually better grade, but gave no specifics. The deposits contain lesser, but anomalous amounts of selenium (10 to 700 ppm, averaging 190 ppm), molybdenum (1 to 800 ppm, averaging 100 ppm), arsenic (30 to 1800 ppm, averaging 420 ppm), nickel (4 to 200 ppm, averaging 35 ppm), and cobalt (5 to 200 ppm, averaging 60 ppm). The association with anomalous selenium has been used successfully as a prospecting tool, with selenium indicator plants such as Astragalus occurring over, or adjacent to, concealed deposits (Cannon, 1964)

Potential: Although no known reserves are known, the area has potential for uranium and vanadium production and discovery of additional reserves. Ore remains in many of the deeper mines in the northwestern part of the area in the Johns Incline, Ringtail, Blackjack, and School Section 2 areas. Most of these mines are flooded and would require pumping and rehabilitation. An estimated 70,000 st at 0.25% U_3O_8 and 1.5% V_2O_5 remains in and adjacent to these northern workings based on typical size of deposits in the area and past production.

Cannon (1964) identified a number of geologically favorable, near-surface areas based on geobotanical prospecting and wide-spaced drilling. Some of these areas have been subsequently drilled and developed, but others are probably still untested. There is also potential for continuation of the known favorable areas and trends to the north and northeast. Butler and Fisher (1978) estimate a resource of 260,000 st at 0.225% U_3O_8 and 1.5% V_2O_5 for this area at depths of less than 1000 feet with most of the resource at depths of less than 500 feet. Atlas Minerals did some drill testing for deeper deposits from 1980 to 82, but results are unavailable. Although the geologically favorable area continues even farther northeast, the Moss Back Sandstone Member becomes more deeply buried along the Sager Wash syncline and any deposit would be too deep for cost-effective mining.

The Yellow Cat district is ranked as having moderate potential. Most of the near-surface deposits were small to moderate size, but several of the deeper, unoxidized deposits produced significant amounts of uranium (60,000 to 70,000 pounds U_3O_8). The ore contains moderate amounts of vanadium and can be treated at existing mills. Mineralization remains in many of the mines and moderate exploration potential exists to the north and east along favorable trends. Deposits would be at reasonable depths of 200 to 1000 feet, but mine workings at that depth would require groundwater pumping. Negative features include the remoteness of the district, the distance from existing mills, and the lack of infrastructure.

16. Polar-Beaver Mesa Districts, Gateway Area

Polar-Beaver Mesa districts are in Grand County (Plate 1) and the uranium mineralization in the Gateway area extends into adjoining portions of Colorado as the Uravan mineral belt. The Gateway area lies on the very gently dipping, southwest limb of the Sagers Wash syncline. The Jurassic Salt Wash Member of the Morrison Formation is the primary uranium host in the districts. The Salt Wash Member here is slightly over 300 feet thick and ore occurs predominantly in the light-brown to light-gray, 10- to 80-foot thick, "Payoff" sandstone horizon in the upper portion of the unit (Utah Geological and Mineralogical Survey, 1974). Minor mineralization also occurs in the basal Brush Basin Member and at the base of the Chinle Formation.

Mineralization is associated with fossilized logs, carbonized vegetal matter, and seams of mudstone. Individual ore bodies are tabular, amoeboid-shaped, and range in size from 100 to 5700 st, but the deposits tend to cluster (Utah Geological and Mineralogical Survey, 1974). Both oxidized and unoxidized ores are known, but unoxidized ores are the most important producers. Pyrite is abundant in the ores along with uraninite, coffinite, montroseite, and doloresite (Utah Geological and Mineralogical Survey, 1974). The ores typically average about 0.3% U_3O_8 and 1.2% V_2O_5.

Cohenour (1969) estimated production from the Gateway area at 210,691 st at 0.31% U_3O_8 producing 1,326,518 pounds U_3O_8 and 4,380,000 pounds V_2O_5 to 1967. The Utah Geological and Mineralogical Survey (1974) estimated a total inferred resource of 55,070 st averaging 0.25% U_3O_8 representing 246,680 pounds of U_3O_8 and about four times as much V_2O_5. Although the Polar Mesa district was explored and some claims were staked in 1998, there is only one currently permitted operation, the Petrified Tree # 8 (section 34, T. 24 S., R. 25 E.) owned by Umetco.

Reserves:

Bonanza-La Sal	19,900 st at 0.30% U_3O_8, sold to Umetco by Atlas mostly in Utah, some in Colorado.
October	15,850 st at 0.322% U_3O_8, sold to Western State Reserve, known reserve mostly in Utah.
South October	5250 st at 0.569% U_3O_8, sold to Western States Reserve.

Potential: Although the Polar-Beaver Mesa districts are not near a mill, the shallow depths to mineralization (less than 500 feet), moderate by-product vanadium content, and presence of known reserves are all positive factors. There is believed to be moderate exploration potential in the eastern portion of the Polar Mesa district and along north-northeast-trending channels in the southwestern portion of the Beaver Mesa district.

17. Spor Mountain District

The Spor Mountain district is located in central

Juab County (plate 1) approximately 40 miles northwest of Delta (plate 1). The part of the district with a history of uranium-beryllium-fluorite production covers an area of approximately 40 square miles in the southern part of T. 12 S., R. 12 W. and the northern part of T. 13 S., R. 12 W. The district is best known for its fluorite and beryllium deposits, both of which are uraniferous in part, but also contains several uranium-only deposits in sandstone and volcaniclastic host rocks (figure 16).

Production: According to Chenoweth (1990a), between 1948 and 1970, Juab County produced 425,957 pounds of U_3O_8 and 45 pounds of V_2O_5 from 105,356 st of ore at a low average grade of 0.20% U_3O_8. Nearly all of this production was from the Yellow Chief mine. Very minor uranium was also produced from secondary uranium (carnotite?) ores associated with fluorite deposits and/or from uraniferous opal at the Buena No. 1 and Autunite No. 8 prospects. More recently some uranium has been produced as a by-product of processing beryllium ore (Lindsey, 2001).

Reserves: Little, if any, uranium remains at the Yellow Chief mine. To the north the host unit is cut off by a due-east- to N. 30° E.-trending fault. To the west the host unit extends only a short distance down dip beyond the pit limits before it, too, is cut off by a generally north-trending fault. Some limited potential may exist to the south. Lindsey (1978) reports that the favorable host unit is traceable to the south in drill holes beneath alluvial cover. Polaris Resources reported uranium mineralization in a drill hole about 1000 feet south of the Yellow Chief mine (Mining Engineering, 1978), and SITLA (2004) reported a low-grade deposit still further to the south. Tonnages and grades are not known; it is not even known if any of the mineralization is ore grade.

Uranium is also associated with the beryllium deposits, mostly as uraniferous opal and within fluorite. The beryllium deposits contain 50 to 200 ppm uranium and according to a U.S. Department of Energy estimate, 20,000 to 40,000 pounds of U_3O_8 could be recovered yearly from beryllium mining (U.S. Dept. of Energy, 1979). Current (2003) company-reported beryllium reserves (proven and possible) are 7.75 million st. At 125 ppm U_3O_8, the known beryllium reserves could contain approximately 1.9 million pounds U_3O_8. Recoverable uranium would be significantly less (see potential section).

Ore Deposits: Uranium occurs in four environments in the Spor Mountain district: (1) in tuffaceous sandstone and conglomerate at the Yellow Chief mine, (2) in beryllium deposits in air fall/base surge tuff near the top of the "beryllium tuff member" of the Spor Mountain Formation, (3) in fluorspar veins, pipes, and breccias mostly in Paleozoic limestones, and (4) in opaline silica veinlets and fracture fillings in volcanic and older sedimentary units. Nearly all of the uranium production was from the first category with lesser production from the other three categories.

Most of the primary uranium mineralization is related to alkali rhyolites and, in particular, the older Spor Mountain Formation episode (<21 m.y.), but some may be related to the younger Topaz Mountain Rhyolite episode (<6 m.y.). Both alkali rhyolite episodes consisted of an early explosive phase forming air fall and base surge tuffs followed by rhyolite flows, plugs, and domes often with associated vitrophyres. The early explosive-phase material contains clasts of pre-rhyolite volcanic and carbonate rocks. Hydrothermal fluids associated with the later stages of these alkali rhyolite episodes moved up faults, fractures, and breccia zones. The fluids deposited: (1) fluorite, beryllium, and uraniferous opal within the porous tuff, (2) uraniferous opal in fractures in rhyolite and other competent units, and (3) uraniferous fluorite in Paleozoic units by reaction with carbonate host rocks. According to Lindsey (1981), no primary uranium minerals have been recognized and the uranium is likely contained within the fluorite or opal lattice.

The enigmatic Yellow Chief uranium mine in the Thomas Range of western Juab County does not fit well into any of the usual uranium deposit types. The ore is hosted in a west-tilted block of the beryllium tuff member of the Lower Miocene Spor Mountain Formation within the Thomas caldera (Lindsey, 1982). Production at the Yellow Chief is estimated at 100,000 st averaging about 0.21% U_3O_8 (Bowyer, 1963). The Yellow Chief does not have the associated fluorine, beryllium, and lithium of the hydrothermal uranium occurrences to the west at Topaz Mountain, nor does it have the copper, vanadium, chromium, silver, and molybdenum typical of the sandstone-hosted ores of the Colorado Plateau (Lindsey, 1982). The uranium likely was transported as a uranyl (+6)-fluorine complex with precipitation of uranium due primarily to breakdown of the fluorine complex by reaction with carbonate rocks to form fluorite, and secondarily by cooling. These primary uranium occurrences and possibly the topaz rhyolite tuff are thought to have provided the uranium for groundwater-remobilized, secondary uranium deposits within the tuffs themselves or in clastic units like at the Yellow Chief deposit. Lindsey (1978) proposed that the tuffs within the Topaz Mountain Rhyolite could have also acted as a uranium source. Near the Yellow Chief mine, the tuff is "extensively zeolitized, leached of alkali metals, and likely to have been leached of uranium by groundwater" (Lindsey, 1978).

Uranium mineralization at the Yellow Chief mine (figure 16) occurs as lenses of disseminated secondary uranium minerals (mostly beta-uranophane) in a 100- to 120-foot-thick sequence of conglomerate and tuffaceous sandstone that directly underlies the "beryllium

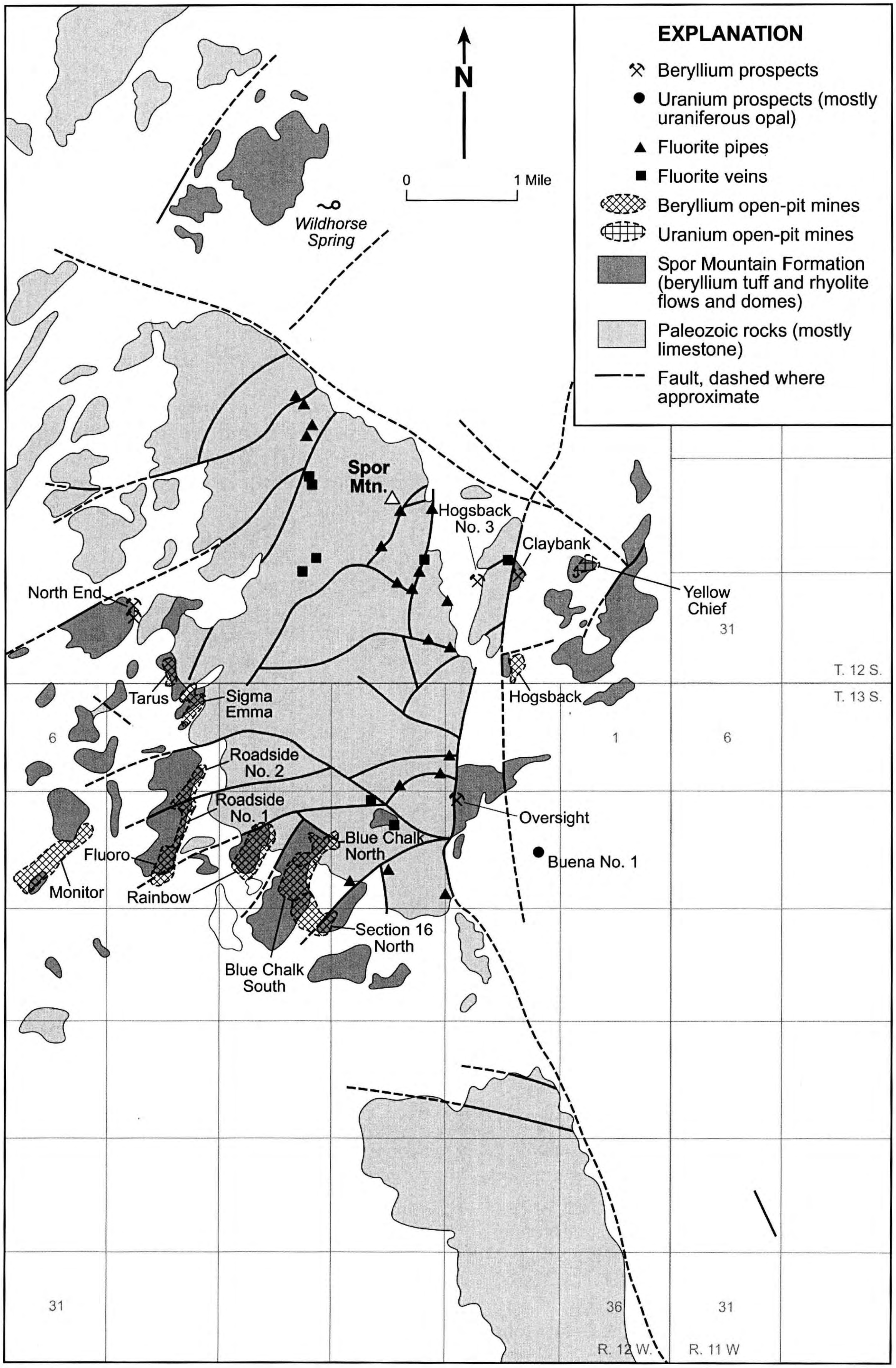

Figure 16. Spor Mountain mining district, Juab County, Utah, showing beryllium, fluorite, and uranium deposits (from Lindsey, 1982).

tuff member" of the Spor Mountain Formation. (Note: Historically this host unit was considered to be part of the "beryllium tuff member" as interbedded sandstone and conglomerate, but Lindsey (2001) now considers it to be below the "beryllium tuff member.") Ore at the Yellow Chief mine is confined to an elongate zone 500 feet wide and 2000 feet long that trends N. 30° E. The host rock is a massive, poorly sorted, coarse-grained sandstone or grit with lenses of conglomerate, fine-grained sandstone, and shaley material. The interbedded conglomerates and conglomeratic sandstones are in lenses less than a foot to over 6 feet thick. The sandstone is stratified, but bedding is indistinct. The sandstone consists of angular, detrital grains of quartz, sanidine, plagioclase, and minor mafic minerals in a matrix of undifferentiated clay, micaceous material and glass. The matrix forms 37% of the rock and is partially altered to smectite. A cross section by Lindsey (1978) indicates that the unit is more conglomeratic in the lower parts. The cross section also shows a thin (1- to 6-foot) limestone conglomeratic unit at the top of the clastic sequence. The clastic sequence is underlain by white, fine-grained, laminated tuff and overlain by white to pink bentonitic tuff. The underlying tuff is not named, but is probably part of the Dell Tuff. The overlying tuff is the basal part of the "beryllium tuff member" of the Spor Mountain Formation.

In the conglomeratic sandstone, uranium occurs as beta-uranophane. The ore zones are generally conformable, small lenses 30 feet wide by 2 to 6 feet thick (locally up to 20 feet thick) and up to 300 feet long. The thicker ore bodies are in coarse-grained, gritty sandstone with few conglomerate lenses, but ore also occurs in conglomerate lenses. In the limestone conglomerate, uranium occurs as weeksite. Ore zones are lenticular, less than 3 feet thick, and up to 30 feet long. The uranium minerals occupy interstices, fractures, and coat sand grains and clasts in the sandstone and conglomerate. The ore is not anomalous in beryllium, fluorite, or lithium, (elements associated with the primary mineralization in the beryllium tuffs), suggesting that it is secondary. The ore is also not anomalous in vanadium, molybdenum, or selenium, elements generally associated with Colorado Plateau uranium deposits (Lindsey, 2001). According to Lindsey (1982), the deposit was formed by groundwater carrying uranium leached from primary deposits and/or overlying tuffs, most likely as a uranyl carbonate complex. No reducing agents or rolls are found in the deposit, suggesting deposition by contact between two chemically distinct groundwaters. The uranium was likely precipitated from groundwater as a uranyl phase. The Yellow Chief mineralization may represent either a distal, low-temperature manifestation of the hydro-thermal U-F-Be ores of the Spor Mountain district, or unique variation on the sandstone-hosted uranium ores in a volcanic setting.

Uranium associated with the beryllium deposits occurs in fluorite and as uraniferous opal. The highest uranium grades generally occur in, or below, the main beryllium zone near the contact of the "beryllium tuff member" with the overlying porphyritic rhyolite member of the Spor Mountain Formation. At the Roadside mine, the beryllium zone is about 25 feet thick and contains 50 to 100 ppm uranium. A uranium-rich zone, 2 to 30 feet thick, containing 100 to 200 ppm uranium is present immediately below the beryllium zone. At other mines, the highest uranium content occurs with the highest beryllium content. Better grade uranium occurs within the fluorite-opal nodules in the beryllium zone with some nodules containing up to 2000 ppm uranium (2360 ppm U_3O_8). The beryllium/uranium deposits occur along north-trending faults in the eastern part of the district on the west side of The Dell (Claybank and Hogsback) and along north-northeast trending zones in the southwestern part of the district (Monitor, Fluro, Roadside, Rainbow, Blue Chalk, and others) (figure 17). The beryllium deposits are tabular, typically 5 to 20 feet thick, up to 1200 or more feet wide, and 10,000 or more feet long. Generally only one horizon is mineralized, but as many as three beryllium ore zones may be present in the "beryllium tuff member."

Uranium is also present in the altered "beryllium tuff member" of the Spor Mountain Formation away from significant beryllium mineralization. Some altered tuff in drill cuttings, from a hole on the east side of Fish Springs Flat, contained 200 to nearly 600 ppm uranium, but less than 0.2% BeO. Lindsey (1981) attributed the wider distribution of uranium and lithium than beryllium as a result of greater mobility of these elements in the hydrothermal fluid. However, some of the non-beryllium-associated uranium may be due to secondary remobilization of "primary" uranium by groundwater.

Uranium may also occur in some of the fluorite pipes and veins in the district, but not all fluorite pipes contain uranium. The uranium is contained within the fluorite lattice itself with uranium substituting for calcium (Sharpe, 1963). Assayed fluorspar samples contained up to 0.33 percent uranium, but most were in the range 0.012 to 0.03 U_3O_8 (Lindsey, 1982, quoting Staatz and Carr, 1964). Secondary uranium minerals, such as weeksite, carnotite (?) and beta-uranophane (?), are associated with some of the pipes. Some pipes contain up to 0.10 to 0.20% U_3O_8. Sharpe (1959) reported that the southern pipes are richer and that pipes at the south end of Spor Mountain contain about four times as much uranium as those on the northern end. The most significant uranium content is at the Bell Hill pipe in the extreme southeast corner of section 10, T. 13 S., R. 12 W.

Fracture fillings and veinlets of uraniferous opal are known in volcanic and pre-volcanic sedimentary

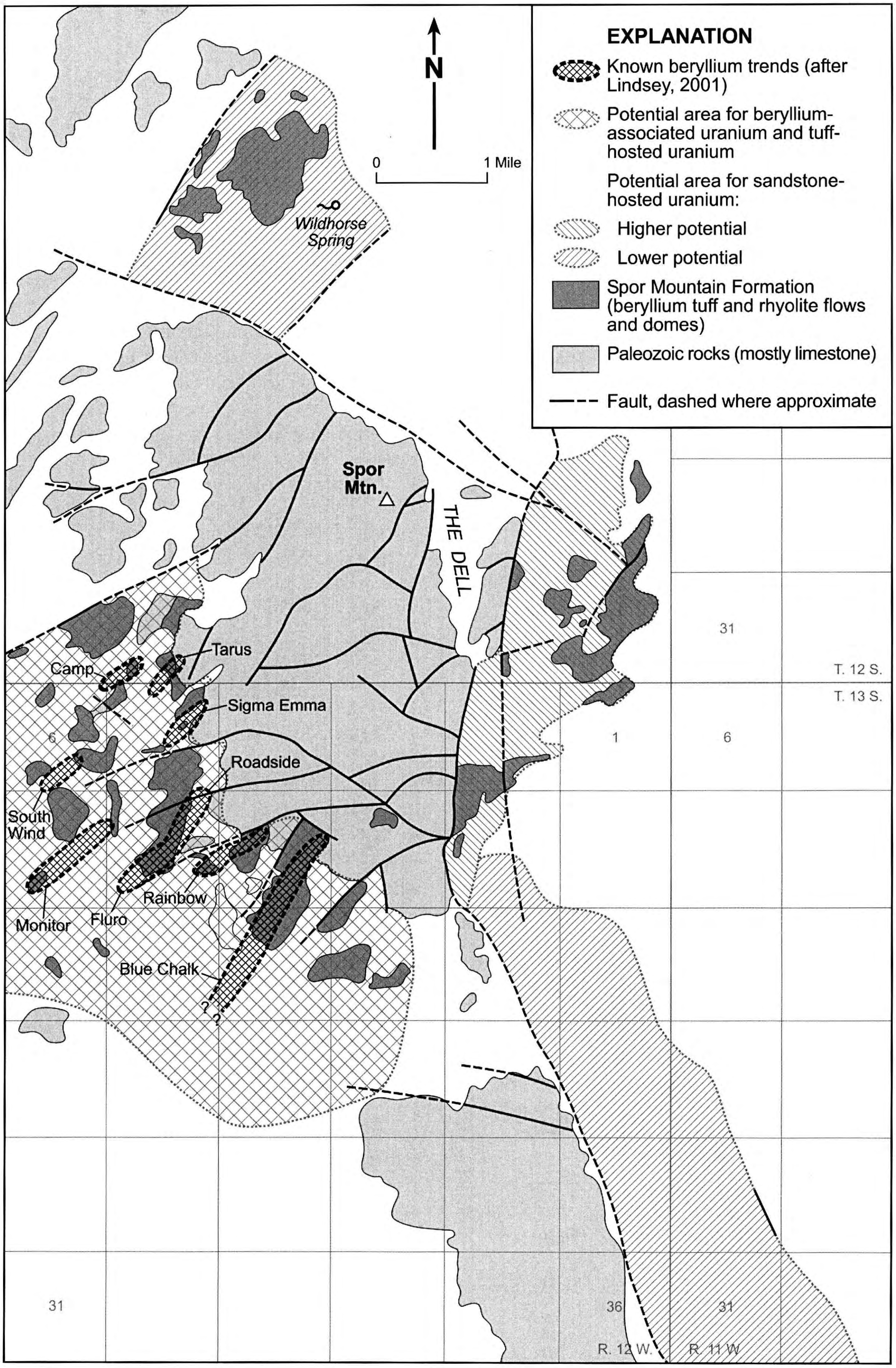

Figure 17. Uranium potential areas of the Spor Mountain mining district, Juab County, Utah [modified by R.W. Gloyn from Lindsey (1982 and 2001)].

rocks, generally in brittle units. Uraniferous opal occurs as fracture fillings cutting the (1) Dell Tuff (Autunite No. 8 prospect and in The Dell area), (2) Topaz Mountain Rhyolite (Buena No. 1 prospect and above the Autunite No. 8 prospect), (3) "beryllium tuff member" of the Spor Mountain Formation, and (4) porphyritic rhyolite member of the Spor Mountain Formation (Wildhorse Springs). The fracture fillings are small, less than 4 to 6 inches wide and occur both singly and in zones less than 30 feet wide and 100 feet long. The opal is often associated with calcite, quartz, and fluorite and may contain secondary uranium minerals (weeksite). The veinlets are often zoned with zoning defined by varying sizes of fibrous crystallites orientated perpendicular to the veinlet walls. Uranium is concentrated in the opal parallel to the zoning. Uraniferous opal formed over a period of 18 million years or more; radiometric ages range from 21 Ma (associated with Spor Mt. Formation) to 3 Ma. No significant ore has been produced from any of the veinlet occurrences. More massive uraniferous opal occurs as replacements in the beryllium deposits (see above) and may have some resource potential, but the fracture/veinlet occurrences are not viable targets be-cause of their small size and extent.

Potential: There is limited potential for discovery of better grade (>0.10% U_3O_8) uranium deposits in the Spor Mountain district, but moderate to good potential for discovery or development of low-grade deposits where uranium might be produced as a by-product. Better grade deposits would include secondary, sandstone- or conglomerate-hosted deposits like the Yellow Chief or hypothetical vein/replacement deposits (see below). Low-grade deposits or by-product deposits would include uranium within the "beryllium tuff member" of the Spor Mountain Formation (with or without beryllium) and deposits associated with some of the fluorite pipes.

Estimating potential and delineating favorable areas for sandstone- or conglomerate-hosted uranium deposit similar to the Yellow Chief is particularly difficult. Only one significant deposit is known and the factors controlling the location and extent of the uranium mineralization are not known. Of critical importance in locating new targets is knowing whether the source of the remobilized uranium came from: (1) fluorite pipes, (2) altered Spor Mountain or Topaz Mountain tuffs, (3) uranium-beryllium deposits (Hogsback, Claybank), or (4) a combination of two or more of the above. Four areas, thought to have potential, are listed below:

1. The Dell area has obvious potential because all possible sources are present and the favorable host unit is, at least locally, present. However, it is likely that the area has been extensively drilled and no deposits were reported. The area includes the south half of sections 25 and 26 and all of section 35 and 36, T. 12 S., R. 12 W.

2. The southern end of The Dell is also favorable for source units, particularly high-uranium fluorite pipes, but it is not known if favorable clastic host units are present. It is likely that this area has also been extensively drilled. The favorable area covers sections 2 and 11, T. 13 S., R. 12 W.

3. The northern end of the Joy graben likely contains favorable clastic host units derived from the Dell Tuff, but potential uranium sources are more distant. The area is mostly covered, but probably has been at least partially drilled. The favorable area covers sections 14, 24, and 25, T. 13 S., R.12 W. and possibly sections 30, 31, and 32, T. 13 S., R. 11 W.

4. The Wildhorse Spring area, particularly within the graben, has uranium source rocks (fluorite pipes and Topaz Mountain and Spor Mountain tuffs), but the presence of a favorable clastic host unit is conjectural. The area has likely been partially drilled. The favorable area includes sections 4, 8, 9,16, 17, and 21, T. 12 S., R. 12 W.

Potential for sandstone- or conglomerate-hosted secondary uranium deposits also exists to the east of the Yellow Chief in the Thomas Range. Favorable host rock would be expected in down-faulted blocks now covered by the Topaz Mountain Rhyolite. The area has low potential because exploration would be blind, and any deposits discovered would be at depths of 500 to 1500 feet or more.

Lindsey (1982) postulated that uraninite or coffinite veins, similar to those near Marysvale, could be present in a hypothetical pluton of alkali rhyolite. Based on the distribution of Spor Mountain eruptive centers, the distribution of the Spor Mountain Formation, and the intensity of mineralization, he located this hypothetical pluton beneath Spor Mountain approximately ? mile west of Eagle Rock Ridge. Uranium potential is extremely speculative and, even if present, any mineralization would be deep and likely uneconomic.

Potential exists for low-grade uranium in the "beryllium tuff member," both associated with economic beryllium mineralization and away from known beryllium deposits. The favorable area is located in the southwest part of the district where the "beryllium tuff member" of the Spor Mountain Formation is thicker and better developed. The area has been extensively drilled; the near-surface beryllium deposits have been delineated and Brush Wellman personnel are likely aware of other low-grade uranium resources in the area. The U.S. Department of Energy (1979) estimated that the "beryllium tuff member" contained probable "reserves" of 4 million pounds of U_3O_8 and possible "reserves" of 12 million pounds of U_3O_8. The critical question is the cost of recovery. Most of the uranium is likely contained in fluorite or opal and would require the fluorite and opal to be dissolved. Costs would be prohibitive except as a by-product of beryllium recovery. The uranium resource and the amount of recoverable uranium depends on the beryllium reserves and the incremental cost of adding a uranium circuit. Based on known "reserves," and an estimated average uranium content of 80 ppm uranium, the area contains a potentially recoverable uranium resource of 1.25 million pounds of U_3O_8.

There is little potential for recovery of uranium from the fluorite deposits. As with the beryllium tuff, most of the uranium is held in the fluorite lattice and would be expensive to extract. Possibly some of the end users of the fluorspar could add a circuit to extract the uranium if the price of uranium justified the extra cost.

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