UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

TRONA DEPOSITS IN THE GREEN RIVER BASIN, SWEETWATER, UINTA, AND LINCOLN COUNTIES, WYOMING

By

M. J. Burnside and W. C. Culbertson

Open-File Report 79-737

1979

CONTENTS

ILLUSTRATIONS
[Plates in pocket]

Contents--continued

TABLES

CONVERSION TABLE

To convert	Multiply by	To obtain
feet	0.3048	meters
miles	1.609	kilometers
sq. miles	2.590	sq. kilometers
short tons	.907	metric tons
acre-feet	1.233×10^{-3}	hectometers^3

TRONA DEPOSITS IN THE GREEN RIVER BASIN, SWEETWATER, UINTA, AND LINCOLN COUNTIES, WYOMING

By M. J. Burnside and W. C. Culbertson

INTRODUCTION

The trona deposits of the Eocene Green River Formation in the Green River Basin of southwestern Wyoming are the world's largest. Trona is naturally occurring sodium sesquicarbonate ($Na_2CO_3.NaHCO_3.2H_2O$) and contains 70 weight percent soda ash (Na_2CO_3), an important industrial chemical. Trona mining has gradually increased since 1953, when it began on a large scale. By 1976, it accounted for 70 percent of the total production of soda ash in the United States, and has replaced much of the production once furnished by Solvay soda-ash plants. In 1977, the four mines operating in Wyoming produced 11.3 million short tons of trona.

This report updates the resource estimates for trona and mixed trona and halite made by Bradley and Eugster (1969, table 4) and Culbertson (1966, table 2). The report includes two geophysical-log correlation sections of the trona deposits, a structure-contour map on the base of the Wilkins Peak Member of the Green River Formation, and isopach maps of trona beds 1 through 25. The purpose of this report is to provide geologic data to aid in the evaluation of the trona deposits of southwestern Wyoming.

PREVIOUS WORK

Culbertson (1961, 1966, and 1971), Fahey (1962), Deardorff (1963), Love (1964), Bradley (1964), Bradley and Eugster (1969), Eugster (1971), and Deardorff and Mannion (1971) studied the origin and described and mapped the trona-bearing Wilkins Peak Member of the Eocene Green River Formation.

ACKNOWLEDGMENTS

We thank the Rocky Mountain Energy Company; FMC Corporation; Tenneco, Inc.; Allied Chemical Corporation; Olin Corporation; PQ Corporation; and Yates Drilling Company for furnishing data used in this report. We also thank Arne Matilla and the USGS staff at Rock Springs, Wyo., for their assistance in locating trona information.

HISTORY OF TRONA MINING DEVELOPMENT

The first indications of sodium carbonate in southwest Wyoming came from water, oil, and gas wells drilled in the late 1800's. Sodium-carbonate brine was found at a depth of 125 feet in a well drilled in 1896 near the town of Green River, Wyo. (Thomas, 1966). In 1907, Western Alkali Corporation attempted to exploit this resource by pumping the brine to the surface, evaporating it until the sodium minerals crystallized, and processing the crystals into caustic soda (sodium hydroxide) and washing soda (hydrous sodium carbonate). Production ceased after World War I.

In 1938, Mountain Fuel Supply Co. drilled an oil-and-gas well in sec. 2, T. 18 N., R. 110 W., Sweetwater County, Wyo. They cored parts of the Green River Formation and found numerous thin stringers of trona, plus one 10-foot-thick bed. From 1940 to 1942, Union Pacific Railroad drilled several core holes to establish the extent of this thick trona bed; from 7 to 11 feet of trona was found in all holes. From 1944 to 1946, Westvaco drilled additional core holes through this same bed, locally named the Westvaco bed (trona bed no. 17). In 1946, Westvaco (now known as FMC Corporation) sank a 1,500-foot shaft in T. 19 N., R. 110 W., and began mining trona bed no. 17. From about 1957 to 1960, FMC tested the practicality of solution-mining trona. Their method was not economical for three reasons: (1) too much energy was needed to heat the water to dissolve the trona; (2) not enough of the trona was dissolved; and (3) the hot water preferentially leached soluble organic material which greatly lowered the quality of the trona recovered (A. Mattila, oral commun., 1978).

In 1962, about 8 miles northeast of the Westvaco mine, Stauffer Chemical Company began mining trona at a depth of 800-900 feet from the upper and lower Big Island beds (trona beds no. 25 and 24, respectively). Shortly thereafter, Allied Chemical Corporation began mining the Westvaco bed southeast of the FMC mine. In 1969, Texas Gulf Sulfur Company began mining trona beds no. 19 and 20 in T. 20 N., R. 111 W. Tenneco recently announced plans to begin mining trona in T. 18 N., R. 110 W. At present, all trona produced in the Green River Basin is shaft-mined by the room-and-pillar method. Additional trona mines and processing plants will undoubtedly be built in the future because of the increasing demand for soda ash. There has been some interest in recovering the sodium-carbonate brine ("black trona water") encountered in wells near the town of Farson, Wyo., but no commercial ventures have yet been launched (A. Mattila, oral commun., 1978).

The total soda-ash production in the United States derived from Wyoming trona increased to 70 percent in 1976 (Cameron Engineers, 1977), and according to Dan Hausel of the Wyoming Geological Survey (oral commun., 1978), 11,287,960 tons of Wyoming trona were mined in 1977. (About 1.8 to 2.0 tons of run-of-the-mine trona yields 1 ton of soda ash.) While the production of soda ash from trona has been rapidly increasing in the U.S., production of synthetic soda ash by the Solvay process has steadily declined. The strict anti-pollution laws, costs of fuel and raw materials, and competition from the trona industry have contributed to the decline of production by the Solvay process in this country.

STRUCTURE

The trona deposits occur in the Green River Basin, which is an asymmetric structural and depositional basin whose deepest part in the trona area is near its southern margin (plate 1). The term "Green River Basin" is used in this report to refer to the area bounded on the west by the Overthrust Belt, on the north by the Gros Ventre Mountains, on the northeast by the Wind River Mountains, on the east by the Rock Springs Uplift, and on the south by the Uinta Mountains. In general, the trona-bearing beds are nearly flat lying, dipping less than 1 degree almost everywhere. Much of the margin of this basin is marked by small- and large-scale faulting, but no faults are known to displace the trona-bearing beds.

STRATIGRAPHY

The trona deposits are in the Wilkins Peak Member of the Green River Formation of Eocene age. The Eocene strata in this basin have a maximum thickness of about 7,000 feet, and are subdivided, from the base upward, into three formations: the Wasatch, Green River, and Bridger Formations. The Wasatch consists predominantly of red and gray stream-laid deposits that are locally conglomeratic. The Green River Formation consists of predominantly lacustrine sediments in shades of gray and brown, and conformably overlies the Wasatch Formation and intertongues laterally with it. The Green River Formation is gradational upward with the Bridger Formation, and also intertongues laterally with it. The Bridger Formation consists of stream-deposited tuffaceous sediments in shades of gray, brown, and green.

Green River Formation

The Green River Formation was deposited primarily from Lake Gosiute, a large shallow lake that existed for about 4 million years in Eocene time. The first deposits from this lake, or its precursor, are the beds of sandstone, mudstone, oil shale, mollusk-bearing limestone, and lignite that are assigned to the Luman Tongue of the Green River Formation (Culbertson, 1965). The Luman Tongue has a maximum thickness of about 400 feet and occurs only in the southern part of the Green River Basin where it is overlain and underlain by beds of the Wasatch Formation.

Tipton Shale Member.--The first widespread unit of the Green River Formation is the Tipton Shale Member. It consists almost entirely of oil shale (Culbertson, 1969) with several thin persistent beds of altered tuff; locally, it contains beds of marlstone and claystone in the middle. Its base is marked almost everywhere by a thin limestone containing abundant fossil mollusks and ostracodes. This unit represents deposition when Lake Gosiute was a large freshwater lake. The Tipton is thickest in the southeastern part of the basin, where it generally ranges in thickness from 130 to 200 feet and, locally, obtains a thickness of 330 feet.

In about T. 18 N., a wedge of sandstone appears in the middle of the Tipton and thickens northward (plate 3). The upper part of the Tipton thins northward and disappears by onlap on this sandy unit, which is called the New Fork Tongue of the Wasatch Formation.

Wilkins Peak Member.--The Wilkins Peak Member represents a time when Lake Gosiute had receded, and its outlet had closed. Its sediments belong primarily to a saline facies characterized by thick beds of trona or trona-halite, abundant crystals of shortite ($NaCO_3.NaHCO_3$), and numerous other rare minerals (Bradley and Eugster, 1969). The bulk of the Wilkins Peak sediments consists of thin persistent beds of oil shale, marlstone, claystone, trona or trona-halite, limestone, and tuff. In the southeastern part of the basin, the Wilkins Peak also contains thick persistent units of mudstone and crossbedded siltstone and sandstone.

The Wilkins Peak Member has a maximum thickness of about 1,300 feet in the southeastern part of the basin, and thins northward to extinction by onlap on the New Fork Tongue of the Wasatch, and by wedging out of the beds of sandstone, mudstone, trona, and trona-halite. In the southwestern part of the basin a sandy unit appears in the upper part of the Wilkins Peak Member and thickens westward at the expense of the rest of the Wilksin Peak (plate 2). This sandy unit is equivalent to the Cathedral Bluffs Tongue of the Wasatch Formation. Southward, the Wilkins Peak Member disappears abruptly by interfingering with the conglomeratic Wasatch Formation.

A composite stratigraphic column of the Wilkins Peak Member (plate 2) shows the relationship of various persistent beds and zones and the reactions of gamma-ray and acoustic logs to this lithology. The 77 persistent beds of oil shale identified by a letter-number symbol have been verified by numerous assays of core by the U.S. Bureau of Mines. The 25 persistent thick beds of trona, or mixed trona and halite, are numbered from the base of the member upward. An additional 17 thin or nonpersistent beds of trona are unnumbered. The positions of 18 of the radioactive zones of uraniferous phosphate described by Love (1964) are also shown. Some of these zones are persistent across large areas. Numerous thin beds of altered tuff have been identified in cores, some of which are laterally very persistent. Three of the persistent tuffs are named: the Firehole bed, the Main tuff, and the Tollgate tuff. The Tollgate tuff, named from its occurrence on Tollgate Rock at Green River, Wyo., is a uniquely layered tuff that can be recognized in cores and outcrops across about 3,000 square miles in the Green River Basin. The sandstone-mudstone units labeled A through I are present only in the southeastern part of the basin.

Laney Member.--After Wilkins Peak time, Lake Gosiute enlarged again and became a freshwater lake. Beds of the Laney Member were deposited which consist of laminated oil shale, marlstone, sandstone and mudstone, with minor beds of limestone and tuff. The Laney has a maximum thickness of about 1,050 feet in the southern part of the Green River Basin, and thins northward by interfingering with, and being replaced by, the stream-laid beds of the Bridger Formation. Thus, shortly after the start of Laney time, fluvial deposits encroached on Lake Gosiute from the north. Lake Gosiute retreated southward and disappeared at the beginning of Bridger time.

ECONOMIC GEOLOGY

Isopach maps (plates 4 to 28, inclusive) for each of the numbered trona or trona-halite beds show the limits of the trona and the distribution of halite within these beds. The lines are uncertain in some places because of the scarcity of cores and geophysical logs. Trona beds of thinner than about 1 foot cannot be determined with certainty from geophysical logs.

Gamma-ray-neutron or gamma-ray-sonic logs are the best geophysical logs for distinguishing trona or trona-halite beds. Caliper logs are useful because they show the abrupt borehole enlargement that usually occurs through these beds. Correlation sections A-A' and B-B' (plates 2 and 3) illustrate how the trona and trona-halite beds appear on these logs. The oil-shale markers used in correlating the trona beds are shown on the log sections.

Halite, thin interbeds of marlstone and shale, and some organic matter are the principal impurities in the trona beds, with halite exceeding the other two in quantity. Halite cannot be easily differentiated from trona on geophysical logs, and corehole data are scarce in the southern part of the trona area where the halite is concentrated. However, on the basis of available data, we can make these observations: Halite occurs in minor amounts in beds 2, 3, and 7; in moderate amounts in beds 5, 12, 14, 16, 17, and 18; and in major amounts in beds 6, 9, 10, 11, and 15; it is not known to occur in beds 1, 4, 8, 13, and 19 through 25. Halite is clearly associated with the thicker parts of the bed in which it is found. In most beds, the halite forms a distinct facies and trona may grade laterally basinward into essentially all halite. The depocenters for halite are found commonly along the southwest and south sides of the trona beds. Thin interbeds of marlstone may amount to as much as 50 percent of a trona bed, but more commonly range from 1 to 20 percent. However, the data are still too meager to assess accurately the amount of marlstone impurities in the trona beds. Fahey (1962, table 17) determined that the water-insoluble residue of the Westvaco bed (2 samples 500 feet apart) amounted to 5 percent by weight. Deardorff and Mannion (1971) reported that those parts of trona beds being mined in the Green River Basin usually contain 85-95 percent trona. Table 1 includes three chemical analyses of trona beds, probably the lower and upper Big Island beds (trona beds 24 and 25) reported by the same authors.

Table 1.--Some analyses of trona beds in the Green River Basin

[From Deardorff and Mannion, 1971. NA, not analyzed]

	Analyses (in percent)		
	Bed A 10 feet thick	Bed B 10.9 feet thick	Bed C 5 feet thick
Water soluble constituents:			
$Na_2CO_3NaHCO_3$	93.80	90.26	85.52
NaCl	.08	.040	.123
Na_2SO_4	.03	.024	.027
SiO_2	.001	.003	NA
Free H_2O	1.09	NA	NA
Water insoluble	4.90	10.01	14.365
Organic	trace	trace	NA

Each of the 25 persistent trona and trona-halite beds locally exceeds 4 feet in thickness and 100 square miles in area (table 2). Beds 1, 2, 12, and 17 exceed 20 feet in thickness. Of these, trona beds 1 and 2 are the thickest (over 37 and 35 feet, respectively). Beds 12, 15, 16, and 17 exceed 800 square miles in area. Bed 17 is the most widespread, with an area of 870 square miles. Bed 2 contains the largest resource of halite-free trona in a single bed (9.8 billion tons). Bed 17 has the largest combined resource of trona and mixed trona and halite (12.3 billion tons). These 25 beds contain a total of 81.7 billion tons of trona and 52.7 billion tons of mixed trona and halite for a combined total resource of 134.4 billion tons. This value for the total resource increases by one-third the earlier estimate made by Culbertson (1966, table 2). These trona- and trona-halite-bed resource estimates and areas (table 2) were derived by planimetering the isopach maps. A conversion factor of 2,900 short tons per acre-foot of trona was used.

The structure-contour map of the base of the Wilkins Peak Member (plate 1) is tentative in the southern part because the Wilkins Peak Member rapidly changes facies to clastic sediments in the southern part of the basin, compounding the difficulty of choosing an accurate contact. These clastics, a part of the Wasatch Formation, commonly extend only about 15 miles north of the Uinta Mountains into T. 13 N. of the Green River Basin. No trona beds appear to extend this far south.

Table 2.--Estimated identified resources of trona, and intermixed trona and halite, by bed, in the Green River Basin, southwestern Wyo.

[Areas are in square miles and short tons are in billions]

Bed No.	Total Resources		Trona Resources				Mixed Trona - Halite Resources			
	Trona and mixed trona - halite		< 4 ft. thick		≥4 ft. thick		< 4 ft. thick		≥ 4 ft. thick	
	Area	Short tons	Area	Short tons	Area	Short tons	Area	Short tons	Area	Short tons
1	324	5.4	104	0.4	220	5.0	---	---	---	---
2	469	10.0	100	0.4	364	9.4	---	---	5	0.2
3	442	3.5	242	0.9	194	2.5	---	---	6	0.1
4	528	6.3	190	0.7	338	5.6	---	---	---	---
5	712	9.5	221	0.8	401	6.6	5	<0.1	85	2.1
6	587	6.0	219	0.8	78	0.9	---	---	290	4.3
7	617	3.6	381	1.4	221	2.1	9	<0.1	6	0.1
8	431	1.9	373	1.4	58	0.5	---	---	---	---
9	733	9.6	270	1.0	70	0.8	29	0.1	364	7.7
10	459	4.8	56	0.2	26	0.3	119	0.4	258	3.9
11	615	6.9	235	0.9	32	0.4	2	<0.1	346	5.6
12	811	10.7	201	0.7	344	4.5	---	---	266	5.5
13	370	1.8	305	1.1	65	0.7	---	---	---	---
14	774	12.0	151	0.6	372	5.4	---	---	251	6.0
15	848	11.8	232	0.9	271	3.7	2	<0.1	343	7.2
16	860	7.2	524	1.9	117	1.3	---	---	219	4.0
17	870	12.3	199	0.7	429	7.0	3	<0.1	233	4.6
18	276	1.4	104	0.4	6	0.1	117	0.4	49	0.5
19	208	1.5	118	0.4	90	1.1	---	---	---	---
20	217	1.9	103	0.4	114	1.5	---	---	---	---
21	310	1.3	290	1.1	20	0.2	---	---	---	---
22	267	1.2	234	0.9	33	0.3	---	---	---	---
23	293	1.2	268	1.0	24	0.2	---	---	---	---
24	153	1.4	92	0.3	61	1.1	---	---	---	---
25	105	1.2	50	0.2	55	1.0	---	---	---	---
	TOTALS	134.4		19.5		62.2		0.9+		51.8

REFERENCES

Bradley, W. H., 1964, Geology of the Green River Formation and associated Eocene rocks in southwestern Wyoming and adjacent parts of Colorado and Utah: U.S. Geological Survey Professional Paper 496-A, 86 p.

Bradley, W. H., and Eugster, H. P., 1969, Geochemistry and paleolimnology of the trona deposits and associated authigenic minerals of the Green River Formation of Wyoming: U.S. Geological Survey Professional Paper 496-B, 71 p.

Cameron Engineers, Inc., 1977, USGS oil shale program--An overview: Synthetic Fuels Quarterly Report, v. 14, no. 4, p. 2-15 through 2-16.

Culbertson, W. C., 1961, Stratigraphy of the Wilkins Peak Member of the Green River Formation, Firehole Basin quadrangle, Wyoming, in Short papers in the geologic and hydrologic sciences: U.S. Geological Survey Professional Paper 424-D, p. D170-D173.

______ 1965, Tongues of the Green River and Wasatch Formations in the southeastern part of the Green River Basin, Wyoming, in Geological survey research 1965: U.S. Geological Survey Professional Paper 525-D, p. D139-D143.

______ 1966, Trona in the Wilkins Peak Member of the Green River Formation, southwestern Wyoming, in Geological survey research 1966: U.S. Geological Survey Professional Paper 550-B, p. B159-B164.

______ 1969, Oil shale in the Green River Formation, Green River Basin, Wyoming, in Wyoming Geological Survey 21st Annual Field Conference Guidebook, p. 151-195.

______ 1971, Stratigrphy of the trona deposits in the Green River Formation, southwestern Wyoming, in Contributions to geology, trona issue: Laramie, University of Wyoming, v. 10, no. 1, p. 15-24.

Deardorff, D. L., 1963, Eocene salt in the Green River Basin, Wyoming, in Symposium on Salt, Cleveland, 1962: Cleveland, Ohio, Northern Ohio Geological Society, p. 176-195.

Deardorff, D. L., and Mannion, L. E., 1971, Wyoming trona deposits, in Contributions to Geology, Trona Issue: Laramie, University of Wyoming, v. 10, no. 1, p. 25-38.

Eugster, H. P., 1971, Origin and deposition of trona, in Contributions to Geology, Trona Issue: Laramie, University of Wyoming, v. 10, no. 1, p. 59-55.

Fahey, J. J., 1962, Saline minerals of the Green River Formation: U.S. Geological Survey Professional Paper 405, 50 p.

Frint, W. R., 1971, Processing of Wyoming trona, _in_ Contributions to geology, trona issue: Laramie, University of Wyoming, v. 10, no. 1, p. 43-48.

Jacobucci, John, 1955, Discovery and development of trona deposits in Sweetwater County, Wyoming, _in_ Wyoming Geological Association 10th Annual Field Conference Guidebook, Green River Basin: p. 203-204.

Love, J. D., 1964, Uraniferous phosphatic lake beds of Eocene age in intermontane basins of Wyoming and Utah: U.S. Geological Survey Professional Paper 474-E, 66 p.

Milton, Charles, and Fahey, J. J., 1960, Green River mineralogy--A historical account, _in_ Wyoming Geological Association 15th Annual Field Conference Guidebook, Overthrust Belt of Southwestern Wyoming: p. 159-162.

Ogg, J. H., 1969, Trona--Sweetwater County, Wyoming, _in_ Symposium on Tertiary rocks of Wyoming, Wyoming Geological Association 21st Field Conference: Casper, Wyo., Petroleum Information, p. 183-184.

Smith, G. I., Jones, C. L., Culbertson, W. C., Ericksen, G. E., and Dyni, J. R., 1973, Evaporites and brines: U.S. Geological Survey Professional Paper 820, p. 197-216.

Thomas, H. D., 1966, Trona, _in_ Mineral resources of Wyoming: Wyoming Geological Survey Bulletin 50, p. 171-172.

U.S. Bureau of Mines, 1975, Mineral facts and problems, Bull. 667, 1259 p.

U.S. Bureau of Mines and U.S. Geological Survey, 1976, Principles of the mineral resource classification system of the U.S. Bureau of Mines and U.S. Geological Survey: U.S. Geological Survey Bulletin 1450-A, 5 p.