Chapter 16

Structure Contour Map of the Top of the Dakota Sandstone, Uinta-Piceance Province, Utah and Colorado

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By Laura N.R. Roberts

Chapter 16 *of*

Petroleum Systems and Geologic Assessment of Oil and Gas in the Uinta-Piceance Province, Utah and Colorado

By USGS Uinta-Piceance Assessment Team

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Structure Contour Map of the Top of the Dakota Sandstone, Uinta-Piceance Province, Utah and Colorado

By Laura N.R. Roberts

Abstract

The structure contour map of the top of the Dakota Sandstone in the Uinta-Piceance Province highlights the major structural trends of the present-day Uinta and Piceance Basins. This map is unique because it combines data from oil and gas wells, from digital geologic maps of Utah and Colorado, and from thicknesses of overlying stratigraphic units where such data for the Dakota are sparse. A two-dimensional grid of this structural surface on top of the Dakota was used to generate a derivative map of the depth to the top of the Dakota Sandstone. The depth map is a direct result of subtracting two surface grids—the topographic surface of the Uinta-Piceance Province, in the format of a Digital Elevation Model, minus the surface of the top of the Dakota Sandstone. This depth map, coupled with drill-hole data of current hydrocarbon production, provides important information as to the range of depths to producing intervals in the Dakota Sandstone. The vast majority of wells that produce from the Dakota Sandstone are less than 10,000 ft deep.

Introduction

Purpose

The structure contour map of the top of the Dakota Sandstone (fig. 1) depicts a representation of the present-day surface for the base of the source rock of the Mancos/Mowry Total Petroleum System (Kirschbaum, Chapter 6, this CD-ROM) within the Uinta-Piceance Province. The Dakota Sandstone was chosen as a datum because it is an identifiable stratigraphic unit that is mapped throughout much of the province (fig. 2) and because it is easily recognized in the subsurface from geophysical well logs. This structure contour map is unique in that it is the result of using not only well data and digital data from geologic maps and a Digital Elevation Model (DEM), but also data from other stratigraphic horizons. The map highlights the major structural features of the Uinta and Piceance Basins (fig. 3) and was used to generate a derivative map of the depth to the top of the Dakota Sandstone. This depth map, coupled with drill-hole data of current hydrocarbon production, provides important information about the range of depths to producing intervals in the Dakota Sandstone.

Sources of Data

Sources of data for the map of the top of the Dakota Sandstone were the Petroleum Information/Dwights Petro-ROM well history data (IHS Energy Group, 2000), digitally derived outcrop elevations, and scattered outcrop elevations from published geologic maps and unpublished data.

Approximately 4,000 wells were selected from the Petro-ROM database by searching for wells that contain a record for the depth to the top of the Dakota (fig. 4). Preliminary modeling of these data using EarthVision (Dynamic Graphics, Inc., 1999, v. 5) revealed obvious inaccuracies (“bull’s eyes”), which were removed or edited within the data set.

Approximate outcrop elevations for the top of the Dakota (fig. 5) were primarily derived using the ArcView (Environmental Systems Research Institute, 1998, v. 3.1) map calculator function within the ArcView Spatial Analyst Extension. From the digital geologic map of Utah (Hintze and others, 2000) a line coverage was generated by selecting lines that represent the contact between “K1” (Dakota) and “K2” (Mancos Shale). Similarly, from the digital geologic map of Colorado (Green, 1992), a line coverage was generated by selecting lines that represent the contact between the Dakota Sandstone and the Mancos Shale. These two line coverages were combined into one coverage and used to represent the estimated limit (outcrop) of the Dakota Sandstone in the Uinta and Piceance Basins. In ArcView, the line coverage was converted to a grid that contained cell values of zero along the outcrop and cell values of “NO DATA” everywhere else.

A DEM that covers the area of the Uinta-Piceance Province (fig. 6) was compiled by the Earth Surface Processes Team of the U.S. Geological Survey (USGS) from four DEMs at a scale of 1:250,000. This DEM was directly imported into ArcView as a grid. By intersecting the grid of the outcrop line and the grid of the DEM, another grid was created that recorded the cell value of the DEM grid (elevation) where the DEM grid intersected the outcrop grid. That is, wherever there was a cell value of zero (from the outcrop grid), an

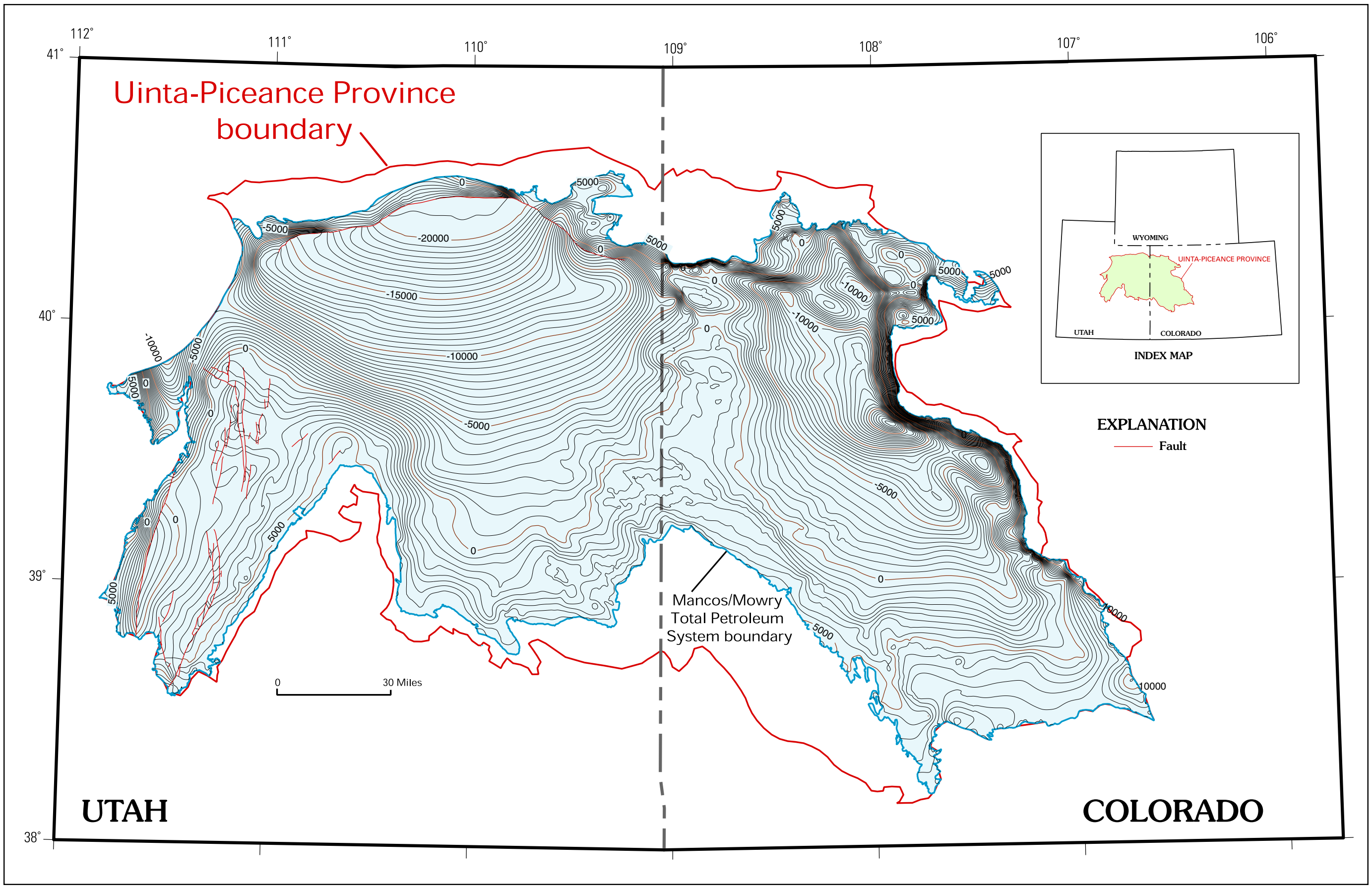


Figure 1. Structure contour map of the top of the Dakota Sandstone, Uinta-Piceance Province, Utah and Colorado. Contour interval 500 ft.

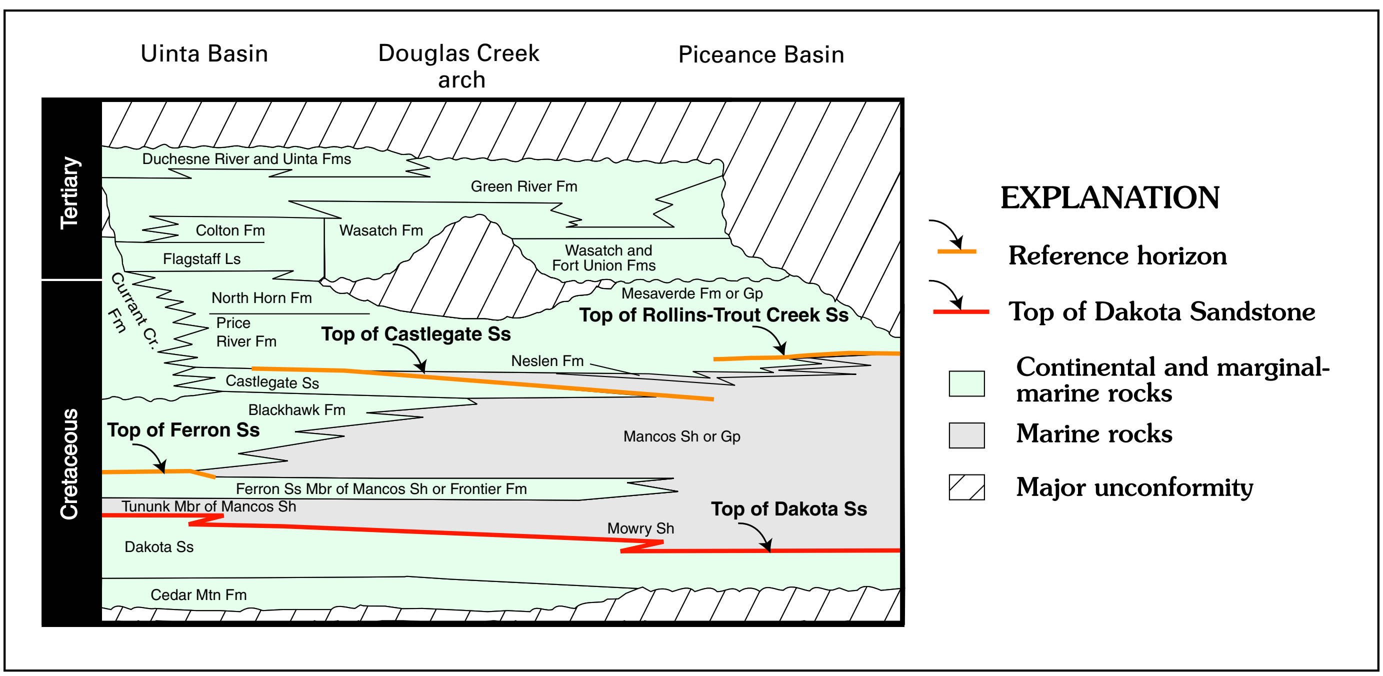


Figure 2. Generalized stratigraphic chart of Cretaceous and younger rocks from west to east across the Uinta and Piceance Basins. Key stratigraphic horizons used to generate the structure contour map of the top of the Dakota Sandstone are designated as "reference horizon." Modified from Sanborn (1977) and Spencer and Wilson (1988).

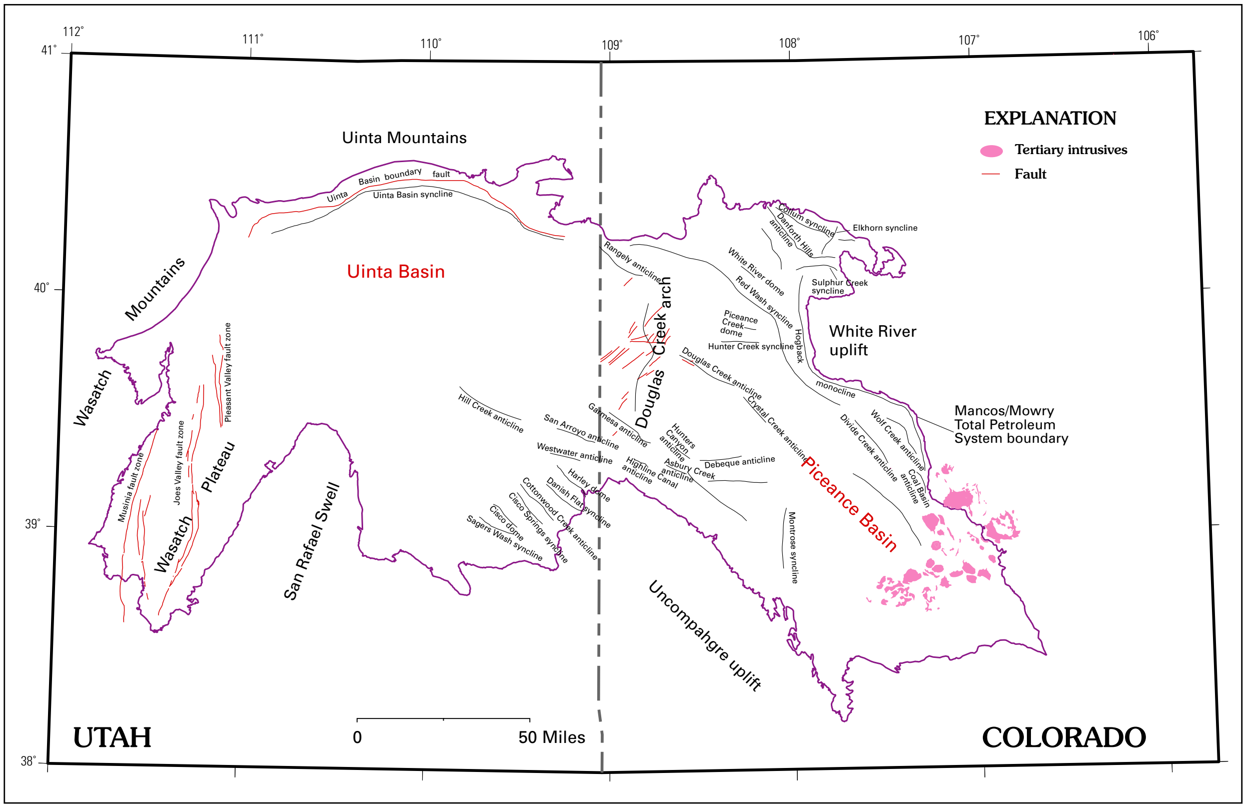


Figure 3. Major structural features of the Uinta and Piceance Basins, Utah and Colorado.

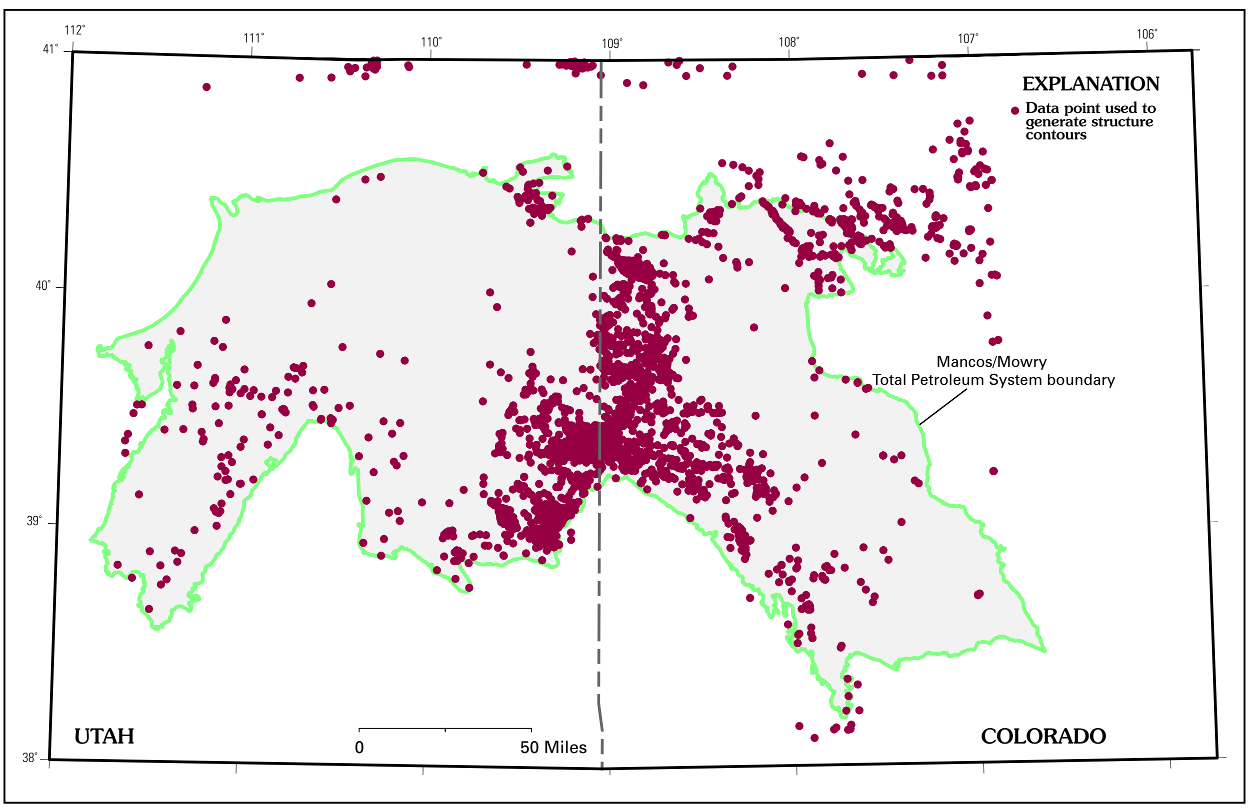


Figure 4. Distribution of data points that have records for the depth to the top of the Dakota Sandstone, Uinta and Piceance Basins, Utah and Colorado.

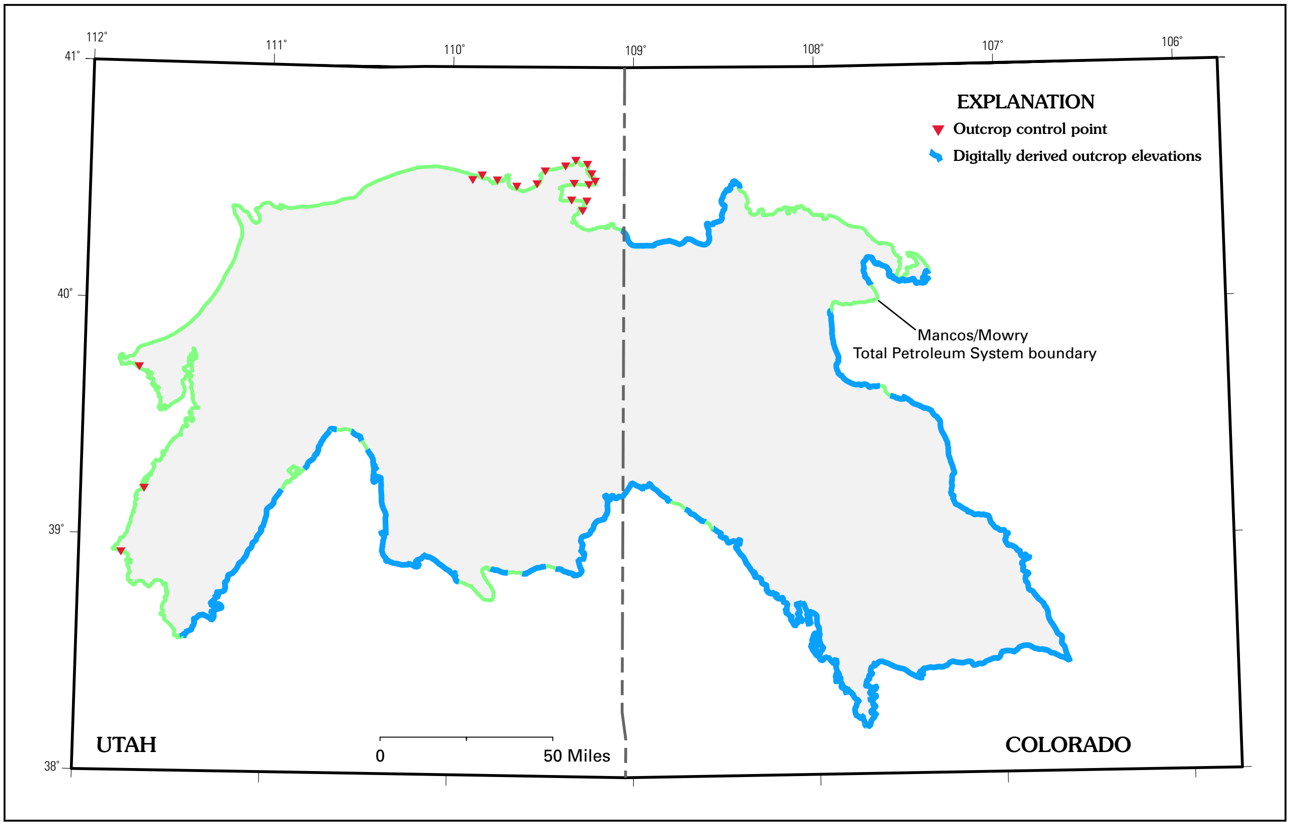


Figure 5. Distribution of control points along the outcrop of the Dakota Sandstone.

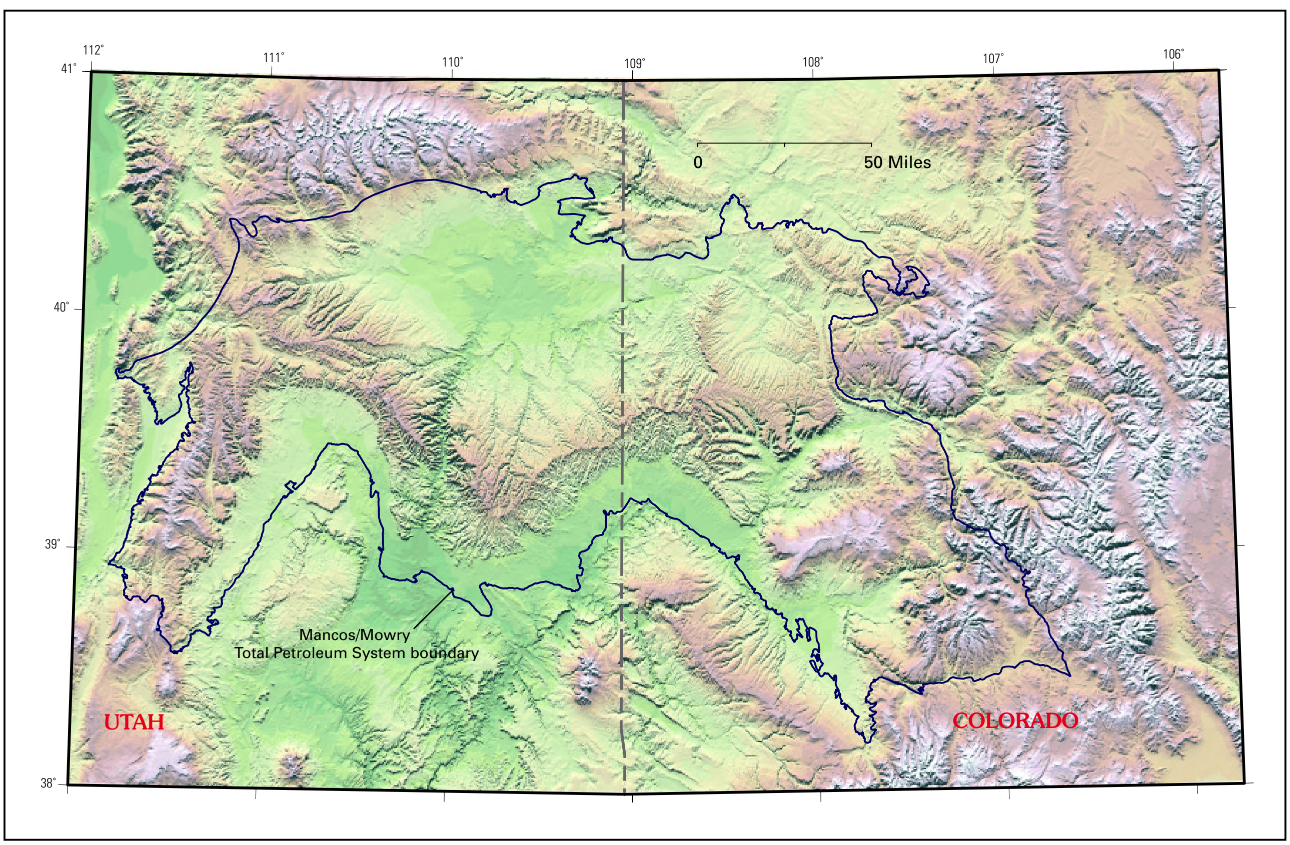


Figure 6. Shaded-relief topography generated from a Digital Elevation Model (DEM), Uinta and Piceance Basins, Utah and Colorado.

elevation, in feet above mean sea level, was recorded (from the DEM grid). This process created a grid that is readable in ARC/INFO (Environmental Systems Research Institute, 1998, v. 7.1.1); the ARC/INFO command “gridpoint” was then used to convert the grid to an ARC/INFO point coverage of elevations along the estimated outcrop. The point coverage was then imported into EarthVision and converted to a scattered-data file that consists of x and y fields for location, and a z field for elevation.

Additional scattered-data points for the approximate elevation of the Dakota outcrop were added to the data set from geologic maps and unpublished data for the western and northern parts of the Uinta Basin (fig. 5).

Fault lines shown on the map (fig. 1) are from several sources. The fault that extends across the northern part of the Uinta Basin is from Campbell (1975) and Bryant (1992). It represents the approximate surface projection of the “basin-boundary fault”—a concealed thrust fault. Fault lines in the Wasatch Plateau were selected from the digital geologic map of Utah (Hintze and others, 2000).

Method Used to Generate Structure Contour Map

Digital Data for Structure on Key Horizons

Elevation data for the top of the Dakota from drill holes (fig. 4) and along the outcrop (fig. 5) are not evenly distributed across the Uinta and Piceance Basins. Most of the drill-hole data are concentrated on the Douglas Creek arch (fig. 3) and to the southwest and southeast of the arch. Exposures of the contact between the Dakota Sandstone and the Mancos Shale are sparse or absent along major parts of the northern and western margins of the Uinta Basin. A method was devised to extrapolate the structure contours for the Dakota across areas with little or no data by using structure contour maps of three other easily recognizable stratigraphic horizons, referred to here as “reference horizons” (fig. 2).

Rollins and Trout Creek Sandstone Reference Horizon

Johnson (1983) constructed a structure contour map combining the top of the Rollins Sandstone Member of the Mesaverde Formation in the southern Piceance Basin and its correlative unit in the northern Piceance Basin, the Trout Creek Sandstone Member of the Iles Formation. Johnson’s map was electronically scanned and converted into a two-dimensional grid representing the combined top of the Rollins, Trout Creek Sandstone Members (fig. 7). A data set was created from the PetroROM database that contains thickness values from the top of the Dakota Sandstone to the top of the Rollins and Trout Creek Sandstone Members. In general, this thickness interval increases from about 4,000 ft in the southern Piceance Basin to about 7,000 ft in the northern Piceance Basin (fig. 8). A grid of thickness values was generated and subtracted from the grid of elevation data on top of the Rollins–Trout Creek Sandstone Members, resulting in a grid that represents a “pseudo”-structural surface on top of the Dakota. By this process, the structural trends, the major folds, and the Piceance Basin axis that are present within the Rollins–Trout Creek horizon (fig. 7) are also represented in the structure contour map of the top of the Dakota. The resultant pseudo-grid was then adjusted with elevation values from the drill-hole and outcrop data using EarthVision. Remarkably, the contours plotted from this adjusted grid did not shift significantly from the contours generated for the pseudo-grid. This exercise produced a realistic surface representation for the top of the Dakota Sandstone for the Piceance Basin.

Castlegate Sandstone Reference Horizon

The same method used to create a grid for the top of the Dakota in the Piceance Basin was used to create a grid in the eastern and central parts of the Uinta Basin. A structure contour map (Johnson, 1986) of the top of the Upper Cretaceous Castlegate Sandstone in the eastern and central parts of the Uinta Basin and the western part of the Piceance Basin (fig. 9) was scanned and converted into a two-dimensional grid. From the PetroROM database, a data set was created that contains values of the thickness interval from the top of the Dakota Sandstone to the top of the Castlegate Sandstone. In general, this thickness interval increases from 3,500 ft in the southeastern part of the Uinta Basin to about 7,000 ft in the northwestern part of the basin (fig. 10). This thickness trend is consistent with thicknesses shown in a cross section across the same area by Kirschbaum (Chapter 6, this CD-ROM). A grid of the thickness data was generated and then subtracted from the grid for the elevations on top of the Castlegate Sandstone, resulting in a grid that represents a “pseudo”-structural surface on top of the Dakota. Structural trends displayed by the Castlegate Sandstone structure contour map (fig. 9) are maintained in the structure map for the top of the Dakota. The resultant pseudo-grid was then adjusted with elevation values from the drill-hole and outcrop data using EarthVision.

Ferron Sandstone Reference Horizon

The Wasatch Plateau occupies the southwestern part of the Uinta-Piceance Province (fig. 3). The area is characterized by basin-and-range faulting that has produced major displacement of strata along north-northeast-trending fault zones. In this area, the top of the Ferron Sandstone Member of the Mancos Shale (fig. 2) is the reference horizon used to model the top of the Dakota for this report. T.M. Finn (USGS,

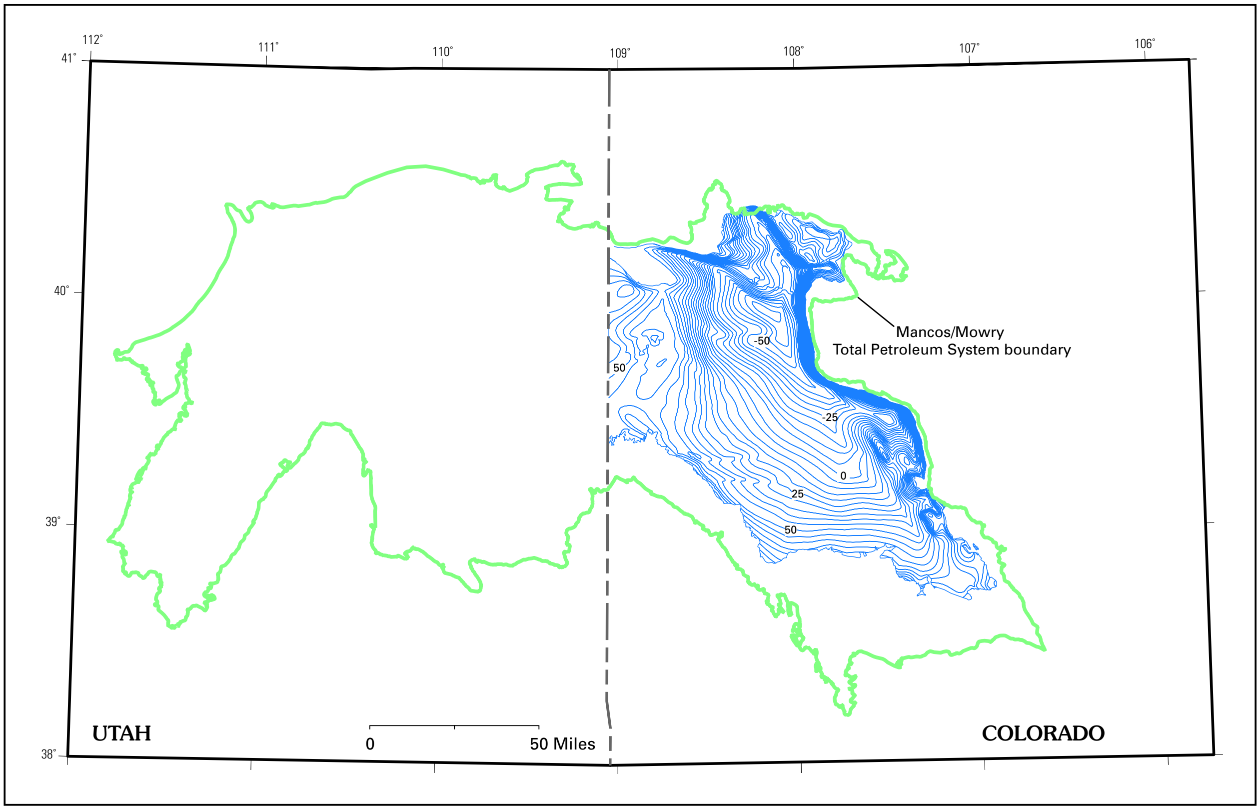


Figure 7. Structure contour map of the top of the Rollins Sandstone Member of the Mesaverde Formation in the southern Piceance Basin, Colorado, and its correlative to the north, the Trout Creek Sandstone Member of the Iles Formation (Johnson, 1983). Contour interval 500 ft; values in hundreds of feet.

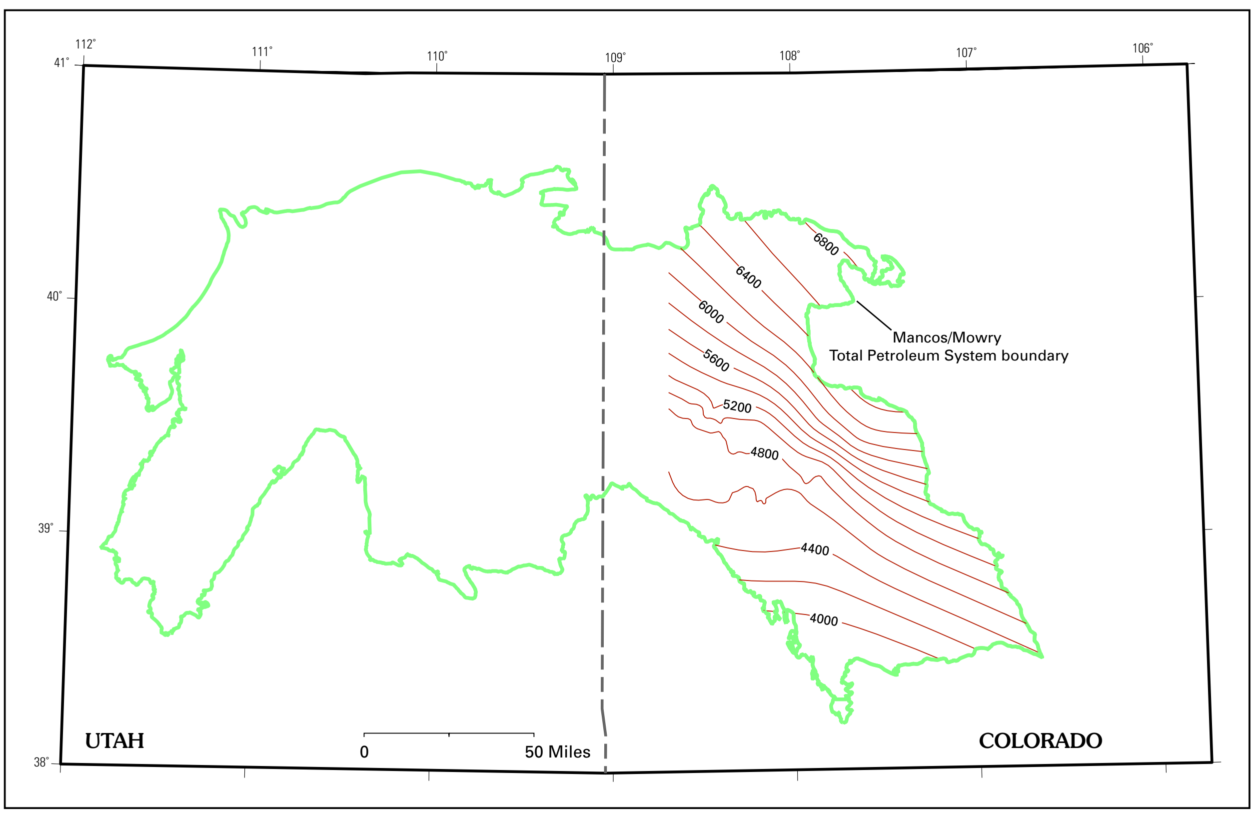


Figure 8. Isopach map of the interval from the top of the Rollins and Trout Creek Sandstone Members to the top of the Dakota Sandstone in the southern Piceance Basin, Colorado. Contour interval 200 ft.

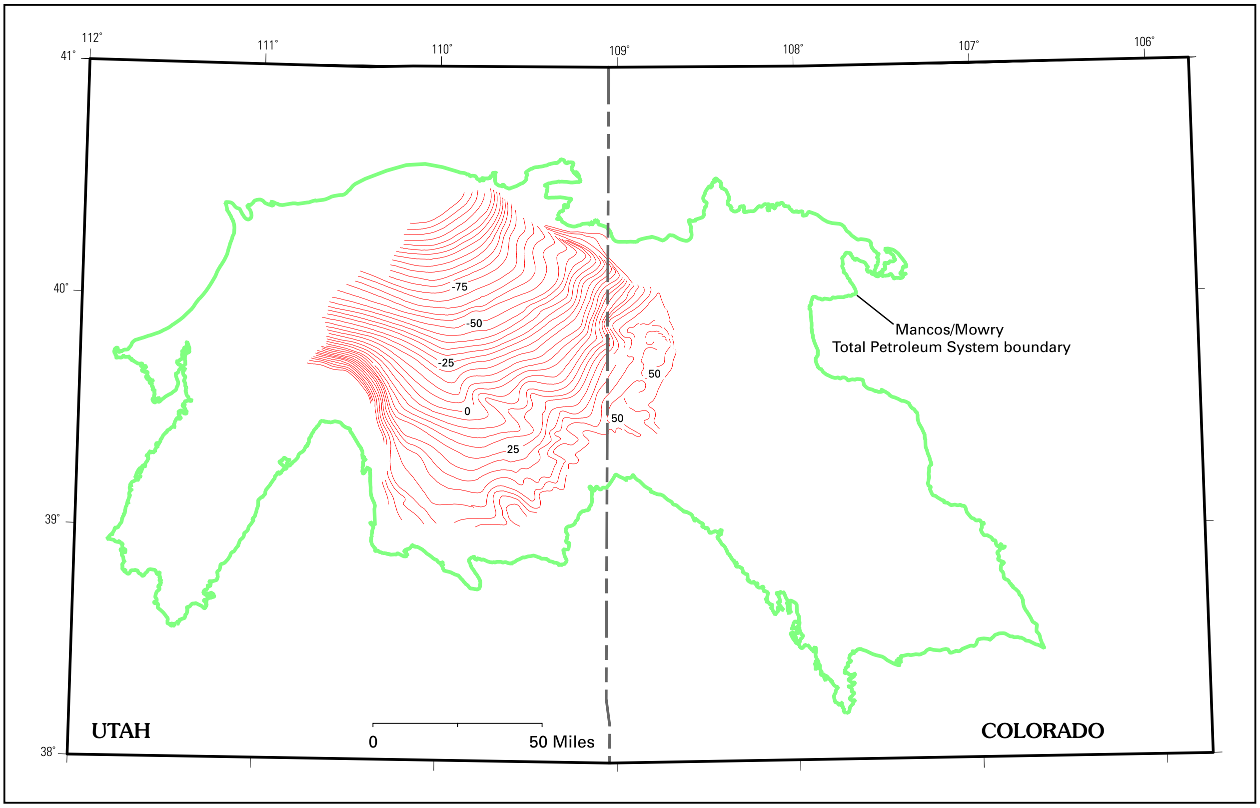


Figure 9. Structure contour map of the top of the Castlegate Sandstone, Uinta and Piceance Basins, Utah and Colorado (Johnson, 1986). Contours locally not shown in faulted areas. Contour interval 500 ft; values in hundreds of feet.

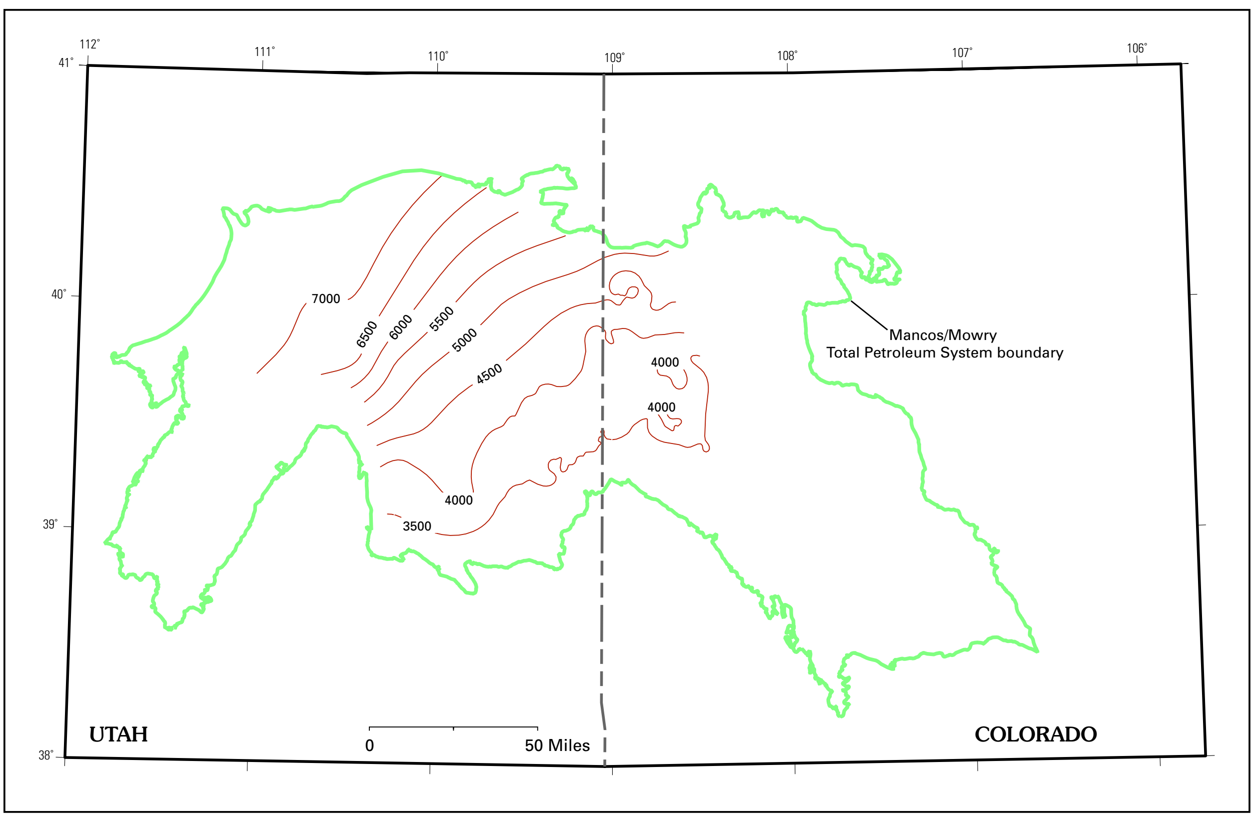


Figure 10. Isopach map of the interval from the top of the Castlegate Sandstone to the top of the Dakota Sandstone, Uinta and Piceance Basins, Utah and Colorado. Contour interval 500 ft.

written commun., 2000) performed a detailed study of the available well logs in the area of the Ferron/Wasatch Plateau Total Petroleum System in the eastern half of the Wasatch Plateau. He determined depths to tops of pertinent stratigraphic units and created a map of his interpretation of the structure on top of the Ferron Sandstone (fig. 11) as well as isopach maps of the Ferron Sandstone and the underlying Tununk Member of the Mancos Shale. For this Dakota Sandstone study, a line coverage for the contours on top of the Ferron was imported into EarthVision and converted to a scattered-data file. Selected fault lines from the digital geologic map of Utah (Hintze and others, 2000) were used in modeling the surface for the top of the Ferron Sandstone and a two-dimensional grid of the surface was generated.

Line coverages for the thicknesses of the Ferron Sandstone and the underlying Tununk Member were imported into ArcView and converted to grids. Through this gridding process, the lines are converted to cells that "follow" the lines and maintain a value of thickness for those lines; all other cell values are "NO DATA." The two grids were added together using the map calculator function within the ArcView Spatial Analyst Extension. The output is a new grid with cells containing values for the sum of the cell values where the two input grids intersect. For example, where the cells representing the 300-ft line for the Tununk isopach intersect the cells representing the 500-ft line for the Ferron isopach, a cell value of 800 is recorded in the new grid file.

This resultant grid was converted to a point coverage, which was then imported into EarthVision as a scattered-data file. The data were modeled to create a grid representing the thickness between the top of the Ferron Sandstone and the top of the Dakota Sandstone. In general, the thickness of the interval increases from east to west from about 300 to about 1,700 ft (fig. 12). This thickness trend is consistent with the combined isopach maps of the Ferron Sandstone and the Tununk Member in Ryer and McPhillips (1983). The thickness grid was subtracted from the grid of the elevations of the top of the Ferron Sandstone to result in a "pseudo"-structure for the top of the Dakota Sandstone. The resultant pseudo-grid was then adjusted with the drill-hole and outcrop data available in this area for the Dakota by using the EarthVision software.

Discussion

Drill-hole and outcrop data pertinent to the Dakota Sandstone are lacking over large parts of the Uinta and Piceance Basins, and because of this the structure contour map cannot have the same level of accuracy throughout. Also, the extent of the three reference horizons does not cover the entire area of interest. Figure 13 shows the two major areas where the structure contours must be considered speculative.

In the Wasatch Plateau, the exact displacement of the Dakota Sandstone is not known along the numerous normal faults. Although Walton (1955) presented a detailed structure contour map of the top of the Ferron Sandstone in the northern part of the Wasatch Plateau, it is not practical to project the detail from the Ferron structure to the top of the Dakota at the scale of this study. However, the major faults and generalized contours (fig. 1) indicate that it is a structurally complex area and that more drilling is necessary to accurately determine the structure on top of the Dakota in the Wasatch Plateau.

In the northern part of the Uinta Basin, along the concealed trace of the Uinta Basin boundary fault (fig. 3), the structure contours were modified from Bryant (1992), who described the location of the contours on his map as "very approximate." Few wells penetrate the Dakota in that area, so his contours were mostly extrapolated downward from wells reported to penetrate Cretaceous rocks. The exact location of the Uinta Basin boundary fault itself is unknown, but its position is limited by well data (Campbell, 1975).

In the extreme southeastern part of the Piceance Basin, few wells were drilled to the top of the Dakota and none of the reference horizons extend into this area. The contours, therefore, are strongly affected by the outcrop elevations that were digitally derived using the process described earlier in this report. As in the Wasatch Plateau, more drilling is necessary to accurately determine the structure on top of the Dakota in this area.

The area represented on the structure map in the vicinity of the Douglas Creek arch and to the southeast and southwest of the arch is probably the most accurate. The abundant drill-hole data were used to adjust the grids generated from the reference horizons of the Rollins–Trout Creek Sandstone Members and the Castlegate Sandstone, and therefore, provide ground truth to the structure contours in this area.

Depth Map

With the structure contour map completed, it is a fairly simple process to generate a map showing depths to the top of the Dakota Sandstone. The DEM that covers the area of the Uinta and Piceance Basins (fig. 6) was imported into EarthVision, which created a two-dimensional grid of the surface elevation. Using the "formula processor" within EarthVision, the grid for the elevation of the top of the Dakota Sandstone was subtracted from the grid for the Earth surface to produce a grid of the depth to the top of the Dakota (fig. 14).

Conclusions

The structure contour map of the top of the Dakota Sandstone in the Uinta-Piceance Province is unique because it is the result of using not only the well data from PetroROM and digital data from geologic maps and DEMs, but also data from other stratigraphic horizons. The contours display the major structural trends of the basins. The map of depth to the top of the Dakota Sandstone is a direct result of subtraction of two

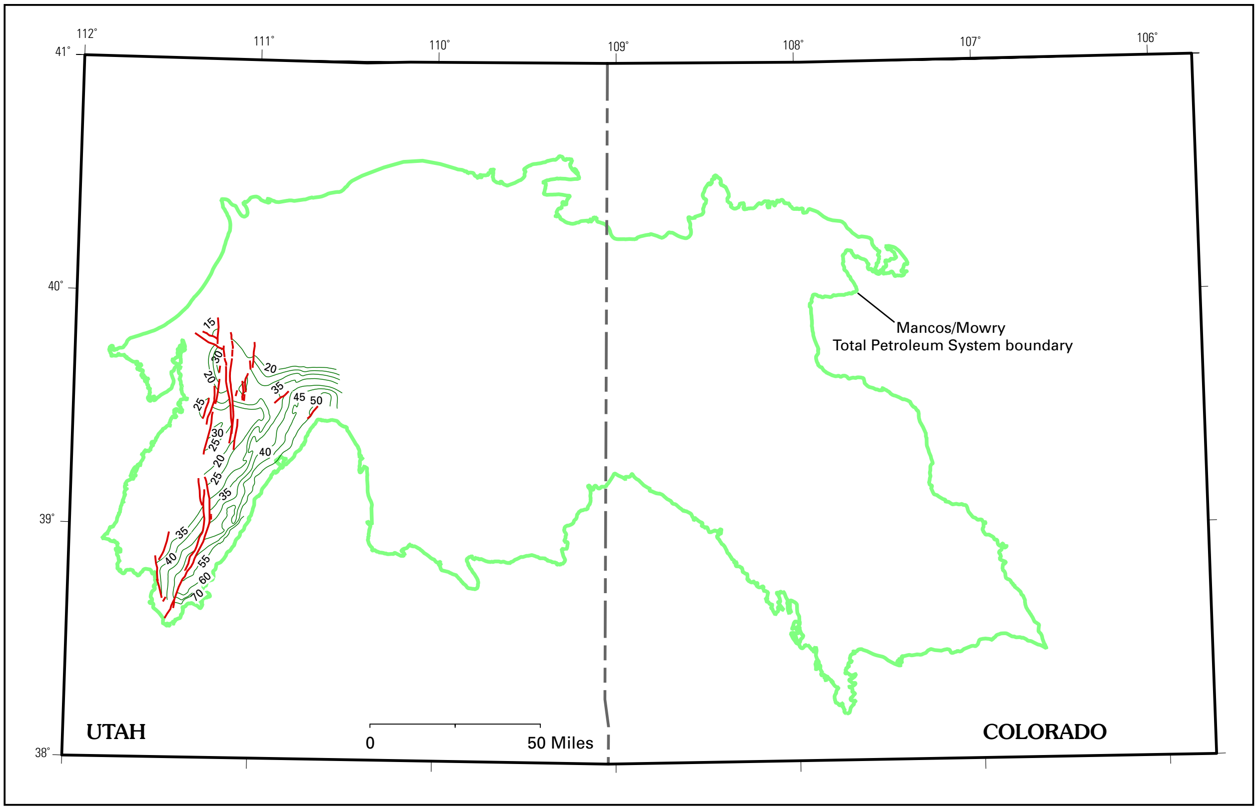


Figure 11. Structure contour map of the top of the Ferron Sandstone, Wasatch Plateau, Utah (T.M. Finn, USGS, written commun., 2000). Contours locally not shown in faulted areas (red lines). Contour interval 500 ft; values in hundreds of feet.

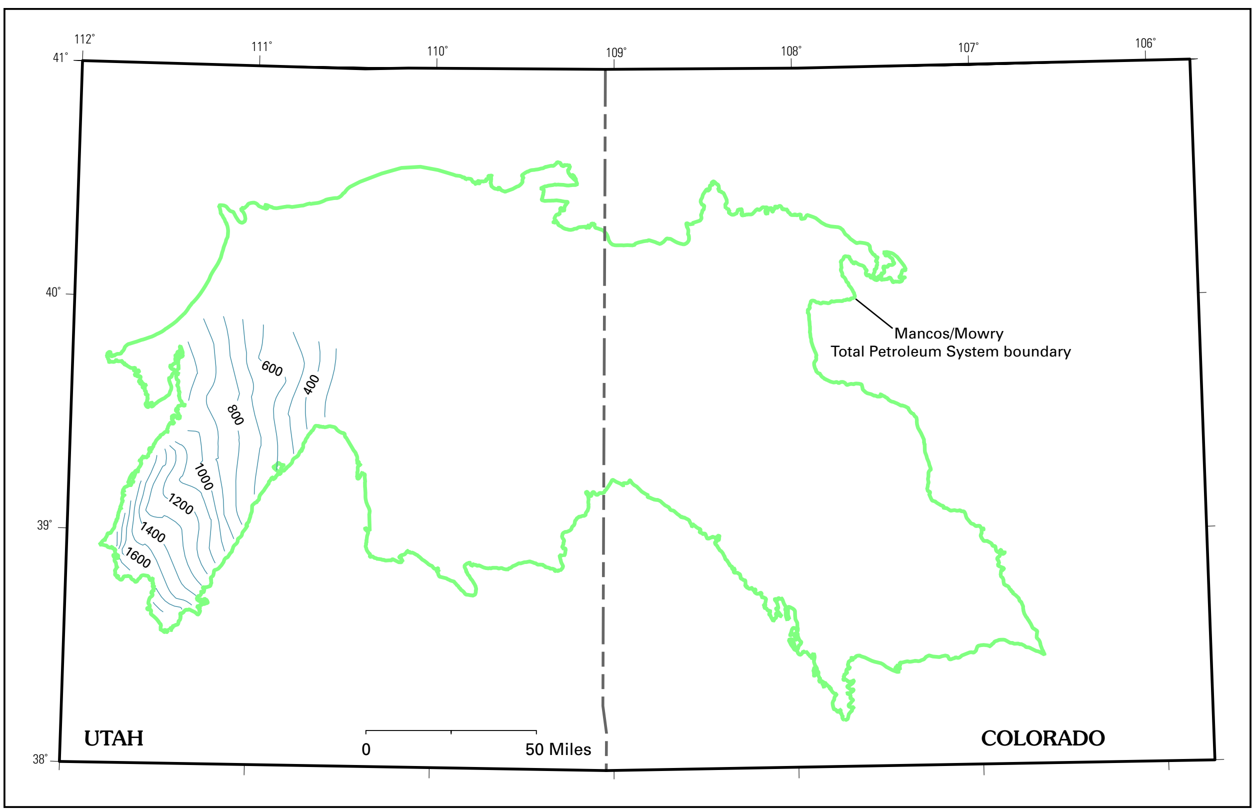


Figure 12. Isopach map of the interval from the top of the Ferron Sandstone to the top of the Dakota Sandstone, Wasatch Plateau, Utah. Contour interval 100 ft.

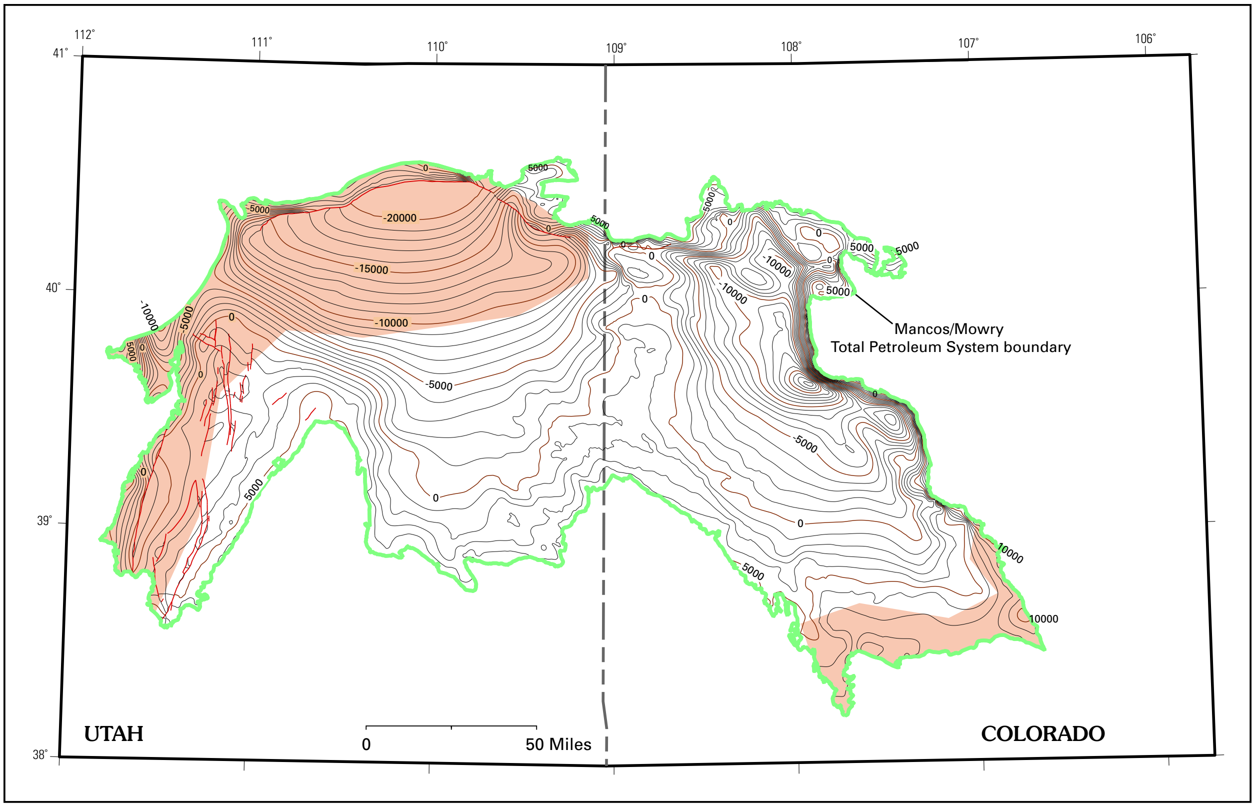


Figure 13. Structure contour map of the top of the Dakota Sandstone showing areas (shaded brown) where the contours are considered speculative due to lack of data, Uinta and Piceance Basins, Utah and Colorado. Contour interval 1,000 ft.

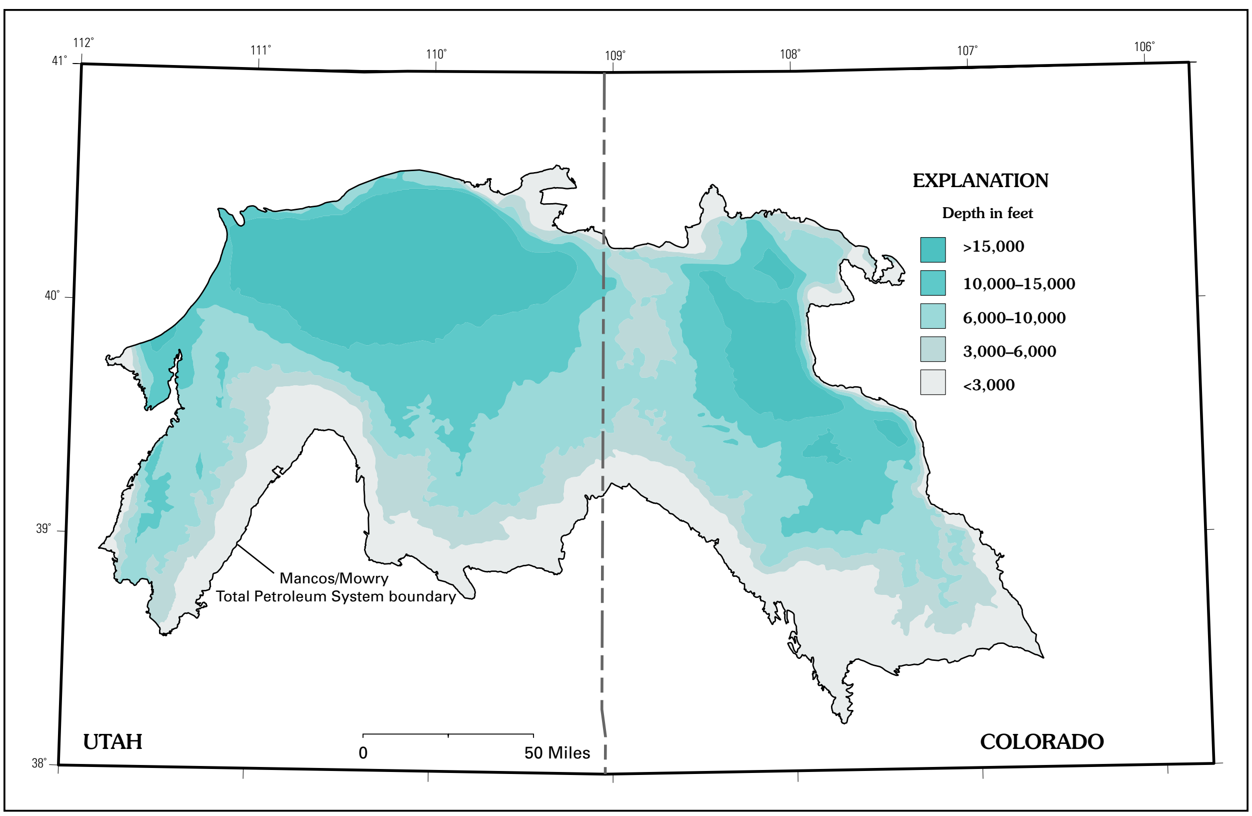


Figure 14. Contour map of depths to the top of the Dakota Sandstone, Uinta and Piceance Basins, Utah and Colorado.

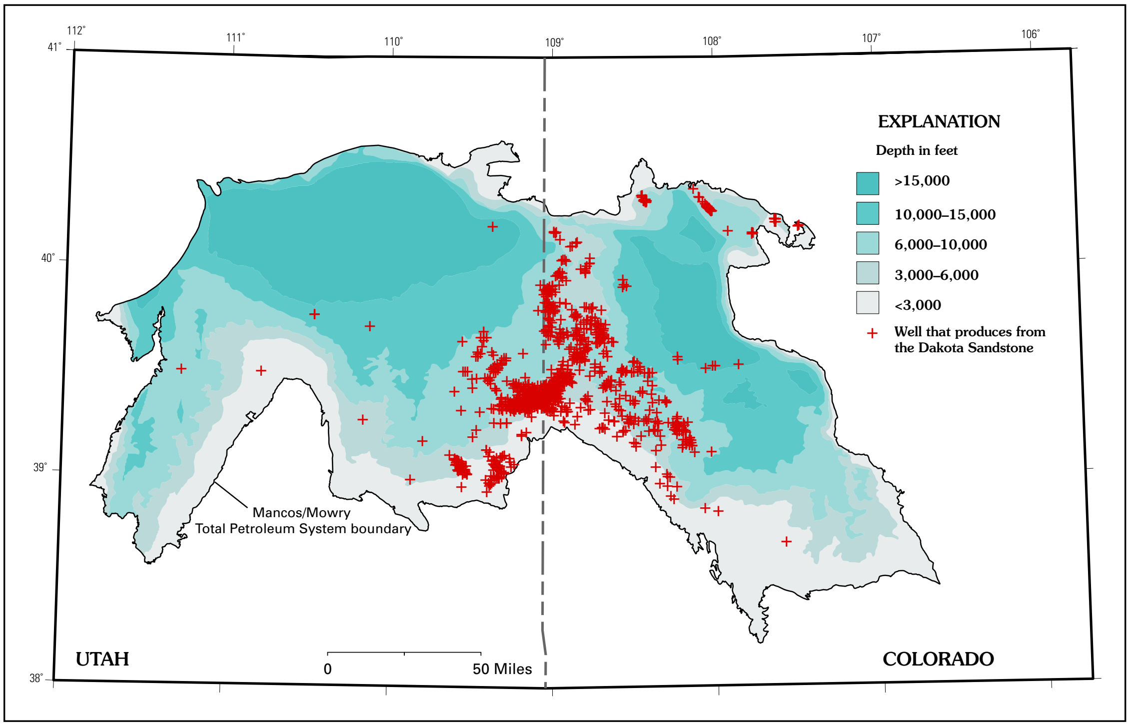


Figure 15. Locations of wells that produce gas from the Dakota Sandstone and contours of the depth to the top of the Dakota Sandstone, Uinta and Piceance Basins, Utah and Colorado.

surface grids—the topographic surface of the Uinta-Piceance Province minus the surface of the top of the Dakota Sandstone. When superimposed with a map of the location of wells that produce gas from the Dakota (fig. 15), the depth map depicts the range of depths from which most of the gas is produced. The vast majority of wells that produce from the Dakota Sandstone are less than 10,000 ft deep.

References Cited

Bryant, Bruce, 1992, Geologic and structure maps of the Salt Lake City 1° x 2° quadrangle, Utah and Wyoming: U.S. Geological Survey Miscellaneous Investigations Series Map I–1997, 3 plates, scale 1:125,000.

Campbell, J.A., 1975, Structural geology and petroleum potential of the south flank of the Uinta Mountain Uplift, northeastern Utah: Utah Geology, v. 2, no. 2, p. 129–132.

Green, G.N., 1992, Digital geologic map of Colorado in ARC/INFO export format: U.S. Geological Survey Open-File Report 92–0507. [Available at URL ftp://geology.cr.usgs.gov/pub/open-file-reports/ofr-92-0507/]

Hintze, L.F., Willis, G.C., Laes, D.Y.M., Sprinkel, D.A., and Brown, K.D., 2000, Digital geologic map of Utah: Utah Geological Survey, Department of Natural Resources, in cooperation with United States Geological Survey, Map 179DM, scale 1:500,000.

IHS Energy Group, 2000, Petroleum Information/Dwights PetroROM well history data on CD-ROM: IHS Energy Group, 15 Inverness Way East, D205, Englewood, CO, 80112, U.S.A.

Johnson, R.C., 1983, Structure contour map of the top of the Rollins Sandstone Member of the Mesaverde Formation and Trout Creek Sandstone Member of the Iles Formation, Piceance Creek Basin, Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF–1667, 1 plate, scale 1:253,440.

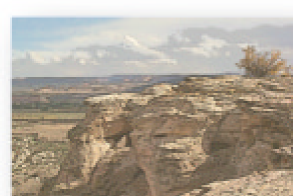
———1986, Structure contour map of the top of the Castlegate Sandstone, eastern part of the Uinta Basin and western part of the Piceance Creek Basin, Utah and Colorado: U.S. Geological Survey Miscellaneous Field Studies Map MF–1826, 2 plates, scale 1:253,440.

Ryer, T.A., and McPhillips, M., 1983, Early Late Cretaceous paleogeography of east-central Utah, *in* Reynolds, M.W., and Dolly, E.D., eds., Mesozoic paleogeography of the west-central United States: Society of Economic Paleontologists and Mineralogists, Rocky Mountain Section, Rocky Mountain Paleogeography Symposium 2, p. 253–272.

Sanborn, A.F., 1977, Possible future petroleum of Uinta and Piceance Basins and vicinity, northeast Utah and northwest Colorado, *in* Veal, H.K. ed., Exploration frontiers of the central and southern Rockies: Rocky Mountain Association of Geologists, p. 151–166.

Spencer, C.W., and Wilson, R.J., 1988, Petroleum geology and principal exploration plays in the Uinta-Piceance-Eagle basins Province, Utah and Colorado: U.S. Geological Survey Open-File Report 88–450–G, 35 p.

Walton, P.T., 1955, Wasatch Plateau gas fields, Utah: American Association of Petroleum Geologists Bulletin, v. 39, no. 4, p. 385–421.



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