HISTORY OF URANIUM AND DEVELOPMENT OF COLORADO PLATEAU ORES WITH NOTES ON URANIUM PRODUCTION IN UTAH

by

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EARLY HISTORY

In 1895 Roetgen found that the glow from a Crooke's tube (early vacuum tube) contained penetrating rays which he designated as x-rays. Later Professor Henri Becquerel, while investigating phosphorescent substances, found that uranium salts had the capacity of producing impressions on photosensitive materials even though the salts were enveloped in opaque substances. The presence of x-rays from the salts subsequently caused Becquerel to assign to Marie Sklodowska (later to become Madame Curie) the task of determining how and why uranium could emit penetrating rays which he had proved to be electrical in character. Madame Curie, using an electroscope, examined a larger number of minerals containing uranium and thorium. She discovered that some specimens of pitchblende exhibited four times as much activity as uranium metal. She also discovered that a synthetic copper uranium phosphate showed only the activity represented by the uranium it contained whereas a natural copper uranium phosphate was more than twice as active as its contained uranium. She, thus, concluded that the impurities in uranium minerals were responsible for the increased activity. Exhaustive chemical analysis led her to the discovery of polonium. Later in 1898 the Curies discovered radium, a substance which is several million times as radioactive as uranium, Radium, though intimately associated with uranium has an abundance only 3 ten millionths as great.

Subsequent investigations of the radioactive elements determined that radium is one of the products of the decay of uranium and that uranium is a mixture of radioactive isotopes which comprise a metallic element designated number 92 in the periodic table. Three isotopes, U^{238}, U^{235}, and U^{234}, all with nearly identical chemical properties, occur together as the natural element. The most abundant isotope, U^{238}, comprises 99.28% of the element, whereas U^{235} represents 0.71%, U^{324} is only 0.01% and is one of the daughter products of U^{238}.

Uranium^{238} is the ancestor of lead 206. U^{238} and its daughters decay sequentially by emitting eight alpha particles and six beta particles to become lead. The decay proceeds at a statistically even rate; thus half of a starting quantity of U^{238} will decay to Pb^{206} in 4.5 billion years. Similarly U^{235} emits seven alpha particles and four beta particles and in 710 million years half of it will be Pb^{207}.

The decay of uranium to lead is as shown in Figure 1:

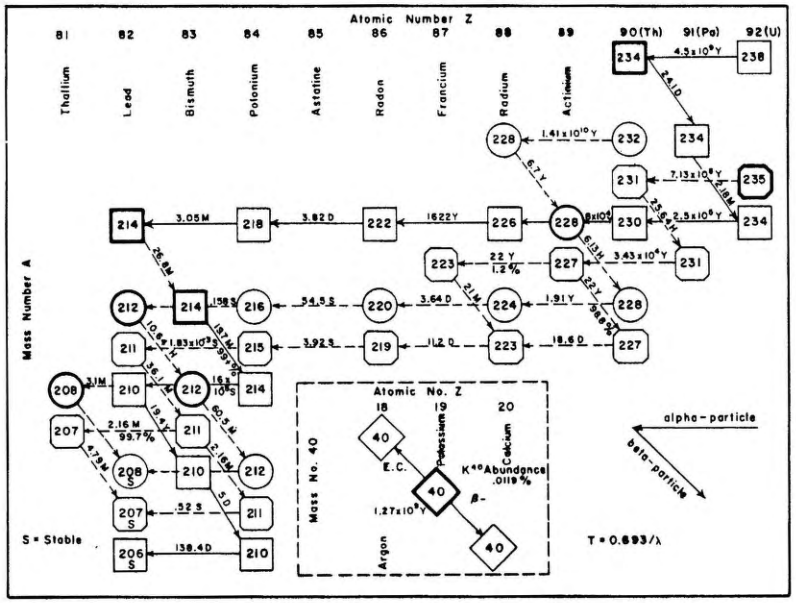

Figure 1. — Generalized diagram of the natural decay series of uranium, thorium, and potassium. Gamma ray emitters in heavier blocks are of major interest.

The U-238 series, in square blocks, includes Pb-214 and Bi-214 which supply over 85 percent of the gamma rays from "uranium" detected by field counters, airborne units, and hole probes. Being daughters after radium-226 and radon-222, these can be and commonly are out of equilibrium with the parent U-238. Therefore "quantitative" measurements by radiometric equipment yields an equivalent or eU$_3$O$_8$ analysis, and may not indicate the actual uranium concentration.

The thallium-208, circles, in the "natural" thorium-232 decay series is used as the indicator of thorium. Because of short half-lives and geochemistry of thorium (one oxidation state and low solubility) this series tends to be in equilibrium more than the uranium. Actinium-228, Pb-212, and Bi-212 from the series are also measured in gross gamma counting.

The insert block shows the decay of K-40. It goes to Argon-40 by electron capture and immediately drops to a stable state by emitting the 1.46 mev gamma ray.

Of the several energies of gamma protons it is possible to distinguish the high energy (2:62 mev) Tl-208 in the thorium series, the 1.46 mev K-40, and the 1.76 mev gamma from Bi-214. Others can be measured but these are generally resolved sufficiently for identification and in certain cases may be used for quantitative evaluation of uranium, thorium, and potassium. By gamma spectroscopy whether airborne, carborne, on the outcrop, or in the borehole, these characteristic gamma energies can be used to identify the origin or source of radiation commonly detected by field radiometric instruments.

THE ATOMIC AGE

Sir James Chadwick discovered the neutron in 1932. Subsequently, experiments with radioactive elements led others to the discovery in 1939 that the U^{235} nucleus could be split by bombarding it with slow neutrons thus releasing relatively enormous amounts of energy.

Because of its nuclear instability U^{235} splits or fissions naturally with the emission of neutrons, which can then split other U^{235} atoms. But other U^{235} atoms are not naturally available as targets for the neutrons because of their dispersion in the mass of U^{238} atoms, which cannot be split by slow neutrons. If, by some refining process, the concentration of U^{235} can be increased, then both the number of natural fissions per unit volume and increase of U^{235} in concentration causes increased total fissioning, the total being the sum of natural plus neutron-induced fissioning. If the U^{235} concentration is great enough, each fission produces another fission, and a selfsustaining chain reaction is produced. If the U^{235} concentration is further increased, each fission induces more than one additional fission, and an explosion results, even if the U^{235} is not confined.

In late 1939 Drs. Albert Einstein and Leo Szilard were responsible in informing Dr. Alexander Sachs, advisor to President Roosevelt, that a nuclear chain reaction in a mass of uranium may be possible. Sachs recommended to the President that steps be taken to develop the atomic bomb. On October 11, 1939, President Roosevelt acted and a working committee was set up and met on October 21, 1939. The committee submitted to the President on November 1, 1939, a report "Possible use of Uranium for Submarine Power and High Destructive Bombs" and recommended procurement of four metric tons of graphite and 50 tons of U_3O_8. The committee met again on April 27, 1940, and discussed program costs; the first stage was between $30,000 and $50,000; the second, between $250,000 and $500,000.

On December 2, 1942, a nuclear reactor at the University of Chicago functioned for the first time. On July 16, 1945, the first atomic bomb was tested successfully at Los Alamos, New Mexico. The bomb was detonated 100 feet above ground in a steel tower. The explosion resulted in temperatures estimated in millions of degrees that vaporized the tower and fused the earth's surface in a circular area with a diameter of about 2,400 feet. The blast created a rapidly ascending mushroom cloud of debris and compressed the earth beneath the tower into a bowl approximately 117 feet in diameter and 25 feet deep. Three weeks later on August 6 and 9, 1945, atomic bombs were dropped on Hiroshima and Nagasaki, Japan. They were detonated from greater heights and

most of the destruction was due to blast and incendiary effects of the explosions.

MINING HISTORY

Except for the possibility that carnotite-type uranium ores were first mined by Indians for use as pigments, the first recognition of yellow uranium minerals by white men from the Colorado Plateau was in 1881. At that time, Tom Talbert, a prospector, mined a yellow rock from a shallow shaft in the Roc Creek area, an area later included in the Uravan mining district, Montrose County, Colorado. A sample of the rock was sent to Leadville, Colorado, for analysis. It contained only traces of gold and silver and attempts to identify the yellow mineral were unsuccessful. Subsequently, in 1887, the claim was relocated, probably by Captain S. N. King, of Utah, and named the Copper Prince since the rock was then suspected to contain a chrome-copper mineral. Later, after other unsuccessful locators, the prospect was relocated by Tom Dullan in 1896 who held the Roc Creek claims until 1898. However, in 1897 Gordon Kimball, who was aware of the yellow mineral, met a French chemist, Charles Poulot, who was looking for uranium ores. Since the true nature of the yellow rock defied conventioual analyses, Kimball produced a sample of the material for Poulot in the spring of 1898. Poulot identified the mineral as autunite or uranochre, and by May 1898 Kimball had leased the mine. In June 10 tons of ore, mainly from one pocket, were mined and shipped by burros and wagons 92 miles to Placerville, Colorado, where it was shipped by rail to Denver and sold for $2,600. The shipment averaged nearly 21.5 percent U_3O_8 and sold for $12.50 a unit ($0.625/pound) which was a penalty price because the ore averaged 15 percent vanadium. In a letter to the editor of Engineering and Mining Journal in 1905, Mr. Kimball mentioned that he suspected that a sample of the Roc Creek ore was used in 1899 by French assayers Charles Friedel and E. Cumenge in naming the mineral "carnotite" in honor of the French physicist, Marie-Adolphe Carnot.

The discovery of uranium at Roc Creek, though significant, did not have much immediate impact on the domestic uranium-radium market because of the Austrian radium supply and the need for improving carnotite milling techniques and for lack of domestic radium recovery plants. Records of production indicate that the United States radium mines and recovery plants were sufficiently developed by 1912 and that the United States monopolized the world radium market from 1913 through 1922. In 1922 foreign processing of extremely high-grade pitchblende ores from the Shinkolobwe mine of the Belgian Congo

broke the United States monopoly. The Belgian monopoly was established by offering elementary radium for $70.00 a milligram, some $35 to $50 below the previous price. This pricing was maintained from 1923 into the late 1930's, and forced the termination of domestic uranium production. From about 1925 to the 1940's any surviving uranium mine depended principally on the vanadium content of its ores.

The 11 year tenure of the U.S. monopoly in radium resulted in the extraction, mainly domestic, of approximately 197 grams of radium. Production of radium from domestic ores, for the period 1898 through 1928, amounted to approximately 250 grams of radium. The difference of 83 grams roughly represents the radium extracted overseas from Colorado Plateau ores exported from 1900 through 1912. The total world production of radium through 1928 amounted to 575 grams of which the United States produced 250 grams or 43 percent.

Radium ores were mined in Utah from about 1905 through 1928. They were mainly from the Thompsons, San Rafael, and Henry Mountains mining districts and accounted for approximately 5 percent of the U.S. production or about 12.5 grams of radium; the radium is representative of between 3,500 and 4,000 tons of ore containing at least 2 percent U_3O_8 and 0.9 percent V_2O_5.

From 1926 to early 1944 most of the Colorado Plateau production was based on vanadium. The vanadium market became glutted in 1944 and mining practically ceased when the Metals Reserve Company stopped buying vanadium in early 1944. The tenor of the ore is estimated to be 1.50 percent V_2O_5 and 0.25 percent U_3O_8. By the end of 1943 eight vanadium mills were in operation with a combined capacity of 795 tons per day. Two of the mills were in Utah; one at Cottonwood, Utah, operated by Blanding Mines Company, had a capacity of 20 tons per day; the other at Monticello, Utah, with a capacity of 100 tons per day was operated by the Vanadium Corporation of America, agent for the Metals Reserve Company (a federal agency). The Blanding mill ceased operations in mid-1944, whereas the Monticello mill continued operations for another six years; for three years until 1947 the Monticello facility principally concentrated the uranium contained in the mill tailings.

The value of uranium cannot be accurately established for the period of the early 1940's since all of it was being consumed in the highly secret and costly atomic bomb project which as of November 29, 1945 had cost $2.1 billion. In 1943 uranium oxide was priced at $7.00 per pound and in 1946 at $20.00 In previous years the oxide had been valued at approximately one dollar per pound after the radium had been extracted.

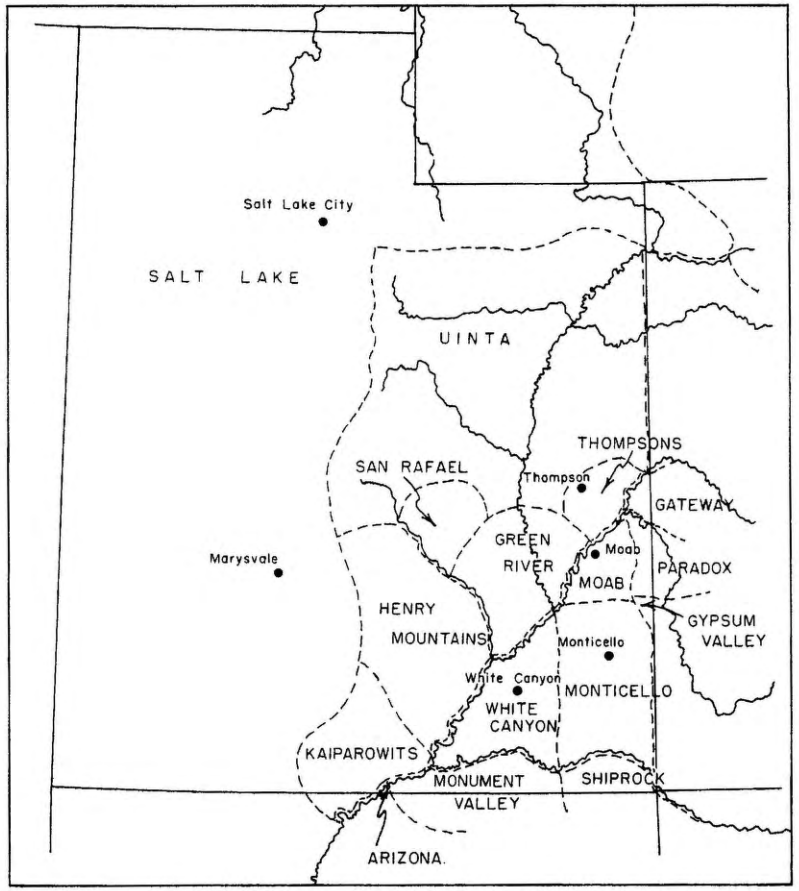

Figure 2. — Sketch map of Utah showing uranium districts and Atomic Energy Commission buying stations as of the mid-1950's.

The Atomic Energy Commission was established by President Truman on October 28, 1946. The AEC's early procurement program was essentially a continuation of the war-time programs of other federal agencies. From 1945 through 1947 uranium was recovered from the vanadiferous carnotite-roscoelite ores and from vanadium mill tailings.

In 1948 the AEC established an ore-buying schedule and began to establish ore-buying stations; subsequently 16 stations were established, 12 were in the Colorado Plateau area. Six ore-buying stations were in operation in Utah until 1962; they were situated at Salt Lake City (Vitro Uranium Co. mill), Thompson, Marysville, Moab, Monticello

(Vanadium Corp. of America mill), and White Canyon (See Figure 2). In the mid and late 1950's other mills were in operation at Green River, Mexican Hat, and Moab; in 1967, only two mills were in operation, the Vitro mill in Salt Lake City was wholly converted to the recovery of vanadium from furnace slags from phosphate plants, the Atlas Minerals mill at Moab was the only mill engaged solely in the recovery of uranium.

Government incentives such as guaranteed ore prices, haulage and mine development allowances, the production bonus for the first 10,000 pounds of U_3O_8 produced, grade premium allowance and fringe area allowances all stimulated the industry through the early and middle 1950's.

Private interests and the AEC, through its contractors, have since 1948 been responsible for about 22.5 million feet of exploration drilling on the Colorado Plateau; about 37 percent, or approximately 8.4 million feet, was in Utah. In Utah considerable acreages of public domain were withdrawn from mineral entry for purposes of government exploration drilling. All but approximately 3,000 acres in the Elk Ridge and Cottonwood Wash areas of San Juan County have been restored, these have been retained because the drilling proved the presence of mineralized ground and they may be leased from the AEC.

Field crews of government geologists, engineers and technicians were widely deployed during the uranium boom. More than 500 such men were on the payroll of the AEC and its contractors during the peak of exploration activity in mid-1950's. AEC funds supported much basic research in the geology and metallurgy of uranium and related elements.

From March 1952 through mid-1956 the AEC did considerable airborn radiometric surveying. Roughly 10 percent of the region, including the 11 western states and portions of North and South Dakota and Texas, was surveyed by AEC airborn radiometric reconnaissance teams. Over 185 anomaly maps have been published, 19 of them pertain to Utah areas. These rim flyers often stimulated claim staking in areas that had no anomalous radiation. During the peak of the uranium excitement, if an AEC rim flyer circled an area more than once it most likely would be staked, often in a matter of a few hours.

Prospecting for uranium was moderately pursued from the inception of the AEC's buying program until the discovery of the Lisbon Valley deposits in 1952. In the mid-1950's prospecting reached its highest pitch, a veritable uranium rush. Unlike the gold rushes to Sutter's diggings and the Klondike the prospector was generally well supported.

Instead of one or a few grubstakers many prospectors now allowed multiples of investors to participate in the risks. As a result perhaps the greatest 'get-rich-quick' boom this or any country will ever experience was initiated. The 'penny' uranium stocks appeared and on the local level the industry achieved 'criticality' resulting in the fission of vast tracts into mining claims held by an ever increasing number of uranium companies. The result was that for several years there was a rash of exploratory drilling and some fairly significant additions to Utah's uranium reserves. Further, much negative drilling work was accomplished which essentially proved the unfavorability of some tracts once thought to be of high potential. The boom ended when the AEC curtailed its buying program.

Chronologically the more significant uranium discoveries in Utah have been the deposits in White Canyon, especially after earlier discovered Happy Jack protores became commercial in 1947; the vein deposits of Marysvale in 1939; the Delta mine in the San Rafael Swell and the Mi Vida mine in Lisbon Valley, both in 1952.

The discovery of the Mi Vida ore deposit was perhaps the turning point in the history of uranium mining on the Colorado Plateau and in Utah; for shortly afterwards other major ore bodies along the trend of the Lisbon Valley anticline were found and quickly brought into production. The uranium production from the Lisbon Valley anticline to date has amounted to over 7 million tons of ore which represents nearly 65 percent of Utah's production tonnage. Further, the Lisbon ores contained 0.37 percent U_3O_8 which amounts to nearly 54 million pounds or about 72 percent of the total pounds of uranium oxide milled from Utah ores.

THE AEC 1967 PROCUREMENT PROGRAM

The last of the government incentives ended on March 31, 1952. At this time the guaranteed ore prices and other scaled incentives of the Domestic Uranium Program Circular 5, Revised, were terminated.

The AEC domestic procurement program from 1962 through 1966 involved buying only the concentrate from ores derived from properties with allocations, based on ore reserves which were developed before November 24, 1958, or in some cases on historical production during the fiscal years 1956-1960. In 1967 and 1968 concentrates derived from ores of producers having allocations of less than 20,000 pounds U_3O_8 per year will be purchased from property units that produced at any time during the period April 1, 1962 through December 31, 1966. A producer who marketed ore during the April 1, 1962 through December

31, 1966 period under an allocation of 20,000 pounds of U_3O_8 in ore, and who voluntarily reduced his production rate to 20,000 pounds of U_3O_8 in ore from January 1, 1963 through December 1966, will be allowed to market ore, the concentrate from which is for sale to the AEC, at the rate of 20,000 pounds of U_3O_8 in ore per year during the 1967 and 1968 period. Those producers with allocations of over 20,000 pounds of U_3O_8 in ore per year who did not reduce production to 20,000 pounds per year during the January 1, 1963 through December 31, 1966 period, must come under the "stretchout" program beginning January 1, 1963, under which these producers will be allowed to market in 1967 and 1968 that amount which was reduced from the total allocation during the 1963 through 1966 period.

THE PRIVATE MARKET

The current boom in uranium results from the increase in the market for uranium as a fuel in electric power generation which is now competitive with electric plants using the fossil fuels. It is estimated that the current uranium reserves will not fill the needs of the domestic market beyond 1980 (Johnson, 1966). This private market is separate from any purchases by the government.

URANIUM PRODUCTION IN UTAH

Uranium production in Utah is summarized in Tables I and II. Table I is the summary of uranium production as of December 31, 1966. Table II lists the uranium ore production by districts, exclusive of the ores mined during the period from 1904 through 1947 when uranium production records were incomplete because the ores were commercial either for their radium or vanadium content.

TABLE I

Summary of Uranium Production by Fiscal Year for the State of Utah 1904-1967°

Fiscal Year°°	Tons of Ore	Pounds of Contained U_3O_8	Weighted Av. Grade-% U_3O_8
1904-1947	115,500	700,000	0.25
1948	20,408	101,596	0.25
1949	38,512	169,980	0.22
1950	69,886	369,368	0.26
1951	99,874	509,559	0.26
1952	105,688	583,382	0.28
1953	86,813	571,378	0.33
1954	264,916	1,702,302	0.32
1955	543,099	3,467,277	0.32
1956	770,814	4,803,082	0.31
1957	1,017,487	6,873,667	0.34
1958	1,187,768	8,527,502	0.36
1959	1,226,226	8,630,006	0.35
1960	1,145,633	7,578,185	0.33
1961	1,095,409	6,442,587	0.29
1962	979,674	5,653,407	0.29
1963	727,456	5,721,532	0.39
1964	764,017	5,910,840	0.39
1965	565,028	3,942,913	0.35
1966	446,753	2,569,667	0.29
1967 (1st ½)	116,054	585,910	0.25

°°Compiled by the Ore Reserves Branch, U.S. AEC, Grand Junction Office.
°Fiscal Year ends on June 30 of year numbered.

TABLE II

ORE PRODUCTION SUMMARY BY DISTRICTS TO END OF SECOND QUARTER—FISCAL YEAR 1967°

District	Tons of Ore	Contained U_3O_8	Av. Grade-% U_3O_8
Gateway	210,691	1,326,518	0.31
Green River	542,116	2,565,365	0.24
Gypsum Valley	8	63	0.41
Henry Mountains	56,837	457,523	0.40
Moab	99,884	598,039	0.30
Monticello	7,287,284	54,438,650	0.37
Monument Valley	81,675	480,128	0.29
Paradox	156,348	893,764	0.29
San Rafael	593,809	3,033,566	0.26
Shiprock	8,882	60,017	0.34
Thompsons	106,177	526,683	0.25
Uinta	580	1,958	0.17
White Canyon	1,680,105	8,439,065	0.25
Arizona	38	63	0.08
Salt Lake	445,179	1,883,093	0.21
Unnamed Districts	1,875	9,450	0.25
All Districts,	11,271,488	74,713,941	0.33

°Compiled by the Ore Reserves Branch, U.S. AEC, Grand Junction Office.

SELECTED REFERENCES

Dare, W. L., Lindblom, R. A., and Soule', J. H., 1955, Uranium Mining on the Colorado Plateau, U.S. Bur. Mines Inf. Circ. 7726.

DeMille, John B., 1947, Strategic Minerals, McGraw-Hill Inc., p. 525-545.

Dodd, P. H., Droullard, R. F., and Lathan, C. P., 1967, Borehole Logging Methods for Exploration and Evaluation of Uranium Deposits: Canadian Centennial Conference on Mining and Groundwater Geophysics. October 1967. (Will be published, probably in transactions)

Hilpert, L. S., and Dasch, M. D., 1964, Uranium *in* Mineral and Water Resources of Utah, Utah Geol. and Mineralog. Survey Bull. 73, p. 124-132.

Huleatt, W. P., Hazen, Scott W., Jr., and Traver, William M., Jr., 1946, Exploration of Vanadium Region of Western Colorado and Eastern Utah, Rept. Inv. 3930.

Johnson, Wilfrid E., 1966, Uranium—The Supply and Demand Situation, Remarks before Amer. Mining Congress, Sept. 14. 1966, Salt Lake City, Utah.

Kimball, Gordon, 1904, Letter to the Editor, Eng. and Mining Jour., v. 77, p. 965.

Production Evaluation Division U.S.A.E.C., 1966, U.S.A.E.C. Airborne Radiometric Reconnaissance in Arkansas, Colorado, Montana, Texas and Utah 1952 to 1955, U.S. Atomic Energy Comm. RME-148, Grand Junction, Colorado.

Tyler, P.M., 1930, Radium, U.S. Bur. Mines Inf. Circ. 6312.

STRUCTURAL FEATURES OF SOUTHEASTERN UTAH AND THEIR RELATIONS TO URANIUM DEPOSITS

by

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Southeastern Utah is a part of the Colorado Plateau. This major structural province lies within the Grand Cordillera of North America. The Colorado Plateau is bounded on the north by the Uinta Basin, on the west by the High Plateaus of Utah, on the south by the Basin and Range Fault block belt of Arizona and New Mexico and on the east by the Southern (Colorado) Rockies.

Shoemaker (1956) indicates that the structural features of the Colorado Plateau could be classified into three main categories on the basis of the origin of the stress under which the structures were formed. These three are "(1) structures related to regional warping or strain, or major uplifts and basins; (2) structures formed in response to plastic deformation of evaporites (surface structure is not necessarily reflected in the basement complex), or salt plugs and salt anticlines; and (3) structures formed in response to magmatic intrusion or volcanic explosion or mountain domes, laccoliths, dikes, diatremes, and cryptovolcanos." There are many occurrences which are complexes of the three. None of these is completely separate from the others.

Major Uplifts and Basins

Within the Colorado Plateau in southern Utah are several basins and uplifts. These include the Henry, Uinta, Kaiparowits, and Blanding Basins, the Castle Valley Sag, San Rafael Swell, La Sal Dome, Monument Upwarp, Henry Domes, the Circle Cliffs, and the Kaibab Uplifts (Figure 1). For the most part the structural relief of these structures is measured on formations of Mesozoic age. The structure is similar from one uplift to another and relief ranges from 7500 to 9000 feet. The area involved in the uplifts is listed by Kelley (1955) as follows:

Uplift	*Area (Sq. Miles)*	*Relief (feet)*
San Rafael	2,600	4,000
Monument	2,500	3,000
Kaibab	2,500	3,000

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