Oil Shale Assessment Project Fact Sheet

Nahcolite Resources in the Green River Formation, Piceance Basin, Northwestern Colorado

Using a geology-based assessment methodology, the U.S. Geological Survey estimated an in-place resource of 43.3 billion short tons of nahcolite (sodium bicarbonate) in the oil shale deposits of the Parachute Creek Member of the Eocene Green River Formation in the Piceance Basin, northwestern Colorado. More than 69 percent, or 29.9 billion short tons, of the estimated nahcolite resource is found in the R–4, L–5, and R–5 oil shale zones.

Introduction

The U.S. Geological Survey (USGS) recently completed an assessment of in-place nahcolite ($NaHCO_3$) resources in the Piceance Basin, northwestern Colorado (fig. 1). Nahcolite is present in the oil shale deposits of the Parachute Creek Member of the Eocene Green River Formation. It occurs as disseminated aggregates, nodules, bedded units of disseminated brown crystals, and white crystalline beds associated with dawsonite ($NaAl(OH)_2CO_3$) and halite (NaCl). The nahcolite-bearing facies are divided into an unleached part containing the nahcolite and halite, which is estimated to be as much as 1,130 ft thick, and an upper leached part several hundred feet thick containing minor nahcolite aggregates and nodules. Locally, thick beds of halite and brown fine-grained nahcolite lie in the depocenter of the basin (figs. 1 and 2), but thin laterally away from the basin center and grade into beds of white, coarse-grained nahcolite. In the central part of the study area, the top of the nahcolite-bearing rocks range in depth from about 1,300 to 2,000 ft.

Dissolution of water-soluble minerals, mostly nahcolite and halite, in the upper part of the nahcolite-bearing facies has created a collapsed leached zone as much as 580 ft thick that consists of laterally continuous units of solution breccia and fractured oil shale containing solution cavities. The top of the leached zone is not yet defined in the basin, but it probably extends into the A groove in the upper part of the Parachute Creek Member (fig. 2).

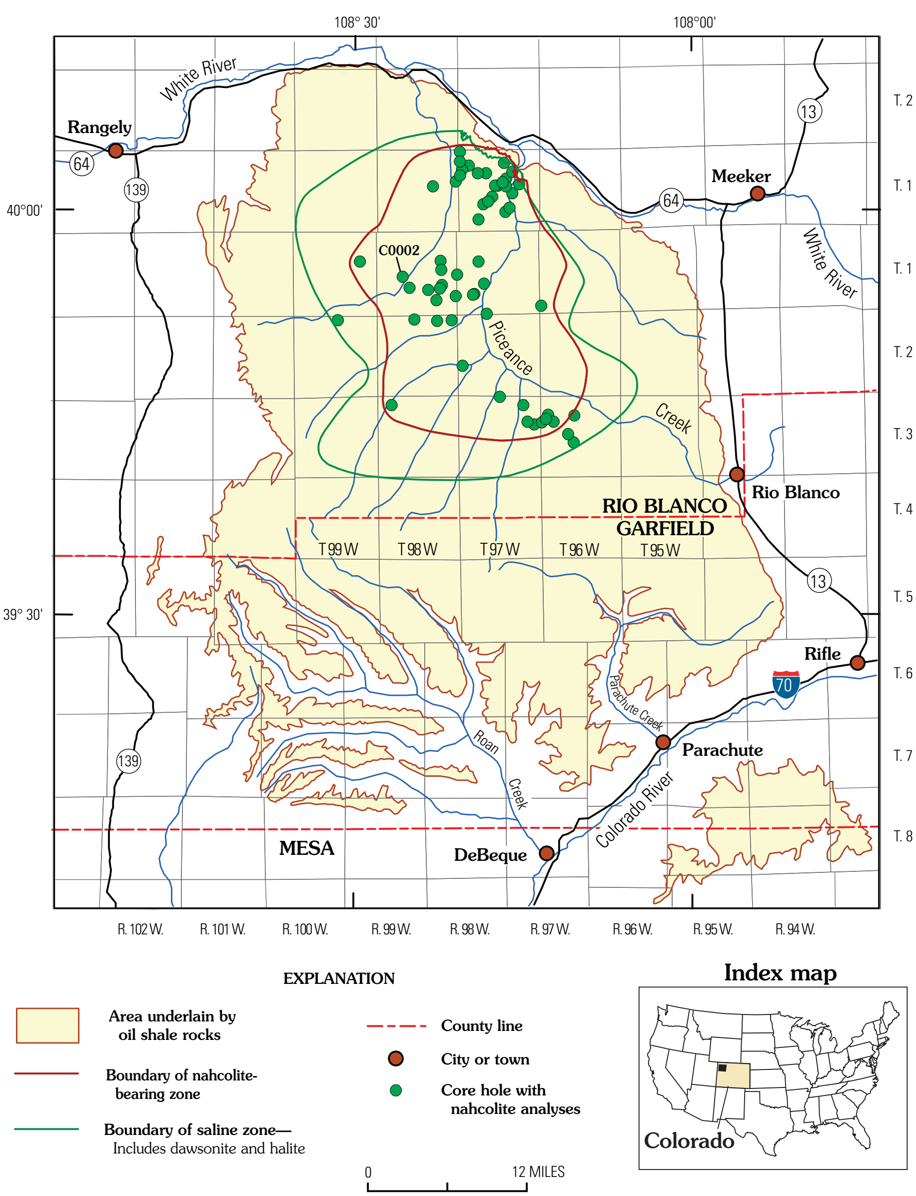

Figure 1. Map of northwestern Colorado showing locations of nahcolite-bearing core holes, the inferred boundaries of the nahcolite-bearing zone and saline zone of Pitman and others (1989), and generalized outcrops of the oil shale-bearing rocks in the Parachute Creek Member of the Eocene Green River Formation in the Piceance Basin.

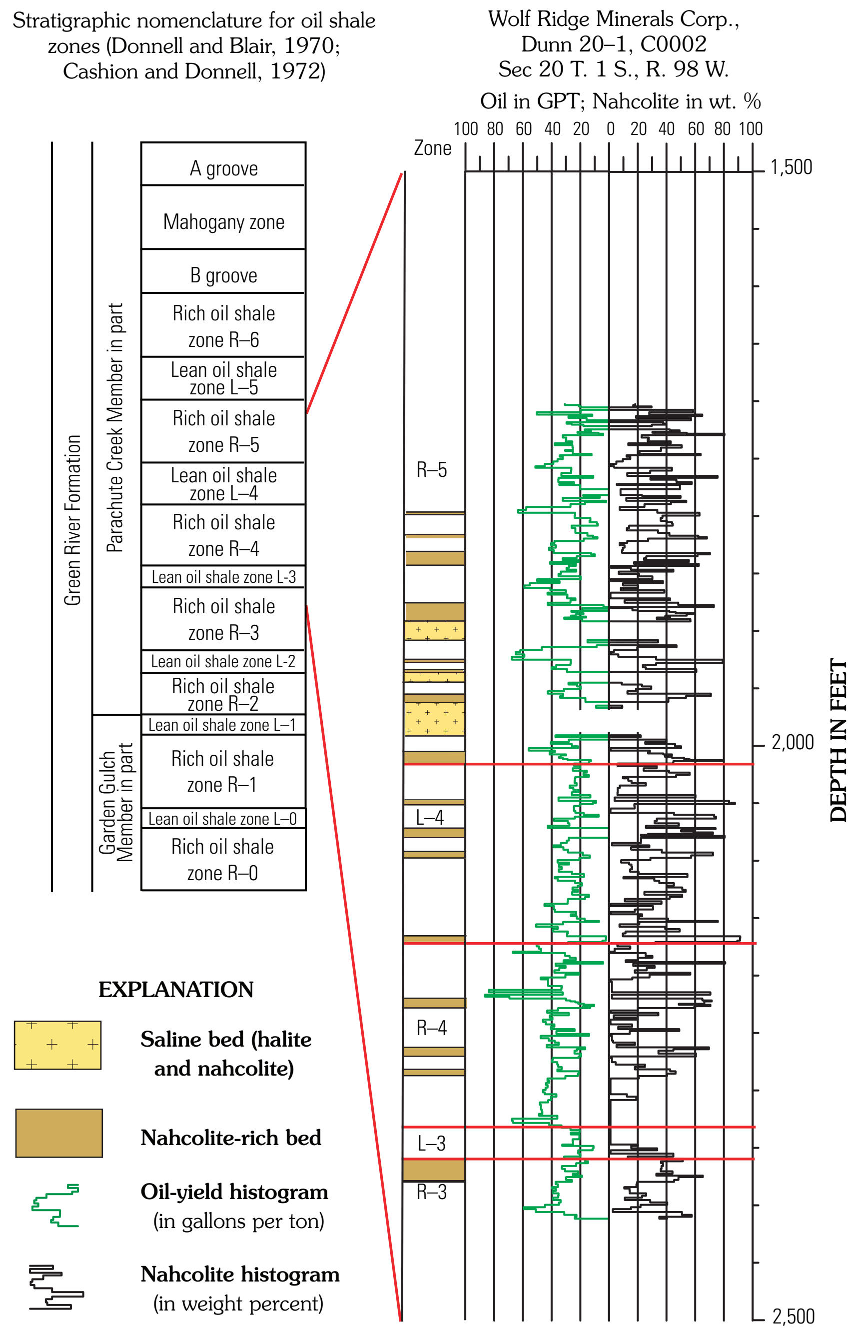

Figure 2. Plot showing oil-yield (gallons per ton, GPT) and nahcolite (weight percent, wt. %) histograms and stratigraphic nomenclature for oil shale zones (Donnell and Blair, 1970; Cashion and Donnell, 1972) for the Wolf Ridge Minerals Corp., Dunn 20–1 core hole, north-central Piceance Basin, Colorado.

The presence of nahcolite is a concern for the surface retorting and in-place oil shale processes because nahcolite decomposes to natrite (Na_2CO_3) or soda ash, carbon dioxide, and water at temperatures near 100°C during the two recovery processes. In addition, nahcolite is considered a leasable mineral and thus must not be destroyed during processes used to recover oil from oil shale. Nahcolite is a potential raw material for the manufacture of a variety of basic industrial chemicals (for example, baking soda), but the mineral has perhaps received more attention for its potential use in removing sulfur dioxide from industrial stack gases. Because nahcolite seems to be a potentially valuable coproduct of oil shale, it becomes important to know where and in what abundance it occurs in the oil shale.

Methodology

In this assessment, a spatial interpolation and extrapolation method for generating resource maps and computing resource volumes was used—the Radial Basis Function (RBF) in ArcGIS GeoStatistical Analyst (Environmental Systems Research Institute, Inc. (ESRI), Redlands, Calif., 2006, v. 9.2).

The RBF method in GeoStatistical Analyst is an exact interpolator; it will honor all data points and not introduce errors at those locations. Where it is important for the modeling method to honor the measured values, RBF can also extrapolate values above or below the actual values away from the data point locations. The final resource models for each nahcolite-bearing zone were created using a sampling method containing ten moving window sectors with fifteen neighbors in each sector, except for the L–5 zone where the model was limited to ten neighbors or data points.

Although the RBF method does not generate as complete an error estimate as kriging, it does give the difference between the predicted and measured value for each control point, and it does give an overall difference value for an entire oil shale zone model. To obtain the difference between the predicted value and the measured value, the RBF method predicts a value at a given control point from the nearest control points (in this assessment either 10 or 15) without knowing the actual value measured at that control point. That predicted value is then compared with the measured value, and the difference between the two is calculated.

Nahcolite resource models using weight-percent nahcolite data were created using the RBF, which interpolated (and extrapolated) surfaces using a multiquadratic gridding method. Once the models were created, we quantified total tonnages of nahcolite by using ESRI Spatial Analyst's Zonal Statistics function. That is, tonnages could be determined by township using the nahcolite resource model (208.71 ft = 63.615-m cell size) and a township grid that had been clipped with an outcrop file derived from the base of the Mahogany zone of the Green River Formation for both the nahcolite resources in the oil shale zones and the total in-place nahcolite within the inferred extent of the nahcolite-bearing interval (figs. 1 and 3).

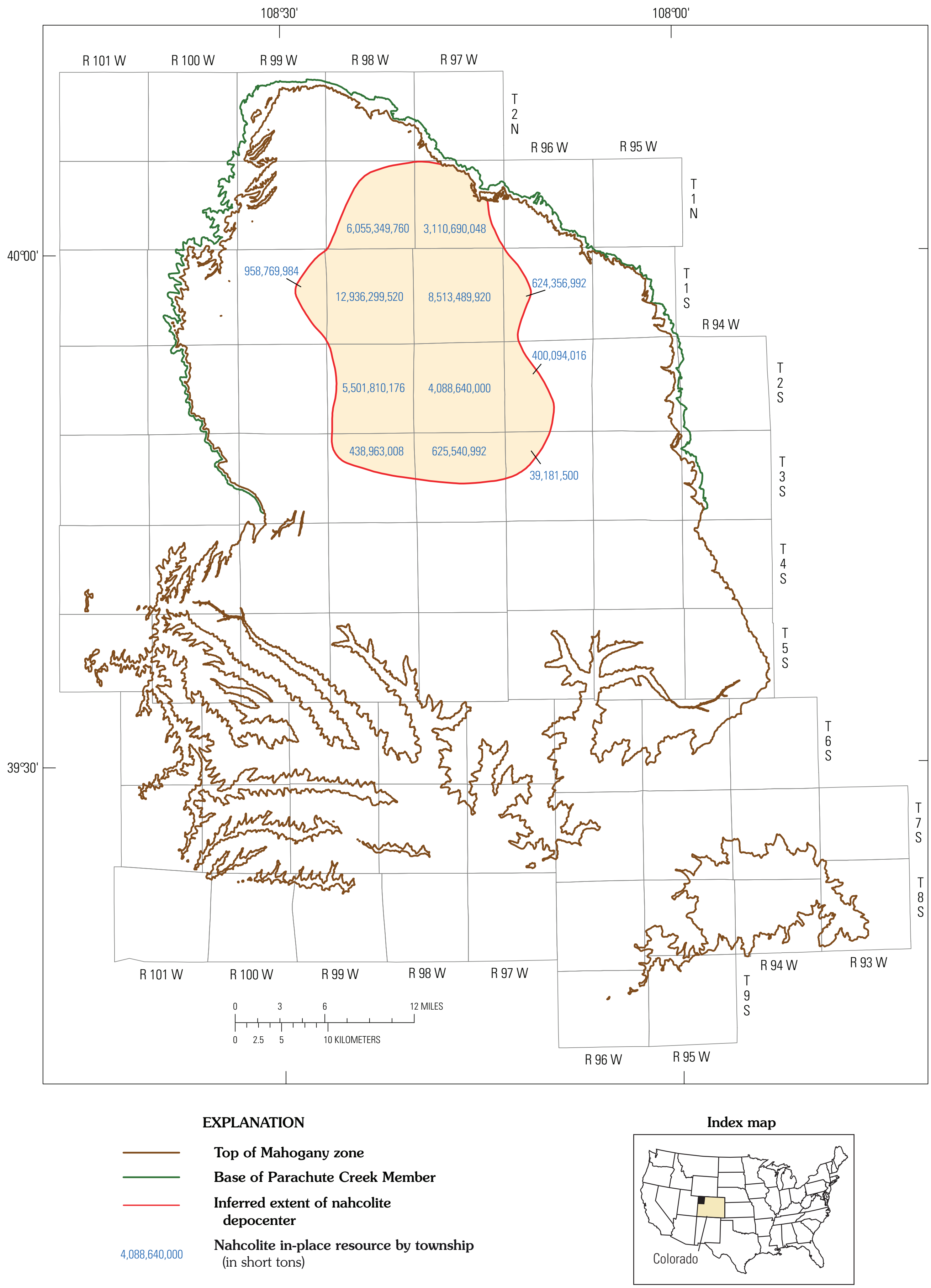

Figure 3. Map showing in-place nahcolite ($NaHCO_3$) resource volumes (in short tons) in the lower and middle parts of the Parachute Creek Member of the Eocene Green River Formation by township, Rio Blanco County, northwestern Colorado. Inferred extent of nahcolite depocenter outlined in red.

Resource Summary

Based on the methodology outlined above, the U.S. Geological Survey (USGS) assessed the nahcolite resources in the lower and middle parts of the Parachute Creek Member of the Green River Formation in the north-central part of the Piceance Basin. In some areas, nahcolite is economically minable as a separate commodity. However, because most of the nahcolite forms in variable sized aggregates scattered through oil shale beds, in most areas it is subeconomic unless recovered as a coproduct of oil shale extraction. Oil shale zones R–3, R–4, L–4, and R–5, from 150 to about 370 ft thick, contain the largest amounts of nahcolite by weight (fig. 2); in-place estimates are shown by township in figure 3 and listed in table 1. Total amounts of nahcolite in the Parachute Creek Member are extrapolated from estimated mineral contents of 58 core holes (fig. 1). The total in-place resource is estimated at about 43.3 billion short tons (table 1).

For Additional Information

Supporting geologic studies of nahcolite-bearing units, assessment units, oil shale and nahcolite analyses, and the methodology used in assessing the nahcolite resources in the Parachute Creek Member of the Green River Formation in the Piceance Basin are in progress. Assessment results are available at the USGS Central Energy Team website: *http://energy.cr.usgs.gov/other/oil_shale/*.

Contact Information

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References

Cashion, W.B., and Donnell, J.R., 1972, Chart showing correlation of selected key units in the organic-rich sequence of the Green River Formation, Piceance Creek basin, Colorado, and Uinta Basin, Utah: U.S. Geological Survey Oil and Gas Investigations Chart OC–65.

Donnell, J.R., and Blair, R.W., Jr., 1970, Resource appraisal of three rich oil shale zones in the Green River Formation, Piceance Creek basin, Colorado: Colorado School of Mines Quarterly, v. 65, no. 4, p. 73–87.

Pitman, J.K., Pierce, F.W., and Grundy, W.D., 1989, Thickness, oil-yield, and kriged resource estimates for the Eocene Green River Formation, Piceance Creek basin, Colorado: U.S. Geological Survey Oil and Gas Investigations Chart OC–132, 6 sheets with 4-page text.

Table 1. In-place nahcolite resources and tons per acre, estimated by township, in the nahcolite-bearing interval of the Parachute Creek Member of the Eocene Green River Formation, Piceance Basin, Rio Blanco County, northwestern Colorado.

[All values calculated by ESRI's ArcGIS GeoStatistical Analyst extension with a Radial Basis Function (RBF) Multiquadratic Gridding Function; 1 acre = 4,047 m]

Township	Acres	Area (m^2)	Estimated tons per acre	Estimated in-place resource, in short tons
T. 1 N. R. 97 W.	16,671	67,465,300	186,593	3,110,690,000
T. 1 N. R. 98 W.	16,193	65,530,900	373,948	6,055,350,000
T. 1 S. R. 96 W.	4,844	19,603,000	128,893	624,360,000
T. 1 S. R. 97 W.	24,450	98,945,900	348,200	8,513,490,000
T. 1 S. R. 98 W.	23,844	96,493,500	542,541	12,936,300,000
T. 1 S. R. 99 W.	4,881	19,752,800	196,429	958,770,000
T. 2 S. R. 96 W.	9,719	39,331,500	41,166	400,090,000
T. 2 S. R. 97 W.	23,478	95,012,400	174,148	4,088,640,000
T. 2 S. R. 98 W.	20,507	82,989,100	268,289	5,501,810,000
T. 3 S. R. 96 W.	3,956	16,009,400	9,904	39,180,000
T. 3 S. R. 97 W.	12,838	51,953,700	48,726	625,540,000
T. 3 S. R. 98 W.	8,613	34,855,700	50,965	438,960,000
Total	**169,994**	**687,943,200**		**43,293,190,000**