

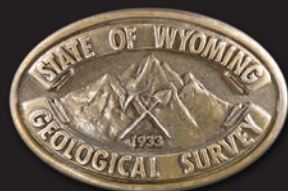
Wyoming Trona

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Introduction

Trona is a sodium carbonate compound, which is mined and processed into soda ash, an economically important commodity worldwide. The dominant use for soda ash is in manufacturing glass, accounting for more than half of global demand. Baking soda, found in a box in countless refrigerators, is a common household use for the mineral.

Sweetwater County, Wyoming is a major contributor of trona to the world. It is the state's top international export. Wyoming also supplies about 90 percent of the nation's soda ash.

In 2013, Wyoming mines produced more than 16 million tons of trona and employed 2,328 people. In addition to the United States, trona is mined in China, Turkey, Africa, and Mexico.

The largest known trona deposits in the world are in southwestern Wyoming in the Wilkins Peak Member of the Green River Formation. The layered trona deposits range in depth from 800 to 2,200 feet below the surface. Known as "bedded trona," this resource was deposited 40 to 50 million years ago in a freshwater lake called Lake Gosiute, which covered most of what is now the Green River Basin.

The word "trona" as well as its use dates back to ancient Egypt, when nearly 5,000 years ago the Egyptians used the mineral to make glass containers and ornaments. Today, in addition to the large market for glass, soda ash produced from trona is

used for chemicals, paper, detergents, textiles, and water treatment products.

A Mineral

Trona is the common name for sodium carbonate (Na_2CO_3), a white odorless powder. The mineral is semi-translucent and yellowish brown to amber in color (fig. 1) which tends to weather to white or gray. The amount and type of organic impurities and other minerals, such as halite, affect the color and texture. Trona has a vitreous or glassy luster and often forms large, prismatic crystals (fig. 1, left; also see photo on cover) or thick layers of massive fine-grained crystals which have a cloudy appearance (fig. 1, center and bottom).

Many minerals contain sodium carbonate, but trona is by far the most important. The widely-used products *soda ash* and *sodium bicarbonate* are produced from trona, primarily by heating the material to drive off the water content, followed by refining and purification.

Uses

Soda ash is an essential ingredient in the manufacturing industry, from industrial chemicals to home products such as baking soda. The number one use for soda ash is for making glass; soda ash lowers the melting point of silica. Besides other chemicals, soda ash is used in making soaps and detergents, water

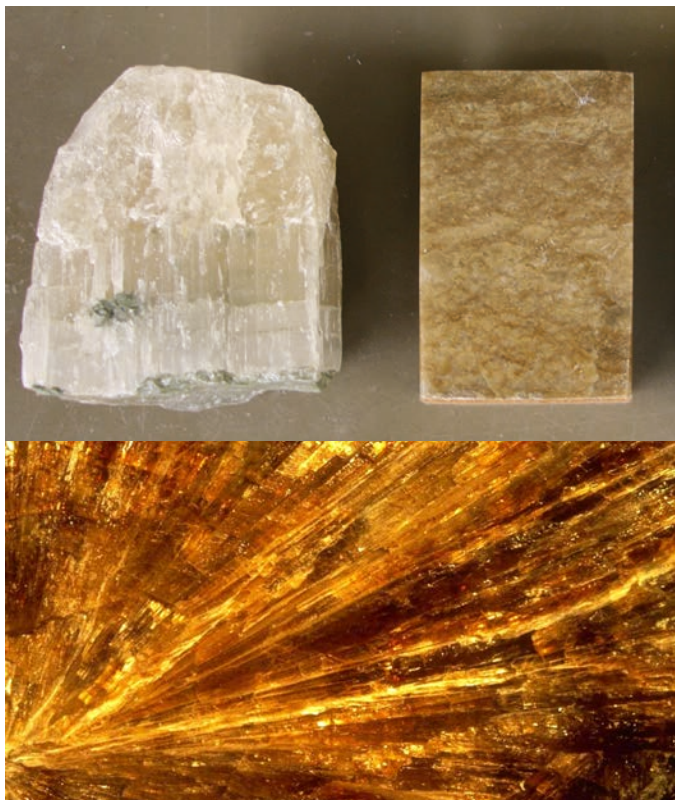


Figure 1. Three varieties of trona: Spar trona (left, top) is mineralogically the purest, while the maple sugar variety (right, top) contains other minerals and minor amounts of organic matter (photo by Jacob D. Carnes, 2014). The third variety (bottom) is Root Beer (photo courtesy of Terry Leigh, 2014).

purifiers, flue gas desulfurization equipment, paper, and numerous other products.

Geology

During the Eocene Epoch, approximately 45 to 50 million years ago, there was abundant volcanic activity throughout what today covers the western states. Much of the ash and other debris from the volcanoes made their way (either by falling from the atmosphere or by being transported by rivers and streams) into a large freshwater lake called Lake Gosiute, which occupied much of what is now the Green River Basin.

The lake is believed to have covered over 15,000 square miles (see map on back cover). Over a period of several million years, Lake Gosiute fluctuated dramatically in size, in response to alternating wet and dry climate variations. When it shrunk in size, the waters became supersaturated with elements such as sodium (Na), calcium (Ca), magnesium (Mg), and many others. These elements represent the building block molecules that, when combined, form minerals such as trona. The massive beds of trona and other minerals were then deposited by precipitation, and through evaporation, the shrinking volume of water could no longer keep those compounds in suspension. Interbedded with the trona beds are successions of marly calcareous shales, oil shales, siltstones, and sandstones.

Resources and Reserves

The Green River Basin of southwestern Wyoming contains the largest trona resource in the world at over 127 billion tons, of which more than 40 billion tons are reserves (economically minable with current technology). At the current rate of production and assuming a moderate growth in that rate of 1 to 2 percent, Wyoming's trona reserves should last well over 2,000 years.

In 2013, Wyoming produced 16 million tons of trona. World production amounted to 14 million tons and came from Botswana, Kenya, Mexico, Turkey, Uganda, and a few other countries. More than 39 million tons of synthetic soda ash were also produced in 2013, primarily in China and India.

Mining

Trona mining became the leading natural source of soda ash in 1974. Previously, most soda ash was produced synthetically, which still occurs in countries such as China and India. In Wyoming, natural soda ash has replaced what was known as the Solvay process, a synthetic process using salt brine and limestone for sodium carbonate or soda ash production.

Wyoming produces natural soda ash from four trona mining and processing operations (all located in Sweetwater County): FMC Minerals, OCI Chemical Corp., Tata Chemicals, and Solvay Chemicals Inc.

In 1948, two companies, Westvaco Chemical and Food Machinery and Chemical Corp. merged and began producing trona in Sweetwater County. The company produced more than 39,700 tons of calcined trona; the final product sold at that time. Calcination is the process in which water and excess CO₂ are removed from the trona by heating, creating calcined trona.

The minable trona beds of the Green River Basin lie between 800 and 2,200 feet underground. Of the more than 40 known beds, 25 are mineable with today's technology and the others hold potential for solution mining techniques. The lower beds (numbered from 1 to 17) commonly contain significant amounts of halite; consequently, they are relatively amorphous and gener



Figure 2. Longwall mining. Photo by Ray E. Harris.

ally harder than the upper beds.

There are two primary methods of mining trona: *longwall* mining and, the more common, *room and pillar* method. Longwall mining involves dividing the seam into rectangular panels or blocks and cutting drifts along the sides of the blocks for material transport and ventilation. A cross-cut connects the parallel drifts, along which the longwall cutter is installed. As the cutter moves back and forth, the ore is transported away by a conveyor system (fig. 2).

The second and most common method of mining trona is the room and pillar technique. There are two different types of machinery used with this technique; a continuous miner (also used in coal mining) and a bore miner. With the room and pillar process, a series of parallel drifts are cut at regular intervals which are carefully surveyed and measured. What are called continuous bore miners cut out 'rooms' of trona ore, leaving roughly equally-sized 'pillars' behind for support. Once the trona has been removed, it is crushed and transported to the surface and processed into soda ash.

Production

Based on the existence of local springs known to contain soda, sodium carbonate was first produced in Wyoming in 1896 from brines drawn out of wells in the Green River area. The first known trona beds were discovered in a well operated by Mountain Fuel Supply. Geologist William Nightingale, of the U.S. Geological Survey, identified trona in a core from the well along with other soda-bearing minerals such as shortite, bradleyite, northrupite, and prissonite.

FMC Minerals, in Wyoming, is the largest global and U.S. trona company. In 2013, the company produced more than 3.34 million of tons of trona.

Wyoming produces what is known as natural soda ash from trona, which is significantly cheaper to produce than synthetic soda ash. It takes about 1.8 tons of trona to produce 1 ton of soda ash, after dewatering and purification. Interestingly, sharp increases in crude oil prices since 2005 has meant that the difference in natural and synthetic soda ash production costs has widened significantly, according to IHS Inc., a global information company. Global demand and pricing has also led to an increase in the production of Wyoming trona (fig. 3).

According to the report, "The 2014 IHS Chemical Soda Ash Analysis," global annual consumption of soda ash accounts for more than 55 million metric tons (MMT) and it is expected to increase to almost 73 MMT by 2023, reflecting a nearly 34

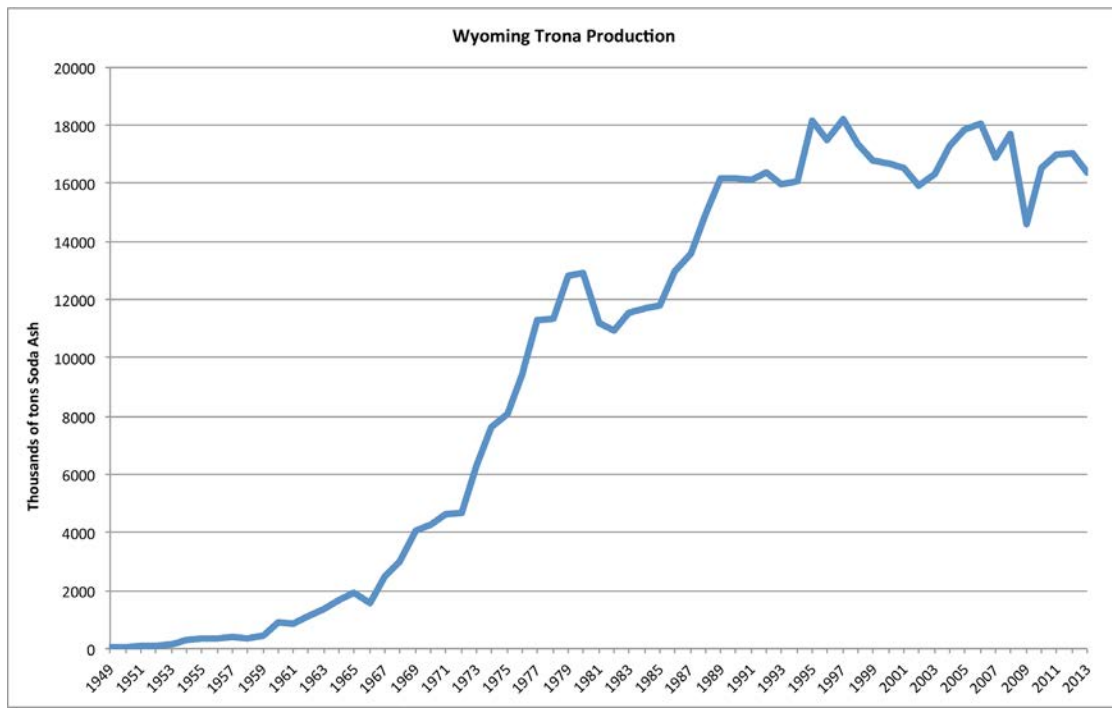


Figure 3. Wyoming's natural soda ash production since the late 1940s.

percent increase in volume. The global average annual demand is expected to grow by 2.9 percent over the next decade, with large regional differences.

Prior to 2003, the U.S. was the largest producer of soda ash in the world, but China's efforts to become self-sufficient in soda ash supply resulted in the country becoming the world's largest producer. However, the study noted while both countries are important in the global soda ash industry, the two markets differ significantly. For the U.S., which relies entirely on natural sources, exports are as important as the domestic market. China, meanwhile, is primarily focused on meeting its own domestic needs but relies primarily on synthetic production, which is more costly.

Economic Benefits

Economic diversity in Wyoming's minerals portfolio is important to minimize the effects of downturns in the overall economy. Trona is a non-energy commodity that is not directly affected by the price of oil, natural gas, or coal. In 2013, the trona industry employed 2,328 people, not counting contract personnel. Severance taxes paid by trona companies to the state in 2013 amounted to more than \$17.5 million. The companies also paid taxes and other fees of more than \$37.5 million to Sweetwater County where trona is produced.

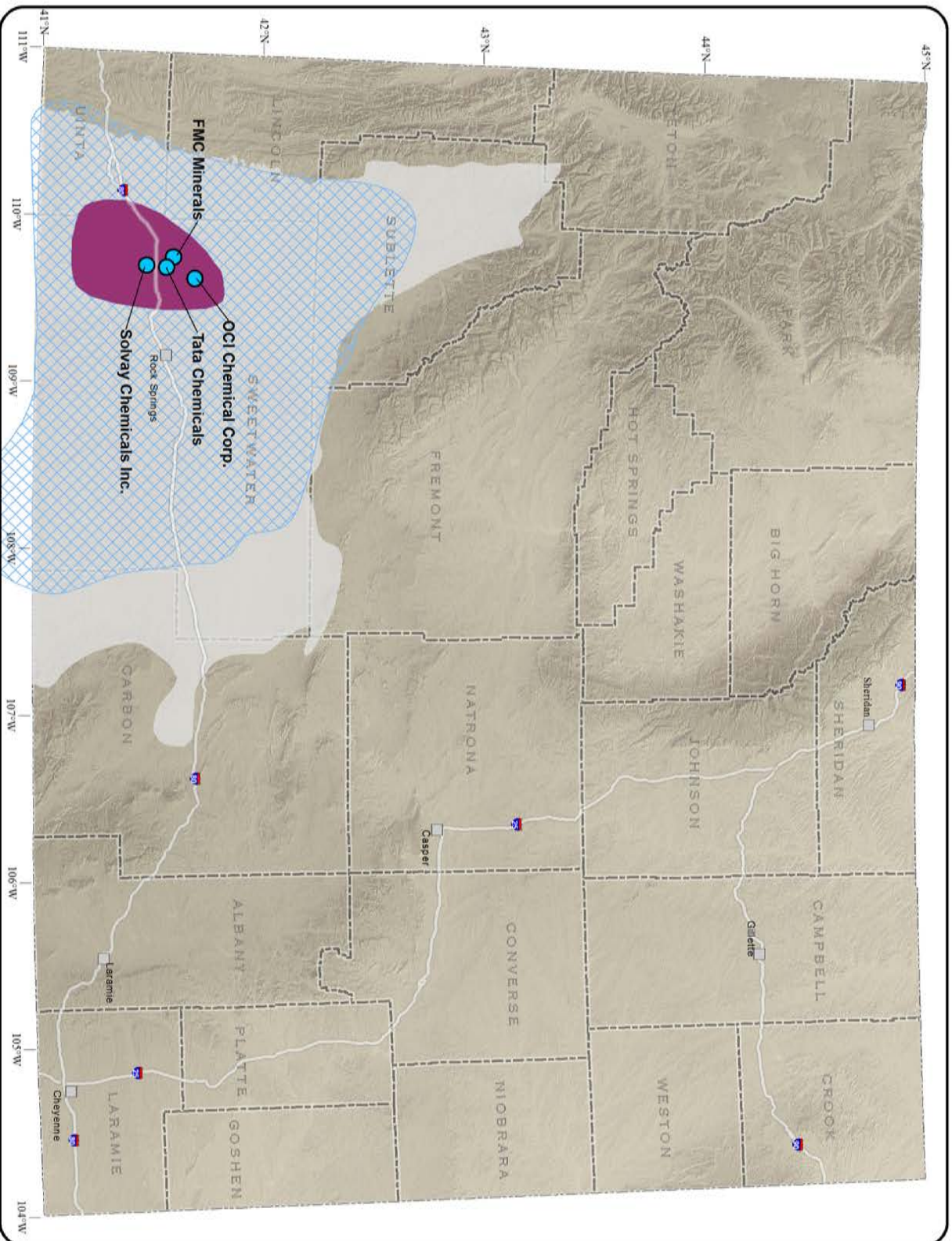
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Geology - Interpreting the past - Providing for the future

WYOMING STATE GEOLOGICAL SURVEY
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EXPLANATION

- Bedded trona deposits
 - Maximum extent of Lake Gosiute in Wyoming
 - Trona mines/ soda ash plants (not to scale)
 - Green River Basin
 - Interstate highway
 - City or town
 - County boundary
- N
 0 10 20 40 Miles
 0 15 30 60 Kilometers

Map design and layout by Phyllis Ranz, 9/2014.

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