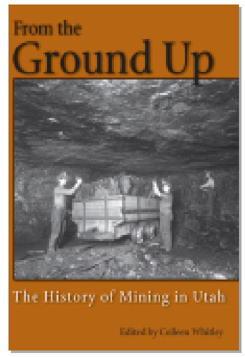
Maps - Non-Metallic Mineral Resources of Utah: Maps follow page 106 in Chapter 5



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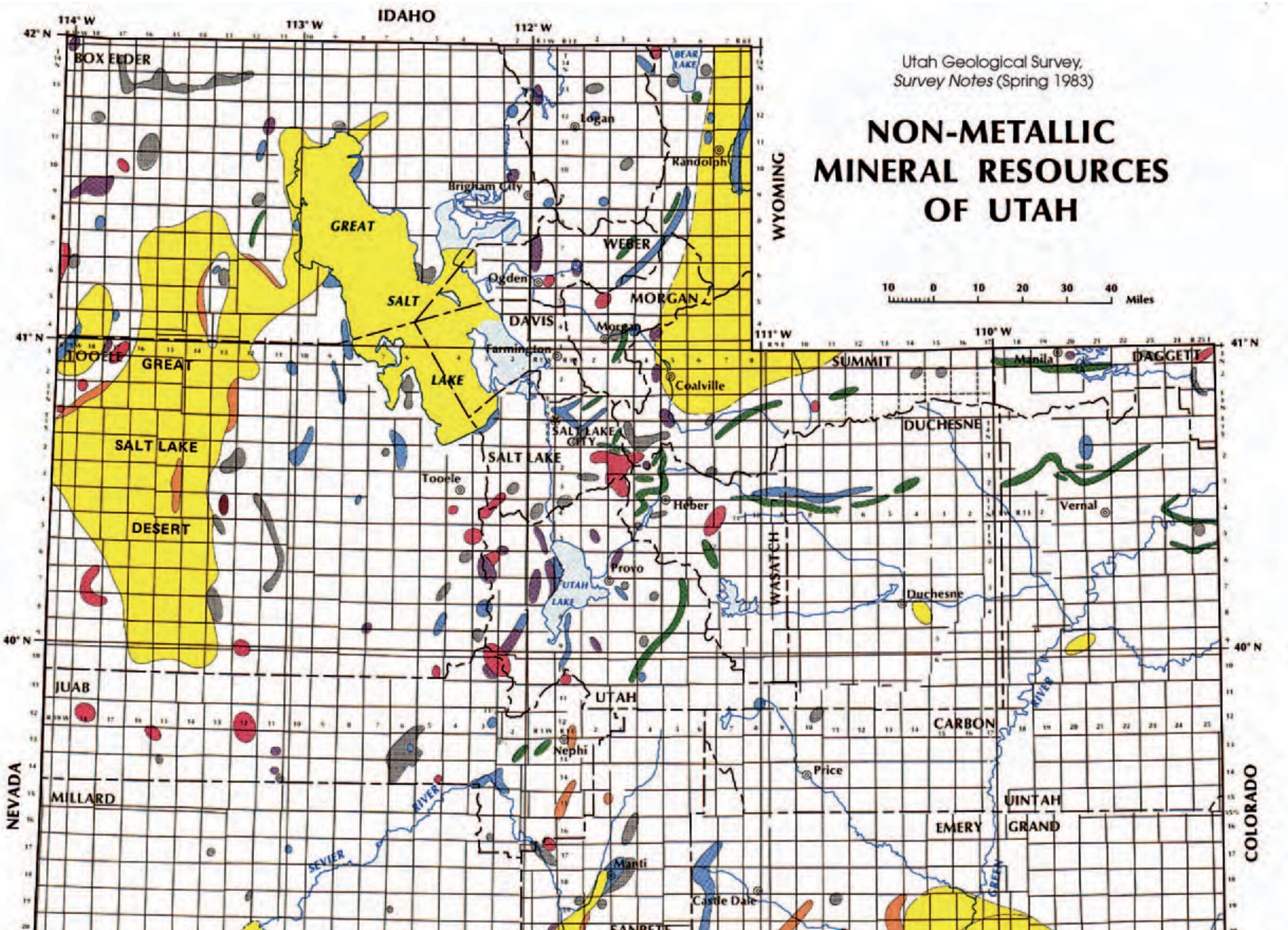
Utah Geological Survey,
Survey Notes (Spring 1983)
NON-METALLIC MINERAL RESOURCES OF UTAH
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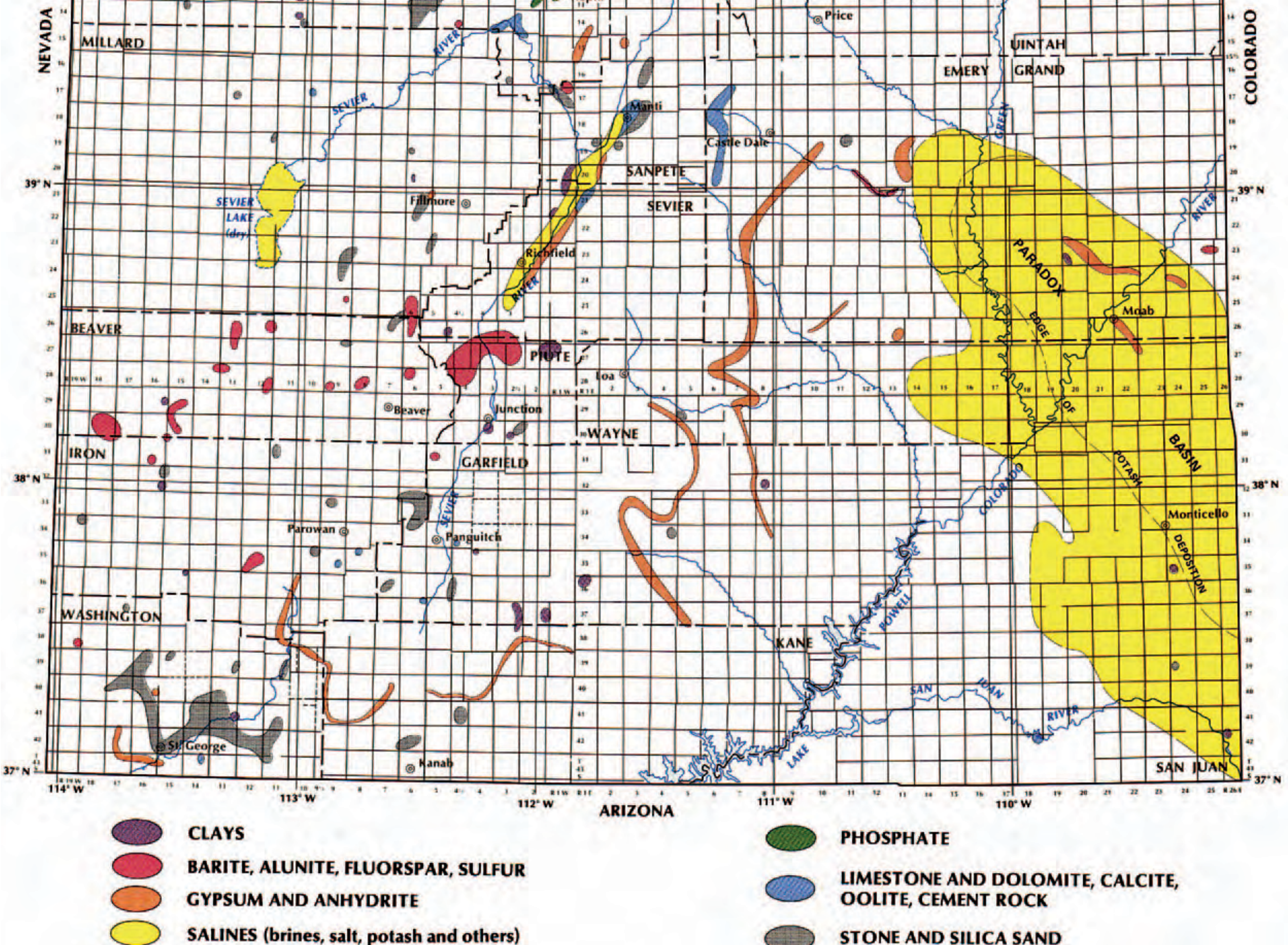
IDAHO
WYOMING
NEVADA
COLORADO
114° W
113° W
112° W
111° W
110° W
42° N
41° N
40° N
BOX ELDER
TOOELE
JUAB
MILLARD
WEBER
MORGAN
DAVIS
SALT LAKE
SUMMIT
DAGGETT
DUCHESNE
WASATCH
UTAH
CARBON
UINTAH
GRAND
EMERY
SANPETE
GREAT SALT LAKE
GREAT SALT LAKE DESERT
UTAH LAKE
BEAR LAKE
Logan
Randolph
Brigham City
Ogden
Morgan
Farmington
Coalville
Salt Lake City
Tooele
Heber
Provo
Nephi
Manila
Vernal
Duchesne
Price
Manti
Castle Dale
SEVIER RIVER
GREEN RIVER


NEVADA
COLORADO
ARIZONA
MILLARD
UINTAH
EMERY
GRAND
SANPETE
SEVIER
BEAVER
PIUTE
WAYNE
IRON
GARFIELD
WASHINGTON
KANE
SAN JUAN
Price
Manti
Castle Dale
Fillmore
Richfield
Loa
Beaver
Junction
Parowan
Panguitch
St. George
Kanab
Moab
Monticello
SEVIER LAKE (dry)
SEVIER
RIVER
GREEN
COLORADO
POWELL
LAKE
SAN JUAN
PARADOX BASIN
EDGE OF POTASH DEPOSITION
39° N
38° N
37° N
114° W
113° W
112° W
111° W
110° W
CLAYS
BARITE, ALUNITE, FLUORSPAR, SULFUR
GYPSUM AND ANHYDRITE
SALINES (brines, salt, potash and others)
PHOSPHATE
LIMESTONE AND DOLOMITE, CALCITE, OOLITE, CEMENT ROCK
STONE AND SILICA SAND

Early Companies on the East and North Shores of Great Salt Lake

George Payne built one of the first salt works on Great Salt Lake's eastern shore in 1880. The ponds were located on the south side of the Syracuse road, southwest of the town. William W. Galbraith later bought up shore land near Payne's property that apparently included it and organized the Syracuse Salt Company. He constructed 90 acres of salt ponds. Lake brine was moved to the ponds by three steam-engine-powered pumps. Most of the salt was shipped directly to the Montana silver mills without processing to be used in refining silver. Syracuse Salt produced 12,000 tons the first year and 2,000 tons the next year. There are no records that salt was produced after 1888.

By 1887 William Galbraith had sold more than half his acreage to the Adams and Kiesel Salt Company, which was incorporated on 17 May 1886. Adams and Kiesel built not only a salt works but also the Syracuse Resort and were involved in cutting and selling cedar posts. The company apparently did not own an extensive refining operation and simply shipped crude salt to the silver mills. From 1889 to 1892, production records indicate that Adams and Kiesel Salt sold 15,000 to 20,000 tons of salt a year. On 19 April 1899, William B. Clarke of Kansas City, Missouri, purchased the company for $30,000. There is no indication that Clarke ever produced any salt.

The Deseret Salt Company, incorporated on 9 October 1883, was located on Farmington Bay, southwest of the town of Farmington. A steam-engine-driven pump lifted the water from the lake into its ponds. Deseret Salt produced crude salt for the silver-mill market. There is no reference to the company after 1892.

The Gwilliam Brothers Salt Company (established about 1890) was located about two miles north and west of the Syracuse Salt Company. Gwilliam Brothers changed the company name to Solar Crystal Salt Company in 1892. It produced salt during the 1890s, but exact production records are missing. In 1901 George W. Gwilliam re-incorporated the company, but how long it was able to operate in competition with Inland Crystal Salt is not a matter of record.

The Sears Utah Salt Company located its operation between Syracuse and Kaysville. Sears Utah Salt, along with several other companies, existed in 1903, but how long it lasted after that is unknown.

For a short time, a salt company owned by A. H. Nelson operated near Brigham City. The company did not report its production in 1891 and discontinued its operation in 1892. The Nelson Company is typical of dozens of small companies that entered the salt business to take advantage of the market for crude salt.

Salt Companies from 1916 to 1970

Salt Companies on the South Shores of Great Salt Lake

Inland Crystal Salt lacked any serious competition in Utah's salt industry until Morton Salt leased a potash plant at Burmester (north of Grantsville) in 1918 and established a foothold. In 1923 Morton Salt purchased controlling interest in the Inland Company from the Church of Jesus Christ of Latter-day Saints. By 1927 the remaining stock was acquired, and Inland Crystal Salt was reincorporated as a wholly owned subsidiary under the name of Royal Crystal Salt Company. Morton Salt produced salt from its plant at Burmester and also from its subsidiary plant at Saltair until 1933, when production and refining facilities were combined at Saltair. Although both companies operated from the same plant, Royal Crystal Salt maintained its separate identity until 1958. When antitrust litigation brought against the company three years earlier resulted in the dissolution of Royal Crystal Salt, the plant subsequently became Morton Salt Company.

Until 1923 the Burmester plant employed manual labor to harvest salt. Machines were subsequently used after experiments proved their feasibility. Ed Cassidy introduced mechanized salt harvesting when he brought his farm tractor to the ponds to replace horses in pulling the salt plows. Machines had not previously been used because of the fear that their heavy weight would break through the thin salt floor of the evaporation ponds into the underlying mud. Following Cassidy's successful trial, however, the company purchased Fordson tractors to plow the salt. These tractors were discontinued in 1936 in favor of eight new machines called "Hootin' Nannys," which were Fordson tractors with a three-quarter-ton-capacity scoop in front. In 1949 the Hootin' Nanny was replaced by another machine called a "Jackrabbit," which used an air-cooled engine and could hold more salt. The Jackrabbit was replaced during the late 1950s by a machine called the "Scoop-mobile," which was larger and had a hydraulic scoop bucket in front. The Scoop-mobile was replaced in 1964 by a revolutionary new machine called the "Palmer-Richards Salt Harvesting Combine," which picked up salt as it moved down a preformed *windrow* (salt piled in a long, straight row) and dumped it into a truck moving alongside it.

Solar Salt Company and Its Predecessors

Growth of the Saltair facility enabled Morton Salt to retain a dominant position in the Intermountain market. Its near monopoly faced a temporary competitive threat from several new plants around the lake during the late 1930s and early 1940s; however, none of the new companies lasted more than three or four years. It was not until the late 1940s and early 1950s that a strong, competitive challenge arose when the Lake Crystal Salt Company, Deseret Livestock Company, and Stansbury Salt Company gained footholds in the salt business and retained them. These new companies benefited from being organized at a time when the salt market was expanding. In the 1960s the market increased 50 percent and doubled again in the 1970s. Although Morton Salt now shared the market with three other companies, the company's production still increased.

Crystal White Salt Company was organized in 1938 to produce salt for the California market. The new company selected a site six miles from Grantsville on the mud flats south of Stansbury Island. It chose the west side of the lake because of the purity and concentration of the lake brine, the accessibility to the railroad, and the geography of the salt flats. Construction began in late summer of 1938, and by the following year, there were 35 acres of ponds. The system was in full operation by June 1939, but the company went out of business in 1941, and the property lay dormant until the newly incorporated Stansbury Salt Company reactivated it.

The Stansbury Salt Company was formed when the properties of the defunct Crystal White Salt Company were sold at a sheriff's auction on 21 June 1948 to Mrs. Mary Godbe Gibbs for $2,500. Her husband, Lorin W. Gibbs, and others then organized Stansbury Salt. A refinery was built in 1950 on the north side of the intersection of U. S. Highways 40 and 50 and the Stansbury Island road. The plant was originally designed to produce 10,000 tons per year. By operating 24 hours a day the plant increased production to 40,000 tons in 1956.

Growth of Stansbury Salt required more capital than was available, and thus limited progress occurred until representatives of Hooker Electro Chemical Company and Pen Salt Chemical Company contacted it in 1954. These two companies organized the Chemical Salt Production Company and engaged Stansbury Salt as agent to build a large, salt-evaporating complex adjacent to the property. In 1956 the two chemical companies merged with Stansbury Salt, and the new combination was incorporated under the name of Solar Salt Company.

Solar Salt was initially incorporated with the intention of shipping salt to the two parent chemical firms in the Pacific Northwest. The new operation was completed in 1960. The ponds were designed to produce 160,000 to 200,000 tons of salt annually, but no more than 50,000 tons per year were shipped to the chemical plants. In 1967 National Bulk Carriers, which needed its own source of salt, purchased Solar Salt's facilities.

Nearly 50 years lapsed between Weir's abortive attempt to enter the salt industry at Lake Point in 1901 and the time when the Deseret Livestock Company reactivated the site in the spring of 1949. In late 1952 or early 1953, David Freed and David Robinson purchased Deseret Livestock, including the Lake Point salt works. In 1955 they offered the salt works to Council McDaniel, a former executive in a West Coast salt firm, for $300,000. McDaniel incorporated under the name Deseret Salt Company and operated the salt works until the latter part of 1958, when he sold it to Leslie Salt Company. In 1961 the Federal Trade Commission charged Leslie, the largest salt producer on the West Coast, with creating a monopoly. The proceeding was settled through a divestiture order requiring Leslie to sell its Utah holdings. On 2 November 1965, Hardy Salt Company of St. Louis, Missouri, purchased Leslie's Lake Point plant.

The pond system constructed by Deseret Livestock consisted of a series of 15 ponds laid out on high ground south of the mill. Later, 10 more ponds were constructed on the relicted lands between the mill and the Western Pacific Railroad. Subsequent owners have added ponds in both locations. Porous soil underlying the floor of the ponds had been a problem for salt producers at Lake Point since 1901.

Constructing seal trenches around the ponds finally solved this problem. Freshwater springs within the ponds have also presented problems.

Salt Companies on the East Shore of Great Salt Lake

Three sites around the east and north portions of the lake have been used for salt production: Spring Bay on the extreme north end of the lake, Promontory Point, and the mud flats west of Syracuse. From the turn of the century until 1939, there was no significant activity on the eastern shore of the lake. Inland Crystal Salt and its successors, Morton Salt and Royal Crystal Salt, were firmly established on the south shore, providing the market with the diversified products it required and jealously guarding their position in the industry. Inland or Morton owned much of the shore land around the lake suitable for salt production and made it very difficult for new companies to locate.

In 1939 the lake stabilized at the bottom of a 15-year declining cycle, exposing large areas of relicted land. The available shore land encouraged C. J. Call to organize the Ritz Salt Company. After constructing an access road and about 55 acres of evaporation ponds, Ritz Salt harvested about 5,000 to 6,000 tons of salt that fall. Plans were made to construct a salt refinery, but it was never built. Call sold his holdings to Morton Salt in 1941 after the company threatened him with a lawsuit for trespassing.

Call moved to the eastern tip of Promontory Point and built a few ponds between the lake's edge and the tracks of the Southern Pacific Railroad. There is no record of production from this site, and the rising lake would have inundated Call's ponds by 1950.

A.T. Smith, owner of Smith Canning Company in Clearfield, became interested in producing salt for his cannery and selling it on the regular market and formed the Solar Salt Company about 1940. Ponds were located a mile below the meander line, straight west of Syracuse. The meander line is a surveyed boundary around the lake below which is state property. A canal was dug from the ponds to the lake, and a gasoline-powered pump lifted the water from the canal into the ponds. Dikes were constructed with wooden shoring filled with clay. During 1940 3,000 tons of salt were harvested. A small mill consisted of a rotary kiln, screens, and a roller for crushing the salt into smaller particles. In 1945 rising waters washed away the dikes and dissolved 20,000 tons of salt. In 1949 the mill was dismantled and used to construct Deseret Livestock's salt plant at Lake Point.

Salt Companies on the Northern Shore of Great Salt Lake

In addition to the common problems encountered by salt makers in other locations around the lake, the north shore has never been considered a prime area for salt operations due to its remote location. It did, however, offer some promise shortly after the transcontinental railroad was completed near the north shore in 1869.

The Housel and Hopkins Salt Company constructed its ponds east of Locomotive Springs on the shore of Spring Bay and was reportedly operating during 1871. No other records of this company exist.

Organization of the Quaker Crystal Salt Company in 1939 resulted from a severe earthquake that affected Monument Point on the northern shore of the lake. Three warm springs began to flow, containing from 11 to 15 percent salt. Analysis of the brine indicated its chemical composition was ideal for cheese making. In addition to the springs, water from the lake was also used to make salt. A mill was built in 1939 or 1940 and consisted of an oil-burning, rotary-kiln dryer and screens to separate the salt into four different grades. The mill had a capacity of 2.5 tons per hour. The pond dikes were washed away in 1948 or 1949 and again in 1952. In 1965 fire destroyed the mill.

Lake Crystal Salt Company was incorporated in 1947. Production and refining operations were located at Promontory Point, and sales and storage facilities were in Ogden. Lake Crystal Salt Company had an advantage not shared by competing salt companies on the south arm of the lake. The highly concentrated brine in the north arm of the lake did not require concentration ponds, and all 300 acres of ponds were devoted to harvesting. Mill construction began in 1947 and consisted of a rotary-kiln dryer, screens, and rollers that produced a variety of grades for the market.

Salt Companies from 1970 to the Present

After the Hardy Salt Company of St. Louis purchased the Leslie Salt Company's Lake Point plant in 1965, it subsequently sold the operation to Lakepoint Salt Company in 1977. Lakepoint Salt consisted of a group of local investors and the former local management of the American Salt Company. The existing Hardy plant was shut down for several months while it was extensively refurbished to return it to profitable operation.[2]

In 1982 Domtar, a Canadian company, purchased Lakepoint Salt, retaining the existing management. In about 1983 the entire pond system was flooded when the Union Pacific Railroad installed a culvert through the railroad causeway to equalize the water on both sides of the causeway (Great Salt Lake was beginning to rise at this time). In 1984, with its ponds flooded, Domtar made an agreement to purchase salt harvested from AMAX Corporation's Stansbury Basin ponds and operated for a year under this arrangement. Then Domtar sold the Lake Point operations to AMAX, which changed the name to Sol-Aire Salt and Chemical Company.

In 1986 Diamond Crystal Salt Company from Michigan proposed a partnership with AMAX to build a large salt complex at Timpie, but negotiations were put on hold when AMAX's northern solar-pond dike broke, flooding the entire pond system. When AMAX decided to abandon the flooded pond system in 1987, Diamond Crystal made an agreement with AMAX to purchase the Sol-Aire salt plant at Lake Point and land suitable for a plant site at Timpie. During 1987–88 Sol-Aire did not have any productive solar ponds and purchased salt from Kaiser Chemicals near Wendover to process at Lake Point. During the same time, however, Diamond Crystal constructed an east-west dike through AMAX's Stansbury Basin evaporation pond, providing access to large quantities of salt on the bottom. This salt was taken for washing to Diamond's new plant at Timpie and then trucked to Lake Point for further processing.[3]

In 1989 AKZO, a large European company with salt operations in the United States, purchased Diamond Crystal, and Sol-Aire's name was changed to AKZO Salt of Utah. From 1991 through 1994, AKZO installed a small drying operation, a bulk rail-loading facility, and other improvements that completed the current salt-producing facility at Timpie. The old Lake Point plant was closed and partially reclaimed. In 1995 Nobel (a Swedish Corporation) merged with AKZO to become AKZO Nobel. Finally, in 1997 Cargill Salt, which for a time in the early 1960s operated the Lake Point plant under the name of Leslie Salt, purchased all the AKZO Nobel salt-producing facilities in the United States. Since the purchase, Cargill has invested heavily in the Timpie facility (figure 1) to bring its salt-drying and processing capacity up to the level of the salt-producing solar ponds.[4]

Morton Salt continued to operate successfully on the south shore of the lake until 1982, when heavy rain fell just south of the solar ponds, causing a flood in the C-7 canal that ran between the ponds and Kennecott's tailings. The flood washed over the crystallizing ponds, wiping out dikes and dissolving much of the salt laid down in previous years. It also flowed through the stockpile area, dissolving much of that salt, too. In addition, the rising lake diluted the lake brine, prompting construction of an additional 670 acres of concentrator ponds and elevation of the brine-supply pumps. Because of these problems, Morton was unable to produce enough salt and had to purchase supplemental salt from the AMAX ponds in the Stansbury Basin, located west of Stansbury Island.[5]

In 1991, when Kennecott Utah Copper needed acreage to expand its tailings pond, Morton's adjacent ponding area was a logical choice for acquisition. Kennecott bought the North American Salt Company plant at the south end of Stansbury Island and traded it to Morton Salt for its Saltair plant (figure 1). This trade enabled Morton Salt to continue producing salt from Great Salt Lake. Morton Salt moved some of the old equipment from the Saltair site to the new facility northwest of Grantsville, upgraded the old equipment in the North American mill, built some new facilities, repaired old solar-pond dikes, and added new dikes. At the end of 2000, Morton Salt and its 140 employees were well positioned to continue providing quality salt to a large area of the United States.[6]

After the Solar Salt Company (located on the southern end of Stansbury Island) was purchased by National Bulk Carriers in 1967, the North American Salt Company entered the Utah salt market. In 1972 North American Salt, owned by D. George Harris and Associates, purchased Solar Salt and became one of the largest producers in Utah.[7] North American Salt operated at the south end of Stansbury Island until 1991, when Kennecott purchased the entire facility for its trade with

Morton Salt. As a result of the trade, North American's management moved north to the Great Salt Lake Minerals and Chemicals Corporation's salt plant, also owned by D. George Harris and Associates (figure 1). The Great Salt Lake Minerals plant had been producing salt since about 1970. North American Salt was purchased by IMC Global on 1 April 1998 and renamed IMC Salt, Inc.[8]

On 28 November 2001, IMC Global sold its salt unit (IMC Salt, Inc.) to Apollo Management, LP. This new business entity is now known as Compass Mineral Group with headquarters in Overland Park, Kansas.[9] As part of this transaction, IMC Salt changed its name back to North American Salt Company.[10]

During World War II, National Lead Industries began to develop technology to produce magnesium by operating a government-owned plant at Lucky, Ohio. The company gained additional metals-production expertise in 1951 with the formation of a jointly owned company, Titanium Metals Corporation of America (TIMET), at Henderson, Nevada.

During the early 1960s, National Lead began investigating the possibility of producing magnesium metal and searching for sources of magnesium. The company joined with Hogle-Kearns, a Utah investment firm, and Kerr McGee, a diversified chemical company, in a venture to assess Great Salt Lake's potential for producing magnesium metal. The partners sought rights from the State of Utah to develop a solar-pond system in Stansbury Basin.[11]

During 1965 and 1966, National Lead conducted pilot operations. Scale-model solar ponds were constructed at Burmester, and a pilot manufacturing plant, designed to produce electrolytic-cell feed, was built near Lake Point. Magnesium chloride from this plant was trucked 450 miles and fed into a prototype cell at TIMET in Henderson, Nevada. Construction of the integrated magnesium-production facility began in 1970 with Ralph M. Parsons as the general contractor. The plant was located 10 miles north of Interstate 80 on the west side of Stansbury Basin (figures 1 and 2). In the summer of 1972, magnesium production began. Process difficulties made it necessary to shut down operations completely in 1975 to do some reengineering, with the help of Norsk Hydro, a magnesium producer in Norway. During the mid-1970s National Lead changed its name to NL Industries. In 1980 NL Industries sold the magnesium operation to AMAX Inc., a diversified mining and natural-resource company.[12]

Shortly after the transfer of ownership to AMAX, the lake began to rise. On 7 June 1986, in spite of AMAX's efforts to raise and fortify its dikes, a storm breached the main dike separating the solar ponds from the lake, completely flooding the ponds. During the flooding of the1980s, AMAX continued producing at a reduced rate, using concentrated magnesium chloride brines purchased and trucked in from Reilly Chemical near Wendover, Utah, and Leslie Salt, located near San Francisco. An alternative solar-ponding site was identified near Knolls. Ponds were constructed, and brine was obtained from the Newfoundland pond, part of Utah's West Desert Pumping Project (figure 2). After concentrating the brine at Knolls, it was moved 41 miles to the magnesium plant by pipeline. The West Desert Pumping Project

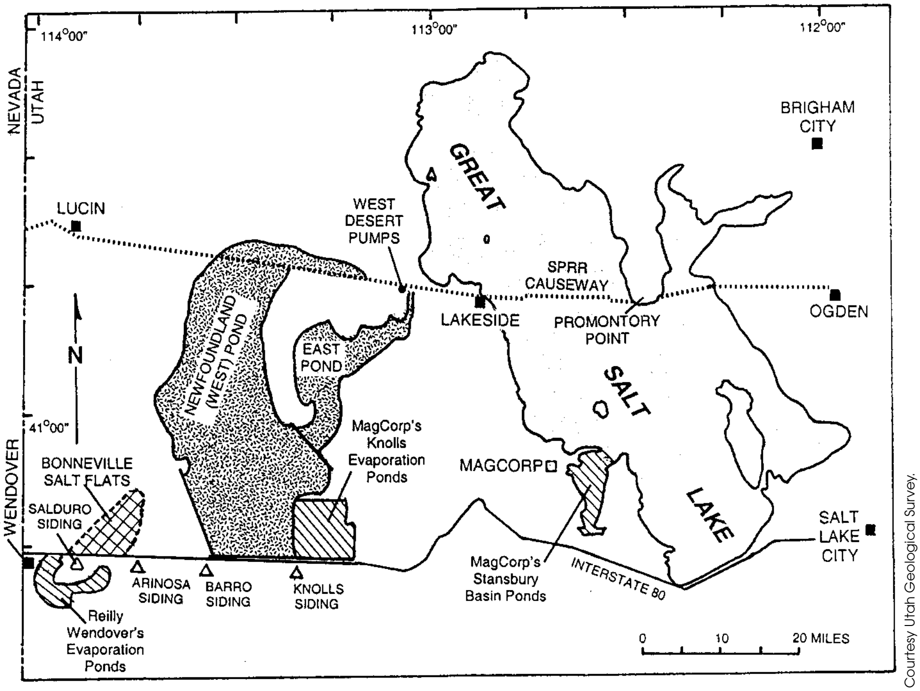


Figure 2. Components of the West Desert Pumping Project, MagCorp's Stansbury Basin and Knolls evaporation ponds, Reilly Wendover's evaporation ponds, sidings on the Union Pacific Railroad (paralleling Interstate 80), and other cultural features.

operated from April 1987 through June 1989 and then shut down.[13] Brine was available to AMAX until mid-1990, when the supply dried up.[14]

In 1989 AMAX sold the magnesium facility to Renco Inc., a privately held company in New York. The magnesium operation was renamed Magnesium Corporation of America (MagCorp). In the late 1980s and early 1990s, the level of Great Salt Lake receded, and by 1992 it had dropped to a level that allowed MagCorp to begin recommissioning the ponds in the Stansbury Basin. In 1995 the first brine harvest from the Stansbury Basin ponds was brought into the plant.[15]

The raw material used to manufacture magnesium metal is concentrated magnesium-chloride brine. Preparing the concentrated brine to feed to the electrolytic cells entails removing unwanted impurities and preventing further concentration. The product is then reduced to a gray $MgCl_2$ powder, melted in the reactor, and fed to the electrolytic cells. Here the molten magnesium chloride is separated into magnesium metal and chlorine gas. Besides magnesium metal (and magnesium alloys) and chlorine gas, other products include calcium chloride, ferrous chloride, and ferric chloride.[16]

In 1965 Lithium Corporation of America (Lithcoa), based in North Carolina, began investigating the production of lithium from Great Salt Lake (figure 1). When it became apparent it was not economical to extract lithium alone, the corporation joined with a German potash company, Salzdetfurth, which had expertise in producing potassium fertilizers (potash). From 1968 to 1998, the potash operation was known as Great Salt Lake Minerals and Chemicals Corporation or GSL. In April 1998 GSL was acquired by IMC Global and renamed IMC Kalium Ogden Corporation.[17] On 28 November 2001, IMC Global sold IMC Kalium Ogden Corporation to Apollo Management, LP. This new business entity is now known as Compass Minerals Group. As part of this transaction, IMC Kalium Ogden Corporation changed its name back to Great Salt Lake Minerals Corporation (GSL).[18]

By 1968 construction of a 12,000-acre solar-pond complex had begun, the production of lithium was placed on hold, and the production of potassium sulfate became the primary goal. To increase potash production, the solar-pond complex was first expanded during 1970 and 1971 to 19,000 acres; a second large expansion in 1991 brought the total pond area to 35,000 acres. A third expansion in 1998–99 increased the area to 40,000 acres. The main body of GSL's solar ponds and the processing plant are located between Little Mountain, about 15 miles west of Ogden, and Promontory Point.[19]

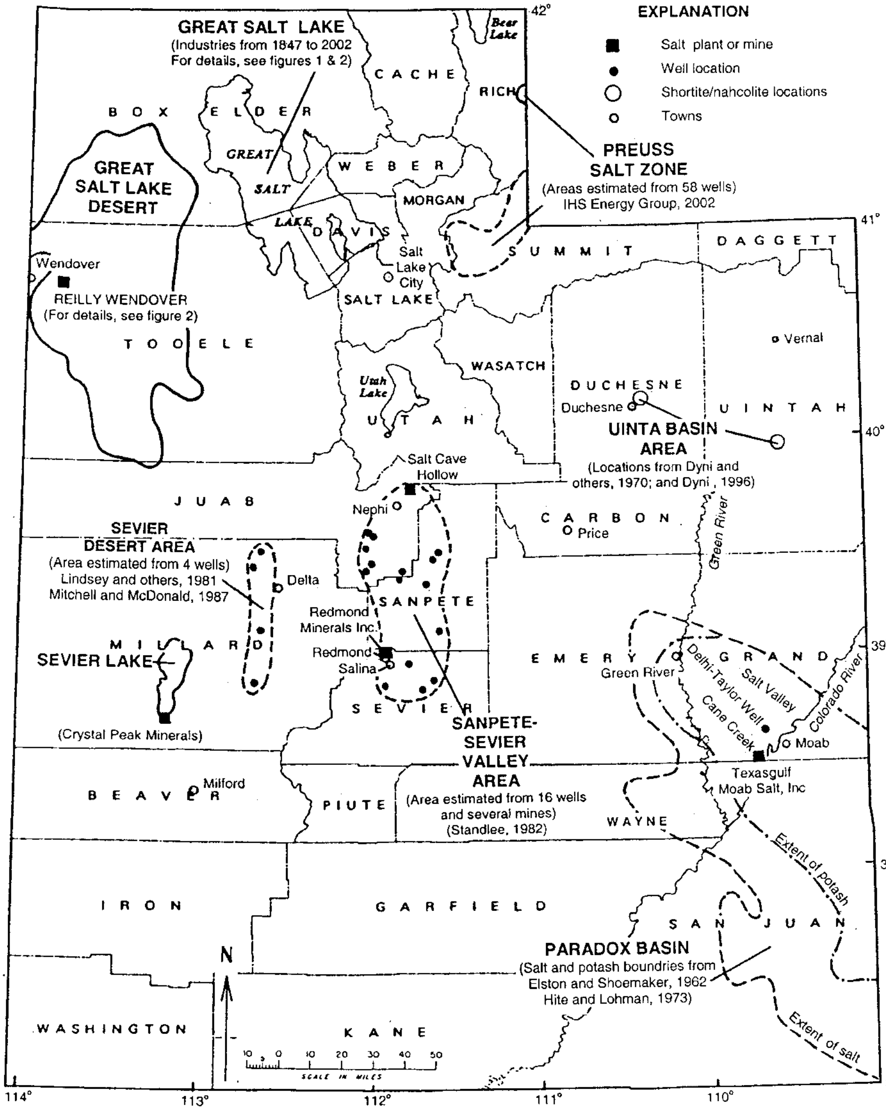
With ever-increasing world-market demands for potassium, GSL constructed solar ponds on the west side of the lake. The brines are transported to the east side using an eastward-sloping, 21-mile-long, underwater canal called the Behren's Trench to a pump station on Promontory Point.

GSL currently produces sulfate of potash (SOP) that is an excellent fertilizer. In addition to being shipped domestically, large quantities of SOP are also exported to the Pacific Rim. Magnesium chloride is also produced in both liquid and solid form. Anhydrous sodium sulfate, also known as salt cake, is another product that can be processed from the lake brine.

In the 1960s Hartley Anderson started selling Great Salt Lake water as a nutritional supplement. The business he started has evolved so that today Mineral Resources International (MRI) and its sister company, North Shore Limited Partnership (North Shore), create both liquid and powder mineral supplements from Great Salt Lake brine. North Shore produces concentrated brines in its 20-acre solar-evaporation complex at the north end of the lake (figure 1). MRI processes this brine into final nutritional supplements at its facilities just west of Ogden.[20]

Development of the Bonneville Salt Flats Potash Resources

The Bonneville Salt Flats, also a remnant of Pleistocene Lake Bonneville, is a salt-crust-covered portion of the Great Salt Lake Desert, located west of the lake in the northwestern portion of Utah (figure 3). The salt flats cover about 70 square miles, and the Great Salt Lake Desert about 4,000 square miles. The salt flats are normally dry during the summer months but are usually covered by water during the winter and early spring. Beneath the surface of both the salt flats and much of the desert, the



Courtesy Utah Geological Survey.

Figure 3. Saline resource areas of Utah with special emphasis on ones from the Preuss salt zone, Uinta Basin, Sevier Desert, Sanpete-Sevier Valley, Paradox Basin, and Sevier Lake areas. Detail for the Great Salt Lake and Bonneville Salt Flats appears in figures 1 and 2.

sediments are saturated with brines of varying salinities. Though the chemical composition of the brine varies from place to place, the following analysis (in dry-weight percentage) represents a typical brine breakdown: Na = 34.4, Mg = 1.6, K = 2.2, Ca = 0.6, Cl = 58.3, SO_4 = 2.9.

This section, originally published in Gwynn (1996)[21] and more recently in Gwynn (2002),[22] outlines the developmental history of the Bonneville Salt Flats from recognition of their salt and potash potential in 1906 or 1907 by Western Pacific Railroad engineers to the production of potash by Reilly Wendover today.

The first 10 to 12 miles of Interstate 80 east of Wendover, Utah, traverse the seemingly endless, flat, white, salt-covered expanse of the Bonneville Salt Flats, known in the early 1900s as the Salduro Salt Marsh. The salt flats and surrounding Great Salt Lake Desert are remnants of the bed of an ancient, large, cyclic lake, whose latest cycle, Lake Bonneville, occurred from about 32,000 to 14,000 years ago. Lake Bonneville was more than 1,000 feet deep and covered an area of 20,000 square miles in western Utah plus small portions of southern Idaho and eastern Nevada. Though the water of Lake Bonneville was relatively fresh, it contained small amounts of dissolved salt, including chlorides and sulfates of sodium, potassium, and magnesium. These dissolved salts precipitated on the surface of the Salduro Salt Marsh as the lake evaporated and are the source material of potash.

The Salduro Salt Marsh played an important role in the early development of a potash industry in the United States. Potash is mostly used as a fertilizer; the chemical industry utilizes lesser amounts. Prior to World War I (1914–18), Germany supplied nearly all of the growing demands for agricultural and industrial potash in the United States. The blockade of Germany by Great Britain during the war, however, cut these supplies off, and the U.S. had to find alternative sources of potash. By the end of the war, at least 128 American plants were producing potassium compounds from kelp, wood ashes, lake brines, alunite, cement dust, sugar-beet waste, blast-furnace dust, and other sources.

As early as 1906 or 1907, the engineers building the Western Pacific Railroad across the western Utah desert brought the existence of the salt beds of the Salduro Salt Marsh to national attention. The salt beds were soon covered by mining claims, and almost immediately the claim owners organized the Montello Salt Company, headquartered in Ogden. After several years of unprofitable attempts to produce salt, the claims were leased to the Capel Salt Company of Salt Lake City. Capel erected a small mill near the Salduro siding, about 10 miles east of Wendover, and produced and sold common salt for a short time.

In about 1916 Capel merged into or was transferred to the potash enterprise of the Solvay Process Company. During the war years, Solvay investigated many saline deposits and in 1917 began to extract potash from the subsurface brines of the Salduro Salt Marsh. The operation was constructed on the south side of the Western Pacific Railroad at the Salduro siding. There, in the center of the marsh salt-beds concentric, circular canals were dug into the salt and underlying muds. Salty water or brine flowed into these canals, where it concentrated through solar evaporation. The most concentrated brines were continually pumped inward, over the dikes separating the outer from the inner concentric canals. Potassium-bearing salts precipitated from the highly concentrated brine within the innermost canal. From there the salts were harvested and processed to produce potassium chloride.

Production of potassium chloride began in 1917, and at the end of 1918, Solvay transferred its interest in the potash operation to the Utah-Salduro Potash Company (USPC). By 1920 USPC was the largest single producer of potash in the United States. In 1921 the plant suddenly closed, mainly due to the fall in high wartime potash prices and the reorganization of the Solvay Process Company. After that time USPC restricted its operations to producing common salt.

In 1919 the Bonneville Potash Corporation (BPC), formed by J. L. Silsbee of Salt Lake City, erected a potash plant at Wendover, Utah, near the Utah/Nevada border (figure 2). From 1920 to 1936, BPC unsuccessfully attempted to produce potash commercially through the solar evaporation of brines. In 1936 a new operating company, Bonneville Limited, formed and built a new plant to recover potassium chloride by flotation from solar-precipitated salts. The first potash from this new plant was shipped in 1938. By 1939 Bonneville Limited was successfully producing potash and went on to become a significant, long-term potash supplier. Since that time, the operation has survived several ownership changes and now operates under the name of Reilly Wendover.

A third company, Chloride Products Incorporated (CPI), formed in 1921 by Frank Cook and a group of California capitalists, also attempted to produce potash from the brines of the Salduro Salt Marsh. CPI constructed canals, evaporation ponds, and a small processing plant near Arinosa, a few miles east of the USPC operation. CPI's developmental work is recorded through at least 1925; after that no further information about it is available.

The development of the potash industry on the Salduro Salt Marsh faced many challenges. The postwar decrease in potash prices made it increasingly difficult for the Utah companies to compete with other domestic and foreign suppliers. The surface conditions on the marsh were another critical factor. During spring the surface was normally covered with water, hindering development work, and wave action frequently destroyed dikes and filled the brine-collection ditches with sediment. Also heavy equipment frequently broke through the salt crust and sank into the underlying mud, necessitating the invention and use of special wide-metal wheels on the equipment. Hot, dry summers and cold winters, accentuated by the ever-present wind, made working conditions on the marsh unpleasant.

Early production of potash from the brines of the Salduro Salt Marsh by Solvay and the USPC played an important and sometimes singular role in supplying the United States with fertilizer during the latter part of World War I. In spite of domestic competition, international competition, and other economical, logistical, and climatological obstacles, the potash industry on the Bonneville Salt Flats survives.

Today Reilly Wendover, the potash industry's lone survivor on Utah's western desert, is an important contributor to potash production in the United States and the economic base of both Tooele County and the State of Utah.

Salt Mining in Central Utah

Salt deposits underlie the Sanpete-Sevier Valley area and probably account for the many local, salt-related names such as Salt Creek, Little Salt Creek, Salt Spring Creek, and Salina. [23] The salt is contained in the Jurassic Arapien shale, which consists of calcareous mudstone, siltstone, sandstone, limestone, and evaporates, including halite and gypsum. The Arapien shale is complexly deformed and shows signs of intense compression. Its thickness is uncertain because of the deformation but is estimated to range from about 4,000 to as much as 13,000 feet.[24]

The journal of the Escalante-Dominguez expedition into Utah in 1776 mentions the salt deposits in the mountains of Nephi, including a comment that the Indians mined their salt from that location. It was not until the Mormon pioneers moved to the area that the deposits were commercially exploited, however. Timothy B. Foote was one of the first white men to mine the salt deposits. In 1854 he built a toll road to his salt works and charged 25 cents for every wagonload of lumber or wood hauled over it. Four years later David Salisbury, Richard Jenkins, and Thomas Booth began mining salt from a cave they located about seven miles north and east of Nephi, probably in Salt Cave Hollow (figure 3). The trio was able to crush, boil, and dry about 500 pounds of salt each day, selling it for six cents a pound. Because of Indian trouble in the area, the plant moved to Nephi in 1862.

After the Eureka mining district opened, thousands of tons of salt were mined and hauled in horse- or mule-drawn wagons to the Shoebridge mill to use in refining ore. Livestock consumed most of the rock salt from Nephi; however, small amounts were boiled down and sold as table salt. Salt was mined intermittently from Nephi until about 1942, but there are no reports of activity at this site after 1943. In fact, any information about salt production from Nephi after 1897 is rare.

A corporation made up of Nephi residents organized the Nebo Salt Manufacturing Company in 1892 with the intention of producing a pure salt from the waters of a spring in Salt Creek Canyon.[25] The company brought water 350 feet from the spring to a 20-by24-foot building constructed to house the boilers, evaporators, and other salt-making machines. The brine was converted into table salt, dairy salt, and packing salt. Analysis of a random sample showed the salt to be 99.172 percent pure NaCl. Nebo Salt operated for about four years before Inter-Mountain Salt Company purchased it in 1897 to eliminate competition.

Like the Nephi area, salt in the Redmond area is concentrated in the Jurassic Arapien shale. Where the Arapien salt is mined near Redmond (figure 3), it appears as near-vertical, much-contorted beds interleaved with reddish brown, calcareous mudstones.[26]

In the late 1800s, the first settlers in Redmond noticed that the Indians camped north of town for a few days at least a couple of times each year. One time after the Native Americans had left, a couple of the settlers rode to the location and found that the Indians had been chipping salt from an outcrop. During the 1870s pioneer locators of the salt formation took a stock interest in the Sevier Valley Salt Company and produced salt for more than 30 years. The Gunnison Valley Salt Company acquired the property in 1909 and mined salt until 1926, when it was sold to the Great Western Salt Company. Six or eight other companies or individuals produced salt from the formation east of Redmond from the 1870s through the 1890s, including I.N. Parker.[27]

In the late 1800s, William P. Poulson, who had worked in the mines in Denmark, came to America. He eventually found his way west, where he worked for a time in the Park City silver mines. Poulson heard of the salt deposits near Redmond, married, and moved to the area. He opened a salt pit east of town near the I.N. Parker claim and formed the Great Western Salt Company. The salt was poor quality, and he soon abandoned the operation. In 1902, after a great deal of prospecting, Poulson opened a new mine on the west side of Arapien Valley with his sons—Francis, John, Milo, and Albert—in a location containing a higher grade of salt. He retained the Great Western Salt Company name. Poulson's sons later bought him out and changed the name to Poulson Brothers Salt Company.

Albert Poulson left his brothers in 1920 and operated the Inland Crystal Salt Company mine (exact location unknown), owned by the Church of Jesus Christ of Latter-day Saints, under his name on a royalty basis. He also purchased adjoining property from L. Jacob of Salina. Inland Crystal sold its mine to Royal Crystal, which in turn sold it to Morton. In 1952 Albert Poulson purchased the mine and operated it under the name of Albert Poulson and Sons until his death in 1980. After Albert's death, his son Willis sold the mine to LaMar and Milo Bosshardt.

John Poulson bought out the remaining two brothers of the Poulson Brothers Salt Company and continued the business with his sons: Blaine, Jewel, and Wallace. The sons later acquired the company from their father and managed it until 1965, when they sold it to Redmond Clay and Salt Company, owned by LaMar and Milo Bosshardt.

Early methods of surface or open-pit mining used a hand drill and a double jack or sledgehammer. The *churn drill,* a long steel rod with a bit on the end, came somewhat later. To operate the churn drill, a person sat down, put the drill between his knees, and began to churn (drop, lift, twist, and drop, etc.). Water was periodically poured down the deepening hole, and when a soupy mixture of cuttings and water formed, it was scooped out with a long spoon. Augers, first turned by hand, were later mechanized. An air-driven hammer, operated by a man sitting on a board pushing the reciprocating drill into the salt with his feet, was really an improvement. The air hammers were later mounted on jacklegs that supported the hammer, then on track-mounted devices. Now large hydraulic drills can auger out a 10-foot hole in three minutes. Early blasting was done with black powder, followed by dynamite, and now ammonium nitrate.

Horse-drawn wagons were first used to haul the rock salt. Chunks of salt too large to lift were rolled up boards and into the wagons. Each wagon hauled about two tons. Ten-wheel trucks replaced wagons, and now semitrucks do the hauling. For many years the salt was mined by open-pit methods, but since the early 1970s, underground mining techniques have replaced them. Large modern equipment, front-end loaders, and hauling trucks have replaced smaller pieces of equipment.

The mined salt was hauled to the mill, where it was crushed and passed through coarse, medium, and fine mesh screens. In some cases the salt was mixed with various chemicals (probably mineral supplements) to give the customer a choice of grades. By about 1968 the two mines in Redmond were producing about 10,000 tons of salt annually, which was shipped as far away as Arizona, Nebraska, and Canada. Most of the salt was used for road deicing with small amounts for livestock.

In 1959 LaMar and Milo Bosshardt went into the salt business under the partnership of Redmond Clay and Salt Company. By 1965 they had installed the first mixer, the first dryer, and the first sewing machine for paper bags in Sevier County. They also purchased the Poulson Brothers operation the same year. In 1966 the Bosshardts installed equipment to make a fourth screen size of salt. In 1968 they built a mill at the mine so all the salt crushing and loading of bulk salt could be done there rather than hauling it to town. By 1969 they became the first local salt company to deliver with a semitruck.

In 1976 the Bosshardts formed American Orsa Inc. as the food division of Redmond Clay and Salt to sell table salt and food-grade clay under the names Orsa Salt and Orsa Clay. In 1980 they purchased Albert Poulson and Sons to become the only operating salt company in the valley for the first time this century. In 1988 the name Orsa Salt was changed to RealSalt, and Orsa Clay became Redmond Clay.

In 1990 the Bosshardts built a new warehouse at the salt mine but continued to operate the old warehouse in town until 1993, when full operation moved to the mine. In 1997 the food division was absorbed into the parent company, and the company name changed to Redmond Minerals Inc. In 1999 the ownership of Redmond Minerals transferred from the Bosshardt family to Rhett Roberts, the present CEO.

The salt and potash deposits of the Paradox Basin of southeastern Utah lie in the Pennsylvanian Paradox formation of the Hermosa group. The area underlain by salt includes parts of Emery, Wayne, Garfield, Grand, and San Juan Counties in Utah (figure 3) and Montrose, San Miguel, Dolores, and Montezuma Counties in Colorado. The area underlain by potash is somewhat smaller, located in the northeastern portion of the basin, and includes parts of Emery, Grand, and San Juan Counties in Utah and the previously named counties in Colorado. The salt and potash in the Paradox Basin were deposited in a series of evaporite cycles. At least 29 salt beds or cycles are recognized, separated from each other by marker beds consisting of variable combinations of anhydrite, shale, mudstone, siltstone, and dolomite. Not all areas of the potash zone are underlain by all 29 salt beds. Eighteen of these cycles are known to contain potash. The thickest sequences of salt occur in 14 northwest-trending, salt-cored anticlines within the northeastern, potash-bearing portion of the basin.[28] In the Cane Creek area, salt 1 (the top cycle) is absent, and the potash section mined is zone 5 (K5), near the top of salt 5.[29]

The existence of potash in the Paradox Basin has been known for many years. The Crescent Eagle well, drilled in Salt Valley in 1925, reported significant signs of potash. In the 1940s Salt Valley experienced active exploration for potash. However, reports at the time indicated that, although potash was present, development should not be undertaken. In 1952 the Delhi-Taylor Oil Company started drilling in the Seven Mile area, about eight miles northwest of Moab and subsequently outlined a large ore (potash) deposit (figure 3). The Cane Creek deposit was recognized in 1956, and tests were so favorable that the Delhi-Taylor Company drilled eight test holes. Texas Gulf Sulphur Company (TGS) optioned the property on 15 April 1960 and, during the next four months, completed nine confirmation and development wells. The drilling program outlined a large, high-grade deposit of sylvinite ore (a mixture of halite and sylvite). Additional pilot holes were drilled during 1960.[30]

On 23 February 1961, TGS began construction of the Cane Creek Mine's head frame.[31] The other surface facilities were constructed from 1961 through 1963. TGS started construction of the underground portion of the Cane Creek Mine in 1962 (figure 3). The potash zone lay 3,000 feet below the land surface. Two parallel shafts were sunk to a depth of 2,789 feet, and then an incline was driven nearly 4,000 feet into potash bed K5.[32] On 13 January 1965, a boxcar was filled with the first load of potash from the Cane Creek Mine and delivered to market on a 36-mile-long Denver and Rio Grande Western rail spur built for the plant. TGS announced that the average thickness of the developed Cane Creek potash ore body was 11 feet, and the grade was between 25 and 30 percent K_2O.[33] The operation produced 439,999 tons in 1969, and by 1970 TGS had cut some 340 miles of headings in a room-and-pillar configuration.

TGS was plagued with problems from the start. The mine contained explosive methane, it was hot, and instead of being level and flat, the ore layer was distorted into undulating sections.[34] On 28 August 1963, during the development of the incline, a methane explosion killed 18 workers.[35] Because of the problems associated with underground mining, management started discussing the possibility of converting to solution mining. Extensive research produced a full report in August 1969, which convinced management that solution mining was, in fact, a practical and economic plan. The board of directors approved the project in July 1970, and the unique program was launched.[36] The facility was converted to solution mining between 1970 and 1972 by abandoning the mine, drilling wells into the mine from the surface, and constructing 420 acres of solar-evaporation ponds. The production record for the solution mine was set in 1974 at 261,002 tons of potash. In 1972 TGS became known as Texasgulf, Incorporated.

To operate the solution mine, water is pumped from the Colorado River, which flows adjacent to the plant. The river water runs across the surface salt tailings to assist reclamation before it is injected into the mine as brine. The brine flows through the mine, dissolving potash from the original pillars and walls and salt from formations above the potash. The brine is then pumped back to the surface and into one of 23 evaporation ponds. Solar evaporation leaves an 8- to 12-inch layer of sylvinite crystals in each pond. Each pond is harvested once per year during the period from September through May. The ponds are not harvested during the summer months to maximize evaporation.

The sylvinite is harvested from the ponds with 25 two-ton scraper loaders. How deep the blades of the scrapers cut is controlled by laser to protect the Hypalon pond liners. The harvested sylvinite is pumped as slurry 3.5 miles to the plant, where the sylvite (KCl) is separated from the salt (NaCl) by flotation. The refined sylvite and the salt are then dried, screened, and stored in large warehouses. Each of the two warehouses has a capacity of about 100,000 tons.

Both standard and granular potash are produced. The standard product reaches industrial and animal-feed markets in the Intermountain area, while the granular goes into agricultural products in the Intermountain region and on the West Coast.

Three grades of salt are produced: fine, medium, and coarse. The fine salt is used primarily for animal feed and hide processing. The medium is sold primarily as feedstock for chlor-alkali plants and other chemical products. Coarse salt is used primarily for water softening and ice control.

A high-capacity bagging and palletizing operation packages about 50,000 tons per year of both salt and potash. Shipments from the facility are via the Southern Pacific Railroad and truck. The plant (located in sec. 24, T. 26 S., R. 20 E., SLBM) is just 30 miles south of Interstate 70, which provides highway access to both the West Coast and the Midwest.

Texasgulf was the original owner of the mine. Moab Salt, Inc., was formed in January 1988 as a joint-venture partner with Texasgulf to market salt while Texasgulf continued to market the potash. Texasgulf bought out Moab Salt in January 1990 to become sole owner once again. Texasgulf was sold to the Potash Corporation of Saskatchewan (PCS) in April 1995, and PCS sold this operation to Intrepid Mining LLC in Denver in February 2000.

Other Saline Resources in the State

Sevier Lake

Sevier Lake, or playa located in central Millard County (figure 3), is a remnant of Pleistocene Lake Bonneville. Though its surface is sometimes covered by water during the spring runoff, most of the year it is dry. Just below the surface, however, muds remain saturated with brine to considerable depth. The 200-square-mile lake lies at the terminus of the Sevier River. The river and its many tributaries drain an area of about 16,200 square miles. A typical analysis of the subsurface brine (in dry-weight percentage) is as follows: Na = 23.4, Mg = 1.9, K = 1.7, Ca = 0.2, Cl = 58.7, SO_4 = 14.1.

Beginning in 1978, Crystal Peak Minerals Corporation started a multiphase, saline-resource-assessment program at Sevier Lake. The program included collecting and multiparameter analyzing brine and sediment samples, determining brine-salt-phase chemical relationships, conducting a gravity survey, characterizing climatological patterns, and determining local hydrologic conditions.[37]

Encouraged by the findings of the assessment program, Crystal Peak moved into resource development. This work included constructing dikes to isolate and protect a 3,000-acre solar-evaporation pond complex and excavating a six- to seven-mile-long, north-trending, brine-collection canal. Roads, a load-out facility, and an operations center were constructed, and salt floors were deposited in the evaporation ponds. Work started on a salt-processing plant and associated facilities. While Crystal Peak planned initially to produce only sodium chloride, future plans included processing potassium sulfate and other potentially profitable saline products once the operation was financially stable. In about 1991 funding for the project terminated, and the project was abandoned.

Preuss Salt Zone in the Wyoming/Utah/Idaho Thrust Belt

A thick salt zone lies at the base of the Jurassic Preuss sandstone throughout much of the Wyoming/Utah/Idaho thrust belt (figure 3).[38] Salt in this formation was mined in the 1920s from outcrops in Crow and Stump Creeks, Idaho,[39] and the extent of the salt was delineated during oil-well drilling in the area.[40] The deposit covers an area of 10,000 to 12,000 square miles, extending 180 miles north and south from Jackson, Wyoming, to the Uinta Mountains of Utah and 60 miles east and west from the Tip Top and LaBarge oil fields in Sublette County, Wyoming, to just west of Bear Lake in northeastern Utah and southeastern Idaho. It is an area of major north-south-trending thrust faults, with eastward displacements of the thrust sheets totaling possibly 60 miles. Folding associated with and generally parallel to the strike of the faults has created traps for many of the oil and gas fields of the area.[41]

The depth to the top of the Preuss salt in Utah varies from a minimum of 38 feet to a maximum of more than 5,000 feet. Maher describes the salt zone in the Pineview area as consisting "primarily of salt and anhydrite with light gray to gray, moderately soft, micaceous shale."[42] The exact extent and distribution of the Preuss salt zone beyond the wells that have penetrated it are not known, and no commercial development of the salt resource within the state has occurred.

Sevier Desert Area

Salt (age and stratigraphic unit uncertain) has been encountered in at least four wells drilled within the Sevier Desert of western Utah in a north-south-trending deposit under the town of Delta (figure 3). The shallowest evaporites encountered to date are at a depth of 2,550 feet in the Argonaut Energy Number-One Federal well (sec. 23, T. 15 S, R. 7 W., SLBM), and the deepest lie at about 8,790 feet in the ARCO Oil and Gas Company Number-One Pavant Butte well (sec. 35, T. 19 S., R. 7 W. SLBM). The salt is 5,152 feet thick in the Argonaut Energy well.[43] No development of the salt has taken place, but the area has been considered for a gas-storage site.

Uinta Basin Area

Saline minerals are found in the Eocene Green River and Uinta formations of the Uinta Basin in eastern Utah (Duchesne and Uintah Counties), mainly within the saline facies of the Uinta formation. The main salt minerals are shortite [$Na_2Ca_2(CO_3)_3$] and nahcolite [$NaHCO_3$]. The saline minerals within the Uinta Basin are not being developed (circles on figure 3). They are, however, valuable in increasing understanding of the complex nature of the Green River formation and the conditions under which it developed.[44]

Oil-Well Brines

The Uinta Basin (Duchesne and Uintah Counties) and the Paradox Basin (Grand and San Juan Counties) produce most of the state's hydrocarbons (figure 3). Sodium chloride brine is often a by-product of oil and gas production. Magnesium, potassium, and sulfate are minor constituents in most cases. The brines with the highest total dissolved solids occur in the Pennsylvanian and Mississippian reservoirs of the Paradox Basin. With few exceptions, these brines are little used, and their proper disposal becomes a costly liability to the producers. An evaporation test on brines from the Lisbon oil field (T. 30 S., R. 24 E., SLBM) by J.G. Gwynn in1989 revealed that potentially valuable products such as sodium, potassium, and magnesium chlorides can be produced from them. [45] Commercial production of salts or other products from these brines requires economic and environmental evaluations of the extraction process and a market study of the final salts and/or concentrated brines.