Uranium in the Wyoming Landscape Conservation Initiative Study Area, Southwestern Wyoming

By Anna B. Wilson

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
mile (mi)	1.609	kilometer (km)
yard (yd)	0.9144	meter (m)
	Area	
square foot (ft^2)	929.0	square centimeter (cm^2)
section (640 acres or 1 square mile)	259.0	hectare (ha)
	Mass	
pound, avoirdupois (lb)	0.4536	kilogram (kg)
ton, short (2,000 lb)	0.9072	metric ton (tonne, t)

SI to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
kilometer (km)	0.6214	mile (mi)
meter (m)	1.094	yard (yd)
	Area	
hectare	0.003861	section (640 acres or 1 square mile, sq. mi.)
	Mass	
kilogram (kg)	2.205	pound avoirdupois (lb)
metric ton (tonne, t)	1.102	ton, short (2,000 lb)

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83)

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Abstract

Wyoming has led the nation as the producer of uranium ore since 1995 and contains the largest reserves of any state. Approximately one third of Wyoming's total production came from deposits in, or immediately adjacent to, the Wyoming Landscape Conservation Initiative (WLCI) study area in the southwestern corner of the state including all of Carbon, Lincoln, Sublette, Sweetwater, Uinta, and parts of southern Fremont Counties. Conventional open-pit and underground mining methods were employed in the study area until the early 1990s. Since the early 1990s, all uranium mining has been by in-situ recovery (also called in-situ leach). It is estimated that statewide remaining resources of 141,000 tonnes of uranium are about twice the 84,000 tonnes of uranium that the state has already produced.

An evaluation of the mineral commodities present in the WLCI study area that may have a role in the development of southwest Wyoming includes uranium. The WLCI study area contains five uranium mineralized areas: Ketchum Buttes, Poison Basin, Shirley Basin, the southern part of Crooks Gap–Green Mountain, and most of Great Divide Basin. Mineralized areas described in the report and outlined on an accompanying map are based on the presence of either contiguous claim blocks, continuous mineralization adjacent to prospective uranium properties, suggestions of mineralization based on site entries in the U.S. Geological Survey's Mineral Resources Data System (MRDS), or extension of geologic host units or structures. Mineralized areas are not the same as mining districts: the latter have defined administrative boundaries.

In the WLCI study area, all uranium areas except Poison Basin and Ketchum Buttes contain roll-front deposits in Eocene (56–34 Ma) sedimentary rocks. Tabular sandstone-hosted uranium deposits are also recognized within the study area.

Introduction

Wyoming has been the nation's leading producer of uranium ore since 1995 and, according to the Wyoming State Geological Survey, contains the largest uranium reserves of any state (Gregory, 2015). Uranium mining in Wyoming began in the early 1950s and peaked in 1979–1980 (fig. 1) (Gregory, 2015; R.W. Gregory, Wyoming State Geological Survey, unpub. data, August 24, 2015). Since the early 1990s all the state's production has been from in-situ recovery (ISR) (Wyoming State Geological Survey, 2012a). Estimates of total statewide uranium production are on the order of 84,000 tonnes uranium (tU) (Dahlkamp, 2010, p. 149). Remaining known resources are estimated at 141,000 tU at a grade of 0.065 percent uranium (Dahlkamp, 2010, p. 149), or not quite twice what has already been produced. Based on Dahlkamp's estimates, total pre-mining endowment statewide would therefore be about 225,000 tU. Similarly, Finch (2003, p. 4) estimates "reasonably assured resources" of 112,700 tU in Wyoming's basins. Approximately one third of Wyoming's total production came from deposits in or immediately adjacent to the Wyoming Landscape Conservation Initiative (WLCI) study area (table 1). The WLCI encompasses most of southwestern Wyoming, including all of Uinta, Lincoln, Sublette, Sweetwater, and Carbon Counties, and only a small portion of southern Fremont County (plate 1).

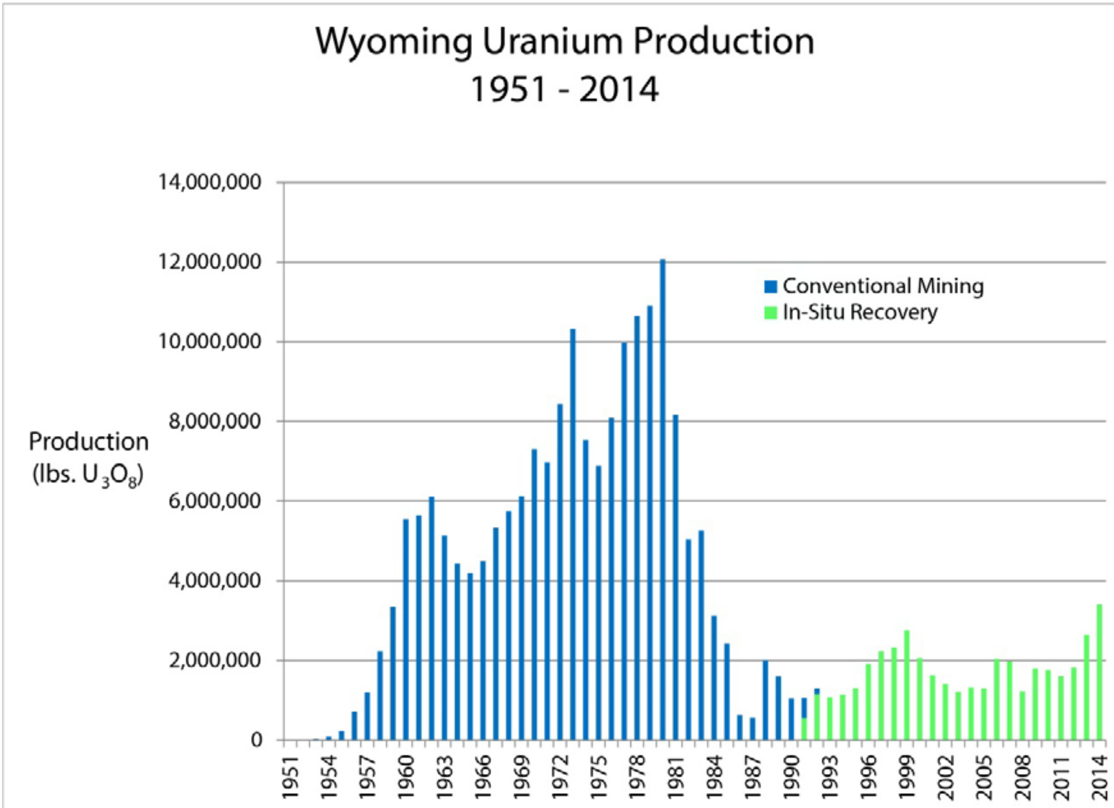


Figure 1. Historic U_3O_8 production in thousands of pounds U_3O_8 (divide by 2204.623 to convert to metric tons and then multiply by 0.848 to convert from U_3O_8 to U) from the State of Wyoming. From R.W. Gregory, Wyoming State Geological Survey, unpub. data, August 24, 2015; Wyoming State Geological Survey, 2012b.

Table 1. Comparison of production, resources, and endowments of each of the uranium mineralized areas in the Wyoming Land Conservation Initiative study area.

[Numbers in red were computed by author]

Uranium Area	Production/ Dahlkamp (2010) t U	Remaining resources/ Dahlkamp (2010) t U	Resource Grade	Total Pre-mining Endowment/ Dahlkamp (2010) t U	Production Gregory and others (2010) t ore	Reasonably Assured Resource Finch (2003) t U
WYOMING	84,000	141,000		225,000		112,700
Ketchum Buttes	NA	NA	NA	NA	1,870	
Poison Basin	350	3,000	.017 to .17	3,350	113,254	
Shirley Basin	18,500		0.07 to 0.5 (mined 0.15 to 0.16)	47,000	16,399,033	
CrooksGap/Green Mtn	8,000	32,000	0.12 to 0.25	40,000	4,388,463	
Great Divide Basin			0.025 to 0.06		2,544,315	
Sweetwater+REB+ENQ	500			10,000		
Lost Soldier/Red Desert				17,230		
Pard					386	
Bison Basin		1,600	0.04 to 0.06	1,600		
TOTAL for WLCI	27,350				23,447,321	

Exact resource and production values for Wyoming are unknown. Comparing values reported by Dahlkamp (2010) to Gregory and others (2010) and Boberg (2010) gives only a sense of the relative amount of ore in each of the uranium areas. Dahlkamp (2010) reports resources and production in metric tons (tonnes) uranium (but for ores with a wide range of grades it is not possible to accurately compute the tonnes of ore). Gregory and others (2010) report short tons of ore produced (converted to metric tons uranium for this study), but not grade or amount of contained uranium. Boberg reports reserves and production in metric tons U_3O_8 (also converted here to metric tons uranium) but not grade or total tonnage of ore. Some reported quantities are ore and others are the amount of contained metal (or U_3O_8). The term "Resources," as used here, refers to ore that is discovered and well established. These amounts do not include "undiscovered" resources. A quantitative resource assessment of the WLCI area is beyond the scope of this study. Previous resource estimates were published as part of the National Uranium Resource Evaluation (NURE) in the early 1980s (U.S. Department of Energy, 1980; Dribus and Nanna, 1982; Morris and Stanley, 1982).

In 1979, there were 17 operating uranium mines statewide and about 25 planned for development (Wyoming State Geological Survey, 2012c). Prices and demand for uranium dropped sharply in response to the Three Mile Island incident in Pennsylvania in 1979 (Anderson and Van Pelt, 2015) and again in 1986, probably in response to the Chernobyl disaster in Ukraine (in the former Soviet Union). From 1991 until May of 2012, when the Willow Creek property in the Powder River Basin began operations (Uranium One, 2012), all uranium production in the state has been from the Smith Ranch–Highland ISR in the Powder River Basin (Gregory, 2015), more than 50 kilometers (km), 30 miles (mi) northeast of the WLCI study area. There were no recently productive mines in the study area until Lost Creek ISR came online in August of 2013 (Ur-Energy, 2013).

Renewed demand for uranium in the last few years increased the price and caused a boom in exploration and development in several areas in and immediately adjacent to the WLCI study area. Uranium mineralized areas (plate 1) at Ketchum Buttes, Poison Basin, Shirley Basin, and Great Divide Basin are nearly all within WLCI, and the southern end of the Crooks Gap–Green Mountain mineralized area in the northeasternmost part of the Great Divide Basin overlaps the northern margin of WLCI. Uranium deposits in Powder River Basin (including Pumpkin Buttes) and Wind River Basin (including Gas Hills and Copper Mountain), many of which are quite large, are not in the study area.

Outlines of the mineralized areas shown on plate 1 should be considered "fuzzy." They have been modified from Gregory and others (2010) (and precursors to that map, such as Harris, 1985), and are based on the presence of either contiguous claim blocks, continuous mineralization adjacent to prospective uranium properties, or suggestions of mineralization based on site entries in the U.S. Geological Survey's Mineral Resources Data System (MRDS) (U.S. Geological Survey, 2013), or extension of geologic host units or structures. Mineralized areas are not exactly the same as mining districts: the latter have defined administrative boundaries.

Geology

Several different uranium deposit types are present in Wyoming. Most of the state's productive uranium deposits are in Paleocene and Eocene sandstones in Tertiary basins. These include roll-front type deposits and tabular sandstone-hosted deposits. Together they make up the vast majority of the state's uranium resource. Other deposit types present in Wyoming include

Tertiary unconformity-related deposits and paleokarst carbonate deposits in Mississippian rocks. There are also subeconomic occurrences of uranium in schroeckingerite and in coal. Only the first two types will be discussed here.

In the WLCI study area, most of the uranium deposits are roll-front types in Eocene (56–34 million years ago (Ma)) (U.S. Geological Survey, 2010) sedimentary rocks. These roll-front type uranium deposits were formed when groundwater migrated through the porous and permeable sedimentary rocks (sandstone and conglomerate). The groundwater leached the uranium from a source rock in an oxygenated environment (possibly from Precambrian igneous or metamorphic basement rocks, or from Paleozoic or Cenozoic volcanic ash-fall deposits (Wyoming State Geological Survey, 2012d)) and redeposited it in a reducing environment (Wyoming State Geological Survey, 2012e). All the uranium areas in WLCI except Poison Basin and Ketchum Buttes are roll-front types in Eocene (56–34 Ma) sedimentary rocks (U.S. Geological Survey, 2010).

Tabular sandstone-hosted uranium deposits are also recognized within the study area. Host rocks for these deposits are the Miocene North Park Formation in Ketchum Buttes (Gregory and others, 2010), Miocene Browns Park Formation in Poison Basin (Gregory and others, 2010), Eocene Wind River Formation in Shirley Basin (Gregory and others, 2010), and the interfingering Eocene Wasatch and Battle Spring Formations in the Crooks Gap–Green Mountain area (Dahlkamp, 2010). Battle Spring Formation is temporally equivalent to the Wind River Formation (Boberg, 2010, p. 658). North Park Formation is considered to be equivalent to the upper part of the Browns Park Formation (Gregory and others, 2010).

Mining Methods

Conventional open-pit and underground mining methods were employed in the study area until the early 1990s. Large volumes of rock and soil containing uranium ore were mined, crushed, and then processed at mills to extract the uranium by solution and concentrate it into yellowcake (Wyoming Mining Association, 2012).

Since the early 1990s, all uranium mining has been by in-situ recovery (ISR, also called in-situ leach). In an ISR operation, oxygenated water (usually with some additives) is pumped underground to dissolve the uranium and that solution is pumped back up to a plant on the surface. The solution is passed through columns or tanks loaded with ion-exchange resin. The uranium is chemically extracted from the resin and concentrated. The rest of the process uses the same methods as for conventional recovery of yellowcake (Wyoming Mining Association, 2012).

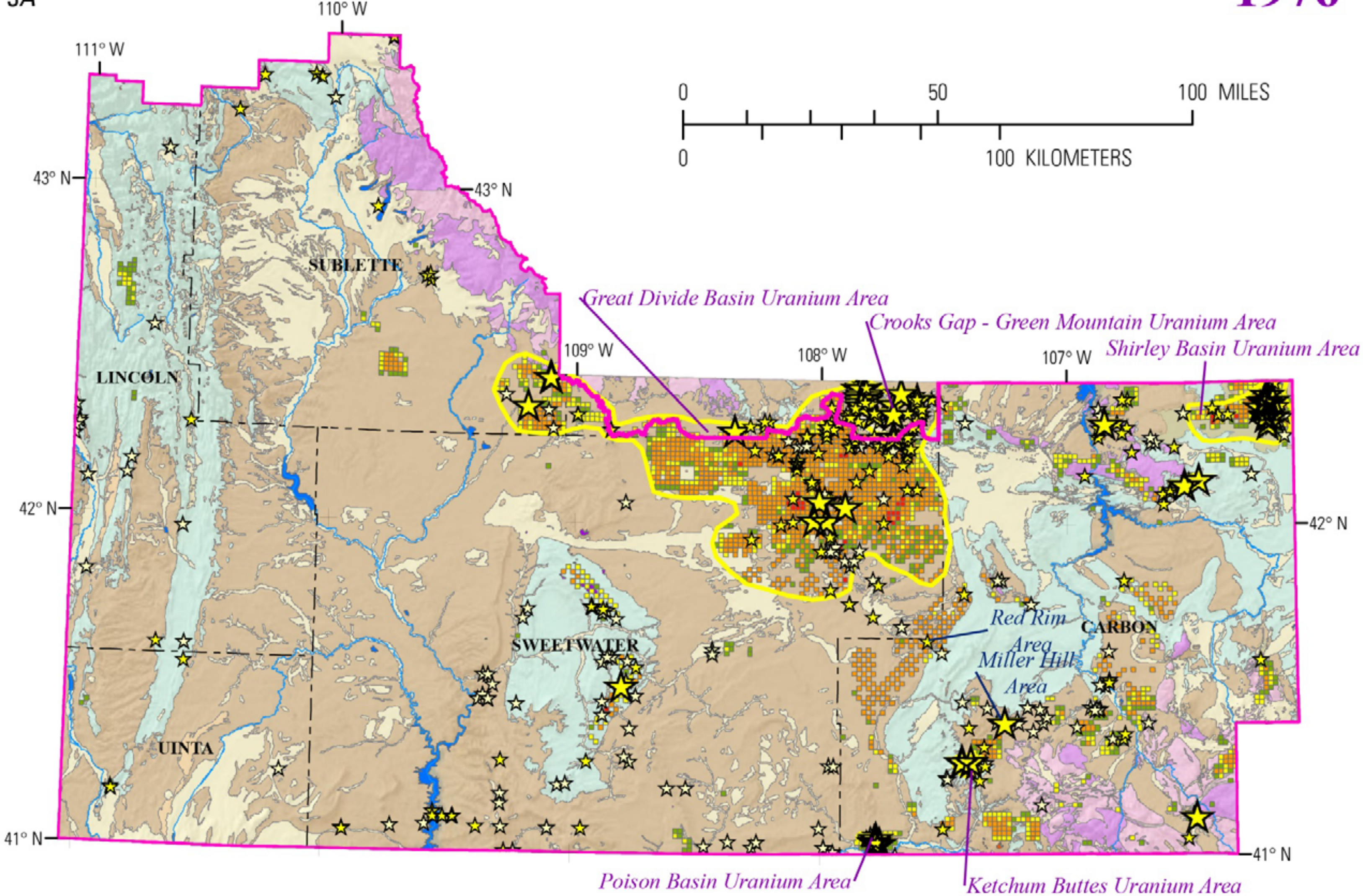
Development of Uranium Resources

Brief visits to each of the uranium areas (plate 1) in WLCI between 2008 and 2010 confirm that most of the sites included in MRDS (U.S. Geological Survey, 2013) have been inactive for decades and that the vast majority of the sites included in the database never produced ore. At Ketchum Buttes, there was no evidence of extensive land disturbance, past or present, other than a long-abandoned site on the western summit of the buttes. Several small abandoned mine sites and tailings piles were evident in the Poison Basin area (fig. 2). Surface activity in Shirly Basin and Crooks Gap–Green Mountain areas since the early 1970s has been mostly limited to reclamation of past mining (Harshman, 1972) although apparently companies are still keeping claims active (fig. 3*H*).

Figure 2. Decades-old waste piles left by uranium mining in Poison Basin, southwestern Wyoming, 2008.

3A

1976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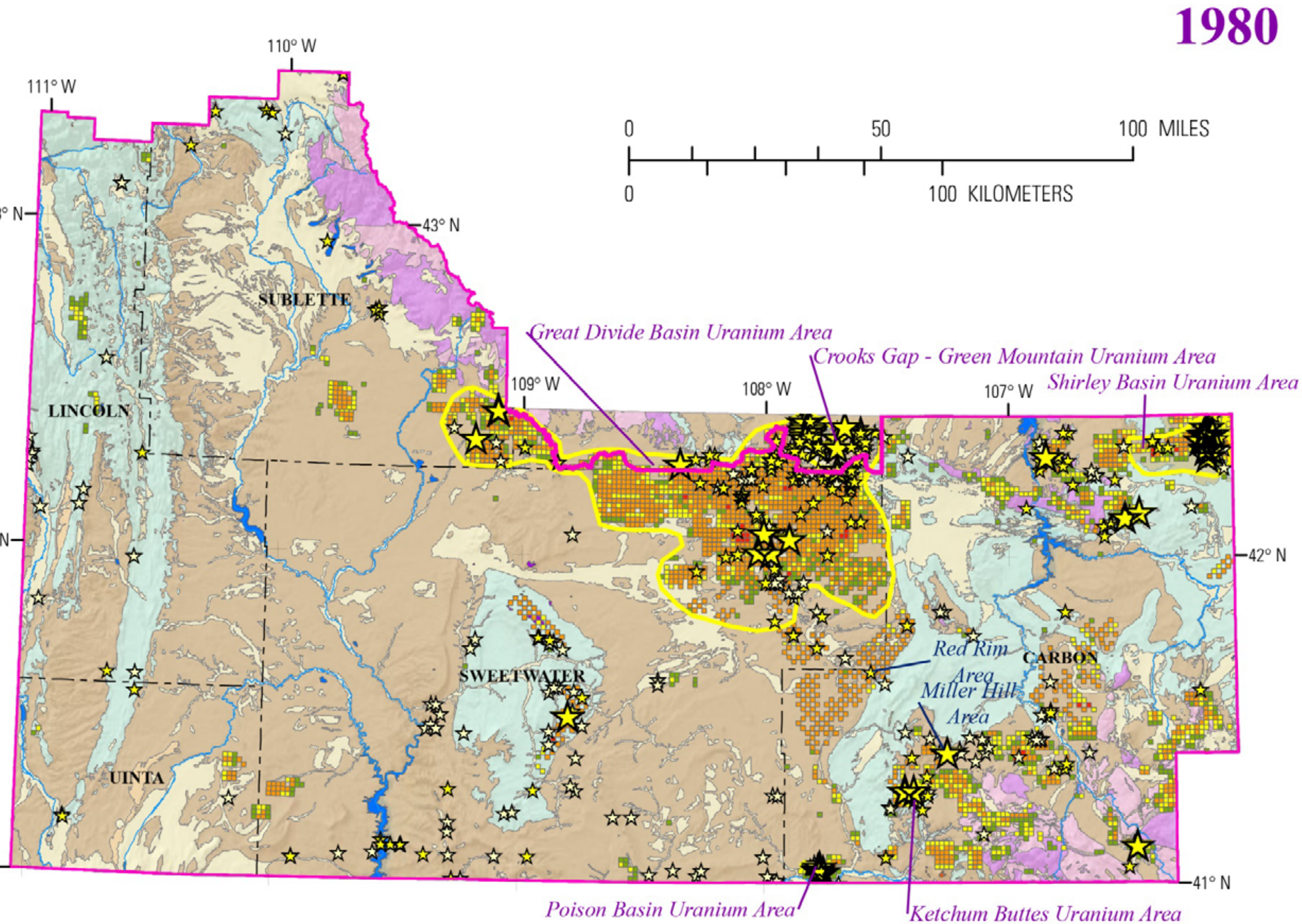
UINTA
CARBON
Great Divide Basin Uranium Area
Crooks Gap - Green Mountain Uranium Area
Shirley Basin Uranium Area
Red Rim Area
Miller Hill Area
Poison Basin Uranium Area
Ketchum Buttes Uranium Area

3B



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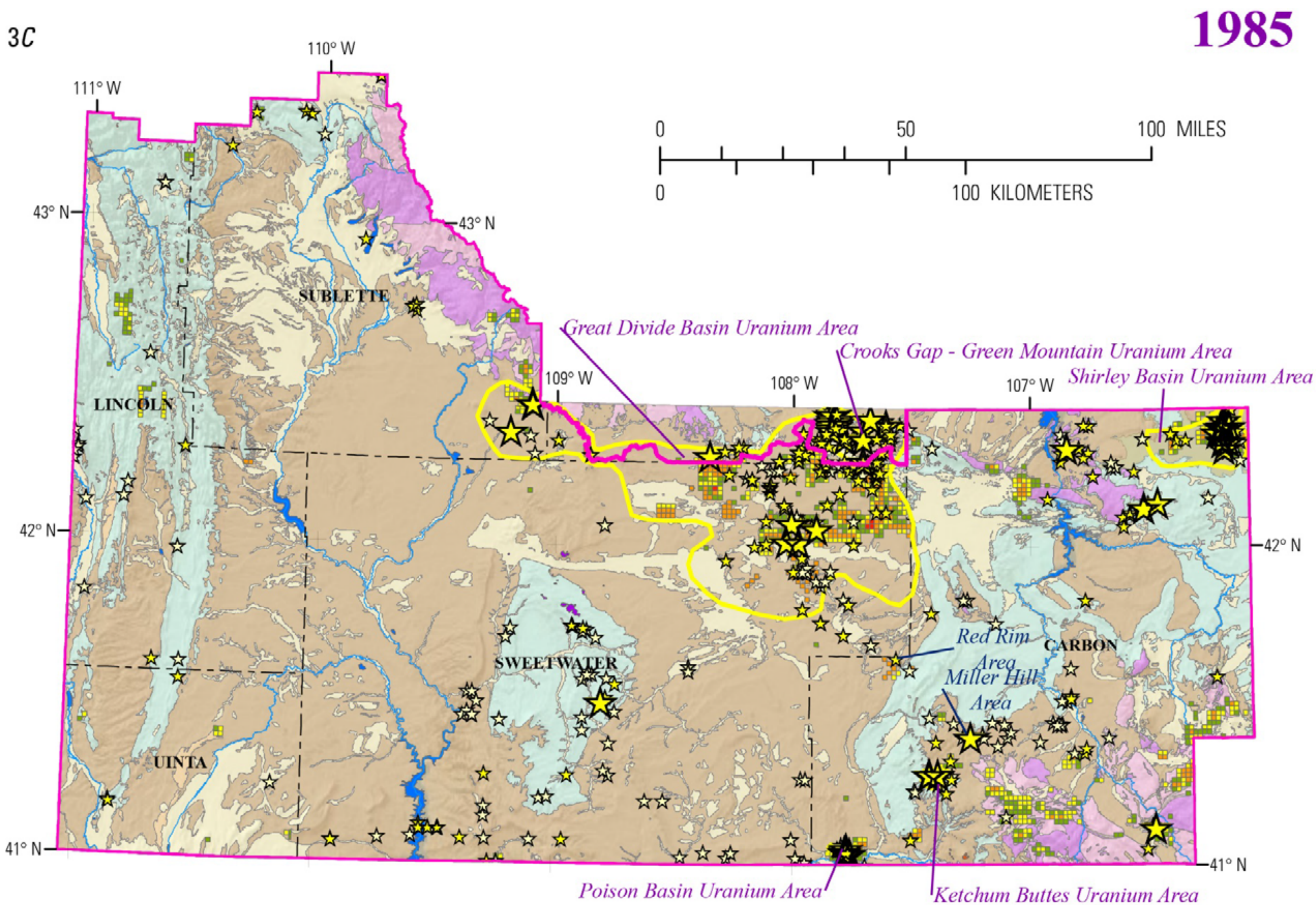
Ketchum Buttes Uranium Area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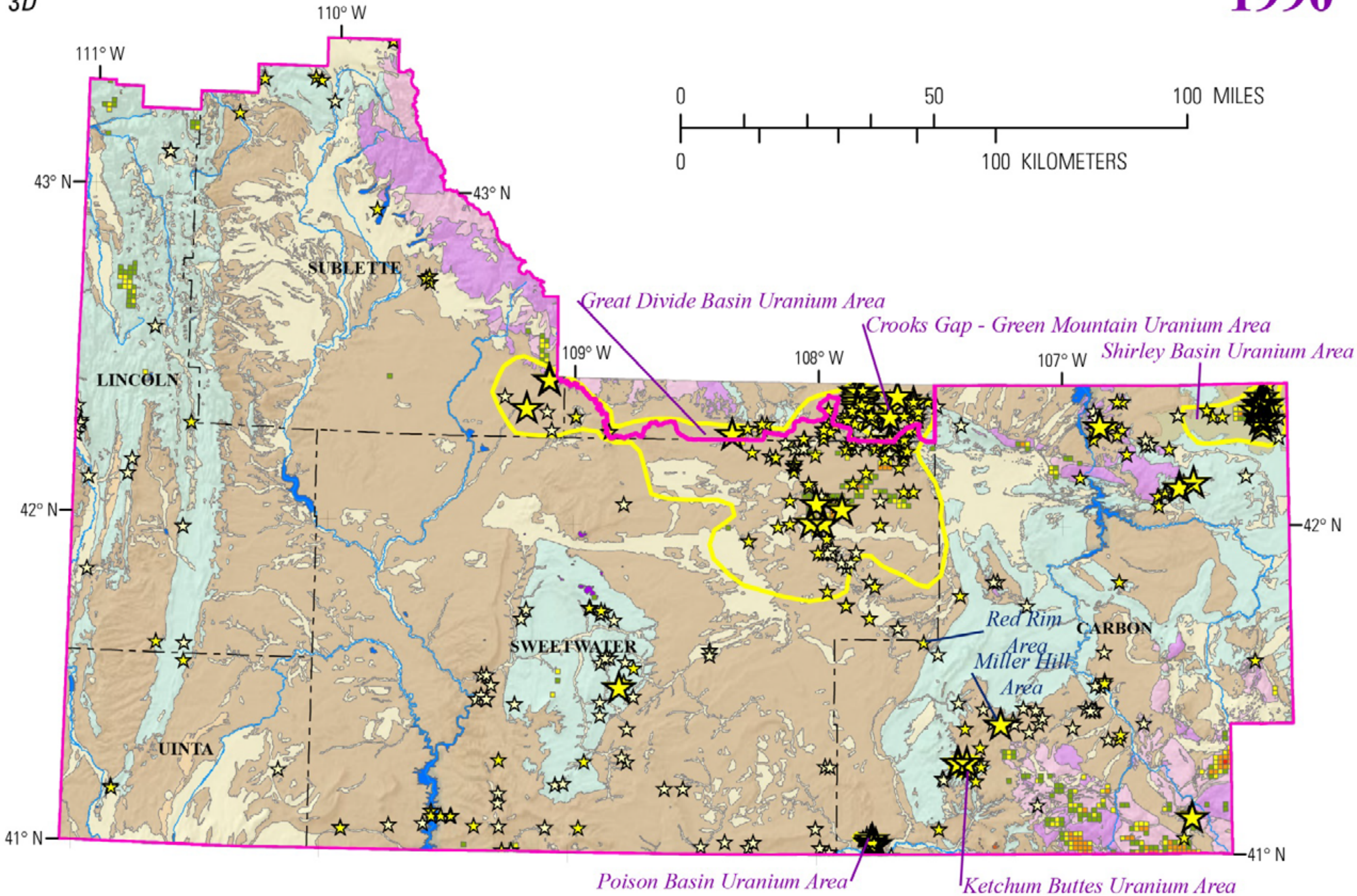
Shirley Basin Uranium Area
Red Rim Area
Miller Hill Area
Poison Basin Uranium Area
Ketchum Buttes Uranium Area

3D

1990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Shirley Basin Uranium Area
Red Rim Area
Miller Hill Area
Poison Basin Uranium Area
Ketchum Buttes Uranium Area

3E

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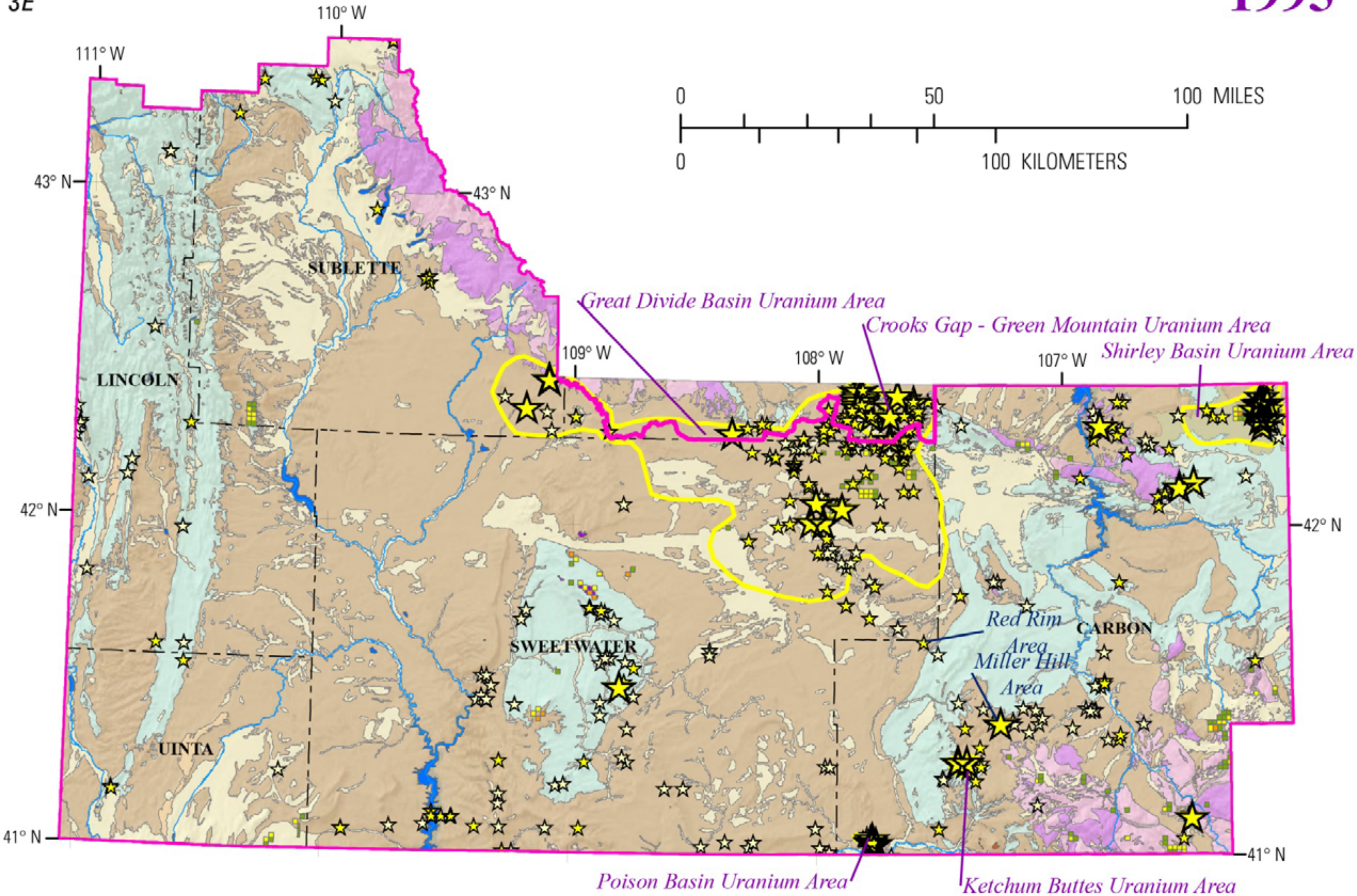

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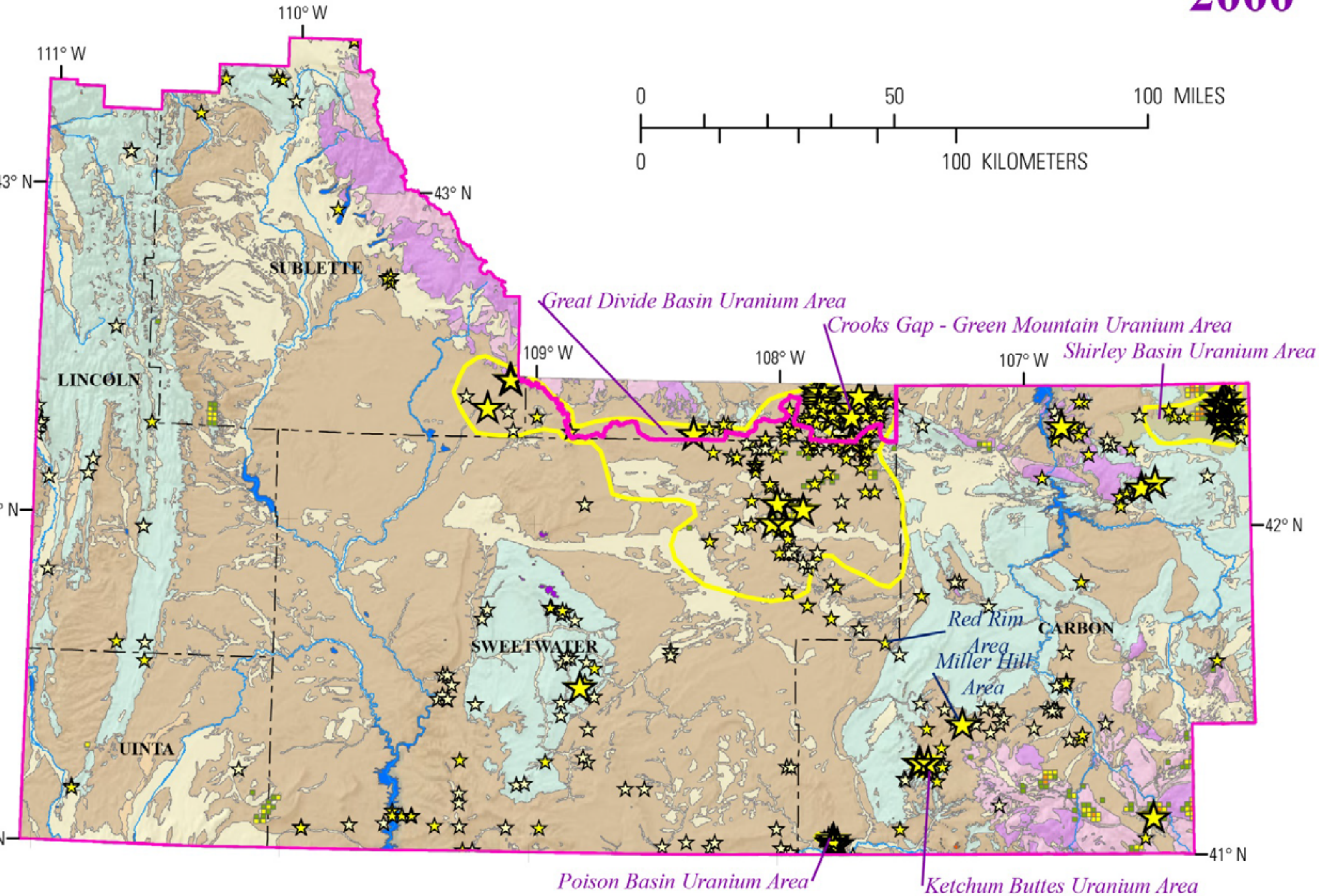
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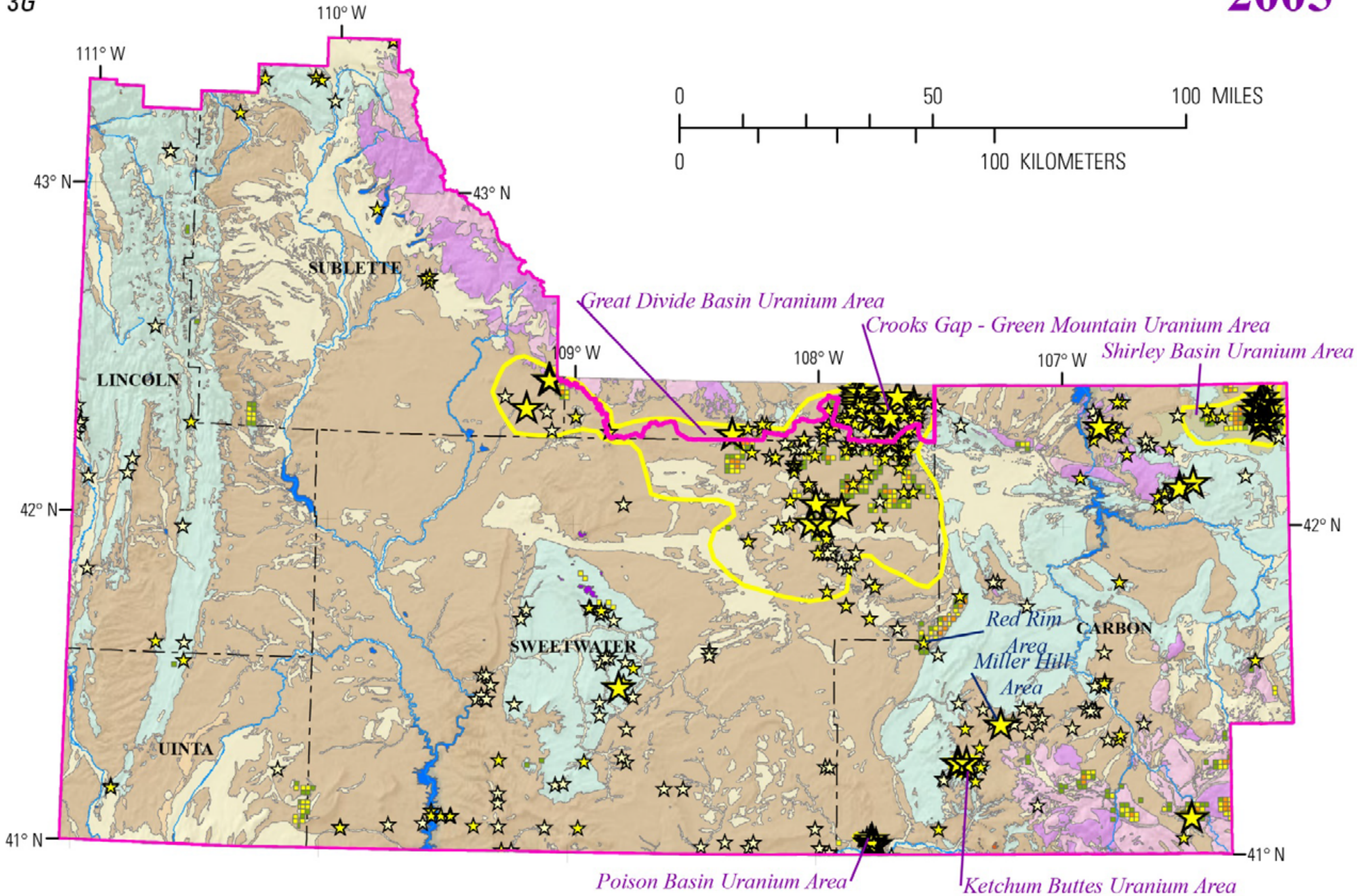
Ketchum Buttes Uranium Area

3G

2005



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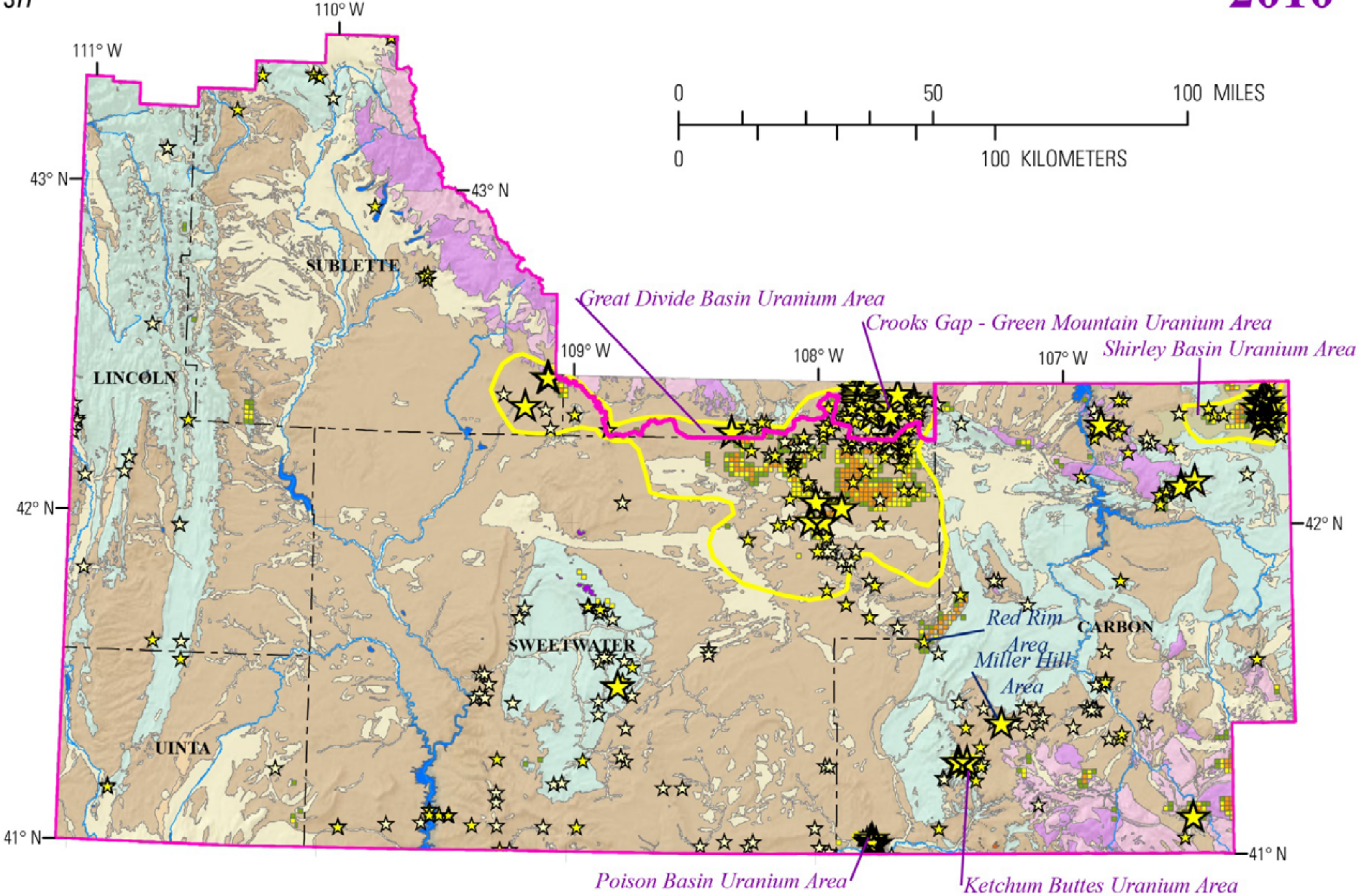
Poison Basin Uranium Area
Ketchum Buttes Uranium Area

3*H*

2010



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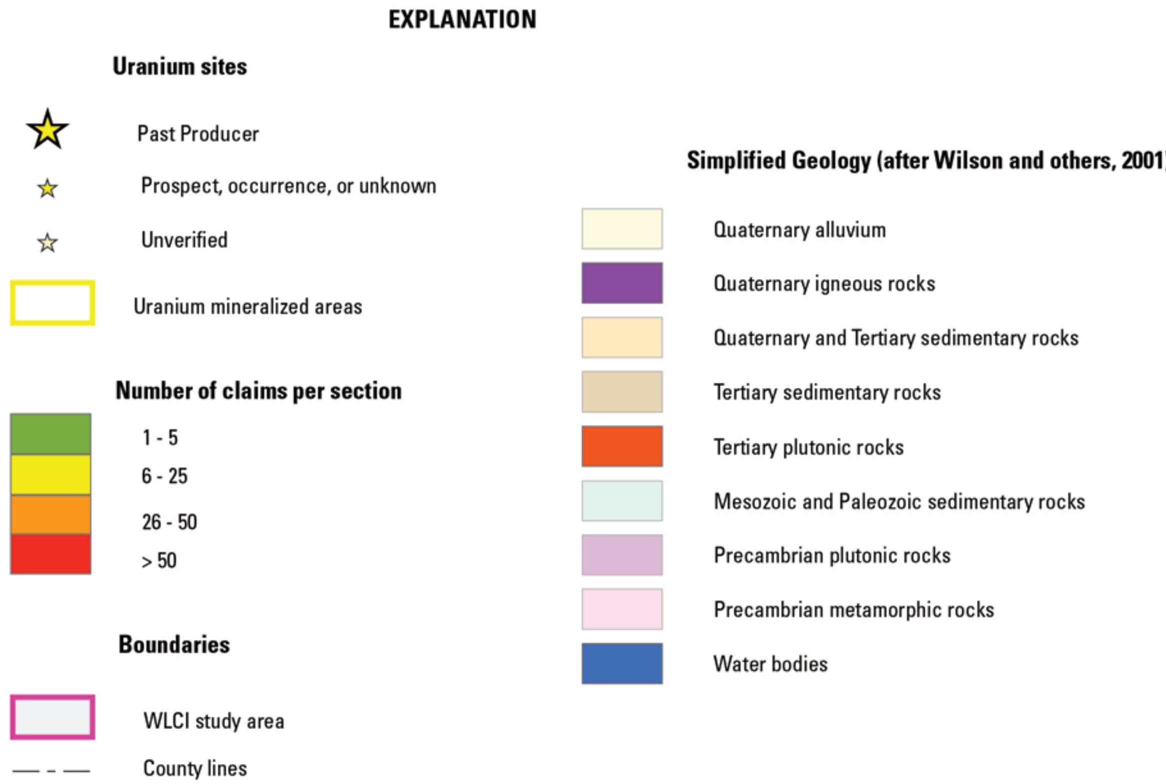


Figure 3. Claim activity, 1976–2010. Five-year-interval time slices (3*A*, *B*, *C*, *D*, *E*, *F*, *G*, *H*) show number of lode claims per section. Lode claims include any locatable mineral, but it is assumed that most claims in and near the uranium mineralized areas or other uranium deposits are for uranium. Data from Causey, 2007 (revised 2011).

The Nuclear Regulatory Commission (NRC) has issued permits for uranium recovery sites at Lost Creek (using in-situ recovery) and the Sweetwater Mill (using conventional uranium mining) (U.S. Nuclear Regulatory Commission, 2012a). Additional information about the Lost Creek project can be found on the Bureau of Land Management (BLM) website (U.S. Department of the Interior Bureau of Land Management, 2012a).

Reviews of the JAB and Antelope projects in the northeastern part of Great Divide Basin submitted in 2008 are deferred (U.S. Nuclear Regulatory Commission, 2012b), as is the proposed project in Bison Basin (also known as West Alkali Creek) (U.S. Nuclear Regulatory Commission, 2012c). Permit requests for the Lost Soldier deposit, submitted to the NRC as a satellite to the Lost Creek project, was inactive as of 2012 (U.S. Nuclear Regulatory Commission, 2012d).

There is a proposed project (Juniper Ridge) in Poison Basin (WISE Uranium Project, 2012). A plan of operations (U.S. Department of the Interior Bureau of Land Management, 2012b) and notice inviting comment until June, 8, 2012 (U.S. Department of the Interior Bureau of Land Management, 2012c) are posted on the BLM website.

Mines, Prospects, and Occurrences

The U.S. Geological Survey maintains a worldwide database, the Mineral Resources Data System (MRDS), of mineral districts, deposits, mines, prospects, and occurrences (U.S. Geological Survey, 2013). A subset of the data for Wyoming, along with supporting GIS data, was released in 2001 (Wilson and others, 2001). Compiled primarily from scientific and mining literature, the database is a repository for information about various deposits. In the course of the WLCI project, many of the records have been revised, new ones for missing properties have been added, and most of the unverifiable and duplicate records have been eliminated for the study area. Table 2 lists the verified producing and formerly producing mines and mineralized areas. Complete MRDS records are provided (in pdf format) for each of the 371 uranium entries within the boundaries of the WLCI and for the 110 verified records for productive sites in the adjacent Crooks Gap–Green Mountain area (appendix A) in Fremont County. These records augment the limited data in the ArcGIS files included in Biewick and Wilson (2014). The most useful field in the full MRDS record for a given mine is the reference field, which is not included in the ArcGIS files because it is not formatted in a compatible manner (see Biewick and Wilson, 2014).

Table 2. MRDS records for Producers or Past Producers of uranium in the study area and the tonnage of ore (in metric tons) produced.

[Districts or areas listed first, followed by sites listed alphabetically. Complete records are included in appendix A]

DEP_ID	SIG	NAME	COUNTY	QUAD250	PRIMARY_CO	SECONDARY_	TERTIARY_C	OPERATION_	DEV_STATUS	WGS84_LAT	WGS84_LON	MAS_ID	MRDS_ID	REC_TP	tonnes ore
10205631	N	Miller Hill area	Carbon	Rawlins	Uranium - (U)			Unknown	Past Producer	41.40416	–107.256	560070654		Deposit	> 7.75
10400480	Y	Crooks Gap - Green Mountain	Fremont	Casper	Uranium - (U)			Surface-Underground	Past Producer	42.38995	–107.83			District	4,389,811
10400478	N	Ketchum Buttes Uranium District	Carbon	Rawlins	Uranium - (U)			Unknown	Past Producer	41.27506	–107.396			District	1,870
10400477	N	Poison Basin District	Carbon	Rawlins	Uranium - (U)	Vanadium - (V)		Unknown	Past Producer	41.04816	–107.793			District	113,277
10400479	Y	Shirley Basin Uranium Area	Carbon	Casper	Uranium - (U)			Unknown	Past Producer	42.33436	–106.238			District	18,080,489
10400646	Y	Great Divide Basin Uranium	Sweetwater	Lander	Uranium - (U)			Unknown	Producer	42.088	–108.088			District	2,805,198
10096609	N	Ajo Claims	Carbon	Casper	Uranium - (U)			Surface-Underground	Past Producer	42.13607	–106.466	560070180	W032735	Site	3.6
10181917	N	Bald Knob	Carbon	Casper	Uranium - (U)			Unknown	Past Producer	42.12106	–106.522	560070130		Site	250
10157558	Y	Bison Basin Project	Fremont	Lander	Uranium - (U)			Unknown	Past Producer	42.28459	–108.353	560370466	DE00263	Site	62,051
10230279	N	Cedar Hills 1-12	Carbon	Rawlins	Uranium - (U)			Unknown	Past Producer	41.05416	–107.774	560070140		Site	18,930
10108470	N	Del Oro	Carbon	Rawlins	Uranium - (U)			Unknown	Past Producer	41.2869	–107.393		DC06931	Site	1858
10157440	N	Del Oro #2 Claim	Carbon	Rawlins	Uranium - (U)			Surface	Past Producer	41.28636	–107.431	560070153		Site	?
10279171	N	Jack Rabbit Group	Carbon	Rawlins	Uranium - (U)			Surface	Past Producer	41.04436	–107.781	560070169		Site	42,638
10157087	N	Jenkins Project	Carbon	Casper	Uranium - (U)			Surface	Past Producer	42.39166	–106.181	560070099		Site	479,522
10133430	N	Juel Creek	Sublette	Lander	Uranium - (U)			Surface	Past Producer	42.35774	–109.189	560350040		Site	?
10081134	N	Ketchum Butte	Carbon	Rawlins	Uranium - (U)			Unknown	Past Producer	41.286	–107.427	560070641	W032860	Site	130
10096604	N	Little Man Mine	Carbon	Casper	Uranium - (U)		Molybdenum - (MO),Copper - (CU),Graphite - (GRF)	Unknown	Past Producer	42.309	–106.846		W032720	Site	"a small shipment"
10091590	N	Lone Wolf	Sweetwater	Lander	Uranium - (U)			Unknown	Past Producer	42.074	–108.008		DC07330	Site	21
10018872	N	Lucky Turk	Sweetwater	Rock Springs	Uranium - (U)			Unknown	Past Producer	41.50884	–108.802	560370062	DC07304	Site	5.4
10181711	N	Nall Lease	Carbon	Casper	Uranium - (U)			Surface	Past Producer	42.37409	–106.157	560070176		Site	4,445
10230604	N	North Walker Mine	Carbon	Casper	Uranium - (U)			Underground	Past Producer	42.3264	–106.161	560070079		Site	671,423

Table 2. MRDS records for Producers or Past Producers in the study area and the tonnage of ore (in metric tons) produced.—Continued

[Districts or areas listed first, followed by sites listed alphabetically. Complete records are included in appendix A]

DEP_ID	SIG	NAME	COUNTY	QUAD250	PRIMARY_CO	SECONDARY_	TERTIARY_C	OPERATION_	DEV_STATUS	WGS84_LAT	WGS84_LON	MAS_ID	MRDS_ID	REC_TP	tonnes ore
10206596	N	Pard	Sublette	Lander	Uranium - (U)			Unknown	Past Producer	42.35744	−109.073	560350023		Site	386
10080431	N	Petrotomics Mine	Carbon	Casper	Uranium - (U)			Surface	Past Producer	42.33026	−106.186	560070187	W031621	Site	8,502,326
10107762	N	Platt Mine	Carbon	Rawlins	Niobium (Columbium) -			Surface-Underground	Past Producer	41.1183	−106.487	560070203	D001896	Site	12
10018832	N	Poison Basin Claim Group	Carbon	Rawlins	Uranium - (U)			Surface	Past Producer	41.03952	−107.76		DC06966	Site	55,338
10281407	N	Prospect Mountains	Sublette	Lander	Uranium - (U)			Surface	Past Producer	42.44134	−109.104	560350041		Site	?
10132282	N	Shirley Basin Mine	Carbon	Casper	Uranium - (U)			Surface-Underground	Past Producer	42.371	−106.194	560070082	W032895	Site	
10278730	N	South Walker-Sullivan	Carbon	Casper	Uranium - (U)			Surface	Past Producer	42.30436	−106.181	560070080		Site	239,497
10133291	N	State School #1	Sweetwater	Casper	Uranium - (U)			Surface	Past Producer	42.01423	−107.978	560370495		Site	203
10205128	N	Sullivan Mine	Carbon	Casper	Uranium - (U)			Surface	Past Producer	42.36686	−106.188	560070105		Site	?
10106208	Y	Sweetwater Mill and Mine	Sweetwater	Casper	Uranium - (U)			Surface	Past Producer	42.05717	−107.903	560370523	W031620	Site	2,482,166
10157661	N	Teton Group	Carbon	Rawlins	Uranium - (U)			Surface-Underground	Past Producer	41.03936	−107.774	560070648		Site	907

The following are other caveats to consider when using the MRDS records:

1. No attempt has been made to ascertain if these sites are currently active or abandoned. However, presence of a record indicates that mineralization of some sort has been reported.
2. All locations are points. In some cases the database contains multiple locations for a single record (for instance, for some mines with multiple workings, or deposits developed by multiple mines). MRDS does not contain an outline of mineralized ground (whether that is a claim, claim block, lease, deposit, or district).
3. The term “mine” has multiple meanings. Sometimes it applies to a single working (or even an undeveloped claim). Other times it refers to a company’s property with many workings. In general, the users cannot use these coordinates to precisely locate the sites described by these records, but they will get to the general vicinity of the property.
4. Accuracy and precision of site locations differ for different deposit types. As most metal mines are fairly compact, the locations are closer than, say, for properties hosting uranium accumulations (especially ISR prospects) which target an areally extensive deposit not exposed at the surface.
5. More than half of the uranium records do not have a valid reference source. These are coded as Not-validated and are shown with small pale yellow stars on plate 1. Records of unknown or unnamed sites, even if they have a reference, are also coded this way. Records that have a valid reference are shown as darker yellow, with Producers as largest stars, Past Producers as medium stars, and Occurrences and Prospects small stars.

MRDS is an active and constantly changing database. The records presented herein are the contents as of January 2013. Capitalization is used as an indication of what data have been edited. Originally, MRDS data were in all caps. Several years ago, a computer script was run on a few selected fields to convert upper case to initial capitals. Since then, a former MRDS team member who edited a record may have corrected some insignificant words such as “And,” “Or,” “If” to “and,” “or,” “if.” A record maintaining such apparent typos has not been revised. Similarly, References appearing in uppercase and lowercase have likely been revised—no attempt to autoconvert those to initial capitals was ever attempted. Revisions and new entries should be correctly displayed in uppercase and lowercase.

Mineral Claim Activity 1976 to 2010

Changes in mineral exploration through time can be seen in the mining claim data (fig. 3*A*–*H*). Mining claim activity on Federal land has been recorded with the BLM since it was required by the Federal Land Policy and Management Act of 1976 (Public Law 94-579), Sec. 314. The claim data for WLCI were excerpted from data for Wyoming that were compiled by Causey (2007, rev. 2011). Claimants do not have to name the commodity that is being sought, so one must assume that the vast majority of claims in the uranium areas are for uranium. Likewise, claims outside known uranium areas but within other known mineralized areas are more likely for commodities known to occur in those areas, such as gold (excluding placer gold), silver, lead, or copper. Claim data are valid only for public lands.

The number of open or valid lode claims are aggregated by Public Land Survey section (roughly 1 square mile) and plotted: green, only 1–5 claims per section; yellow, 6–25; orange 26–50; red, greater than (>)50 (fig. 3). The maximum claim size is 600 feet (ft) × 1,500 ft (claim sizes were mandated by the Mining Law of 1872); therefore, only 31 maximum-sized claims can fit in a section. Sections with more than 31 claims may have smaller or irregularly shaped claims or the claims were overstaked (overlapping) so as not to miss any potentially favorable ground due to surveying errors. The value of the claim data in this application is that it shows where there is the most exploration interest in any given year. Because the change in number of claims tends to be gradual from year to year, the series of maps (fig. 3*A*–*H*) is constructed in 5-year increments. (The data are for 1976 to 2010, therefore the first increment from 1976 to 1980 contains only 4 years.)

The extent of the claims and the "hot spots" varied during these 5-year increments. In the eastern part of Great Divide Basin there were many claims in 1976 (fig. 3*A*) but very few by 1980–1985 (fig. 3*B*, *C*) due to uranium's price decline. The slight rebound since 2005 (fig. 3*G*, *H*) was due to increased price for U_3O_8 and advances in ISR technology. Claim activity in the Shirley Basin area has been less volatile—interest was highest before 1985 (figs. 3*A*–*C*) but many claims have remained open to the present. In the Poison Basin and Ketchum Buttes areas, open claims fell off gradually to 1990 (figs. 3*A*–*D*) when there were no claims in either area. By 2000 (fig. 3*F*) there were several claims in the Poison Basin and increased numbers in 2005 and 2010 (fig. 3*G, H*). After a 20-year absence of claims, as of 2010 (fig. 3*H*) there were a few claims on the northern edge of Ketchum Buttes. The last interest in the Miller Hill uranium area (approximately 2 miles northeast of Ketchum Buttes) was in 1980 (fig. 3*B*). A northeast-trending block of claims at Red Rim, west of Rawlins, is a uranium prospect.

Uranium Mineralized Areas

Ketchum Buttes

Ketchum Buttes, last active in the 1970s(?) is virtually abandoned: only an old pit on the summit of the western butte is still visible. Deposits (or occurrences) in the Ketchum Buttes area are small (Ketchum Buttes, Cloudy Group, Del Oro, Friday, and Siwash Claims; see appendix A) and until recently there has been little interest in the area. Host rocks are mudstones and sandstones of the Tertiary North Park Formation (Vine and Prichard, 1959). These were sandstone-hosted roll-front type deposits containing uranophane assaying as high as 0.32 percent U_3O_8 (0.27 percent uranium equivalent) (MINOBRAS, 1976). The district produced 1,870 tonnes (2,061 short tons) of uranium ore (Gregory and others, 2010). The average grade of the ore is unknown, and so too is the amount of contained uranium. Ketchum Buttes was not included with the Wyoming basins that were evaluated by Dahlkamp (2010).

As of 2006, Strathmore Minerals Corporation owned the mineral rights to the Ketchum Buttes property. The exact location of the property (which includes 21 unpatented lode claims over the Foster ore body) is uncertain. Strathmore reported a near-surface uranium deposit with a planned conventional open-pit uranium mine. The deposit is hosted in sandstone and conglomerate of the Miocene Browns Park Formation. Historically demonstrated resources (not NI 43-101 compliant[1]) are 577 tU (1,500,000 pounds U_3O_8) (Strathmore Minerals Corporation, 2006). Strathmore expected to develop this property as a conventional open pit, extracting the uranium through heap leach, or possibly processing it at the Sweetwater Mill (Strathmore Minerals Corporation, 2006). As of September 2009, there was no visible mineral development

[1]**National Instrument 43-101** (**NI 43-101**) defines rules and guidelines for reporting and displaying information related to mineral properties owned by, or explored by, companies which report these results on stock exchanges within Canada in its *Standards of Disclosure for Mineral Projects*. The purpose is to ensure that misleading, erroneous or fraudulent information relating to mineral properties is not published and promoted to investors on the stock exchanges overseen by the Canadian Securities Authority.

in the area. All of the exploratory drill holes have been plugged and the site has been recontoured. Late in 2012, Stathmore terminated its agreement and withdrew its plan of operations from the Bureau of Land Management (Mark Newman, U.S. Bureau of Land Management, oral commun., January 10, 2013).

Poison Basin

At Poison Basin, old waste piles (fig. 2) and trenches (fig. 4) appear to have been abandoned for decades. Total production from Poison Basin district was 113,254 tonnes (124,867 short tons) of uranium ore (Gregory and others, 2010). Both Crosshair Exploration Corporation (Beahm, 2012)[2] and Strathmore Minerals Corporation (Strathmore Minerals Corporation, 2006, 2010) have shown recent interest in the Poison Basin area.

Figure 4. Abandoned trench in Poison Basin, southwestern Wyoming, 2008.

[2]Indicated Resources: 4,140,000 tonnes at 0.063 percent = 2,608 tonnes U_3O_8 = 2,211 tU (Beahm, 2012).

Sandstone-type uranium deposits in this area were discovered in 1953 near the town of Baggs (population 440 as of 2010 Census) and mined from 1954 through 1981. Production came from eight properties and amounted to about 350 tU in ore with grades averaging 0.17 percent uranium (Dahlkamp, 2010). Based on these numbers a production estimate of 205,882 tonnes ore can be calculated, which is almost twice the 113,254 tonnes (124,867 short tons) reported by Gregory and others (2010)[3]. Most of the mining was from open pits, but there were also some underground workings (fig. 5).

Figure 5. One of the small abandoned underground mines in Poison Basin, southwestern Wyoming, 2008.

The Poison Basin deposit (including Poison Basin, Teton, and Juniper Ridge properties) is hosted in unoxidized and oxidized sandstones of the top 20 meters (m) of the 150-m-thick Miocene Browns Park Formation that forms a depositional syncline cut by normal faults (Dahlkamp, 2010, p. 206–207). The Poison Basin deposit extends approximately 20 m below the

[3]Gregory and others (2010) credits the district with production totaling 113,254 tonnes (124,867 short tons) of ore: Teton Group (1,000 short tons, estimate = 907 tonnes), Cedar Hills (20,867 short tons = 18,926 tonnes), Teton Group (estimated 1,000 short tons = estimated 907 tonnes, but note that this is the same name and same tonnage and may be a duplicate record with alternate location), Poison Basin and Matt 3 (61,000 short tons = 55,327 tonnes), and Jack Rabbit (47,000 short tons = 42,629 tonnes).

surface and consists of weakly mineralized (less than 0.1 percent) Browns Park Formation containing smaller, higher-grade ore bodies (averaging 0.17 percent uranium) with ore-grade mineralization approximately 1 to 3 m thick. Ore bodies are in a lenticular or blanket-like configuration and are essentially concordant with very gently dipping sediments. On the south side of the deposit, natural gas was encountered in drill holes in the Browns Park Formation (Dahlkamp, 2010, p. 207). At the Juniper Ridge[4] property, resources of 3,000 tU at an average grade of 0.05 percent with a cutoff grade of 0.017 percent U in three ore bodies at less than 80 m depth are estimated to be recoverable by open-pit mining (Dahlkamp, 2010). These data suggest an estimate of about 6,000,000 tonnes ore. About one third of this resource is oxidized ore (containing the uranium-bearing minerals autunite and brannerite) above the water table (Dahlkamp, 2010, p. 207). A more recent evaluation estimates the indicated resource at Juniper Ridge at 3,754,980 tonnes at an average grade of 0.063 percent U_3O_8 (by using a 0.1 percent cutoff containing 2,003 tU (Beahm, 2012)).

Shirley Basin

The Shirley Basin uranium area is in the northeast corner of Carbon County. Shirley Basin contained original resources of more than 47,000 tU at grades ranging from <0.07 to 0.5 percent uranium (Dahlkamp, 2010, p. 176). This would compute to somewhere between 67,000,000 to 9,400,000 tonnes of ore. According to the values reported by Gregory and others (2010), the seven productive mines in the Shirley Basin uranium area produced a total of 18,080,489 short tons[5] (16,399,003 tonnes) of ore. There is no mention of the average ore grade; therefore, total contained uranium cannot be directly compared with Dahlkamp's estimate.

Shirley Basin, an intermontane Tertiary basin with continental fill, is one of the smallest basins in Wyoming to contain roll-front type deposits. Uranium deposits occur in the Eocene Wind River Formation in the central part of the basin. The Wind River Formation overlies Precambrian to Cretaceous rocks, and it is overlain by tuffaceous silt and mudstones of the Oligocene White River Formation. The youngest pitchblende ore in the Shirley Basin is about 24±3 Ma, the oldest ore sample formed before 35 Ma (Dahlkamp, 2010, p. 162).

Ludwig (1978) subdivided uranium ore in the Shirley Basin into three types: (a) disseminated pitchblende ore, (b) calcite-cemented ore, and (c) massive pitchblende ore. Uranium content varies from 12 percent in calcite-cemented ore, 1–2 percent in disseminated pitchblende ore, and 65–72 percent in massive pitchblende ore (Ludwig, 1978, p. 34). These categories apply to most deposits in the Wyoming Basins (Dahlkamp, 2010, p. 154).

The Shirley Basin ore bodies are not extensive in lateral dimension or tonnage. Individual mined ore bodies had resources between a few hundred and several thousand tonnes of uranium. These ore bodies rarely persisted in length along the redox front for more than 750 m, and in width for several tens of meters to as much as 100 m. Thicknesses (vertical to the rolls) were commonly a few meters, and occasionally up to 10 m. Trailing ends ranged from a few centimeters to several tenths of a centimeter in thickness. In-situ ore grades ranged from a few hundredths to 20 percent uranium (Dahlkamp, 2010, p. 179).

[4]Urangesselschaft USA estimated the deposit contained 8 to 15 million pounds of U3O8 (4,000 to 7,500 [short] tons) and planned to build a mine with a 2,000 ton per day capacity (ENSR Corporation and Booz Allen & Hamilton, 2003, p. 3–57)

[5]Productive mines included (values reported by Gregory and others, 2010, are in tons of ore, not contained U or U_3O_8): Pathfinder-Shirley Basin (7,170,586 short tons = 6,503,721 tonnes), Night Owl (93 short tons = 84 tonnes, small relative to the others in the area, but this mine is just east of the district), Uranium Supply-Jenkins (528,582 short tons = 479,424 tonnes), North Walker (740,117 short tons = 671,286 tonnes), South Walker (264,000 short tons = 239,448 tonnes), Getty Oil–Petrotomics (9,372,211 short tons = 8,500,595 tonnes), Nall (4,900 short tons = 4,444 tonnes).

There is current claim activity (fig. 3*H*) in Shirley Basin. Projects are underway by Crosshair Exploration and Cameco (Mark Newman, U.S. Bureau of Land Management, oral commun., Jan. 10, 2013)[6]. The major sites that are accessible have been fully reclaimed (fig. 6*A*, *B*) or repurposed (fig. 7*A*, *B*).

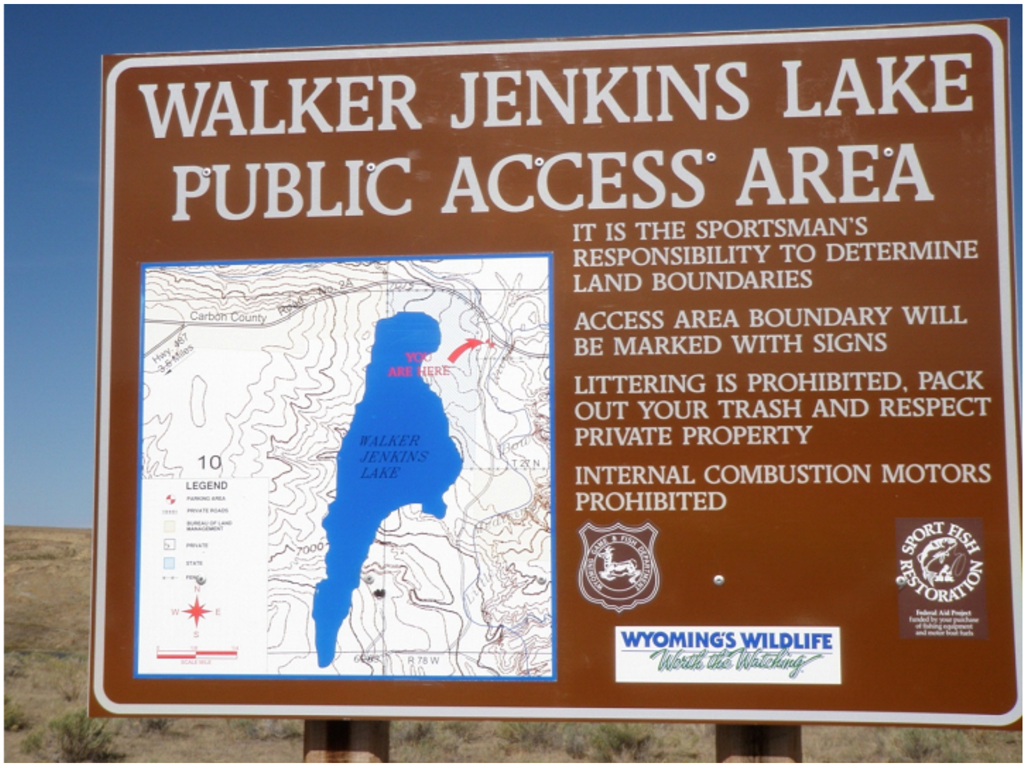
A

B

Figure 6. Shirley Basin, a reclaimed mine site, 2009. *A,* Monument. *B,* Surroundings to horizon.

[6]According to WISE-Uranium Project (http://www.wise-uranium.org/upusawy.html#PMCSHIRLEYB), "On Aug. 30, 2012, Ur-Energy notified the NRC of its intent to recover uranium from the Shirley Basin Project using in situ mining techniques. The company anticipates submitting a license amendment request to the NRC in the first quarter of 2014."

A



B

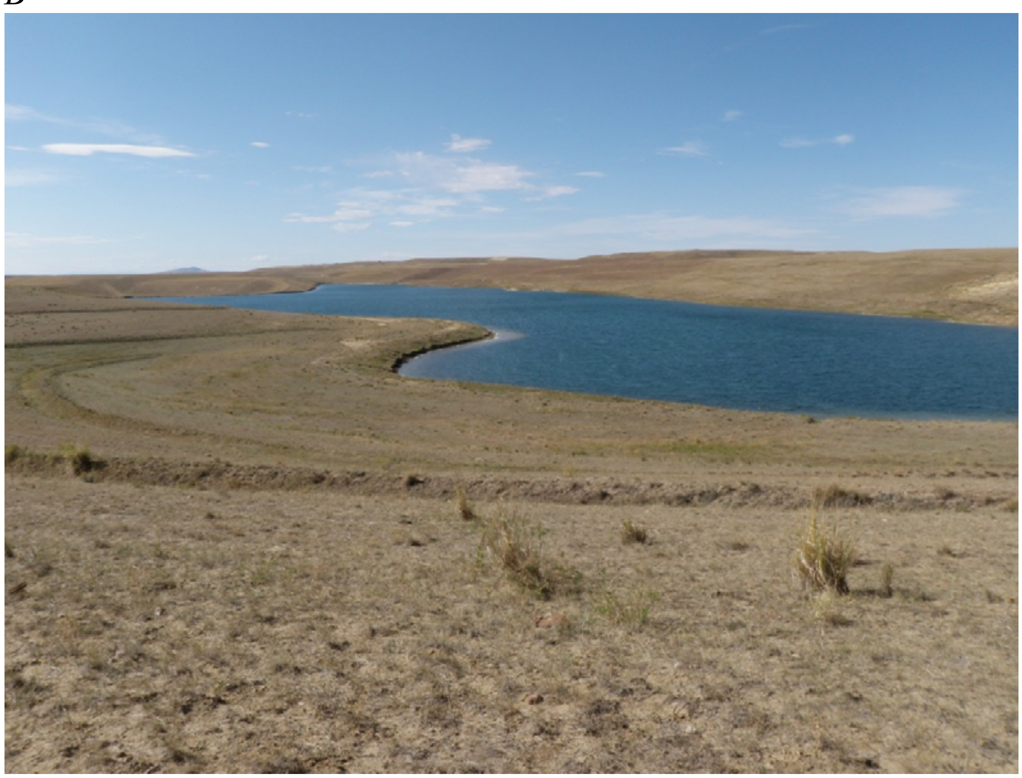


Figure 7. Walker Jenkins Lake, 2009. *A*. Walker Jenkins Lake Public Access Area sign. *B*. The lake, a reclaimed and repurposed open-pit uranium mine in the Shirley Basin, southwestern Wyoming.

Other nearby areas with previously productive mines are the East Shirley Mountains (Ajo and Bald Knob, appendix A), and the Miller Hill area. Neither was of sufficient size or distinction to be defined as a "district" by Gregory and others (2010).

Crooks Gap–Green Mountain Area

Gregory and others (2010) separate the Crooks Gap–Green Mountain area (plate 1) from the rest of the Great Divide Basin area. Dahlkamp (2010) describes the Crooks Gap area and the Green Mountains areas separately as being within the Great Divide Basin (along with the Sweetwater and the Red Desert areas). However it is defined, the Crooks Gap–Green Mountain area is at the extreme northeastern end of the Great Divide Basin. The most productive portion of the Crooks Gap–Green Mountain area is mostly a few miles north of the boundary of WLCI but there is not a clear boundary between the intensely mineralized area at Crooks Gap–Green Mountain and the rest of the Great Divide Basin. Recent exploration and potential for ISR development has been occurring south of the traditional Crooks Gap–Green Mountain area into the Great Divide Basin (as outlined on Gregory and others, 2010). Even though lode claim data (Causey, 2007, rev. 2011) suggest contiguous blocks of mineralized ground, the Crooks Gap–Green Mountain area will be considered separately from the bulk of the Great Divide Basin area.

Uranium was discovered in the Crooks Gap–Green Mountain area in 1954 and mining continued through 1989 (Dahlkamp, 2010). According to the tonnages reported by Gregory and others (2010), the seven productive mines in the Crooks Gap–Green Mountain area produced a total of 4,388,463 tonnes of ore[7]. There is no mention of the ore grade; therefore, the amount of contained uranium cannot be accurately estimated. Dahlkamp (2010) estimated the original resources (in situ and mined) on the order of 40,000 tU, some 8,000 tU of which were produced by 17 underground mines and open pits. Mining grades ranged from 0.12 to 0.25 percent uranium. Using this range of values 6,700,000 to 3,200,000 tonnes of ore were mined, which is consistent with the value reported by Gregory and others (2010). Dahlkamp (2010) does not list the 17 producing mines (other than Big Eagle Pit, McIntosh Pit, Golden Goose, and Sheep Mountain) so it is not possible to compare each mine directly with Gregory and others' (2010) 7 mines (see footnote 7).

Most of the deposits in the district are roll-front-type uranium mineralization, although there are a few on the northern margin of the district (for example, Sheep Mountain and Big Eagle) where the mineralization is structurally controlled, stratiform, and limb-type (Klingmuller, 1989). In unoxidized ground, pitchblende and coffinite are the principal uranium minerals. In oxidized (near surface) ground there are uranyl phosphates, -silicates, -sulfates, and -vanadates (Dahlkamp, 2010, p. 184).

The major deposits in the Crooks Gap–Green Mountain area include Sheep Mountain Deposit (Dahlkamp, p. 181), Big Eagle Pit (fig. 8), McIntosh Pit, and Golden Goose, all at Crooks Gap, and the Jackpot (also called Round Park or Green Mountain), Phase II and Desert View (together called Pathfinder's 6,900 Trend), and the Jan (or Whiskey Peak) deposits (Dahlkamp, 2010, p. 183).

[7] All values are reported here in tonnes of ore. The productive mines are (Gregory and others, 2010): Hazel and Beatrice (21 tonnes), Crooks Gap Mines (2,993,100 tonnes), Green Mountain (474,758 tonnes), Sundog (126 tonnes), Snowball and Pay Dirt (242,574 tonnes), Heald (6,023 tonnes), and Big Eagle (672,315 tonnes). It is not clear exactly how each of these mines corresponds to the entries in the MRDS database.

Figure 8. Big Eagle mine, currently not in use. Image from Google Earth, July 17, 2012; date of image unknown.

Great Divide Basin

The remainder of Great Divide Basin includes Sweetwater (Sweetwater, ENQ, REB deposits), Red Desert (Lost Creek and Lost Soldier deposits), and Bison Basin areas, all described in Dahlkamp (2010, p. 181–192). There are four types of uranium deposits in Great Divide Basin: (1) roll-front sandstone-type deposits, (2) stratiform uranium concentrations (termed limb-type by Klingmuller, 1989), (3) surficial, caliche-type occurrences of schroeckingerite, and (4) uraniferous lignite or subbituminous coal (Dahlkamp, 2010, p. 181). Only the first two types are of economic interest for uranium and will be considered further. Uranium production and established resources are limited to the Sweetwater/Red Desert area in the eastern part of the basin. According to Dahlkamp (2010, p. 181), the entire Great Divide Basin area contains 50,000 tU, of which 40,000 t is attributed to the Crooks Gap–Green Mountain area. Therefore, in spite of the large area covered, Great Divide Basin (excluding Crooks Gap–Green Mountain) is estimated by Dahlkamp to contain only 10,000 tU, including about 200 tU already produced. This number is vastly underestimated and, as will be pointed out in this discussion, is probably closer to 24,000 to 30,000 tU. Gregory and others (2010) report a total of 2,544,315 tonnes[8] of ore produced, of which more than 97 percent came from the Sweetwater mine.

The Sweetwater portion of the Great Divide Basin area is located in the central part of the Great Divide Basin and includes the Sweetwater, ENQ, and REB deposits. Original resources (in-situ and mined) of these three properties, in aggregate, were on the order of 10,000 tU at grades between 0.025 and 0.06 percent uranium. Only the Sweetwater deposit was mined, although a large resource remains. From 1981 to 1983, the Sweetwater open-pit mine produced about 500 tU at an average grade of 0.039 percent. Original resources were estimated at 7,300 tU. No resource numbers have been reported for the ENQ. Resources at the REB are 1,500 tU at a grade averaging about 0.06 percent uranium (Dahlkamp, 2010, p. 191).

In the northeastern part of the Great Divide Basin, in the area associated with the Red Desert area, the Lost Soldier deposit reportedly contains 5,642 tU (computed from Wallis, 2006) to 10,230 tU (Dahlkamp, 2010, p. 191–192) and the Lost Creek deposit contains 7,000 tU at average grade of 0.044 percent (Dahlkamp, 2010, p. 192). The earliest discovery of uranium in sandstones in Wyoming was in 1936 near the surface along Lost Creek, from which schroeckingerite ore was mined intermittently from 1954 to 1966 (Dahlkamp, 2010, p. 192).

At the extreme north edge of the Great Divide Basin area is Bison Basin containing a roll-front sandstone type uranium deposit. Uranium was mined conventionally in the 1960s and 1970s and later, in the 1980s, by in-situ recovery. There is no public record of the actual production. Dahlkamp (2010, p. 192) estimated remaining in-situ resources of about 1,600 tU at grades from 0.04 to 0.06 percent uranium (using a cutoff grade of 0.017 percent uranium).

Finally, in the extreme northwest corner of the Great Divide Basin is the Pard Mine (Harris, 1997; Gregory and others, 2010) which produced 386 tonnes of ore (plate 1). Grade is not given, therefore the amount of contained uranium or U_3O_8 is not known.

[8]Gregory and others (2010) report 2,805,198 short tons of which 2,736,120 short tons came from the Sweetwater Mine. Dahlkamp reports 500 tU at 0.039 percent from Sweetwater, or 1,282,051 tonnes production, or half of Gregory and others' value.

Acknowledgments

This report is a companion to Biewick and Wilson, 2014. That report contains a complete GIS database from which the maps and plate in this report can be constructed. An enormous thank you to Laura Biewick (U.S. Geological Survey Central Energy Resources Science Center, Denver) for ArcGIS expertise and guidance. Thanks, too, to William D. Heran (USGS Mineral and Environmental Resources Science Center) for field assistance and the first manuscript review. George Breit (USGS Mineral and Environmental Resources Science Center, retired) made many suggestions that substantially improved the report and Robert Gregory, Wyoming State Geological Survey, provided updated information, facts, and figures.

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Glossary

Total endowment Tons of uranium in the ground before mining. Ideally the total tons of ore and the estimated grade are known.

Mining claim Tract of public land to which an entity has claimed rights to the minerals. Most commonly an unpatented claim to which the mineral holder does not own the ground. Patented claims are lands to which ownership has been transferred to the claimant.

Original resource The amount of the resource before production (U.S. Geological Survey, 1980).

Reserve The portion of an identified resource that is valuable and from which a usable mineral can be economically and legally extracted at the time of determination; essentially, the recoverable ore (U.S. Geological Survey, 1980).

Resource A concentration of a naturally occurring commodity in such form and amount that economic extraction of that commodity from the concentration is currently or potentially feasible (U.S. Geological Survey, 1980).

Undiscovered resource Resources, the existence of which are only postulated, comprising deposits that are separate from identified resources. Undiscovered resources may be postulated in deposits of such grade and physical location as to render them economic, marginally economic, or subeconomic (U.S. Geological Survey, 1980).

Yellow cake A uranium concentrate (a precipitate in a form of U_3O_8) produced by milling (U.S. Bureau of Mines, 1997).

Appendix A. Complete U.S. Geological Survey Mineral Resources Data System Records for All Primary Uranium Sites and Districts in Wyoming Landscape Conservation Initiative, Arranged by County

AppendixA_WLCI_MRDS_uranium.pdf, included, is composed of several .pdf files.

Any errors or omissions should be brought to the author's attention so that changes can be made to the original database.

Full records are available to internal USGS users at

https://igskaccgvmmrds4.cr.usgs.gov:8443/ords/f?p=130:. A subset of this dataset is served to the public at http://mrdata.usgs.gov/mineral-resources/mrds-us.html. *The internal dataset is the source of the data in the ArcGIS (Biewick and Wilson, 2014).*

For cross referencing purposes, indexes to the contents of the .pdf file are in the accompanying .xls files. The number following the county name is the number of uranium records in that county.

Carbon_157.pdf
ApAa_Carbon_157.xls

Sweetwater_155.pdf
ApAb_Sweetwater_155.xls

Sublette_22.pdf
ApAc_Sublette_22.xls

Lincoln_24.pdf
ApAd_Lincoln_24. xls

Uinta_4.pdf
ApAe_Uinta_4. xls

Fremont_CrooksGap_110.pdf
ApAf_Fremont_CrooksGap_110.xls

Appendix B. Metadata for the U.S. Geological Survey Mineral Resources Data System Records in Wyoming Landscape Conservation Initiative