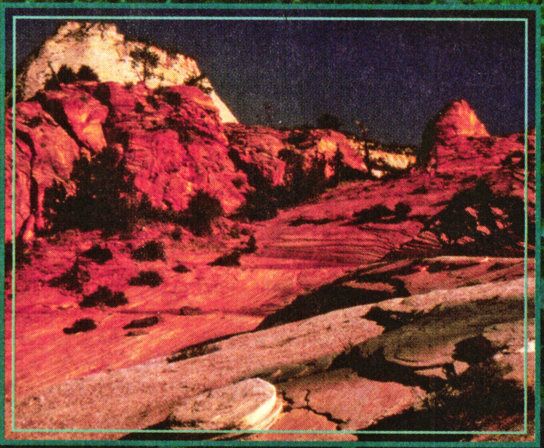
GEOLOGIC RESOURCES OF

Washington County

UTAH



By Miriam Bugden

This booklet is one of a series produced by the Utah Geological Survey's Geologic Extension Service. The purpose of the series is to improve public awareness of Utah's unique formations and resources, thereby evoking appreciation for the state's wealth of diverse beauty and economic strengths.

This text includes sections on geologic background, resources, energy, metals, and non-metals, scenery, and references. Included are maps and diagrams, as well as informative tables highlighting resources.

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Appreciation is extended to all Utah's tourists and residents for their interest in local geology and history, and in the future of our great state. Gratitude is extended to manuscript reviewers, UGS editorial staff, Christine Wilkerson, and the Utah Historical Society.

CREDITS

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Geologic Resources of Washington County, Utah

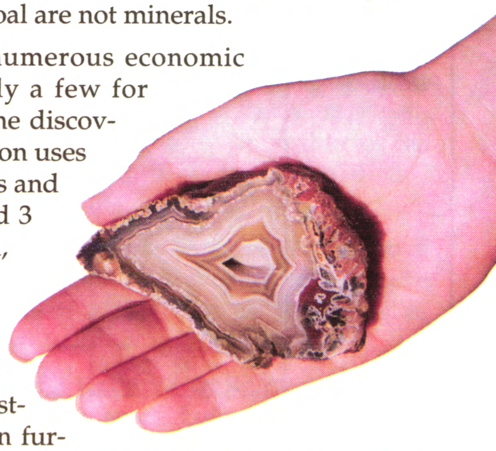
by Miriam Bugden

PREFACE

THIS BROCHURE INTRODUCES THE READER TO WASHINGTON COUNTY'S GEOLOGIC RESOURCES AND INVESTIGATES THE EFFECTS THEY HAVE ON OUR ECONOMY AND DAILY LIVES. UNDERSTANDING THE DYNAMIC FORCES THAT FORMED OUR RESOURCES AND THE FACTORS THAT INFLUENCE THEIR USE HELPS US UNDERSTAND THE INTEGRAL ROLES THAT RESOURCES PLAY IN SOCIETY.

The county's resources are divided into three categories: (1) metallic, (2) non-metallic, and (3) energy. For simplicity, this publication refers to these as "mineral resources." It is important, however, to remember that a few of these substances are not minerals (naturally occurring inorganic elements or compounds) and do not belong in this category. Sand, gravel, and building stone, for example, are often made of more than one mineral, and organic fuels which include natural gas, oil, and coal are not minerals.

Although Washington County has numerous economic resources, this brochure highlights only a few for detailed discussion. The text discusses the discovery, mining history, extraction, and common uses of these resources. Other county resources and pertinent data are listed in tables 1, 2, and 3 located at the back of the text. In addition, a generalized geologic map, geologic time scale, and geologic resource map are included to aid your understanding of the geology and related resources. A selected list of references provides suggested reading for those who are interested in further research. Additional information is available at the Utah Geological Survey.

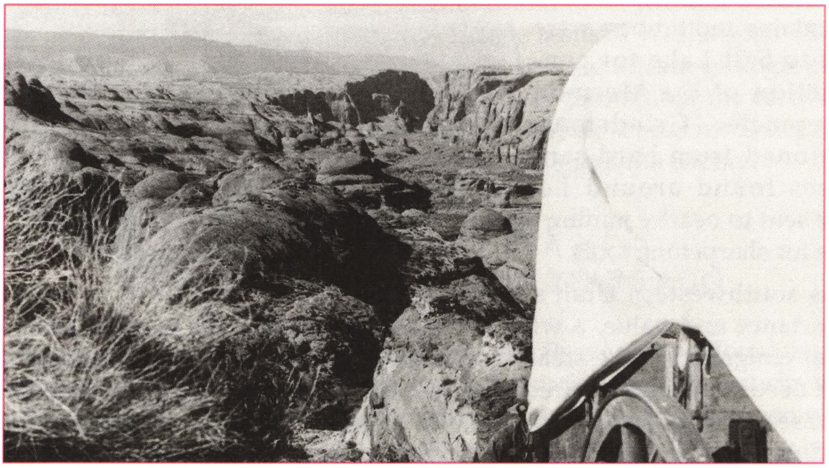


Washington County
Generalized Geologic Time Scale with Significant Geologic Events

Era	Millions of years ago	Period	Significant Geologic Events
Cenozoic		Quaternary	Basalt flows Erosion Basin and Range faulting
	1.6		
		Tertiary	Prominent basalt flows Basin and Range faulting Rapid erosion & terrestrial sedimentation Numerous volcanic events Pine Valley and Bull Valley Mountain intrusions
	66		
Mesozoic		Cretaceous	Terrestrial sediments eroded from western highlands formed by the Sevier orogeny. Virgin anticline formed
	144		
		Jurassic	Desert sand dunes followed by a shallow marine sea
	208		
		Triassic	Rivers and lakes deposited fine-grained terrestrial sediments
	245		
Paleozoic		Permian	Early shallow seas retreated. Evaporites, erosion, deposition of terrestrial sediments, erosion
	296		
		Pennsylvanian	Shallow seas deposited numerous layers of marine sediments
	320		
		Mississippian	
	360		
		Devonian	
	408		
		Silurian	Later tectonic disturbances caused uplift and erosion of Silurian strata
	438		
		Ordovician	Warm, shallow sea waters deposited numerous layers of marine sediments
	505		
		Cambrian	
	570		
Precambrian			Sediment deposition Igneous events Metamorphism

INTRODUCTION

UTAH'S WASHINGTON COUNTY IS A HARSH, RUGGED LAND THAT REFLECTS THE HARDSHIPS OF THE RESOLUTE PEOPLE WHO SETTLED IT. DEEP CANYONS CUT BY TURBULENT RIVERS; CRISP, PRISTINE MOUNTAIN LAKES; AUSTERE, TORRID DESERTS; JAGGED, IMPENETRABLE SHEETS OF BASALT; MULTI-HUED, CORRUGATED ROCKS; AND COLOSSAL PANORAMAS ONLY BEGIN TO DESCRIBE THIS LAND OF CONTRASTS.

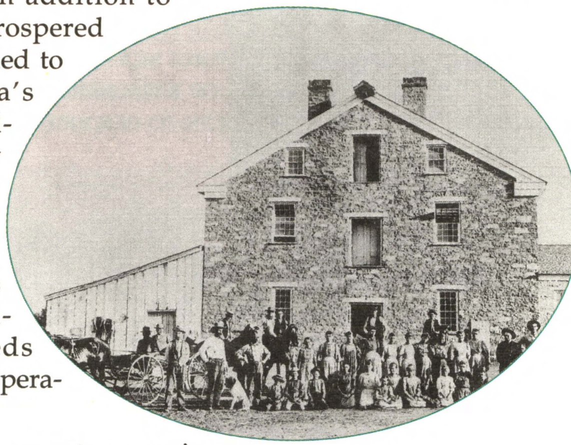


Like a prism scattering light, great variations in Washington County's topography disperse one climate into many. High elevations of the Pine Valley, Beaver Dam, and Bull Valley Mountains experience stinging winter weather. Adjacent valleys and lowlands experience long hot summers, extended growing seasons, and mild winters. These climatic and topographic extremes attracted and ultimately captivated southwestern Utah's early residents and visitors. Over 140 years later, these extremes are responsible for the county's current status as one of Utah's most popular recreation destinations.

The native lands of the Navajo, Paiute, and Ute nations were changed by southwestern Utah's traders and settlers from a remote area to one of relative popularity. Interest in the warm, southern lands escalated when northern Utah's Mormon pioneers traveled to Nevada and California for necessities to sustain communities in northern Utah.

Journeys south acquainted Mormon Church leaders with the warm lands, which led them to encourage colonization of the area. Longer growing seasons would provide new crops and necessities that, in the past, had restricted the level of self-sufficiency attainable by northern settlements. Southern church missions were quickly assigned. The Harmony settlement, or mission, was established in 1852, the Santa Clara Mission began by Jacob Hamblin in 1854, and the St. George mission was established in 1861.

To bolster local economies, residents of the "State of Deseret" soon began exporting an array of commodities. Cotton, cloth, grapes, and wine were among the first exports. In addition to farming, other industries prospered and their products were added to a growing list of the area's exports. Lumbering developed in the Pine Valley Mountains and timbers were sent to Salt Lake for construction of the Mormon Tabernacle. Grindstones fashioned from hard sandstones found around Leeds were sent to nearby mining operations for sharpening tools.



As southwestern Utah's exports grew in importance and value, a wide diversity of people with assorted skills and trades emigrated to the area. By the late 1860s, prospectors discovered silver near Leeds. Miners poured into the area, combing the hills. Population increases brought greater needs for oil to grease wagons, weapons, and tools; building stone for churches and homes; clay and limestone for mortar; and numerous other uses. As needs increased and grew in sophistication, Washington County's dependence on geologic resources became a critical element of the local economy.

Through the years, Washington County has played an important role in Utah's economic development. Included in the area's list of geologic resources are silver, gold, gallium, germanium, oil, gas, sand, gravel, gypsum, and building stone. With responsible resource development and use, Washington County will continue playing an important role in Utah's economy for many years.

Above: *This cotton mill was located near the town of Washington. By establishing settlements in the south, the Mormons increased acreage of their farmlands and used warmer climates to grow a variety of goods like cotton, fruit, and grapes. In 1854, Jacob Hamblin and others established the Santa Clara - Indian Mission in southwestern Utah. Excess warm climate crops from this region were exported for use in the north. A cotton shortage caused by the Civil War encouraged Brigham Young, the area's religious and political leader, to call for a cotton "mission" to help the shortage. Cotton was planted in warm Santa Clara by missionaries in 1855. Some of the cotton was made into cloth and sent to Salt Lake. For years, Washington County has been called "Utah's Dixie."*

GEOLOGIC SETTING

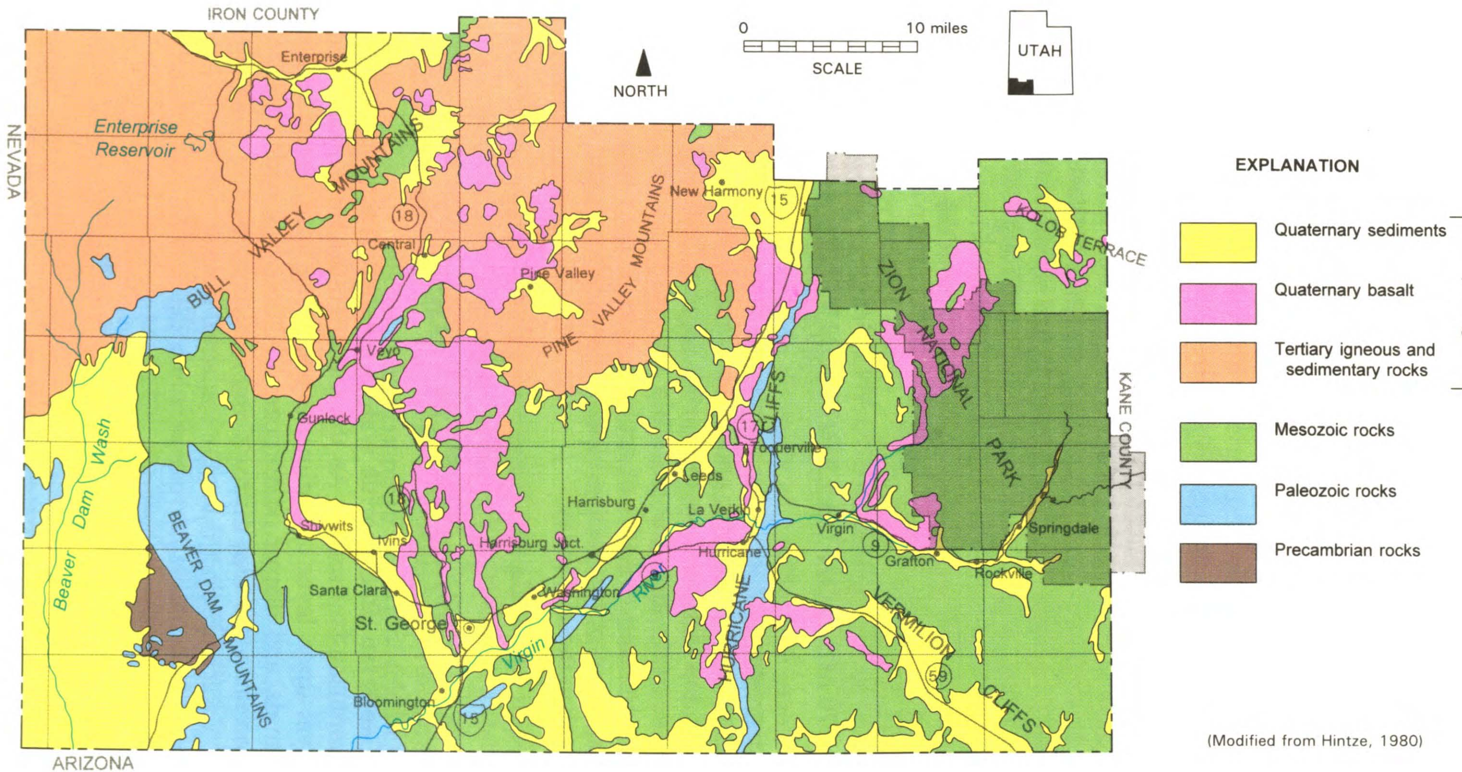
WASHINGTON COUNTY DISPLAYS AN EXTENSIVE CATALOG OF THE EARTH'S PAST HISTORY. THE ONLY MISSING CHAPTERS ARE PRE-PROTEROZOIC STRATA (ROCKS FROM BEFORE 2,500 MILLION YEARS AGO) AND 30 MILLION YEARS OF SILURIAN ROCKS (ROCKS REPRESENTING THE INTERVAL BETWEEN 408 AND 438 MILLION YEARS AGO). This extensive rock record documents hundreds of millions of years of sediment deposition, cementation into rocks, baking by the earth's internal heat, invasion of molten materials, and sculpting into familiar landforms. Careful observation of rocks, their textures, minerals, and other features allows us to understand the dynamic forces that molded the lands of Washington County. The Generalized Geologic Time Scale (page 2) lists significant geologic events that occurred in and around Washington County throughout the earth's history. The Generalized Geologic Map (page 6) shows where rocks deposited during different geologic eras can be found throughout the county.

PRECAMBRIAN ERA - 570 MILLION TO 1.7 BILLION YEARS AGO

In the southwestern corner of the county, the Beaver Dam Mountains host a thick sequence of metamorphic and igneous rocks, the oldest rocks in the county. Baked and contorted by the earth's internal heat and pressure, the rocks have uncertain ages but possibly are as old as 1.7 billion years. Representing numerous episodes of geologic change, their presence reminds us that during most of the earth's history, the landscape and climate were very different than those of today.

PALEOZOIC ERA - 245 TO 570 MILLION YEARS AGO

In early Cambrian time, marine waters invaded Washington County's eroded Precambrian landscape. As the sea migrated from west to east, it deposited layer upon layer of sediments beginning with quartz sands and then ocean muds, and deeper ocean oozes. Although periods of uplift and erosion did occur in the area during Cambrian time, marine sedimentation dominated. A thick, distinct dolomite sequence during mid-Cambrian time suggests a period of marine regression when the seas migrated back westward due to relative uplift of the land.



GENERALIZED GEOLOGIC MAP OF WASHINGTON COUNTY, UTAH

Theories proposed to explain the origin of the Cambrian rocks in southwestern Utah suggest that about 600 million years ago, western Utah was slowly being stretched like taffy as it pulled away from lands to the west. Western Utah and eastern Nevada were part of the continental shelf (relatively shallow water deposition) that widened and deepened as North America parted from the lands to the west. Over time, the blanket of water cyclically deepened, grew shallow, deepened, and grew shallow. Rocks that resulted from the fluctuations include sandstones, shales, limestones, and dolomites. Each group of rocks slowly accumulated as thick, flat sequences and ultimately cemented to forge southwestern Utah's Cambrian-age strata.

Most of Washington County remained submerged under relatively shallow marine waters throughout most of the rest of Paleozoic time. Missing Silurian-age rocks (408 to 438 million years ago) were likely removed by erosion during part of the Devonian period. Geographically close to the equator, the warm Paleozoic waters teemed with life. As in Cambrian time, water depths cyclically changed from deep to shallow to deep, leaving layer after layer of fossil-rich limestones, sandstones, dolomites, shales, and mudstones.

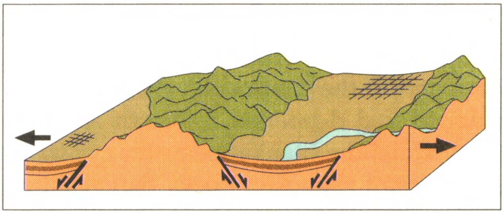
MESOZOIC ERA - 66 TO 245 MILLION YEARS AGO

Rocks deposited between 66 and 245 million years ago belong to the Mesozoic Era. Kaleidoscopic colors of Mesozoic rocks have inspired names like Color Country, the Painted Desert, and the Vermilion Cliffs, and are among the main contributors to southern Utah's vivid desert scenery. The events responsible for depositing these rocks were just as assorted as their colors. Sediments were deposited onto sea floors, coastal flats, stream beds, and flood plains throughout Triassic time (208 to 245 million years ago). Jurassic rocks (144 to 208 million years ago) formed in braided streams, vast deserts, far-reaching shallow seas, and marginal marine conditions.

While the last great sea invaded the continent and blanketed central and eastern Utah during Cretaceous time (66 to 144 million years ago), mountains were forming in eastern Nevada and western Utah. Compressional forces of the North American plate colliding with and against a west-lying oceanic plate forced the continental crust to buckle, thrusting vast wedges of rock eastward and on top of each other. This crustal warping caused some of the county's Jurassic deposits to erode. Many of the county's Cretaceous rocks were deposited as river sands; stream-lain boulders, cobbles, and pebbles; and swamp muds and clays. All are evidence for nearby eroding mountains in western Washington County.

Today, Utah's Mesozoic rocks attract tourists; serve as underground aquifers; yield petrified wood, fossils, coal, silver, copper, uranium, oil, and gas; and provide building stone.

CENOZOIC ERA - THE PRESENT TO 66 MILLION YEARS AGO



Between 25 and 30 million years ago, plate tectonic forces caused portions of western North America to stretch. Steeply inclined breaks, or normal faults, cracked the landscape into blocks that moved down (basins) relative to adjacent blocks (mountains). The mountain-valley-mountain topography that resulted from these events is called the Basin and Range Province. In Washington County, the Beaver Dam Mountains are the eastern edge of this province. The middle of the county is called the Transition zone, and the eastern portion belongs to the relatively stable, flat-layered province of the Colorado Plateau.

Events of the last 66 million years of the earth's history occurred during the Cenozoic Era. These events carved our modern landscape and played a major role in the emplacement of many metallic and non-metallic resources in Washington County. During the first part of the Cenozoic, freshwater lakes blanketed part of the county. About 30 million years ago, volcanic flows, ash, and debris spewed over southwestern Utah and igneous intrusions invaded the region. Igneous events continued until mid-Miocene time (around 20 million years ago). Massive warping or folding of rock layers occurred. About 15 million years ago, basin-and-range-type faulting began, inducing regional uplift, deep erosion, and low-volume eruptions of basaltic lavas.

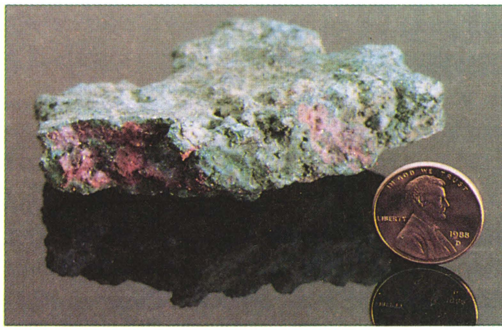
The complex geologic processes discussed above combined to give Washington County its diverse landscape as well as its economic resources. Geologic resources played and still play a vital role in the economic evolution and growth of the county. Geologic processes, active today, make Washington County's landscape as dynamic as any in Utah. All known economic resources are listed in tables 1, 2, and 3, pages 19-25. Their distribu-

The brilliance of Utah's Color Country is readily seen in one of the region's jewels, Washington County. The name Color Country describes multi-hued rocks etched against the azure skies and unique vegetation typical of southwestern Utah. This spectacular landscape is the result of the geological events that formed the area.

tions are shown on the Geologic Resource Map on the last page. Although each commodity has unique qualities, only a few from each category are described in detail. They are chosen for their significance to the county.

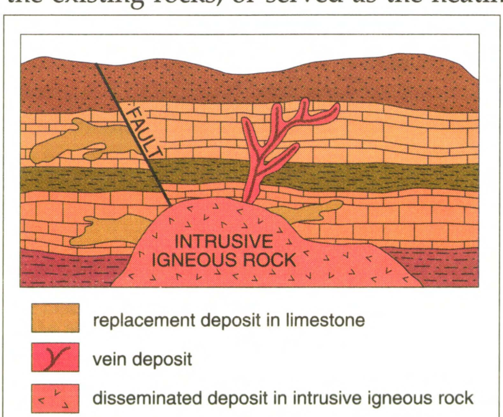
METALLIC RESOURCES

AT ONE TIME OR ANOTHER WE'VE ALL BEEN ENCHANTED BY LEGENDS OF GOLD, SILVER, AND OTHER PRECIOUS METALS. THESE VALUABLE SUBSTANCES HAVE, THROUGH HISTORY, MOTIVATED AND FINANCED ENTIRE NATIONS, EMPOWERED AND INSPIRED ARMIES, ADORNED MONUMENTS, DECORATED ATHLETES, AND CAUSED THEIR SEEKERS TO ENDURE INSUFFERABLE HARDSHIPS AT THE PROMISE OF FINDING LIFETIME TREASURES.



How are metallic minerals set apart from other earth resources? What has distinguished them as subjects of legends? Metallic resources have a shiny, metallic luster and are good conductors of heat and electricity. Metals occur naturally, either as part of a mineral or alone. Copper, for example, is found both raw (unattached to other elements) or as one of many elements in over 12 copper-bearing minerals found in Washington County.

Metallic ore deposits form in a variety of ways. Scientists believe that igneous activity (intrusive or extrusive) either brought metallic minerals into the existing rocks, or served as the heating system that mobilized and reconcentrated minerals that already existed in the sediments. Heat and pressure of metamorphism, as well as physical and chemical weathering, can also serve to focus the originally scattered metals into densely concentrated, economically viable ore bodies. Metallic resources are usually of little use until they are mined and purified (refined) by technological processes.



Washington County has a long history of extracting, using, and exporting metallic and non-metallic resources. The county's first residents, the Native Americans, employed natural resources for many uses. One prominent use was that of hard stones for weapons and grinding tools. Later settlers used this knowledge to produce and export grinding stones made from particularly well-cemented sandstones found near Leeds. High silver values were eventually discovered in the grinding stone rocks. This was the county's first significant discovery of valuable metallic minerals.

Four commodities, gold, silver, gallium, and germanium, are highlighted in this text for their importance in Washington County's economy. Silver played an important historic role, while gold from the Goldstrike mining district and gallium and germanium from the Apex Mine in the Beaver Dam Mountains are more recent contributors to the county's mining industry. A complete list of Washington County's mining districts, ore minerals, type of ore occurrences, and associated metals is provided in table 1, page 19 .

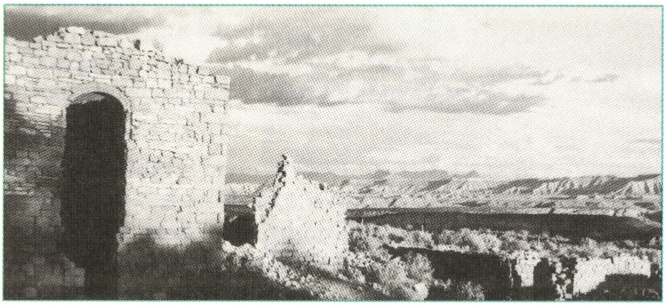
GOLD

Washington County's most contemporary contribution to the list of valuable metallic minerals is gold. The Goldstrike Mine in the Bull Valley mining district is about 35 miles northwest of St. George. Records of the initial gold discovery are meager, but mining claims were staked in the area in 1910. A mill was erected in 1914 to process the ores. Flakes and leaves of gold were mined from cracks and veins in Tertiary-aged Claron Formation limestones (rocks formed from sediments deposited in a freshwater lake that covered portions of central and southern Utah between 30 and 60 million years ago). Although the ore was high grade, the tonnages were small and work ceased in the area within a year or two.

Recent exploration located significant reserves of widely dispersed, very fine (often referred to as "disseminated") flecks of gold within a sandstone-conglomerate layer in the Claron Formation and along contacts with other rocks. From 1988 to 1990, Tenneco Minerals Company reported producing 2,682,720 short tons of gold ore and 105,000 ounces of gold from the Goldstrike Mine. The life of the operation is expected to last for 4 to 5 years. Silver, arsenic, mercury, and antimony are also associated with the microscopic sized, disseminated gold.

SILVER

Although silver is found in association with gold at the Goldstrike Mine, it holds its own place of importance in the history of Washington County. As with gold, grandiose legends of wealth surround this precious metal. Historically it was used as an item of barter and so highly valued that it became a monetary standard during the Roman Empire. It maintained this elevated status until the 16th and 17th centuries when large deposits, discovered in Mexico and Peru, made the once rare metal more abundant. Abundance forced the decline in the metal's value, which has experienced fluctuations throughout history.



The Silver Reef mining district located on the southwestern edge of the Pine Valley Mountains was once home to about 1,500 people. A catastrophic fire, dramatic decline in silver prices, and dwindling ore reserves forced the mines to cease operations in the early 1900s.

Legends surrounding the discovery of Washington County's famous Silver Reef mining district are almost larger than the metal's historical importance. One story indicates that silver was discovered when skeptical Nevada miners tested the credibility of an assayer by having him evaluate what they thought was worthless rock. When surprisingly high values of silver were reported from the broken Leeds grinding stone, one prospector began exploring.

Whether this is myth or truth, mining interests were sparked in the area in the 1860s. Officially, the district's discovery is assigned to John Kemple who, in 1869, located ores with silver assays valued at $17,000. He organized the mining district in 1874. Between 1875 and 1897, the district produced silver from the Springdale Sandstone Member of the Jurassic Moenave Formation (the formation was probably deposited in freshwater lakes that blanketed southwestern Utah between about 196 and 200 million years ago). After 1897, mining was sporadic until the district became inactive in 1909. Silver Reef produced more than 7 million ounces of silver from its inception until dormancy in 1909.

More recent activity in the area was spurred by the uranium rush of the 1950s. Uranium and minor amounts of copper, gold, and vanadium were found with the silver deposits. Silver Reef was once considered to be the only uranium-silver commercial grade ore deposit in the United States. In 1952, Western Gold and Uranium Company began work on a uranium ore body at Silver Reef. A 200-ton mill was constructed and uranium-silver and copper ores were shipped to Salt Lake City for processing.

GALLIUM & GERMANIUM

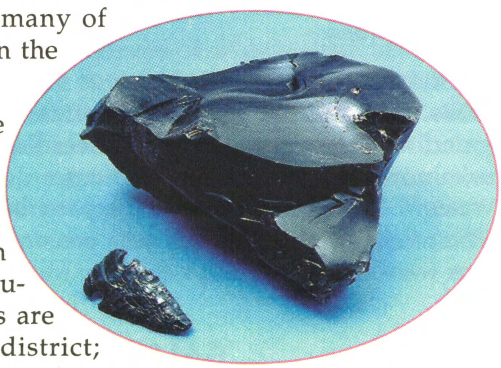
The Apex (Dixie) Mine in the Tutsagubet mining district is about 20 miles west of St. George in the Beaver Dam Mountains. In 1883 it was organized as a mining district where copper, silver, lead, and gold were extracted. Production from replacement ore bodies in a Pennsylvanian-aged limestone was intermittent from 1884 to 1962. During the mine's heyday from 1884 to 1909, smelters were erected locally to process the ores. In 1985, the mine reopened as the world's first to operate primarily for extraction of two space-age metals, gallium and germanium. The Hecla Mining Company reported that in 1986, seven hundred and fifty kilograms of gallium and 2,555 kilograms of germanium were produced from the Apex Mine. An unexpected decline in the price of both commodities caused the mine's closure in the summer of 1990.

Gallium and germanium were mined from the Pennsylvanian Callville Limestone (rocks formed from sediments deposited in shallow marine waters between 290 and 315 million years ago). Germanium was used in 1948 to make the first transistor. Today its uses include electronics, X-ray and gamma ray detectors, high frequency integrated circuits, fiber optics, and infrared optical instruments. Gallium is also used in integrated circuits, electronic devices, lasers, and light-emitting diodes.

NON-METALLIC RESOURCES

GLITTERY, RARE METALLIC RESOURCES ARE NOT THE ONLY VALUABLE SUBSTANCES FOUND IN THE GROUND. OIL, GYPSUM, SALT, ASPHALT, PHOSPHATE, AND BUILDING STONE ARE ALSO NOTABLE PRODUCTS OF OUR PLANET. OUR HIGH STANDARD OF LIVING IS DIRECTLY DEPENDENT ON THE AVAILABILITY OF THESE AND OTHER SEEMINGLY UNIMPRESSIVE COMMODITIES.

Non-metallic resources are rocks and materials that are not processed for their metal content or used as fuels. They form by several geologic processes including igneous, sedimentary, metamorphic, weathering, and ground-water movement. There are numerous non-metallic commodities in Washington County, many of which have played a historic role in the economic evolution of the area.



Modern uses of non-metals have expanded to meet the needs of larger populations and swelling industrial growth. The list of these resources found in Washington County is extensive. Alunite for alumina and halloysite clay for bricks are found in the Bull Valley mining district; quartz monzonite, a coarse-grained intrusive igneous rock used for dimension stone is removed near Beaver Dam Wash; gemstone quality chalcedony is mined from veins and geodes in basaltic rocks near Central; perlite is found near Enterprise and used as a lightweight aggregate; the Shinarump Member of the Chinle Formation is mined for dimension stone near St. George; and gem-quality malachite and azurite have been

In the struggle to survive harsh climatic extremes, early Utahns developed ingenious uses for the earth's resources. Initially, Native Americans used chert and volcanic glass for arrowheads (above), caves for shelters and food storage, and clay for pottery. Known uses expanded when later settlers began using clay for adobe bricks and mortar, field stone for fence construction, and building stone to erect monuments and buildings.

found in the Tutsagubet mining district. A more complete list of the county's non-metallic resources is found in table 2, page 22.

Lower Enterprise Reservoir, shown above, is constructed of rhyolite field stone over slabs of rhyolite dimension stone.

Construction materials currently rank as one of the most extensively used non-metallic commodities in Washington County. Sand and gravel, gypsum, and building and decorative stone are the primary industries currently operating in the county. Due to their economic importance to the county, gypsum and stone are highlighted in the text.

GYPSUM

Gypsum belongs to a family of minerals called evaporites. Typically, evaporites precipitate, or fall, to the bottom of waters that are in a basin with limited or "restricted" inflow. The climate is almost always arid and, as the wind and sun speed evaporation, the remaining basin water becomes more and more saturated with minerals and fine particles. Over time, the concentration of "evaporites" gets too heavy for the water to suspend and the minerals drop to the floor of the basin forming a layer or "bed" of evaporites.

In ancient China, gypsum was sculpted into ornate decorations and jewelry. Gypsum was primarily an artist's tool until about 5,000 years ago when Egyptians discovered that it formed a "putty" when exposed to fire and mixed with water. Smoothed over rough mud and brick walls, it hardened into an even finish. From this early beginning, gypsum's role in the construction industry led to its position of prominence as a main constituent of wallboard and plaster.

As with most other resources, gypsum's uses became more and more sophisticated and innovative as civilizations grew and methods for extending its hardening time developed. By the 18th century, it was also used as a soil conditioner in Europe. Gypsum was first discovered in the eastern United States in 1792 and in the western United States in 1875. It wasn't until 1918, however, that the first wallboard was made in the United States. Demand and uses for gypsum steadily increased. In the mid 1980s, the United States consumed 26 percent of the world's production of crude gypsum, primarily for the purpose of producing calcined gypsum for prefabricated products.

Most of southwestern Utah's gypsum and anhydrite (a dry and very fine-grained variety of gypsum) is found in Permian, Triassic, and Jurassic-aged sedimentary rocks. Alabaster is anhydrite that is often used by sculptors and other artisans. It is found in beds of the Permian-aged Kaibab and Toroweap Formations. The Carmel Formation from the Jurassic Period and the Triassic Moenkopi Formation are southwestern Utah's main suppliers of gypsum. Other uses of gypsum are listed in table 2, page 22.

STONE

Natural stone was one of Washington County's first recognized geologic resources and is critically important to almost every aspect of our lives. Sedimentary, igneous, and metamorphic rocks are used in buildings, building facades, walls, fences, monuments, carvings, railroad riprap, cement, highway construction, and many other areas. The numerous uses and types of stone are separated into three categories below.

Although the famous St. George Mormon temple is one of the most dramatic uses of dimension stone, Washington County has many other spectacular examples of early use of locally quarried stone. This beautiful Toquerville landmark served as the John Conrad Naegle home and winery during the 1800s.

Dimension stone includes blocks, sheets, and slabs of any kind of rock, rough or worked. This category includes building stone, paving blocks, and flagging and is used to add width and length in structural, decorative, or monument construction. All types of rocks are used as long as they can be economically quarried, are sufficiently strong, and are physically appealing. Quarrying dimension stone involves cutting large slabs or blocks of stone from massive rock walls and modifying the blocks to the desired sizes. Quaternary-age basalts and Mesozoic-age sandstones (from the Moenkopi, Chinle, and Navajo Formations) have been quarried in Washington County for use as dimension stone.

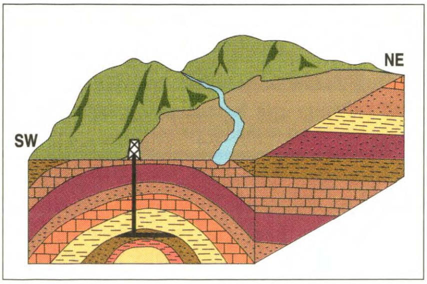
Crushed stone is rock that has been broken, crushed, or ground after it has been quarried. Crushed stone includes all varieties of rocks with textural and structural qualities that improve the ability to crush the rock. These rocks are used for aggregates in concrete, riprap for erosion control, railroad ballast, and highway construction materials. Quarries can be found throughout the county but are usually located close to highway projects or railroad tracks.

Ornamental stone includes all sizes and types of rocks. Typically, it is colorful or has textures that make it desirable for decorating facades or as curiosities. Red and orange banded flagstone has been quarried in Washington County from the Oak Grove area northwest of Leeds. "Picture rock" sandstone has been quarried near the town of Washington. Banded rhyolite or "wonderstone" for bookends and fireplace facades is found in the Beaver Dam Wash. Small amounts of travertine were once quarried near the Bull Valley mining district.

Scattered throughout the county are large and small cinder pits. Cinder is rock that was explosively ejected from a volcano. It is reddish brown to black, filled with holes, and used in decorative landscaping.

ENERGY RESOURCES

ENERGY, THE CAPACITY TO DO WORK, EXISTS IN VARIOUS FORMS. INITIALLY, HUMANS RELIED ON HEAT FROM FIRE AND THE SUN, GRAVITY, WIND, WATER, AND MANUAL ENERGY. WORK WAS HARD, ACCOMPLISHED SLOWLY, AND WITH GREAT EFFORT. Although fossil fuels (coal, oil, gas, tar sands, etc.) were part of ancient cultures, their applications as energy fuels were limited. Egyptians used asphalt (a thick oil) in their mummification procedures, Greeks poured oil onto the sea and ignited it to destroy enemy fleets, Romans and Greeks used coal for heating and lighting, and North American Indians applied oil to skin as a frostbite-preventative measure.

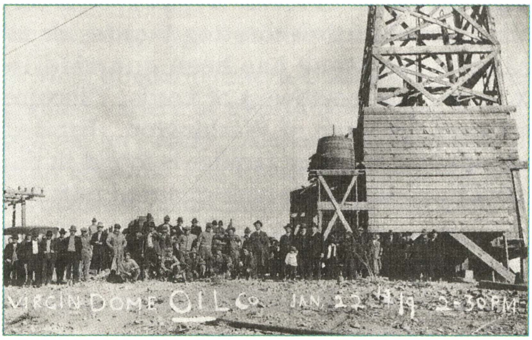


This schematic drawing shows how the Virgin oil field structural petroleum trap may look in the subsurface.

As civilizations grew, energy demands increased and competition motivated people to seek ways of performing tasks with greater ease. More efficient forms of energy increased in popularity and were quickly integrated into daily routines: gas and electricity replaced wood and coal as heat sources; fuel-powered transportation replaced walking and animal transit; and electric freezers and refrigerators replaced root cellars. Through time, nearly all modern cultures grew critically dependent on the earth's energy resources. For this reason, it is important to understand these vital assets and encourage responsible use and maintenance of all energy resources.

Oil and gas, coal, and geothermal resources are Washington County's most prominent energy resources. Oil, gas, and coal will be highlighted in the text for their important historical significance. Geothermal energy is not discussed in detail although a low-temperature geothermal potential exists in the county. A more complete list of the county's energy resources is given in table 3, page 24.

OIL AND GAS



Historical photo of the Virgin oil field discovery well. Courtesy of the Utah Historical Society.

Petroleum (oil and gas) can be a liquid, solid, or a gas. It occurs naturally and is mostly made of hydrogen and carbon (hence the name, hydrocarbon). Like other "fossil fuels," petroleum begins to form with the death and burial of small marine animals, plants, and phytoplankton. Like a good recipe, there are several steps that must take place before the organic matter is "cooked" or mature enough to be removed, purified, and used as an energy source. First, plants and/or animals die and settle to the floor of oxygen-poor waters. Burial, compression, and increased temperatures combine to change the loose sediments into layers of sedimentary rocks. Over time, chemical changes force hydrogen and carbon compounds, originally found in the organisms, to alter to "fossil fuels."

Oil can still be seen oozing from rocks in and around the Virgin oil field.

Like air in a balloon seeking escape into the lower pressures of the atmosphere, petroleum from carbon-rich source beds also seeks lower pressures. As the weight of the overlying rocks pushes down, liquids and gases move through cracks and spaces toward areas of lower pressure in adjacent rocks. Migration continues along the path of least resistance until equilibrium is reached or an impermeable layer (rocks whose grains are packed too tightly to allow passage) is encountered. At this point, the hydrocarbons are "trapped" and begin accumulating in "reservoir" rocks. Faults and folds are often important to these processes. Movement of the earth's crust along faults breaks the rocks allowing oil, gas, and water to move through broken, fragmented rocks. Folds help concentrate the fuels into underground pools and enable accumulation into large economic deposits or "fields."

For years, Washington County residents and visitors were aware of thick, dark oil oozing from rocks near the town of Virgin. Indians and pioneers undoubtedly used this resource in paints, for wagon and weapon grease, and to fuel oil lamps. As demand for the resource increased, so did oil's value. In pursuit of larger reserves, drilling programs were designed to explore the origin of the oil seeps. In 1907, the first well was drilled in the Virgin oil field in Washington County. Although considered to be the oldest oil producing area in the state, the area never yielded enough oil to be considered a commercial producer.

Washington County's Anderson Junction oil field.

The oil is stored between 450 and 800 feet below the ground in Triassic-aged rocks of the Moenkopi Formation (the oil probably didn't originate in these 245 to 250 million year old rocks but moved into their available spaces when seeking lower pressures). Some of the oil may also be stored in the Permian-age Kaibab Limestone (270 to 273 million years old). The oil was probably trapped at the top of a broad anticlinal fold that gently plunges to the northeast.

Total production figures for the field are sketchy since early records are incomplete, but some reports indicate that over 200,000 barrels of oil and 3,760 thousand cubic feet of gas have been produced from this area.

Washington County's second oil field, the Anderson Junction field, was discovered in 1968. The field is about 7 miles northeast of the Virgin oil field on the east arm of an asymmetric anticline that runs northeast-southwest. This geologic structure most likely formed during a mountain building period (the Laramide orogeny) that began about 80 million years ago and lasted until about 40 million years ago. Although the field is not currently producing, oil came from the Pennsylvanian-age Callville Limestone (290 to 315 million year old sedimentary rocks).

COAL

Coal is a sedimentary rock mostly composed of carbon. It forms from freshwater swamp vegetation that was buried and solidified. Over time, heat and pressures of burial slowly alter the vegetation to peat (the earliest stage in the development of coal), lignite, bituminous coal, anthracite, and eventually graphite. Often, a close look at coal will reveal a piece of wood, bark, roots, leaf, stem, or other plant matter. Coal is found in seams or layers in rocks.

During the early part of this century, coal supplied the largest amount of energy used by humans. The extensive nature of its use declined, however, with the advent of oil and gas as fuels in heating and transportation. Coal is still used, however, to provide energy to generate electricity, to manufacture coke for use in iron and steel production, to manufacture medicines, ammonia, gas, light oils, and tar and its derivatives. Coal is also the leading raw material needed to make nylon and various plastics.

In the winter of 1849-1850, Parley P. Pratt discovered coal and iron in southwestern Utah. Locating both resources was fortuitous as coal was used to make coke which was used in blast furnaces for smelting iron. Washington County's coal was mined from Cretaceous-age strata in the Harmony and Kolob fields. It was primarily used for heating and in local mining operations. Coal was mined in southern Utah by pick and shovel, and activity was intermittent until 1940. At that time, production increased as modern mechanized mining methods were developed. Numerous factors including better quality coal from other areas of Utah, more efficient methods of heating, and the decline in iron mining caused the closure of Washington County's coal operations.

SUMMARY

Geologic resources are the by-products of a series of complex conditions that occurred over vast expanses of time. Knowledge and understanding of those events enhance our appreciation of Utah's resources and scenery, and grant us insight to future resource potential. Washington County hosts a wealth of resources that, through history, have enriched southern Utah's economic status. From clay used in drilling muds, to arsenic for insecticides, to copper in plumbing, to petroleum in plastics, uses for the county's resources are limited only by our needs and imaginations. We hope this brochure has encouraged awareness which will lead to a better understanding of the role geology plays in economic growth and in our daily lives.

Table 1

Washington County Metallic Resources

Known metallic occurrences in Washington County. Since mining activity depends on fluctuating economic conditions, not all the resources are currently extracted. This inventory does not include unexploited or undiscovered resources that remain a challenge for future development and utilization.

Commodity	Uses	Mining District	Occurrence or Area	Ore Minerals	Associated Metals
Antimony	batteries ceramics flame retardant glass plastics	Beaver Dam Wash Bull Valley Gunlock	disseminated, replacement fault fissure stringers in limestone	stibnite	bismuth gold manganese uranium
Arsenic	insecticides glass-making wood preservative	Beaver Dam Mtns Bull Valley Goldstrike	 replacement	adamite orpiment realgar	gold
Bismuth	ceramics chemicals machine parts paints plastics	Gunlock	stringers in limestone	bismuth	antimony manganese
Copper	alloys ammunition coinage construction electronic prods heat exchangers plumbing transportation	Bloomington Hill Kolob Mineral Mtn. Silver Reef (Harrisburg) Tutsagubet (Apex Mine)	 disseminated, replacement vein disseminated, replacement, chemical sediments replacement, vein	azurite chalcocite chalcopyrite chrysocolla copper cuprite malachite	gallium germanium gold iron lead molybdenum silver tungsten uranium vanadium zinc
Gallium	integrated circuits light emitting diodes lasers light detectors photoelectric materials calculator, radio and TV components	Tutsagubet (Apex Mine)	replacement	jarosite limonite	copper iron lead silver zinc gold

Table 1, continued

Commodity	Uses	Mining District or Area	Occurrence	Ore Minerals	Associated Metals
Germanium	x-ray detectors infrared optics fiber optics superconducting alloys infrared sensing systems	Tutsagubet (Apex Mine)	replacement	goethite hematite limonite	copper iron lead silver zinc gold
Gold	dentistry electronics jewelry monetary standard ornaments	Beaver Dam Wash Bull Valley Goldstrike Mineral Mtns. Silver Reef Tusagubet Vermilion Cliffs	replacement veins, replacement disseminated by product by product, replacement placer	native gold	antimony arsenic copper lead mercury molybdenum platinum silver tungsten zinc
Iron	ocher pig iron steel	Bull Valley Goldstrike Mineral Mtns.	vein, replacement replacement contact metamorphic vein, replacement contact metamorphic	chalcopyrite hematite limonite magnetite pyrite	copper gold molybdenum silver tungsten
Lead	batteries construction electrical prods gas additive glass paint	Goldstrike Silver Reef Tutsagubet	replacement replacement, vein cave filling	cerussite plumbojarosite	copper germanium gold silver zinc
Manganese	construction batteries machinery pig iron steel alloys transportation	Gunlock Enterprise Santa Clara Toquerville	veins replacement bedded, disseminated	birnessite pyrolusite	strontium
Molybdenum	aircraft automobiles chemicals machine tools	Mineral Mtns.	veins		copper iron gold silver tungsten
Platinum	catalysts in automotive chemical and petroleum industries	Vermilion Cliffs	placer	platinum	gold silver

Table 1, continued

Commodity	Uses	Mining District or Area	Occurrence	Ore Minerals	Associated Metals
Silver	alloys	Beaver Dam Wash		aguilarite	copper
	dentistry	Goldstrike	vein, replace-	argentite	gold
	electrical		ment	cerargyrite	iron
	prods			silver	lead
	electronics	Mineral Mtns.	disseminated,		molybdenum
	jewelry	Santa Clara	replacement		platinum
	photography		disseminated,		tungsten
	sterlingware	Silver Reef	replacement,		uranium
		(Harrisburg)	chemical sedi-		zinc
			ments		
			cave filling		
		Tutsagubet	placer(?)		
		Vermilion Cliffs			
Strontium	magnets	Gunlock		celestite	manganese
	pyrotechnics	Santa Clara	replacement		
	TV picture				
	tubes				
Tungsten	aerospace	Beaver Dam Mtns.	vein	scheelite	copper
	industry	Mineral Mtn.	vein, replace-		gold
	drill bits		ment		iron
	dyes		vein		molybdenum
	lighting	Tutsagubet			silver
	TV tubes				
Zinc	alloys	Goldstrike	replacement	adamite	copper
	brass	Dry Canyon		aurichalcite	gold
	construction	Silver Reef		hydrozincite	lead
	electrical	Tutsagubet	replacement,	rosasite	silver
	prods		cave	smithsonite	uranium
	machinery		fillings		
	photocopies				
	pigments				

Table 2
Washington County Non-metallic Resources

Known non-metallic resource occurrences in Washington County. Since mining activity depends on fluctuating economic conditions, not all of the resources listed below are currently extracted. This inventory does not include unexploited or undiscovered resources that remain a challenge for future development and utilization.

Commodity	Uses	Location	Occurrence
Alunite	alumina source fertilizer	Beauty Knoll Mineral Mountain	vein vein/replacement, hydrothermal
Clays			
bentonite	drilling mud lining water structures	Harrisburg Junction	sedimentary
halloysite	bricks petroleum catalysts	Beauty Knoll Mineral Mountain	vein vein/replacement, hydrothermal
fire clay (kaolin)	refractories tile	Bull Valley Mountains	
Gemstones			
agate	ornaments	Beaver Dam Wash Castle Cliff Central Leeds area	aqueous solutions filling cavities/veins
azurite	ornaments jewelry	Apex mine	altered copper minerals
chalcedony	ornaments	Central	aqueous solutions filling veins and geodes in basaltic rocks
malachite	ornaments jewelry	Apex mine	altered copper minerals
petrified wood	ornaments jewelry	Beaver Dam Wash Tutsagubet Leeds area Santa Clara	fossil wood/replacement
wonderstone (banded rhyolite)	ornaments	Beaver Dam Wash	volcanic
Gypsum	prefabricated products sculpting material soil conditioner wallboard	Bloomington area Diamond Valley Kanarraville area Pine Valley Mtns. St. George area Santa Clara Silver Reef Toquerville Tutsagubet Virgin Canyon	evaporite
Limestone	cement crushed stone lime refractories	Beaver Dam Mountains	sedimentary
Perlite	insulation lightweight aggregate	Enterprise	igneous (volcanic)

Table 2, continued

Commodity	Uses	Location	Occurrence
Sand and Gravel	aggregate for concrete construction fill filtration railroad ballast winter road safety	Anderson Junction Beaver Dam Mtns. Enterprise La Verkin Santa Clara River terrace St. George Virgin River terraces Washington	sedimentary rocks in alluvial fans, river terraces, streams and river channels, talus, alluvial valley fill, river flood plains
Scoria (volcanic cinder)	cinder block lightweight aggregate ornamental	Enterprise Harrisburg La Verkin Pintura Veyo Volcano Mountain	igneous (cinder cone)
Silica	abrasives electronics glass refractories	Hurricane Sand Mountain southwest	sand sand dunes metamorphic (quartzite)
Stone			
dimension stone	construction monuments	Anderson Junction Tutsagubet (Apex mine) St. George area Beaver Dam Wash Leeds area Oak Grove St. George Mineral Mountain	sedimentary (sandstone) igneous (banded rhyolite) igneous (basalt) igenous (quart monzonite) sedimentary (sandstone) sedimentary (sandstone) sedimentary (sandstone) metamorphic (marble)
ornamental stone	decorative displays fireplaces garden walls	Beaver Dam Wash Bull Valley Gunlock Leeds area Oak Grove St. George area Washington	igneous (wonderstone or banded rhyolite) metamorphic (marble) sedimentary (picture stone) sedimentary (flagstone) sedimentary (red sand stone) sedimentary (picture rock sandstone)
Sulfur	sulfuric acid	Toquerville	native sulfur

Table 3

Washington County Energy Resources

Known energy occurrences in Washington County. Since mining and drilling activity depends on fluctuating economic conditions, not all of the resources listed below are currently extracted. This inventory does not list unexploited or undiscovered resources that remain a challenge for future development and utlization.

Commodity	Uses	Location	Occurrence
Carbon Dioxide	compressed gas used in industry dry ice enhanced oil recovery	Virgin	Triassic (Moenkopi Formation)
Coal	fuels industrial products	Harmony coal field Kolob Terrace	subbituminous to semi-anthracite high volatile C bituminous
Geothermal	electricity space heating water heating	Green Spring La Verkin Hot Springs Veyo Hot Spring Washington City Hot Spring Washington Hot Pot West St. George Springs	fault and igneous bodies
Oil & Gas	asphalt fuels plastics solvents waxes	Anderson Junction oil field Virgin oil field	Paleozoic sediments/ anticline Tertiary and Paleozoic sediments/anticline
Tar Sand	fuel paving material	Gould Ranch Hurricane Cliffs North Creek Timpoweap Canyon	Triassic sediments (Moenkopi Formation)
Uranium	nuclear fuels nuclear weapons radio isotopes x-ray targets	Beaver Dam Wash Bloomington Hill Kolob Miners Canyon Silver Reef (Harris-burg) Tutsagubet Vermilion Cliffs Washington area	disseminated, replacement disseminated, replacement replacement disseminated, replacement, chemical sediments disseminated, replacement bedded disseminated, replacement
Vanadium	nuclear fuels nuclear weapons radio isotopes	Kolob Silver Reef (Harris-burg) Vermilion Cliffs bedded	disseminated, replacement disseminated, replacement chemical sediments

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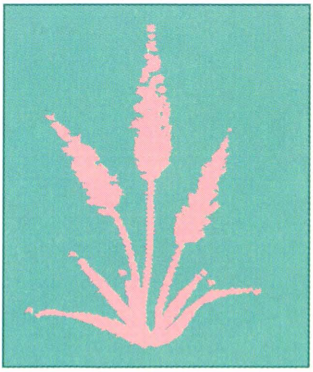

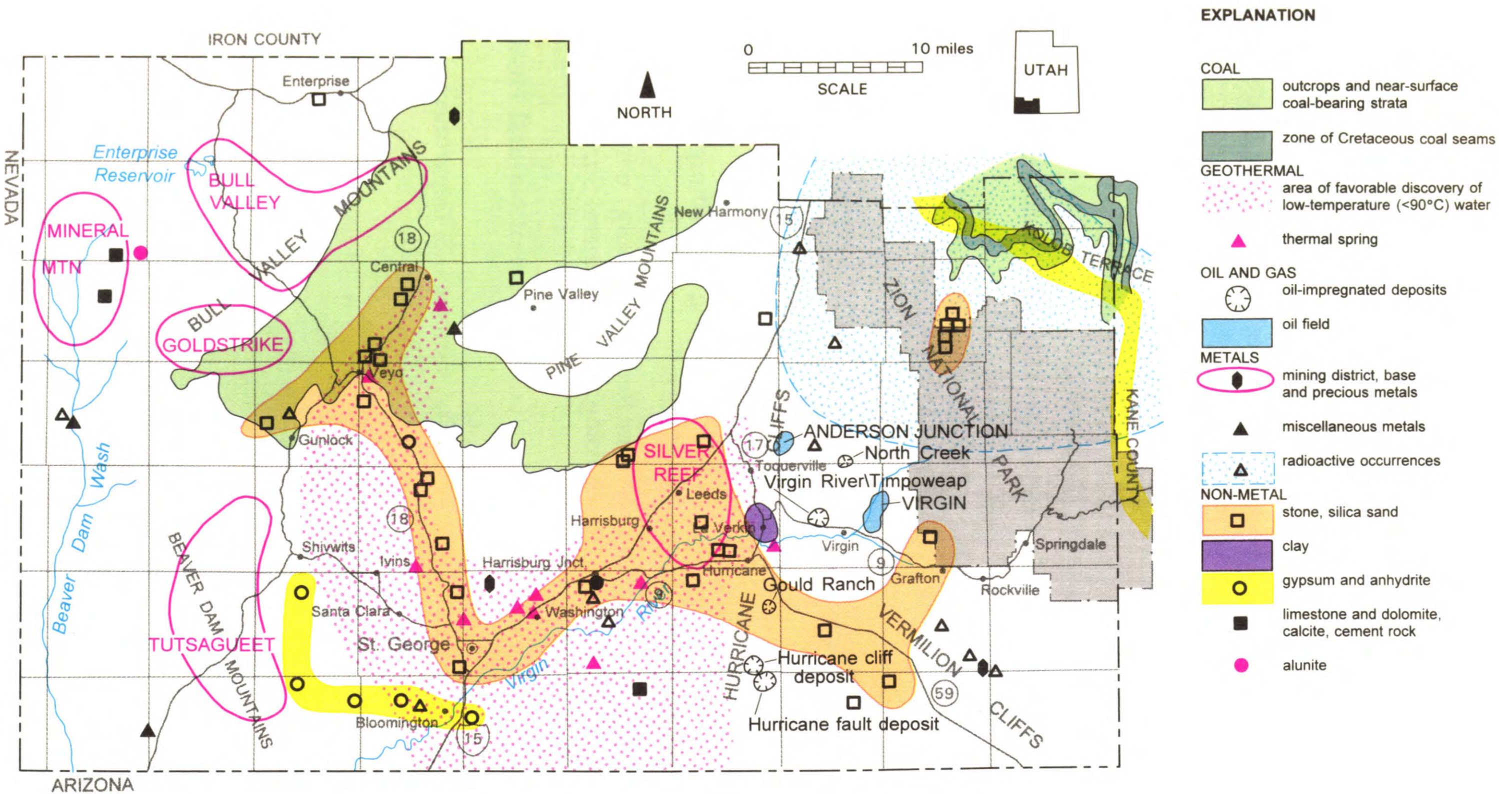

GEOLOGIC RESOURCES OF WASHINGTON COUNTY, UTAH

(Modified from Doelling, 1983; Doelling and Tooker 1983; and UGMS Map 68)