COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
DENVER, COLORADO

Interpretive Geothermal Gradient Map of Colorado

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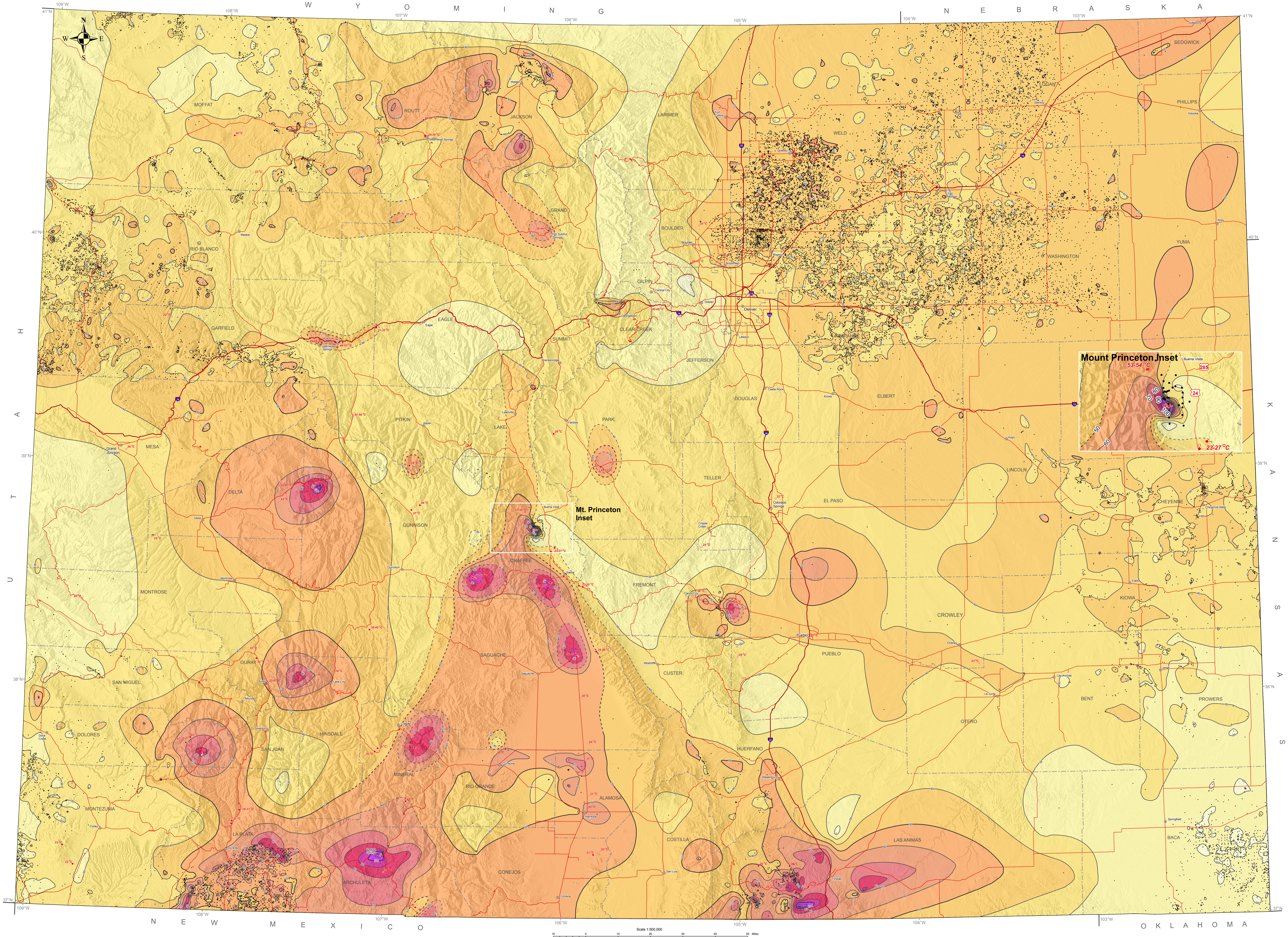

Explanation

Gradient contour lines

(°C/km)

- Major contour (50 °C/km interval)
- Minor contour (10 °C/km interval)
- Major contour, inferred from thermal spring or well data
- Minor contour, inferred from thermal spring or well data

Gradient values

(°C/km)	(°F/100 ft)
<20	<1.10
20-30	1.10-1.65
30-40	1.65-2.19
40-50	2.19-2.74
50-60	2.74-3.29
60-70	3.29-3.84
70-80	3.84-4.39
80-90	4.39-4.94
90-100	4.94-5.49
>100	>5.49

Gradient datapoints

- Well location with calculated gradient value

Thermal reference points

Type, labeled with water temperature

- Thermal spring
- Thermal well

Explanation and Methods

This map is a compilation of geothermal gradient data in Colorado. Thermal gradient is the change in temperature over distance. In geothermal resource assessment, distance is the depth into the Earth provided by a borehole or well. Geothermal gradient is commonly expressed in units of degrees Celsius per kilometer (°C/km) or degrees Fahrenheit per 100 feet (°F/100 ft). Geothermal gradient values are a way to quantify the depth-temperature relationship for use in evaluating geothermal resource potential.

Geothermal gradients are calculated from measurements made in drilled wells. The data shown on this map were derived from several sources - dedicated geothermal test holes, mineral resource assessment drillholes, oil, gas and CO2 wells, and geothermal wells. Not all oil and gas well data were used in compiling the map. Bottom-hole temperature data for the major oil and gas producing areas of Colorado were used as compiled by Dixon (2002, 2004). In oil and gas production areas not covered by the Dixon compilations, the database was augmented by selecting oil and gas wells that had drill-stem test temperature data from the PI/Dwights dataset (IHS Energy) and temperature log data from LogSleuth (M.J. Systems). Heat flow data compiled by Blackwell and Richards (1989) and from the International Heat Flow Commission, Global Heat Flow Database for geothermal test holes and mineral resource drillholes are also contained in the database. Heat flow data are located primarily in the mountainous central and western portion of the state, and are geographically complimentary to the oil and gas dataset. By combining these datasets, a more complete and detailed picture of geothermal gradient in Colorado is produced than was previously available. Data points are shown by small black dots on the map.

The boundaries of many geothermal anomalies lack precise control because of uneven data coverage. In areas of sparse data, hot spring temperature data were used to supplement the available gradient data. A relationship between spring temperature and expected gradient value was derived by plotting hot spring temperature (Cappa and Hemborg, 1995) against nearby drill hole gradient data for the Hortense, Cottonwood, Pagosa, and Shaws hot springs. The resulting least-squares best-fit linear equation, $G = 2.181T - 24.80$, allows a rough estimate of geothermal gradient, G, using hot spring temperatures, T, in Colorado's mountainous areas where down-hole temperature values are not available. Contour lines are dashed where values derived from hot springs influence the contour placement.

Geothermal gradients are calculated by two primary techniques. If multiple temperature-depth measurements are available from a single drillhole or well, the longest section of measurements is taken in which the data define an approximately linear plot. The gradient is calculated as a linear least-squares fit to this sub-set of the data. This is the preferred method of gradient calculation and was used on a limited number of wells for which temperature log data were acquired. For most wells, only one down-hole temperature was available. To derive geothermal gradient in these cases, an estimate of the surface ground temperature was made based on mean annual air surface temperature. The average geothermal gradient in the hole is then given by the difference between the down-hole temperature and the surface ground temperature, divided by the depth to the temperature measurement point.

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This project was co-funded by the Governor's Energy Office (contract C900537) and the Department of Natural Resources Severance Tax Operational Fund.

Basemap data sources:
Colorado Department of Transportation
Colorado Department of Local Affairs
United States Geological Survey

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ISBN: 978-1-884216-13-8