Chapter WN

COAL RESOURCES, WILLISTON BASIN

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COAL RESOURCES—HARMON COAL ZONE, BOWMAN-DICKINSON COALFIELD, WILLISTON BASIN, NORTH DAKOTA

HARMON COAL ZONE RESOURCE ESTIMATES—AN OVERVIEW

- Coal resources are calculated using the specific gravity of the coal calculated from apparent coal rank, which is the weight of coal per unit volume, net coal thickness, and areal extent of the coal.

- Resource tables for the Harmon coal zone in the Bowman-Dickinson coalfield include coal and overburden thickness categories from Wood and others (1983), which are based on apparent coal rank. Resources are also reported by county, Federal coal and surface ownership categories, and 7.5-minute quadrangle.

- Following USGS published guidelines (Wood and others, 1983); coal resource estimates are divided into measured, indicated, and inferred categories according to relative abundance and reliability of data.

- Where data are widely spaced a hypothetical resource may be extrapolated.

- Measured resources are tonnage estimates of coal in the coal zone within a radius of 0.25 mi of a control point where the net thickness of coal is measured.

- Indicated resources are tonnage estimates of coal that is within a radius of 0.25-0.75 mi of a control point where the net thickness of the coal is measured.

- Inferred resources are tonnage estimates of coal that is within a radius of 0.75-3 mi of a control point where the net thickness of the coal is measured.

- Hypothetical resources are tonnage estimates of coal that is beyond a radius of 3 mi of a control point where the net thickness of coal is measured.

- These resource categories assume a high to low degree of geologic assurance. A statistical method that measures levels of uncertainty (confidence limits) for the Harmon resource estimates in the Bowman-Dickinson coalfield is also included in this study.

- Resource estimates are reported in millions of short tons with two significant figures.

HARMON COAL ZONE COAL RESOURCES

The lateral extent (study Limit) of the Harmon coal zone is defined by the Montana/North Dakota State line to the west and the eastern edge of Hettinger and Adams Counties to the east. The northern and southern study extents were based on paleodrainages (erosional and non-depositional "want" areas) modified from Cherven and Jacob (1985) and Rehbein (1977). The entire study area is about 2,936,000 acres (1,188,159 hectares) in size.

Harmon coal resources in the Bowman-Dickinson coalfield, in the Williston Basin of North Dakota were calculated using several software packages and custom programs. Details of the resource calculation methodology are given in Ellis and others (1999, in press).

To calculate the Harmon coal resources data were compiled in a StratiFact* (GRG Corporation, 1996) relational database. Coal beds that made up the Harmon coal zone were correlated in the database. A custom program was used to calculate net coal thickness at each data point (drill hole or measured section) location.

The net coal thickness and overburden were gridded, and isopach maps were produced using EarthVision* (Dynamic Graphics, Inc., 1997) software. The grids were made using an isopach grid option (special handling of 0 values and terminated data) with a grid spacing of 150 x 150 meters.

The spatial parameters for querying the coal resources (for example, 7.5-minute quadrangle map (fig. WN-1) area (U.S. Geological Survey National Mapping Division, unpublished data, undated), Federal coal and surface ownership (fig. WN-2) (Office of Surface Mining, unpublished data, undated), and reliability, net coal thickness (fig. WN-3), and overburden (fig. WN-4) categories) were created on individual layers as ARC/INFO* (ESRI, 1998a) polygon coverages. The coverages were unioned to make one polygon coverage with many attributes for each polygon. The polygons in the union coverage were edited in ARC/INFO* and ArcView* (ESRI, 1998b).

Coal resources were calculated using the EarthVision* (EV) volumetrics tool, which calculates tonnages in each polygon in the union coverage using the net coal thickness grid, the area of each polygon, and a conversion factor of 1,750 short tons per acre-ft for lignite rank coal (Wood and others, 1983). Data from the EV volumetrics report and the union coverage polygon attribute table were combined in Excel* (Microsoft, 1997) spreadsheet software. Data for polygons containing Harmon mines (fig. WN-3) or areas of net coal less than 2.5 ft in thickness were deleted from the data set. Resource tables were created using data from the remaining polygons (see tables WN-1, WN-2, and WN-3). The final resource area (fig. WN-3) (area that met all coal resource criteria) was about 2,586,000 acres (1,046,519 hectares) in size.

*Commercial software package

CONFIDENCE LIMITS FOR HARMON COAL ZONE COAL RESOURCES

A confidence interval is a statistic designed to capture uncertainty associated with a point estimate. In this study we computed 90-percent confidence intervals on the volume (total resource in millions of short tons) of coal in the Harmon coal zone in the measured, indicated, inferred, and hypothetical categories.

The three main potential sources of error that might bias the confidence intervals are preferential sampling, measurement errors, and model fitting. The probabilistic interpretation of a confidence interval is based upon a random sample, which does not apply in this situation, because there is preferential sampling in those areas deemed to be minable. Measurement error can be caused by an error in recording the coal bed thickness or in the definition of coverage areas. Modeling fitting variability and bias result from the choice of models and fitting procedures.

Confidence limits for coal resources of the Harmon coal zone in the Bowman-Dickinson coalfield, Williston Basin, North Dakota were calculated by J.H. Schuenemeyer and H.C. Power. The data set that they used contained net coal measurements from 348 locations. This data set only included locations that contained Harmon coal (no 0 net coal thickness values) and data that were representative of the entire coal zone (no terminated holes).

The confidence limits were derived through a complex series of steps. These steps included modeling coal thickness trends and removing the coal thickness trends using a nonparametric regression algorithm called loess (with span=0.5), using residual thickness to compute a semivariogram, and fitting the semivariogram to an exponential model. Parameter estimates were sill=26.65 ft^2, nugget=3.67 ft^2, and

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range=18.62 miles. Standard deviations of coal thickness were obtained from the semivariogram model. Differences in point densities were compensated for by calculating sample size, called a pseudo *n*, within each reliability category and calculating the variability of volume for each of the reliability categories. Volumes of Harmon coal were then calculated at a 90-percent confidence interval with measurement error. Some of the parameters used and results of the confidence interval calculations are shown in tables WN-5 and WN-6. A detailed description of the methodology used is given in Schuenemeyer and Power (in press) and in Ellis and others (1999, in press).

COAL RESOURCES—HANSEN COAL ZONE, BOWMAN-DICKINSON COALFIELD, WILLISTON BASIN, NORTH DAKOTA

HANSEN COAL ZONE RESOURCE ESTIMATES—AN OVERVIEW

- Coal resources are calculated using the specific gravity of the coal calculated from apparent coal rank, which is the weight of coal per unit volume, net coal thickness, and areal extent of the coal.

- Resource tables for the Hansen coal zone in the Bowman-Dickinson coalfield include coal and overburden thickness categories from Wood and others (1983), which are based on apparent coal rank. Resources are also reported by county, Federal coal and surface ownership categories, and 7.5-minute quadrangle.

- Following USGS published guidelines (Wood and others, 1983); coal resource estimates are divided into measured, indicated, and inferred categories according to relative abundance and reliability of data.

- Where data are widely spaced a hypothetical resource may be extrapolated.

- Measured resources are tonnage estimates of coal in the coal zone within a radius of 0.25 mi of a control point where the net thickness of coal is measured.

- Indicated resources are tonnage estimates of coal that is within a radius of 0.25-0.75 mi of a control point where the net thickness of the coal is measured.

- Inferred resources are tonnage estimates of coal that is within a radius of 0.75-3 mi of a control point where the net thickness of the coal is measured.

- Hypothetical resources are tonnage estimates of coal that is beyond a radius of 3 mi of a control point where the net thickness of coal is measured.

- These resource categories assume a high to low degree of geologic assurance. A statistical method that measures levels of uncertainty (confidence limits) for the Hansen resource estimates in the Bowman-Dickinson coalfield is also included in this study.

- Resource estimates are reported in millions of short tons with two significant figures.

HANSEN COAL ZONE COAL RESOURCES

The lateral extent (study limit) of the Hansen coal zone is defined by the Montana/North Dakota State line to the west and the eastern edge of Hettinger and Adams Counties to the east. The Hansen study area was divided into pods and bounded to the north and to the southwest, based paleodrainages (erosional and non-depositional "want" areas) modified from Cherven and Jacob (1985) and Rehbein (1977). The southeast boundary is defined by the North Dakota/South Dakota State line. The entire study area is about 1,728,000 acres (699,298 hectares) in size.

Hansen coal resources in the Bowman-Dickinson coalfield, in the Williston Basin of North Dakota were calculated using several software packages and custom programs. Details of the resource calculation methodology are given in Ellis and others (1999, in press).

To calculate the Hansen coal resources data were compiled in a StratiFact* (GRG Corporation, 1996) relational database. Coal beds that made up the Hansen coal

zone were correlated in the database. A custom program was used to calculate net coal thickness at each data point (drill hole or measured section) location.

The net coal thickness and overburden were gridded, and isopach maps were produced using EarthVision* (Dynamic Graphics, Inc., 1997) software. The grids were made using an isopach grid option (special handling of 0 values and terminated data) with a grid spacing of 150 x 150 meters.

The spatial parameters for querying the coal resources (for example, 7.5-minute quadrangle (fig. WN-5) map area (U.S. Geological Survey National Mapping Division, unpublished data, undated), Federal coal and surface ownership (fig. WN-6) (Office of Surface Mining, unpublished data, undated), and reliability, net coal thickness (fig. WN-7), and overburden (fig. WN-8) categories) were created on individual layers as ARC/INFO* (ESRI, 1998a) polygon coverages. The coverages were unioned to make one polygon coverage with many attributes for each polygon. The polygons in the union coverage were edited in ARC/INFO* and ArcView* (ESRI, 1998b).

Coal resources were calculated using the EarthVision* (EV) volumetrics tool, which calculates tonnages in each polygon in the union coverage using the net coal thickness grid, the area of each polygon, and a conversion factor of 1,750 short tons per acre-ft for lignite rank coal (Wood and others, 1983). Data from the EV volumetrics report and the union coverage polygon attribute table were combined in Excel* (Microsoft, 1997) spreadsheet software. Data for polygons containing Hansen mines (fig. WN-7) or areas of net coal less than 2.5 ft in thickness were deleted from the data set. Resource tables were created using data from the remaining polygons (tables WN-7, WN-8, and WN-9). The final resource area

(fig. WN-7) (area that met all coal resource criteria) was about 1,655,000 acres (669,756 hectares) in size.

*Commercial software package

CONFIDENCE LIMITS FOR HANSEN COAL ZONE COAL RESOURCES

A confidence interval is a statistic designed to capture uncertainty associated with a point estimate. In this study we computed 90-percent confidence intervals on the volume (total resource in millions of short tons) of coal in the Hansen coal zone in the measured, indicated, inferred, and hypothetical categories.

The three main potential sources of error that might bias the confidence intervals are preferential sampling, measurement errors, and model fitting. The probabilistic interpretation of a confidence interval is based upon a random sample, which does not occur in this situation, as there is preferential sampling in those areas deemed to be minable. Measurement error can be caused by an error in recording the coal bed thickness or in the definition of coverage areas. Modeling fitting variability and bias result from the choice of models and fitting procedures.

Confidence limits for coal resources of the Hansen coal zone in the Bowman-Dickinson coalfield were calculated by J.H. Schuenemeyer and H.C. Power. The data set that they used contained net coal measurements from 258 locations. This data only included locations that contained Hansen coal (no 0 net coal thickness values) and data that were representative of the entire coal zone (no terminated holes).

The confidence limits were derived through a complex series of steps. These steps included investigating coal thickness trends (no significant trend was detected), using coal thickness to compute a semivariagram, and fitting the semivariagram to a spherical model. Parameter estimates were sill=12.14 ft^2, nugget=3.96 ft^2, and range=6.63 miles. Standard deviations of coal thickness were obtained from the semivariogram model. Differences in point densities were compensated for by calculating sample size, called a pseudo n, within each reliability category and calculating the variability of volume for each of the reliability categories. Volumes of Hansen coal were then calculated at a 90-percent confidence interval with measurement error. Some of the parameters used and results of the confidence interval calculations are shown in tables WN-11 and WN-12. A detailed description of the methodology used is given in Schuenemeyer and Power (in press) and in Ellis and others (1999 and in press).

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COAL RESOURCES—BEULAH-ZAP COAL ZONE, BEULAH COALFIELD, WILLISTON BASIN, NORTH DAKOTA

BEULAH-ZAP COAL ZONE RESOURCE ESTIMATES—AN OVERVIEW

- Coal resources are calculated using the specific gravity of the coal calculated from apparent coal rank, which is the weight of coal per unit volume, net coal thickness, and areal extent of the coal.

- Resource tables for the Beulah-Zap coal zone in the Beulah coalfield include coal and overburden thickness categories from Wood and others (1983), which are based on apparent coal rank. Resources are also reported by county, Federal coal and surface ownership categories, and 7.5-minute quadrangle.

- Following USGS published guidelines (Wood and others, 1983); coal resource estimates are divided into measured, indicated, and inferred categories according to relative abundance and reliability of data.

- Where data are widely spaced a hypothetical resource may be extrapolated.

- Measured resources are tonnage estimates of coal in the coal zone within a radius of 0.25 mi of a control point where the net thickness of coal is measured.

- Indicated resources are tonnage estimates of coal that is within a radius of 0.25-0.75 mi of a control point where the net thickness of the coal is measured.

- Inferred resources are tonnage estimates of coal that is within a radius of 0.75-3 mi of a control point where the net thickness of the coal is measured.

- Hypothetical resources are tonnage estimates of coal that is beyond a radius of 3 mi of a control point where the net thickness of coal is measured.

- These resource categories assume a high to low degree of geologic certainty. A statistical method that measures levels of uncertainty (confidence limits) for the Beulah-Zap resource estimates in the Beulah coalfield is also included in this study.

- Resource estimates are reported in millions of short tons with two significant figures.

Beulah-Zap Coal Zone Coal Resources

The lateral extent (study limit) of the Beulah-Zap coal zone is defined by outcrop information from Groenwald and others (1979), erosional "want" areas interpreted from our stratigraphic data, and a generalized western boundary on the two largest western pods of data based on our data limits. The entire study area is about 297,000 acres (120,192 hectares) in size.

Beulah-Zap coal resources in the Beulah coalfield, in the Williston Basin of North Dakota were calculated using several software packages and custom programs. Details of the resource calculation methodology are given in Ellis and others (1999, in press).

To calculate the Beulah-Zap coal resources data was compiled in a StratiFact* (GRG Corporation, 1996) relational database. The coal beds that made up the Beulah-Zap coal zone were then correlated in the database. A custom program was used to calculate net coal thickness at each data point (drill hole or measured section) location.

The net coal thickness and overburden were gridded, and isopach maps were produced using EarthVision* (Dynamic Graphics, Inc., 1997) software. The grids were made using an isopach grid option (special handling of 0 values and terminated data) with a grid spacing of 150 x 150 meters.

The spatial parameters for querying the coal resources (for example, 7.5-minute quadrangle (fig. WN-9) map area (U.S. Geological Survey National Mapping Division, unpublished data, undated), Federal coal and surface ownership (fig. WN-10) (Office of Surface Mining, unpublished data, undated), and reliability, coal thickness (fig. WN-11), and overburden (fig. WN-12) categories) were created on individual layers as ARC/INFO* (ESRI, 1998a) polygon coverages. The coverages were unioned to make one polygon coverage with many attributes for each polygon. The polygons in the union coverage were edited in ARC/INFO* and ArcView* (ESRI, 1998b).

Coal resources were calculated using the EarthVision* (EV) volumetrics tool, which calculates tonnages in each polygon in the union coverage using the net coal thickness grid, the area of each polygon, and a conversion factor of 1,750 short tons per acre-ft for lignite rank coal (Wood and others, 1983). Data from the EV volumetrics report and the union coverage polygon attribute table were combined in Excel* (Microsoft, 1997) spreadsheet software. Data for polygons containing Beulah-Zap mine areas (fig. WN-11) or areas of net coal less than 2.5 ft in thickness were deleted from the data set. Resource tables were created using data from the remaining polygons (tables WN-13, WN-14, and WN-15). The final resource area (fig. WN-11) (area that met all coal resource criteria) was about 257,000 acres (104,004 hectares) in size.

*Commercial software package

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CONFIDENCE LIMITS FOR BEULAH-ZAP COAL ZONE COAL RESOURCES

A confidence interval is a statistic designed to capture uncertainty associated with a point estimate. In this study we computed 90-percent confidence intervals on the volume (total resource in millions of short tons) of coal in the Beulah-Zap coal zone in the measured, indicated, inferred, and hypothetical categories.

The three main potential sources of error that might bias the confidence intervals are preferential sampling, measurement errors, and model fitting. The probabilistic interpretation of a confidence interval is based upon a random sample, which does not apply in this situation, because there is preferential sampling in those areas deemed to be minable. Measurement error can be caused by an error in recording the coal bed thickness or in the definition of coverage areas. Modeling fitting variability and bias result from the choice of models and fitting procedures.

Confidence limits for coal resources of the Beulah-Zap coal zone in the Beulah coalfield, Williston Basin, North Dakota were calculated by J.H. Schuenemeyer and H.C. Power. The data set that they used contained net coal measurements from 2,040 locations. This data set only included locations that contained Beulah-Zap coal (no 0 net coal thickness values) and data that were representative of the entire coal zone (no terminated holes).

The confidence limits were derived through a complex series of steps. These steps included modeling coal thickness trends and removing the coal thickness trends using a nonparametric regression algorithm called loess (with span=0.5). Spatial correlation, as determined from the semivariogram of residual thickness, was negligible. Standard deviations of coal thickness were obtained from the residual

thickness. Differences in point densities were compensated for by calculating sample size, called a pseudo *n*, within each reliability category and calculating the variability of volume for each of the reliability categories. Volumes of Beulah-Zap coal were then calculated at a 90-percent confidence interval with measurement error. Some of the parameters used and results of the confidence interval calculations are shown in tables WN-16 and WN-17. A detailed description of the methodology used is given in Schuenemeyer and Power (in press) and in Ellis and others (1999, in press).

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COAL RESOURCES—HAGEL COAL ZONE, BOWMAN-DICKINSON COALFIELD, WILLISTON BASIN, NORTH DAKOTA

HAGEL COAL ZONE RESOURCE ESTIMATES—AN OVERVIEW

- Coal resources are calculated using the specific gravity of the coal calculated from apparent coal rank, which is the weight of coal per unit volume, net coal thickness, and areal extent of the coal.

- Resource tables for the Hagel coal zone in the Center-Falkirk coalfield include coal and overburden thickness categories from Wood and others (1983), which are based on apparent coal rank. Resources are also reported by county, Federal coal and surface ownership categories, and 7.5-minute quadrangle.

- Following USGS published guidelines (Wood and others, 1983); coal resource estimates are divided into measured, indicated, and inferred categories according to relative abundance and reliability of data.

- Where data are widely spaced a hypothetical resource may be extrapolated.

- Measured resources are tonnage estimates of coal in the coal zone within a radius of 0.25 mi of a control point where the net thickness of coal is measured.

- Indicated resources are tonnage estimates of coal that is within a radius of 0.25-0.75 mi of a control point where the net thickness of the coal is measured.

- Inferred resources are tonnage estimates of coal that is within a radius of 0.75-3 mi of a control point where the net thickness of the coal is measured.

- Hypothetical resources are tonnage estimates of coal that is beyond a radius of 3 mi of a control point where the net thickness of coal is measured.

- These resource categories assume a high to low degree of geologic assurance. A statistical method that measures levels of uncertainty (confidence limits) for the Hagel resource estimates in the Center-Falkirk coalfield is also included in this study.

- Resource estimates are reported in millions of short tons with two significant figures.

HAGEL COAL ZONE COAL RESOURCES

The lateral extent (study limit) of the Hagel coal is defined by outcrop information from the Groenwald and others (1979), erosional "want" areas interpreted from our stratigraphic data, and a generalized western boundary on the two largest western pods of data based on our data limits. The entire study area is 336,000 acres (135,975 hectares) in size.

Hagel coal resources in the Center-Falkirk coalfield, in the Williston Basin of North Dakota were calculated using several software packages and custom programs. Details of the resource calculation methodology are given in Ellis and others (1999, in press).

To calculate the Hagel coal resources data was compiled in a StratiFact* (GRG Corporation, 1996) relational database. Coal beds that made up the Hagel coal zone were then correlated in the database. A custom program was used to

calculate net coal thickness at each data point (drill hole or measured section) location.

The net coal thickness and overburden were gridded, and isopach maps were produced using EarthVision* (Dynamic Graphics, Inc., 1997) software. The grids were made using an isopach grid option (special handling of 0 values and terminated data) with a grid spacing of 150 x 150 meters.

The spatial parameters for querying the coal resources (for example, 7.5-minute quadrangle (fig. WN-13) map area (U.S. Geological Survey National Mapping Division, unpublished data, undated), Federal coal and surface ownership (fig. WN-14) (Office of Surface Mining, unpublished data, undated), and reliability, net coal thickness (fig. WN-15), and overburden (fig. WN-16) categories) were created on individual layers as ARC/INFO* (ESRI, 1998a) polygon coverages. The coverages were unioned to make one polygon coverage with many attributes for each polygon. The polygons in the union coverage were edited in ARC/INFO* and ArcView* (ESRI, 1998b).

Coal resources were calculated using the EarthVision* (EV) volumetrics tool, which calculates tonnages in each polygon in the union coverage using the net coal thickness grid, the area of each polygon, and a conversion factor of 1,750 short tons per acre-ft for lignite rank coal (Wood and others, 1983). Data from the EV volumetrics report and the union coverage polygon attribute table were combined in Excel* (Microsoft, 1997) spreadsheet software. Data for polygons containing Hagel mine areas (fig. WN-15) or areas of net coal less than 2.5 ft in thickness were deleted from the data set. Resource tables were created using data from the remaining polygons (tables WN-18, WN-19, and WN-20). The final resource area

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(fig. WN-15) (area that met all coal resource criteria) was about 256,000 acres (103,600 hectares) in size.

*Commercial software package

CONFIDENCE LIMITS FOR HAGEL COAL ZONE COAL RESOURCES

A confidence interval is a statistic designed to capture uncertainty associated with a point estimate. In this study we computed 90-percent confidence intervals on the volume (total resource in millions of short tons) of coal in the Hagel coal zone in the measured, indicated, inferred, and hypothetical categories.

The three main potential sources of error that might bias the confidence intervals are preferential sampling, measurement errors, and model fitting. The probabilistic interpretation of a confidence interval is based upon a random sample, which does not apply in this situation, because there is preferential sampling in those areas deemed to be minable. Measurement error can be caused by an error in recording the coal bed thickness or in the definition of coverage areas. Modeling fitting variability and bias result from the choice of models and fitting procedures.

Confidence limits for coal resources of the Hagel coal zone in the Center-Falkirk coalfield, Williston Basin, North Dakota were calculated by J.H. Schuenemeyer and H.C. Power. The data set that they used contained net coal measurements from 1,672 locations. This data set only included locations that contained Hagel coal (no 0 net coal thickness values) and data that were representative of the entire coal zone (no terminated holes).

The confidence limits were derived through a complex series of steps. These steps included investigating coal thickness trends (no significant trend was detected),

using coal thickness to compute a semivariagram, and fitting the semivariagram to an exponential model. Parameter estimates were sill=31.99 ft^2, nugget=13.73 ft^2, and range=4.71 miles. Standard deviations of coal thickness were obtained from the semivariogram model. Differences in point densities were compensated for by calculating sample size, called a pseudo *n*, within each reliability category and calculating the variability of volume for each of the reliability categories. Volumes of Hagel coal were then calculated at a 90-percent confidence interval with measurement error. Some of the parameters used and results of the confidence interval calculations are shown in tables WN-21 and WN-22. A detailed description of the methodology used is given in Schuenemeyer and Power (in press) and in Ellis and others (1999, in press).

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REFERENCES CITED

Cherven, V.B. and Jacob, A.R., 1985, Evolution of Paleogene depositional systems, Williston Basin in response to global sea level changes, *in* R.M. Flores and S.S. Kaplan eds., Cenozoic Paleogeography of the West-central United States: Society of Economic Paleontologist and Mineralogists, Rocky Mountain Rocky Mountain Paleogeography Symposium 3, p. 127-170, fig. 12.

Dynamic Graphics, Inc., 1997, EarthVision, v.4: Dynamic Graphics, Inc., 1015 Atlantic Ave., Alameda, CA 94501.

Ellis, M.S., Gunther, G.L., Flores, R.M., Ochs, A.M., Stricker, G.D., Roberts, S.B., Taber, T.T., Bader, L.R., and Schuenemeyer, J.H., 1999, Preliminary report on coal resources of the Wyodak-Anderson coal zone, Powder River Basin, Wyoming and Montana: U.S. Geological Survey Open-File Report 98-789A.

Ellis, M.S., Gunther, G.L., Flores, R.M. Stricker, G.D., and Ochs, A.M., in press, Preliminary report on methodolgy for calculating coal resources of the Wyodak-Anderson coal zone in the Powder River Basin, Wyoming and Montana, U.S. Geological Survey Open-File Report 98-789B.

ESRI-Environmental Systems Research Institute, Inc., 1998a, ARC/INFO, v. 7.1.1: Environmental Systems Research Institute, Inc., 380 New York Street, Redlands, CA 92373, USA.

_____ 1998b, ArcView, v.3.0a: Environmental Systems Research Institute, Inc., 380 New York Street, Redlands, CA 92373, USA.

GRG Corporation, 1996, StratiFact, relational database software, v. 4.5: GRG Corporation, 4175 Harlan Street, Wheatridge, CO 80033-5150, USA.

Groenwald, G.H., Hemish, L.A., Cherry, J.A., Rehm, B.W., Meyer, G.N., and Winczewski, L.M., 1979, Geology and geohydrology of the Knife River Basin and adjacent areas of west-central North Dakota: North Dakota Geological Survey Report of Investigations 64, p. 402, scale 1:100,000.

Microsoft, 1997, Excel spreadsheet software, v. Office 97: Microsoft Corporation, 1 Microsoft Way, Redman, WA 98052.

Rehbein, E.A., 1977, Preliminary report on stratigraphy and depositional environments of the lignites in the Fort Union Formation, west central North Dakota: U.S. Geological Survey Open-File Report 77-69, 23 p.

Schuenemeyer, J. H. and Power H.C., in press, Uncertainty estimation for resource assessment—An application to coal: Mathematical Geology.

Wood, G.H. Jr., Kehn, T.M., Carter, M.D., and Culbertson, W.C., 1983, Coal resource classification system of the U.S. Geological Survey: U.S. Geological Survey Circular 891, 65 p.

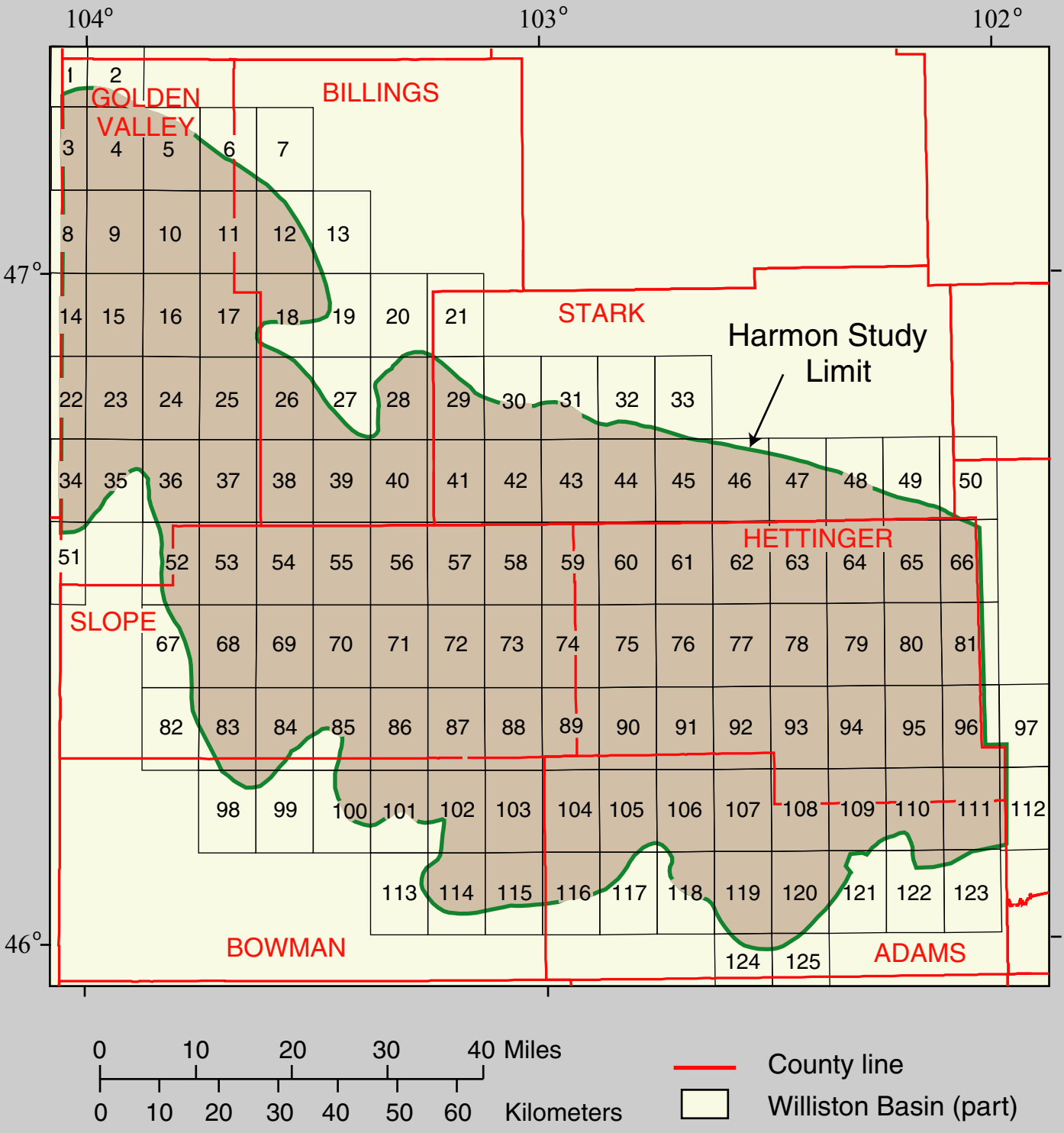

Figure WN-1. Location of 7.5-minute quadrangle maps in the Harmon study limit.

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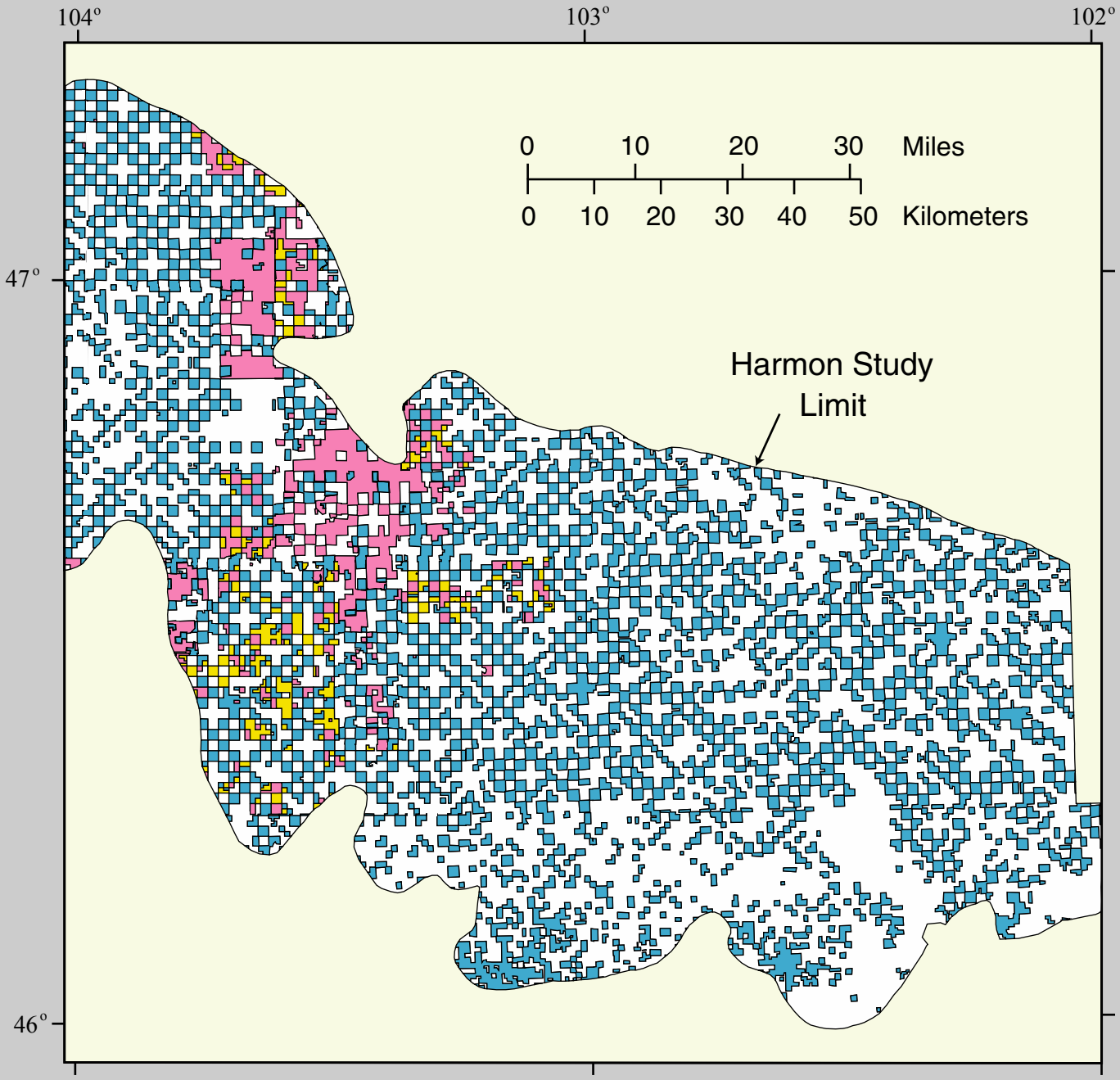
in the toolbar to return.



Federal coal = Federal subsurface management of all minerals, coal only, or oil, gas, and coal

Federal surface = Federal surface ownership

- Federal coal and surface
- Federal coal, but no Federal surface
- No Federal coal, but Federal surface
- No Federal coal or surface
- Williston Basin (part)

Figure WN-2. Federal coal and surface ownership in the Harmon study limit.

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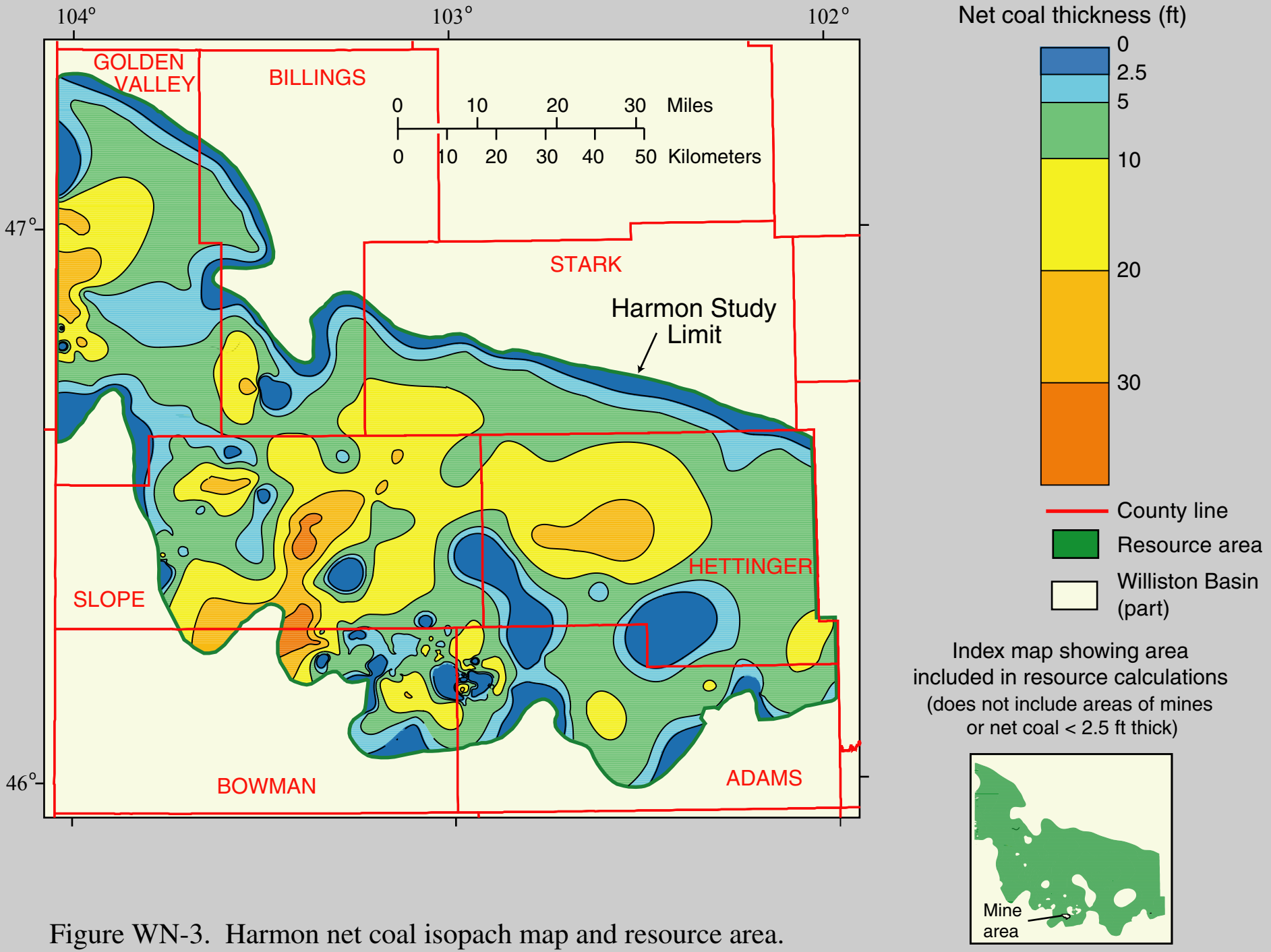

Figure WN-3. Harmon net coal isopach map and resource area.

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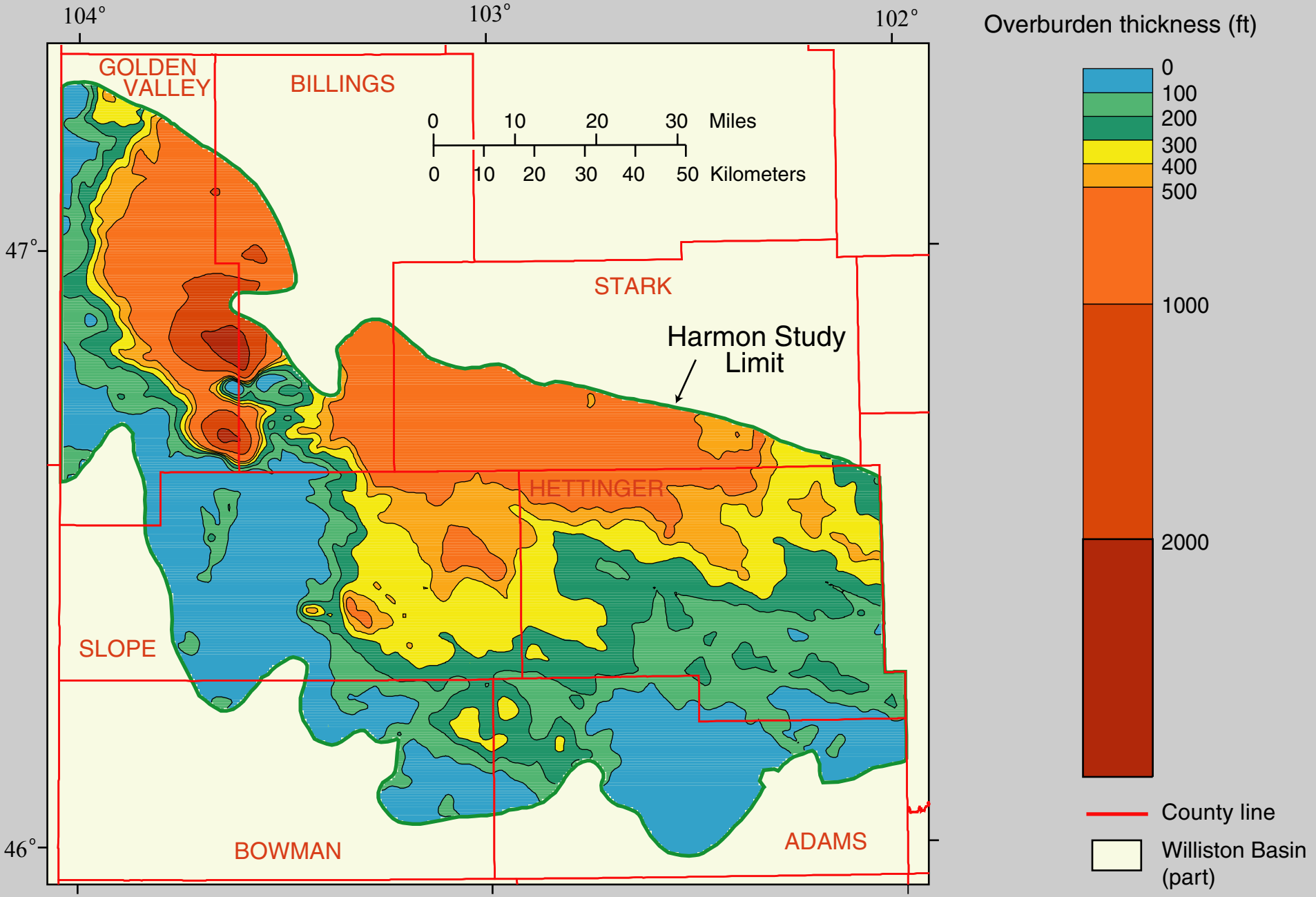

Figure WN-4. Harmon overburden isopach map.

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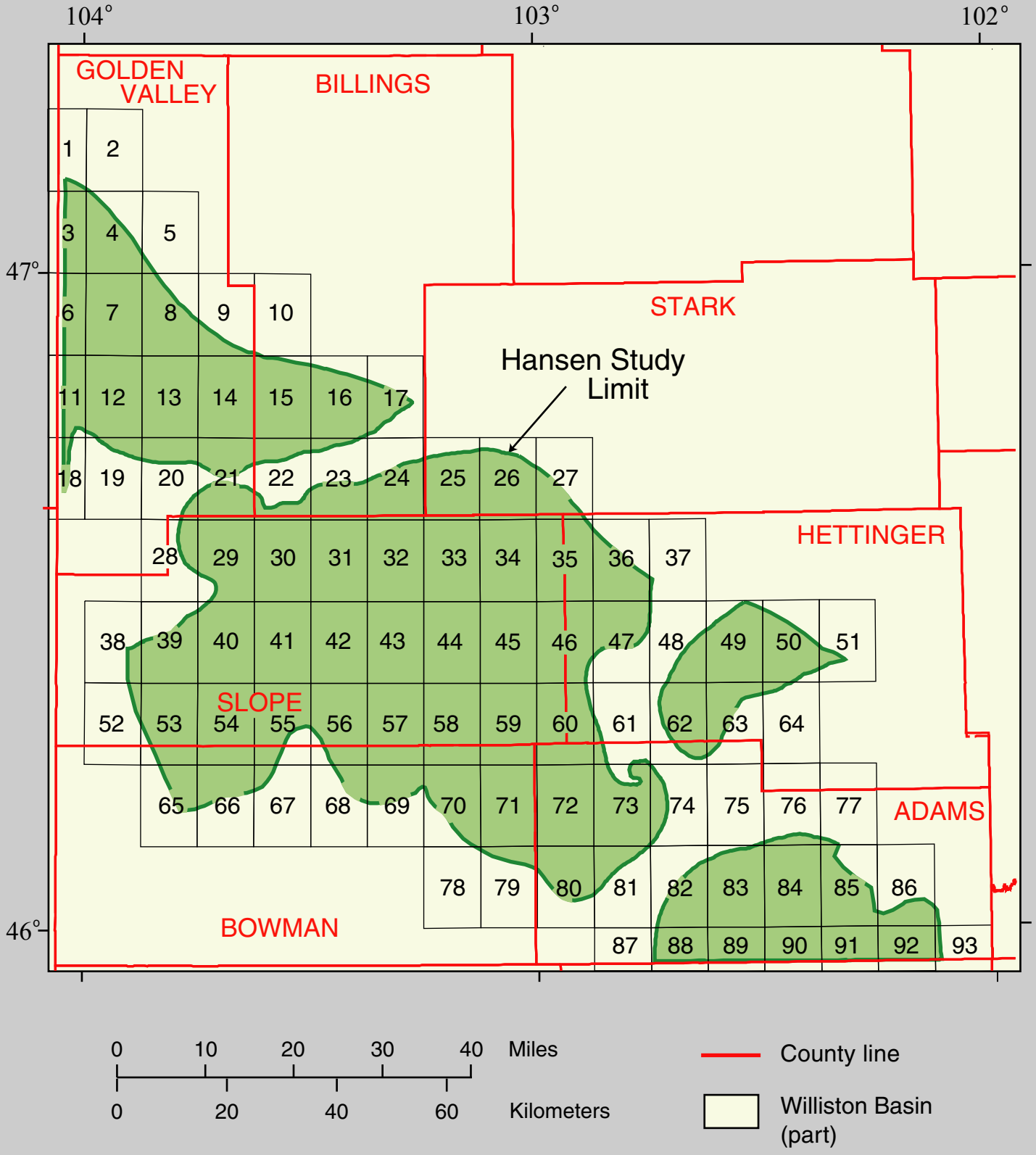

Figure WN-5. Location of 7.5-minute quadrangle maps in the Hansen study limit.

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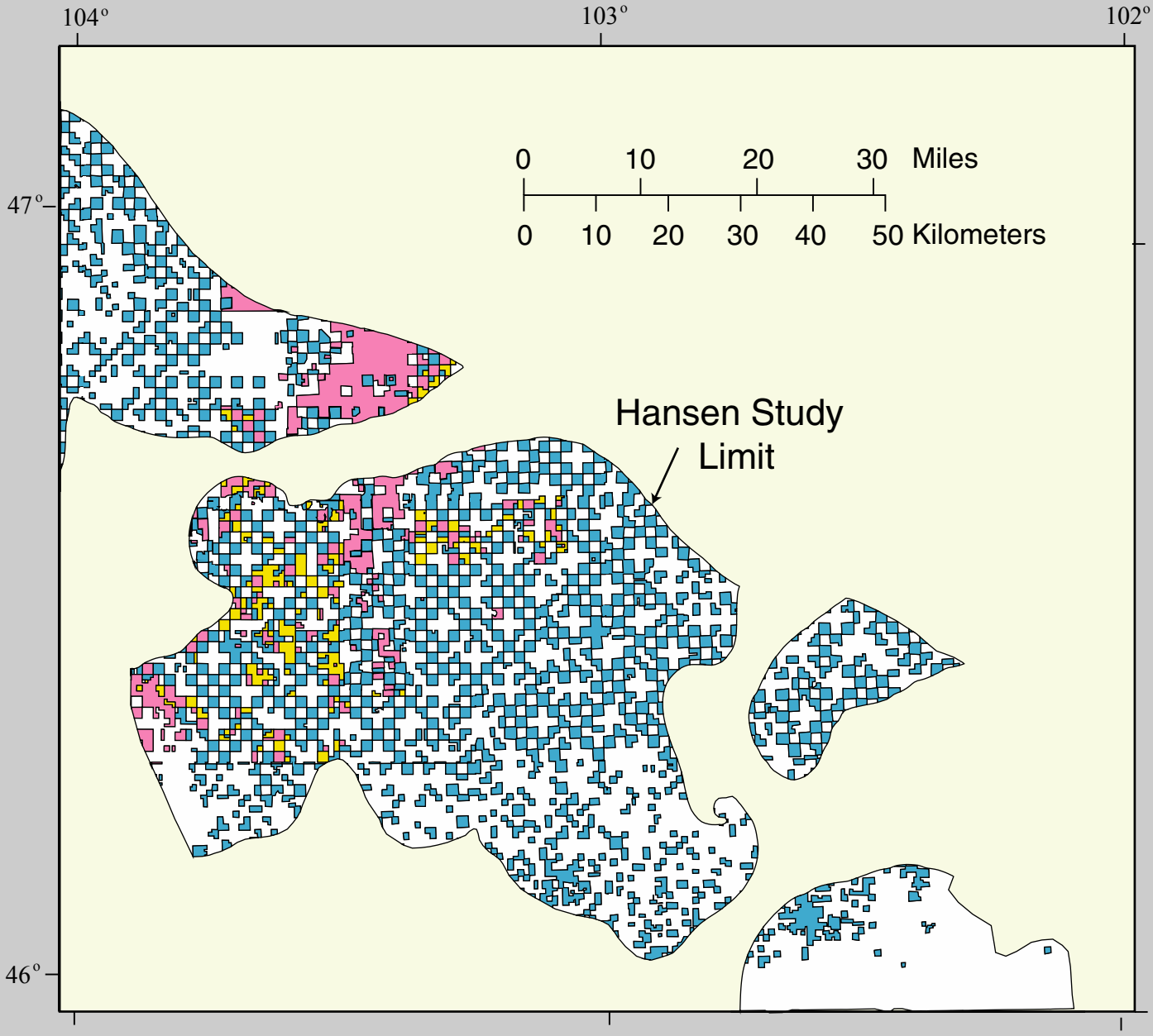

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- Federal coal and surface
- Federal coal, but no Federal surface
- No Federal coal, but Federal surface
- No Federal coal or surface
- Williston Basin (part)

Figure WN-6. Federal coal and surface ownership in the Hansen study limit.

Click here or on this symbol
in the toolbar to return.

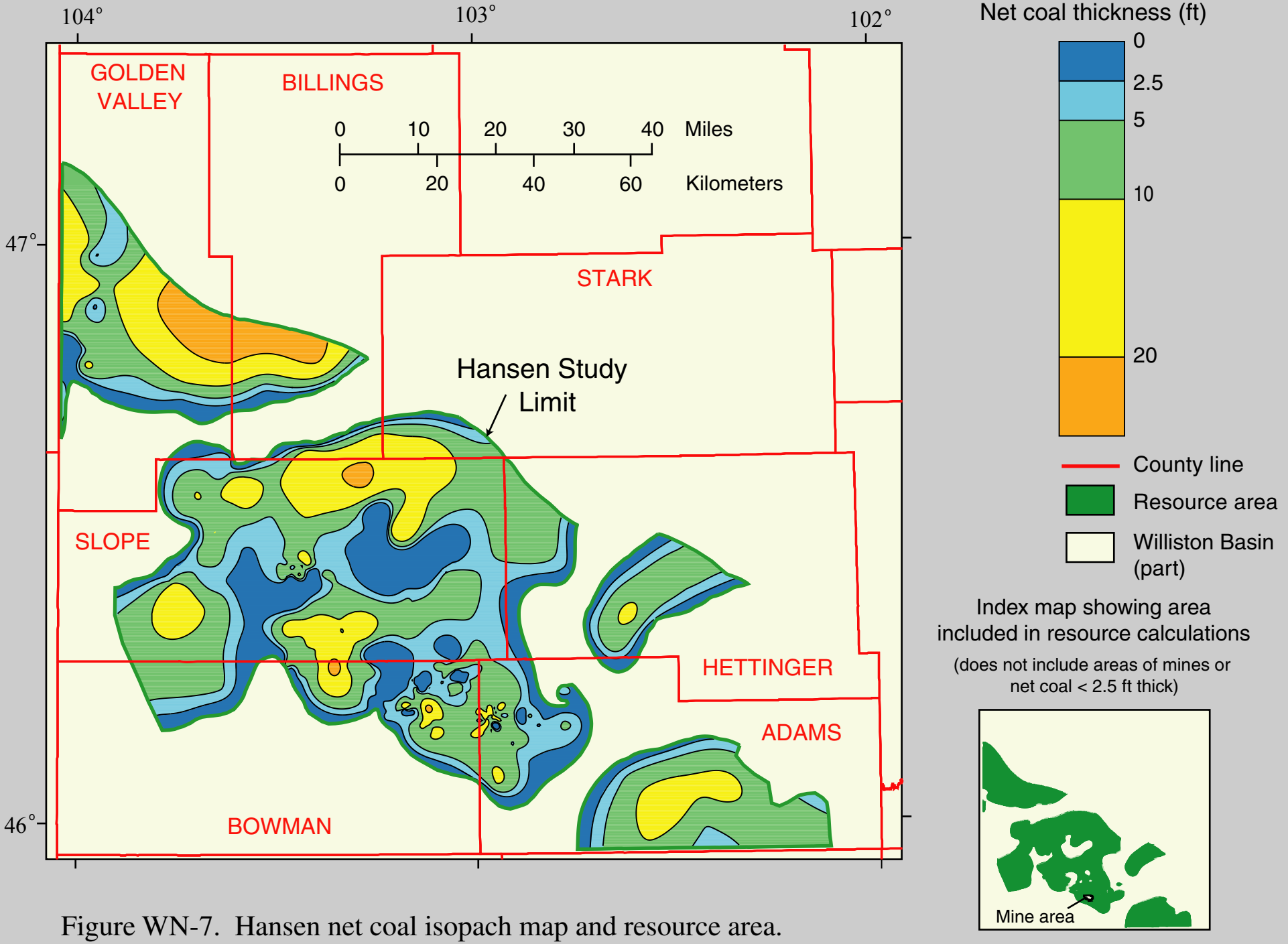

Figure WN-7. Hansen net coal isopach map and resource area.

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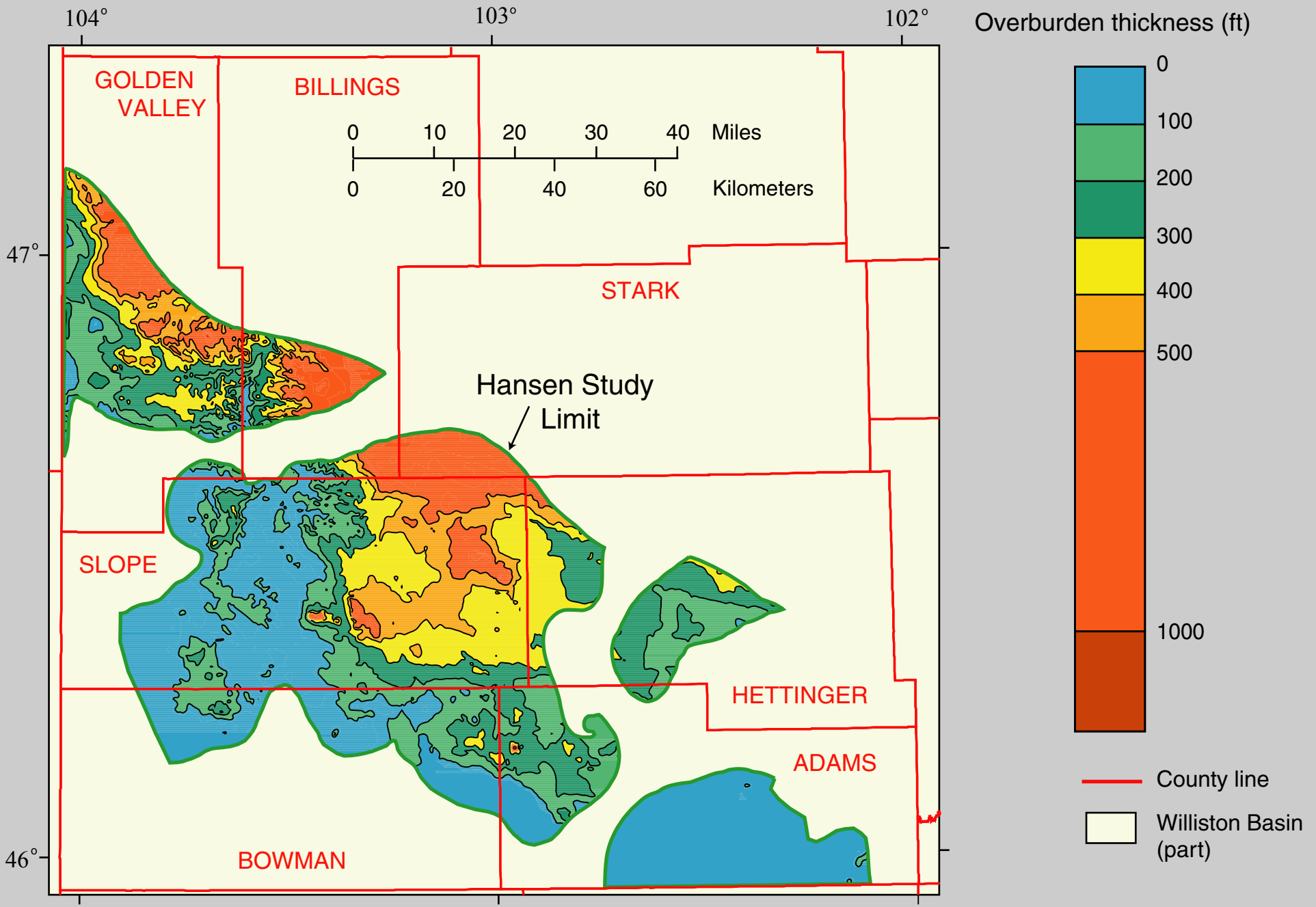
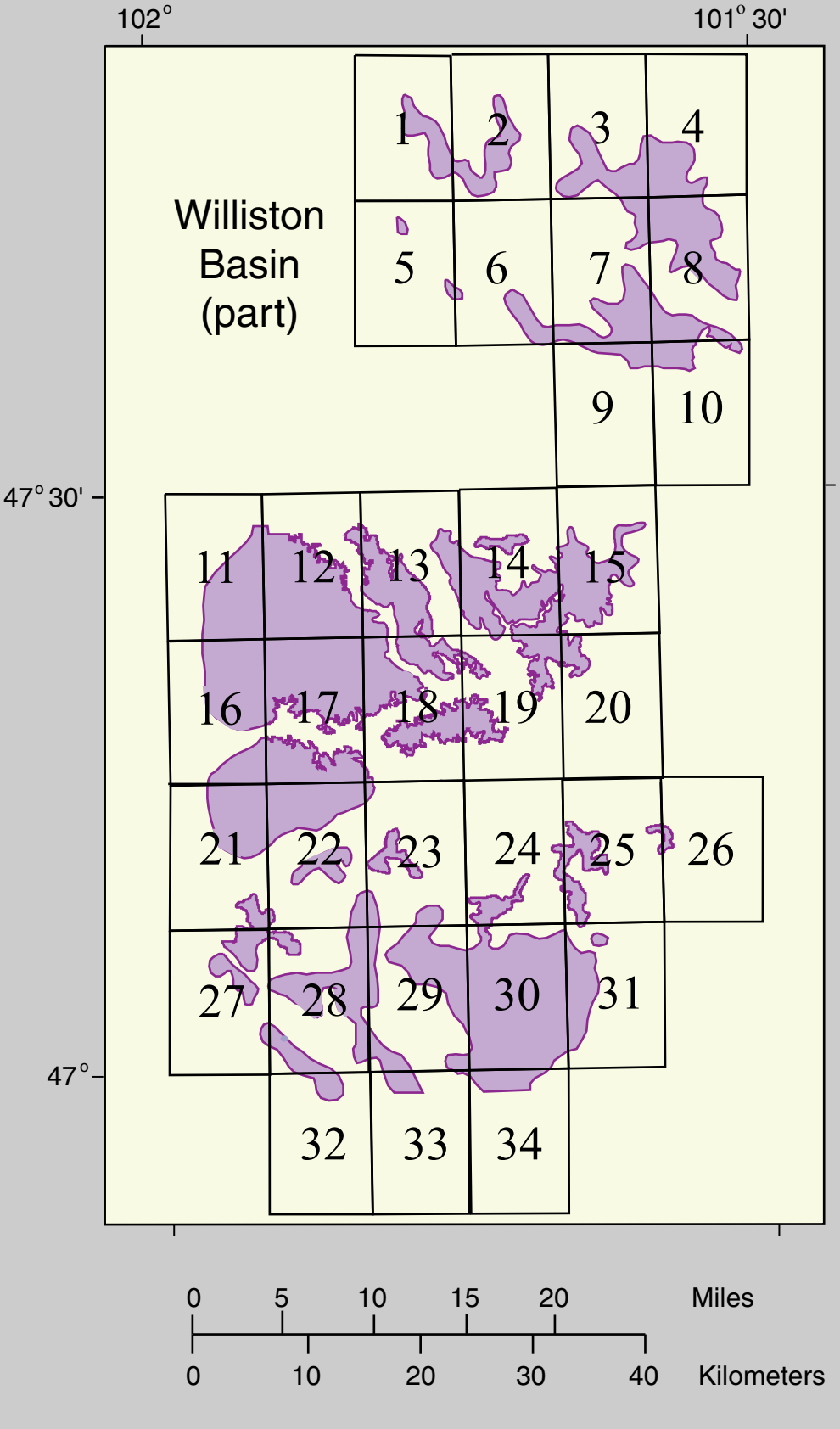


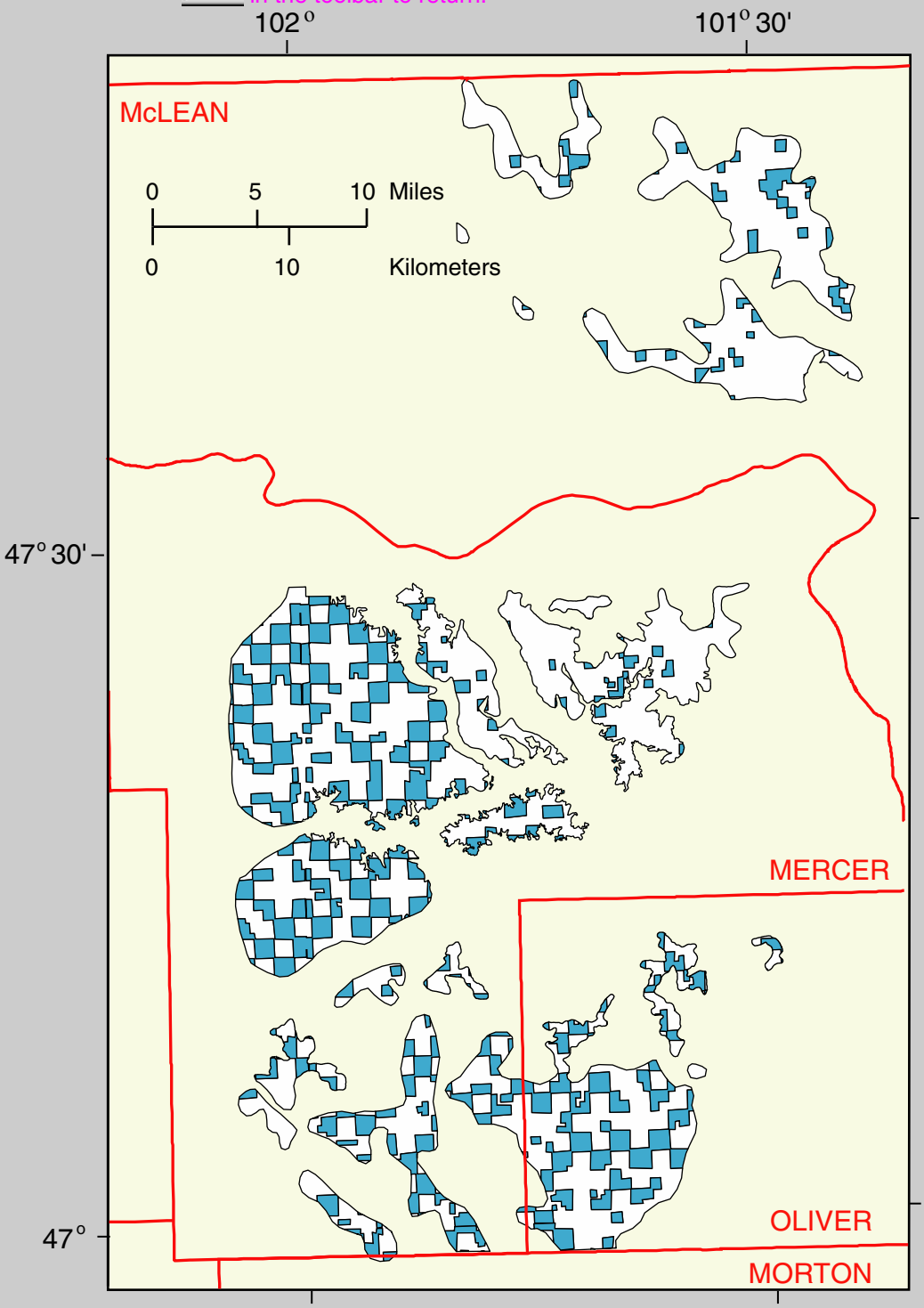
Figure WN-8. Hansen overburden isopach map.



Key to 7.5-minute quadrangle maps

1 Roseglen
2 Blue Hill
3 Douglas West
4 Douglas East
5 Blackwater Lake
6 Emmett
7 Emmett NE
8 Garrison
9 Emmett SE
10 Garrison Dam North
11 Golden Valley NE
12 Beulah NW
13 Beulah NE
14 Hazen NW
15 Hazen NE
16 Golden Valley
17 Zap
18 Beulah
19 Hazen West
20 Hazen East
21 Schaffner Creek NE
22 Medicine Butte
23 Medicine Butte NE
24 Red Butte NW
25 Red Butte
26 Hannover NW
27 Willow Creek East
28 Medicine Butte SW
29 Medicine Butte SE
30 Red Butte SW
31 Otter Creek
32 Glen Ullin NW
33 Glen Ullin NE
34 Hailstone Butte

Figure WN-9. Location of 7.5-minute quadrangle maps in the Beulah-Zap study limit.



Federal coal = Federal subsurface management of all minerals, coal only, or oil, gas, and coal

Federal surface = Federal surface ownership

Federal coal, but no Federal surface

No Federal coal or surface

Williston Basin (part)

County line

Figure WN-10. Federal coal and surface ownership in the Beulah-Zap study limit.

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in the toolbar to return.

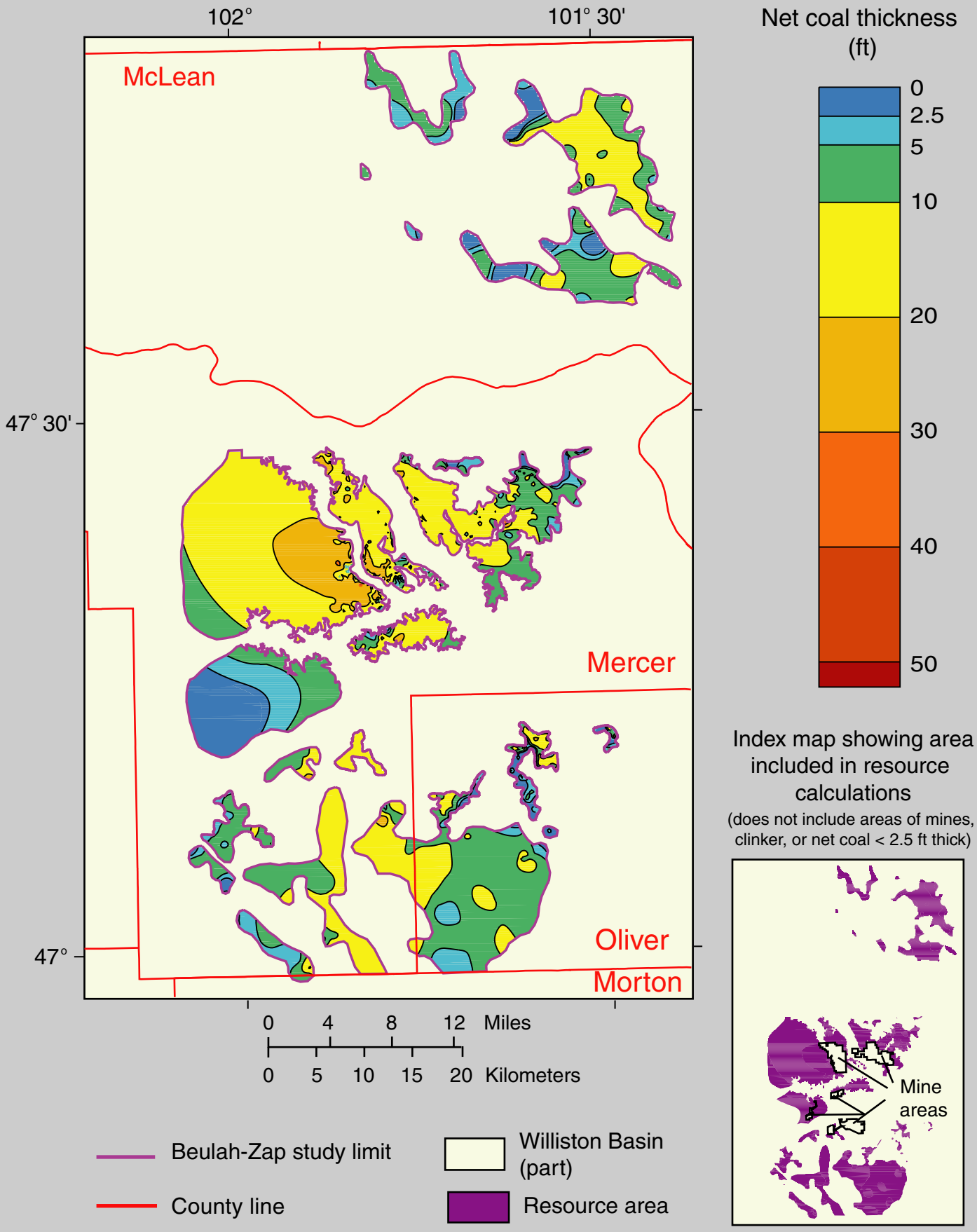

Figure WN-11. Beulah-Zap net coal isopach map and resource area.

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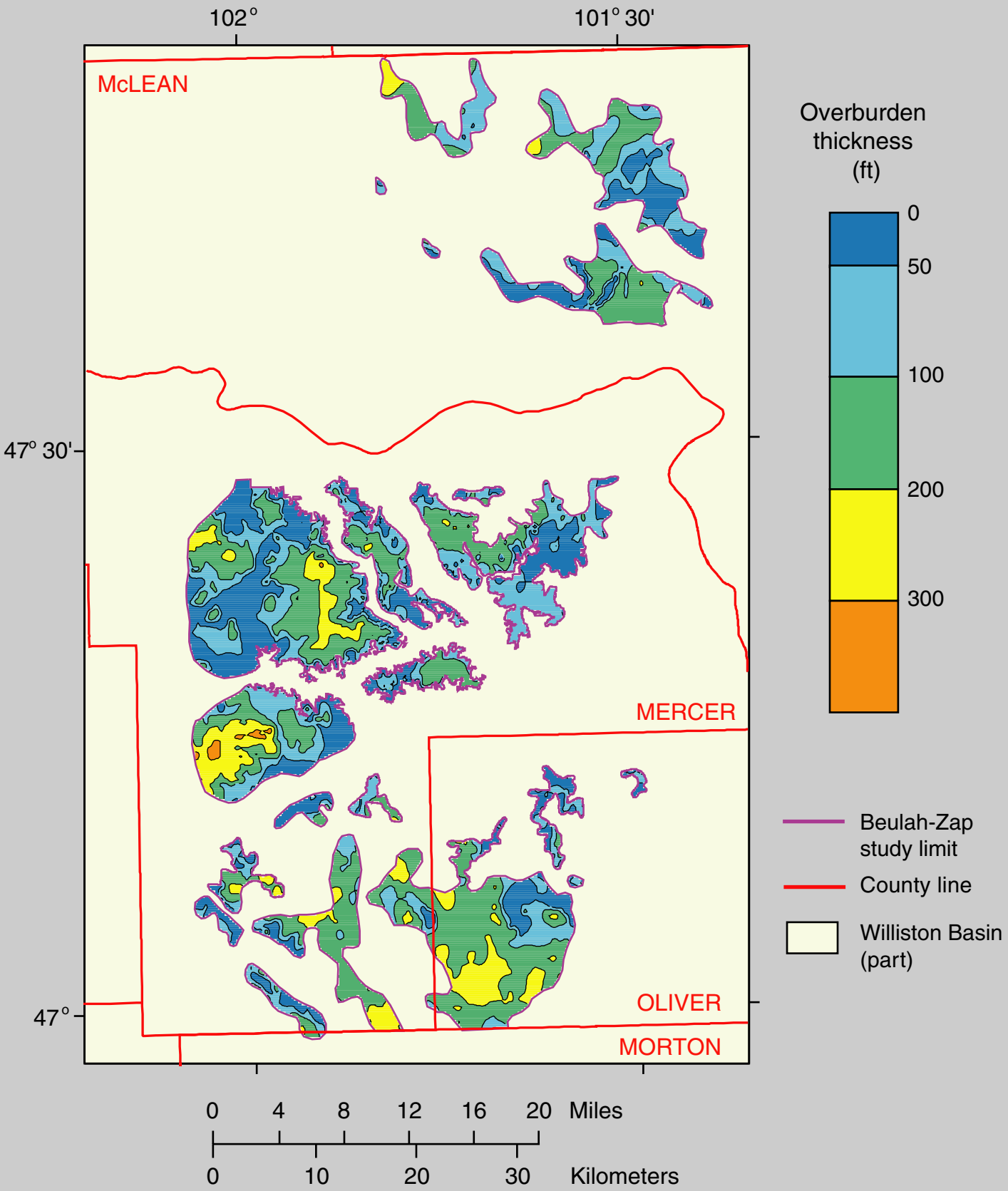
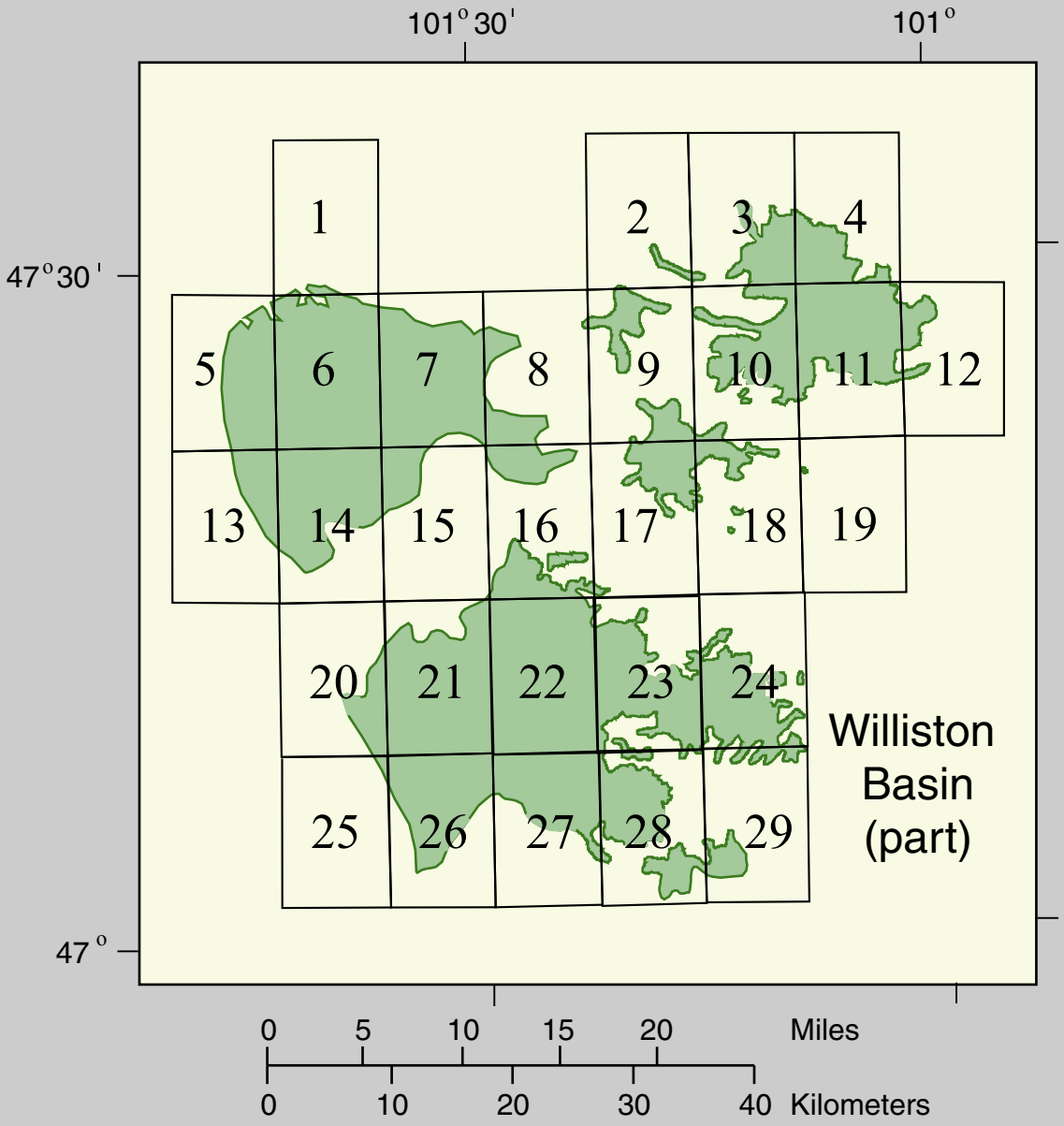


Figure WN-12. Beulah-Zap overburden isopach map.



Key to 7.5-minute quadrangle maps

1	Emmett SW	11	Washburn NE	21	Red Butte
2	Riverdale North	12	Turtle Creek NW	22	Hannover NW
3	Coleharbor	13	Beulah	23	Hannover NE
4	Lake Nettie	14	Hazen West	24	Fort Clark
5	Beulah NE	15	Hazen East	25	Red Butte
6	Hazen NW	16	Stanton	26	Otter Creek
7	Hazen NE	17	Stanton SE	27	Hannover
8	Garrison Dam South	18	Washburn SW	28	Center
9	Riverdale South	19	Washburn	29	Nelson Lake
10	Underwood	20	Red Butte NW		

Figure WN-13. Location of 7.5-minute quadrangle maps in the Hagel study limit.

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in the toolbar to return.

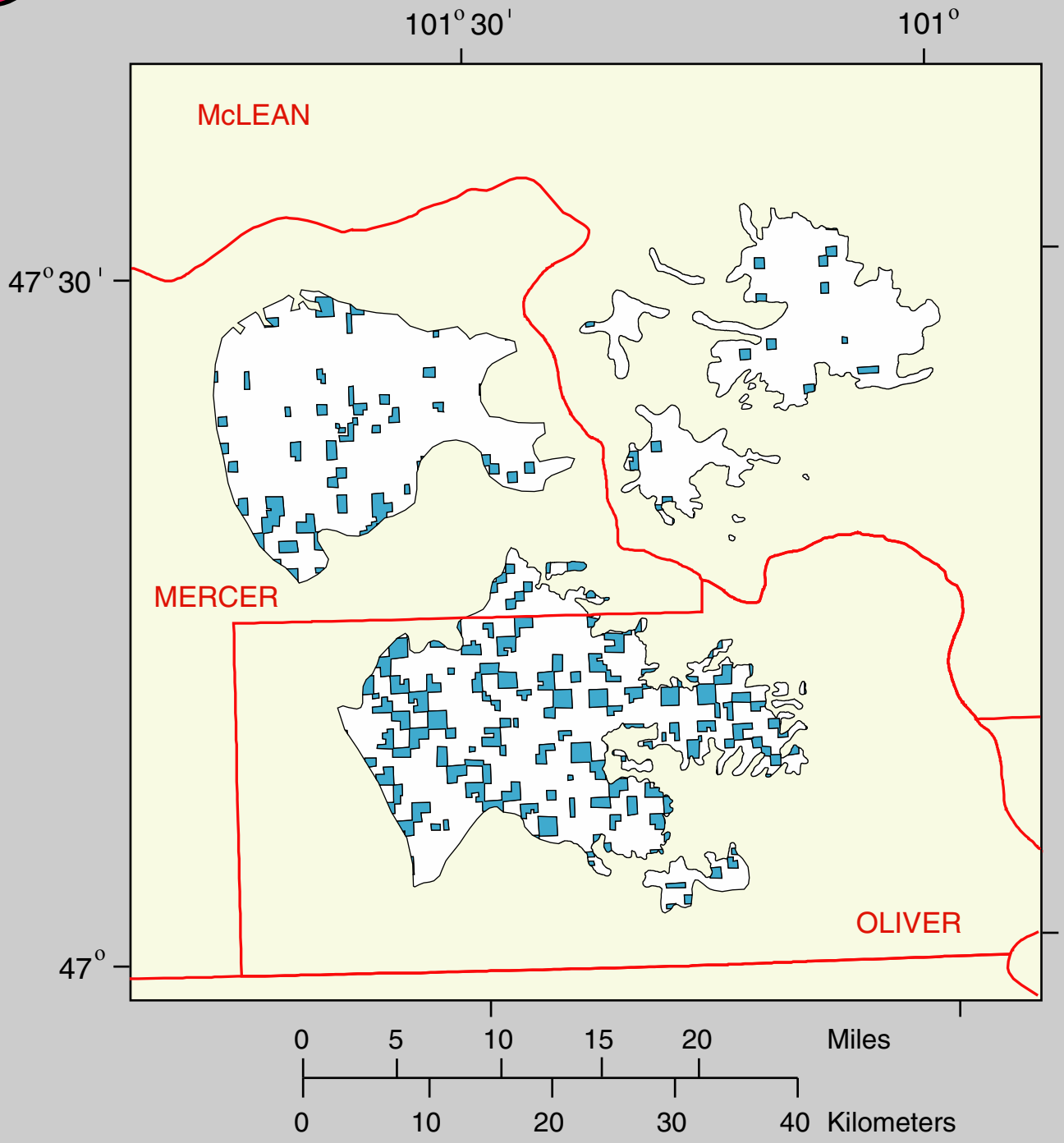

Figure WN-14. Federal coal and surface ownership in the Hagel study limit Center-Falkirk coalfield.

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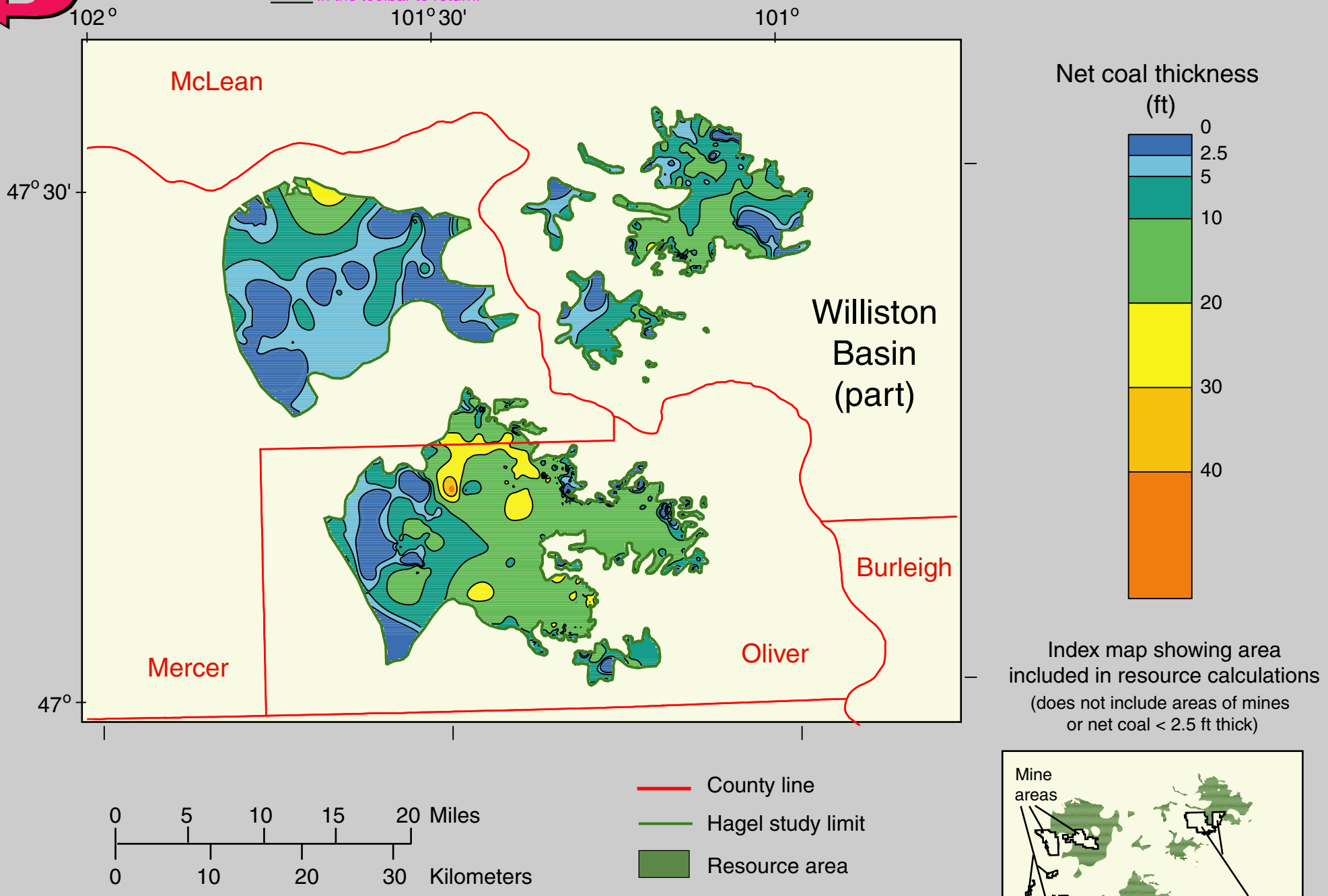

Figure WN-15. Hagel net coal isopach map and resource area.

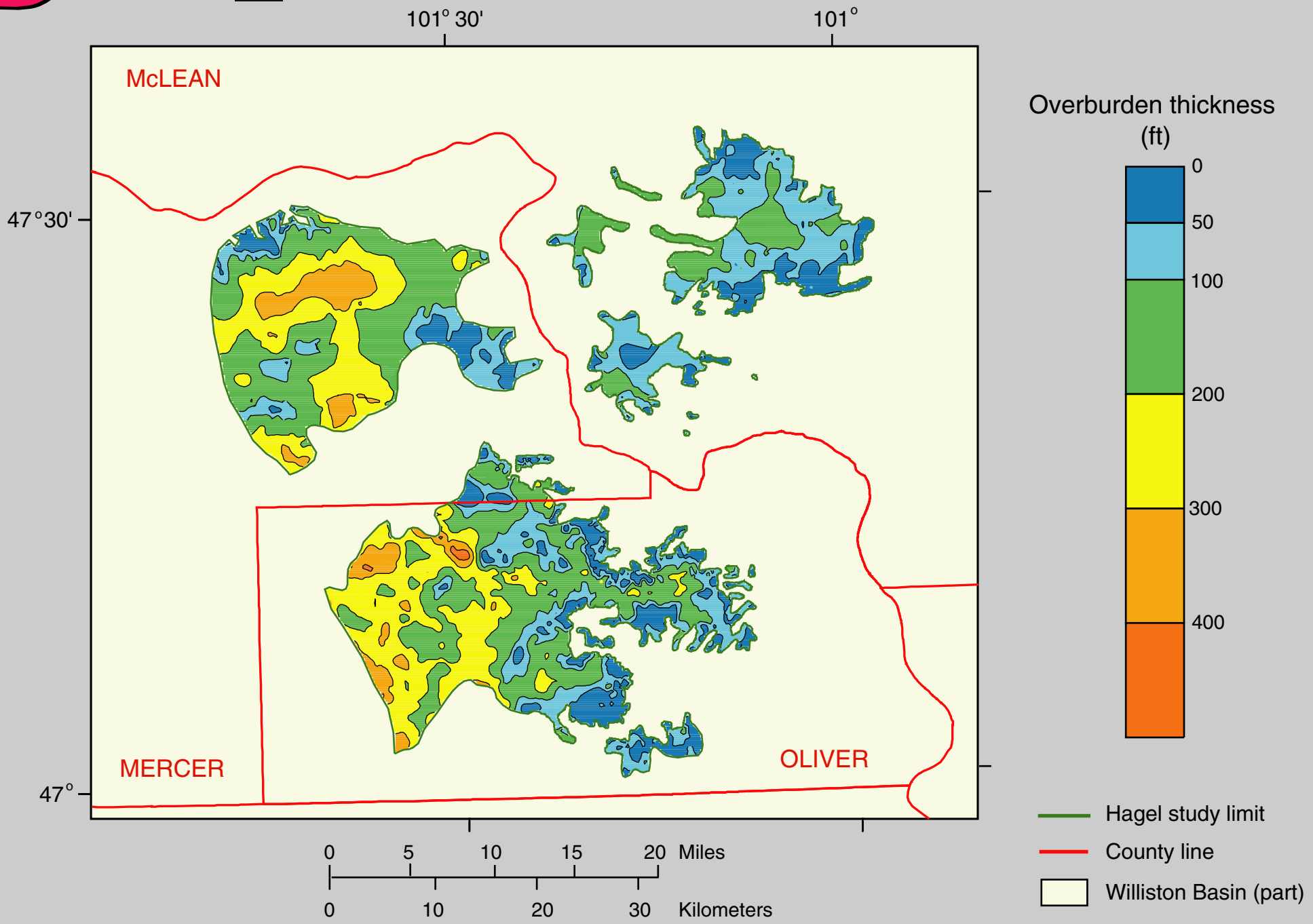

Figure WN-16. Hagel overburden isopach map.

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in the toolbar to return.

Table WN-1. Coal resources of the Harmon coal zone in the Bowman-Dickinson coalfield, Williston Basin, North Dakota, reported by county (fig. WN-1), overburden (fig. WN-4), coal thickness (fig. WN-3), and reliability categories. Zeros (0) indicate areas where no resources were calculated. Table does not include resources for coal less than 2.5 ft thick or coal in mine areas (fig. WN-3). Resources are reported in millions of short tons (MST) with two significant figures. Resource numbers will not sum to match totals due to independent rounding

County	Overburden thickness	Net coal thickness	Reliability category (distance from data point)				Grand total (MST)
			Measured (<1/4 mi)	Indicated (1/4-3/4 mi)	Inferred (3/4-3 mi)	Hypothetical (>3 mi)	
ADAMS	0-100 ft	2.5-5 ft	3.7	20	160	110	290
		5-10 ft	18	120	1,000	690	1,800
		10-20 ft	5.5	39	250	64	360
	0-100 ft total		27	180	1,400	860	2,500
	100-200 ft	2.5-5 ft	3.4	18	110	16	140
		5-10 ft	10	52	260	22	340
		10-20 ft	1.8	18	43	0	63
	100-200 ft total		16	89	410	39	550
	200-500 ft	2.5-5 ft	10	22	25	0	57
		5-10 ft	19	62	51	0	130
		10-20 ft	39	120	68	0	220
		20-40 ft	0.20	0	0	0	0.20
	200-500 ft total		68	200	140	0	410
ADAMS total			110	470	2,000	900	3,400
BILLINGS	0-100 ft	2.5-5 ft	0	0	0.18	0	0.18
		5-10 ft	2.0	10	88	0	100
		10-20 ft	0	6.1	58	0	64
	0-100 ft total		2.0	16	150	0	160
	100-200 ft	2.5-5 ft	0.81	2.1	4.2	9.0	16
		5-10 ft	0	5.3	94	3.8	100
		10-20 ft	4.4	38	92	0	130
		20-40 ft	0	5.5	11	0	16
	100-200 ft total		5.3	51	200	13	270

Table WN-1. Harmon coal resources—continued

County	Overburden thickness	Net coal thickness	Reliability category (distance from data point)				Grand total (MST)
			Measured (<1/4 mi)	Indicated (1/4-3/4 mi)	Inferred (3/4-3 mi)	Hypothetical (>3 mi)	
BILLINGS	200-500 ft	2.5-5 ft	0.072	0.84	36	36	73
		5-10 ft	0.23	2.5	87	69	160
		10-20 ft	9.7	52	190	0	250
		20-40 ft	0.93	5.7	110	0	110
	200-500 ft total		11	61	420	110	600
	>500 ft	2.5-5 ft	0	0	31	200	230
		5-10 ft	4.0	22	330	470	830
		10-20 ft	8.8	58	280	44	390
		20-40 ft	0	0	20	0	20
	>500 ft total		13	79	660	720	1,500
BILLINGS total			31	210	1,400	830	2,500
BOWMAN	0-100 ft	2.5-5 ft	3.3	19	71	73	170
		5-10 ft	9.3	53	210	56	320
		10-20 ft	13	63	440	63	580
		20-40 ft	40	220	420	64	740
	0-100 ft total		66	360	1,100	260	1,800
	100-200 ft	2.5-5 ft	16	42	24	0.10	83
		5-10 ft	24	53	56	0	130
		10-20 ft	37	160	150	0	350
		20-40 ft	20	97	21	0	140
	100-200 ft total		97	350	250	0.10	700
	200-500 ft	2.5-5 ft	8.2	15	6.0	0	29
		5-10 ft	55	120	59	0	230
		10-20 ft	11	30	33	0	74
	200-500 ft total		74	160	98	0	330
BOWMAN total			240	870	1,500	260	2,800

Table WN-1. Harmon coal resources—continued

County	Overburden thickness	Net coal thickness	Reliability category (distance from data point)				Grand total (MST)
			Measured (<1/4 mi)	Indicated (1/4-3/4 mi)	Inferred (3/4-3 mi)	Hypothetical (>3 mi)	
GOLDEN VALLEY	0-100 ft	2.5-5 ft	3.4	27	120	93	240
		5-10 ft	10	59	160	13	240
		10-20 ft	17	74	39	0	130
		20-40 ft	5.0	16	6.9	0	27
	0-100 ft total		35	170	320	110	640
	100-200 ft	2.5-5 ft	0.51	3.3	60	48	110
		5-10 ft	2.5	20	170	48	240
		10-20 ft	31	190	230	0	450
		20-40 ft	31	210	330	22	590
	100-200 ft total		65	420	780	120	1,400
	200-500 ft	2.5-5 ft	0	0	42	120	160
		5-10 ft	3.3	21	270	350	640
		10-20 ft	5.5	63	310	190	570
		20-40 ft	11	61	460	0	540
	200-500 ft total		20	150	1,100	660	1,900
	>500 ft	2.5-5 ft	0	0.14	15	180	190
		5-10 ft	2.7	19	220	1,200	1400
		10-20 ft	0	0	180	1,400	1,600
		20-40 ft	0	0	22	2.5	24
	>500 ft total		2.7	19	440	2,800	3,300
GOLDEN VALLEY total			120	760	2,600	3,700	7,200
HETTINGER	0-100 ft	2.5-5 ft	0	0	0	8.4	8.4
		5-10 ft	0	0	1.6	220	230
		10-20 ft	0	2.8	38	72	110
	0-100 ft total		0	2.8	40	310	350

Table WN-1. Harmon coal resources—continued

County	Overburden thickness	Net coal thickness	Reliability category (distance from data point)				Grand total (MST)
			Measured (<1/4 mi)	Indicated (1/4-3/4 mi)	Inferred (3/4-3 mi)	Hypothetical (>3 mi)	
HETTINGER	100-200 ft	2.5-5 ft	0.9	4.7	37	57	99
		5-10 ft	2.9	33	240	770	1,000
		10-20 ft	0	0	240	1,200	1,400
		20-40 ft	0	6.4	130	18	150
	100-200 ft total		3.8	44	640	2,000	2,700
	200-500 ft	2.5-5 ft	1.3	8.1	68	240	310
		5-10 ft	1.5	9.2	250	1,900	2100
		10-20 ft	9.4	75	1,300	2,900	4,300
		20-40 ft	12	89	800	570	1,500
	200-500 ft total		25	180	2,500	5,500	8,200
	>500 ft	5-10 ft	0	0	0	450	450
		10-20 ft	0	0	0	780	780
	>500 ft total		0	0	0	1,200	1,200
HETTINGER total			28	230	3,100	9,100	13,000
SLOPE	0-100 ft	2.5-5 ft	3.7	16	180	40	240
		5-10 ft	47	240	890	130	1,300
		10-20 ft	27	160	1200	700	2,100
		20-40 ft	54	360	430	110	940
	0-100 ft total		130	770	2,700	980	4,500
	100-200 ft	2.5-5 ft	0.33	2.1	5.3	4.6	12
		5-10 ft	6.7	40	73	15	130
		10-20 ft	27	190	550	7.3	770
		20-40 ft	63	350	280	0	700
	100-200 ft total		97	580	910	27	1,600
	200-500 ft	2.5-5 ft	0.91	5.7	74	12	92
		5-10 ft	8.2	64	850	250	1,200
		10-20 ft	32	280	2,500	410	3,300

Table WN-1. Harmon coal resources—continued

County	Overburden thickness	Net coal thickness	Reliability category (distance from data point)				Grand total (MST)
			Measured (<1/4 mi)	Indicated (1/4-3/4 mi)	Inferred (3/4-3 mi)	Hypothetical (>3 mi)	
SLOPE	200-500 ft	20-40 ft	16	160	1,100	3.9	1,300
	200-500 ft total		57	500	4,600	670	5,800
	>500 ft	2.5-5 ft	0	0	1.7	0	1.7
		5-10 ft	0.73	6.9	86	37	130
		10-20 ft	24	150	660	7.7	830
		20-40 ft	1.3	8.3	15	0	25
	>500 ft total		26	160	760	44	990
SLOPE total			310	2,000	8,900	1,700	13,000
STARK	0-100 ft	10-20 ft	0	0	0	0.083	0.083
	0-100 ft total		0	0	0	0.083	0.083
	200-500 ft	2.5-5 ft	0	0	0	64	64
		5-10 ft	0	0	0	9.6	9.6
	200-500 ft total		0	0	0	73	73
	>500 ft	2.5-5 ft	0	0	0	270	270
		5-10 ft	0	0	28	1,600	1,600
		10-20 ft	3.2	42	610	580	1,200
	>500 ft total		3.2	42	640	2,400	3100
STARK total			3.2	42	640	2,500	3,200
Grand total (MST)			850	4,600	20,000	19,000	45,000

Table WN-2. Coal resources of the Harmon coal zone in the Bowman-Dickinson coalfield, Williston Basin, North Dakota, reported by 7.5-minute quadrangle map area (see quadrangle location map (fig. WN-1) and key (table WN-4)). Resources are reported in millions of short tons (MST) with two significant figures. The table does not include resources for areas containing net coal less than 2.5 ft thick, or coal in mine or lease areas (fig. WN-3). Resource numbers will not sum to match total due to independent rounding

7.5-minute quadrangle map	Index map number	Total (MST)	7.5-minute quadrangle map	Index map number	Total (MST)
ABBEY HILL	92	340	CHIMNEY BUTTE	26	450
ALPHA	36	180	CLARK BUTTE	66	160
AMIDON	71	1,100	CLARK BUTTE NE	50	0
AMIDON SE	86	620	CLARK BUTTE NW	49	0.74
BARTHS BUTTE	121	10	CLARK BUTTE SW	65	300
BEACH EAST	15	1,000	CLIFFS PLATEAU	39	210
BEACH WEST	14	470	COFFIN BUTTES	112	7.2
BELFIELD	21	0	DAGLUM	42	670
BELFIELD SE	30	72	DAGLUM NW	41	730
BELFIELD SW	29	240	DAGLUM SE	58	810
BENTLEY	96	520	DAGLUM SW	57	920
BLACK BUTTE	70	1,100	DEEP CREEK NORTH	54	560
BOWMAN	100	400	DEEP CREEK SOUTH	69	400
BOWMAN SE	113	9.4	DICKINSON SOUTH	32	15
BOYCE CREEK EAST	68	430	DRY BULLION CREEK	37	360
BOYCE CREEK WEST	67	100	DUCK CREEK	22	300
BUCYRUS	117	4.2	EAST RAINY BUTTE	74	250
BUFFALO GAP CAMPGROUND	17	330	EHLER LAKE	106	340
BULLION BUTTE	38	780	ENTERPRISE SCHOOL	90	110
BURT	95	610	FRYBURG	28	170
BURT NW	80	510	FRYBURG NE	20	0
CARLYLE	34	70	FRYBURG NW	19	4.4
CEDAR BUTTE	122	13	GASCOYNE	115	220
CEDAR LAKE	89	400	GOLVA	35	110

Table WN-2. Harmon coal resources—continued

7.5-minute quadrangle map	Index map number	Total (MST)	7.5-minute quadrangle map	Index map number	Total (MST)
GORHAM SW	13	0	NEW LEIPZIG SOUTH	97	3.8
GRIFFIN	99	29	NORTH STAR BUTTE	81	350
HAVELOCK	76	1,100	ODLAND DAM	8	180
HAYNES	125	3.9	ODLAND DAM NE	3	30
HETTINGER NORTH	118	160	OLLIE	51	0
HOOTOWL CREEK EAST	5	220	PEARL BUTTE	120	150
HOOTOWL CREEK SW	9	700	PEARL BUTTE NW	108	220
HOOTOWL CREEK WEST	4	280	PLUM BUTTE	110	400
IVES	83	640	PLUM BUTTE NE	111	510
JUNG LAKE	75	690	REEDER	116	210
JUNIPER SPUR	55	650	REGENT	77	1,200
KID RICH BUTTE	124	33	RHAME	98	97
LEFOR	46	210	ROCKY RIDGE NORTH	40	410
LEFOR SW	61	670	ROCKY RIDGE SOUTH	56	750
LEFOR NW	45	320	ROOSEVELT CREEK EAST	7	0
LEHIGH	33	0	ROOSEVELT CREEK WEST	6	46
LIENS DAMS	91	360	ODLAND DAM	8	180
LONG BUTTE	109	410	ODLAND DAM NE	3	30
MARMARTH SE	82	0.74	OLLIE	51	0
MEDORA	18	120	PEARL BUTTE	120	150
MINERAL SPRINGS	87	580	PEARL BUTTE NW	108	220
MOTT NORTH	79	560	PLUM BUTTE	110	400
MOTT NW	78	900	PLUM BUTTE NE	111	510
MOTT SOUTH	94	400	REEDER	116	210
MOTT SW	93	190	REGENT	77	1,200
NASON HILL	123	9	RHAME	98	97
NEW ENGLAND	60	660	ROCKY RIDGE NORTH	40	410
NEW ENGLAND NW	43	540	ROCKY RIDGE SOUTH	56	750
NEW ENGLAND SW	59	580	ROOSEVELT CREEK EAST	7	0

Table WN-2. Harmon coal resources—continued

7.5-minute Quadrangle map	Index map number	Total (MST)	7.5-minute Quadrangle map	Index map number	Total (MST)
ROOSEVELT CREEK WEST	6.0	46	THREE V CROSSING	52	150
SCHEFIELD	44	460	TRACY MOUNTAIN	27	47
SCRANTON	102	330	TROTTERS	2.0	8.7
SCRANTON NE	103	440	WANNAGAN CREEK EAST	12	170
SCRANTON SW	114	180	WANNAGAN CREEK WEST	11	490
SENTINEL BUTTE	16	580	WARNKE HILL	88	440
SENTINEL BUTTE SE	24	310	WEST FORK DEEP CREEK	84	750
SKAAR	1.0	13	WEST RAINY BUTTE	73	640
SOUTH HEART	31	71	WEST TWIN BUTTE	10	690
SPRING CREEK	53	560	WHETSTONE BUTTES	104	410
SQUARE BUTTE	25	330	WHITE BUTTE EAST	64	390
STEWART LAKE	85	1,200	WHITE BUTTE NE	48	54
STONY BUTTE	62	770	WHITE BUTTE NW	47	140
TALBOT BUTTE	101	200	WHITE BUTTE WEST	63	660
TAYLOR BUTTE	107	320	WHITE LAKE	72	700
TAYLOR BUTTE SE	119	480	WOLF BUTTE	105	140
THELAN	23	520	Grand total (MST)		45,000

Table WN-3. Harmon coal resources in the Bowman-Dickinson coalfield, North Dakota, reported by Federal coal and surface ownership (fig. WN-2). Resources are shown in millions of short tons (MST) with 2 significant figures. The table does not include resources in mine areas or in areas containing less than 2.5 ft of coal (fig. WN-3). Resource numbers will not sum to match total due to independent rounding

Federal ownership	Total (MST)
No Federal coal or surface ownership	27,000
No Federal coal, but Federal surface ownership	790
Federal coal, but no Federal surface ownership	15,000
Federal coal and surface ownership	2,200
Grand total (MST)	45,000

Table WN-4. Key to 7.5-minute quadrangle maps in the Harmon study limit (see figure WN-1 and table 2)

Number	7.5-minute quadrangle map	Number	7.5-minute quadrangle map	Number	7.5-minute quadrangle map
1	SKAAR	27	TRACY MOUNTAIN	53	SPRING CREEK
2	TROTTERS	28	FRYBURG	54	DEEP CREEK NORTH
3	ODLAND DAM NE	29	BELFIELD SW	55	JUNIPER SPUR
4	HOOTOWL CREEK WEST	30	BELFIELD SE	56	ROCKY RIDGE SOUTH
5	HOOTOWL CREEK EAST	31	SOUTH HEART	57	DAGLUM SW
6	ROOSEVELT CREEK WEST	32	DICKINSON SOUTH	58	DAGLUM SE
7	ROOSEVELT CREEK EAST	33	LEHIGH	59	NEW ENGLAND SW
8	ODLND DAM	34	CARLYLE	60	NEW ENGLAND
9	HOOTOWL CREEK SW	35	GOLVA	61	LEFOR SW
10	WEST TWIN BUTTE	36	ALPHA	62	STONY BUTTE
11	WANNAGAN CREEK WEST	37	DRY BULLION CREEK	63	WHITE BUTTE WEST
12	WANNAGAN CREEK EAST	38	BULLION BUTTE	64	WHITE BUTTE EAST
13	GORHAM SW	39	CLIFFS PLATEAU	65	CLARK BUTTE SW
14	BEACH WEST	40	ROCKY RIDGE NORTH	66	CLARK BUTTE
15	BEACH EAST	41	DAGLUM NW	67	BOYCE CREEK WEST
16	SENTINEL BUTTE	42	DAGLUM	68	BOYCE CREEK EAST
17	BUFFALO GAP CAMPGROUND	43	NEW ENGLAND NW	69	DEEP CREEK SOUTH
18	MEDORA	44	SCHEFIELD	70	BLACK BUTTE
19	FRYBURG NW	45	LEFOR NW	71	AMIDON
20	FRYBURG NE	46	LEFOR	72	WHITE LAKE
21	BELFIELD	47	WHITE BUTTE NW	73	WEST RAINY BUTTE
22	DUCK CREEK	48	WHITE BUTTE NE	74	EAST RAINY BUTTE
23	THELAN	49	CLARK BUTTE NW	75	JUNG LAKE
24	SENTINEL BUTTE SE	50	CLARK BUTTE NE	76	HAVELOCK
25	SQUARE BUTTE	51	OLLIE	77	REGENT
26	CHIMNEY BUTTE	52	THREE V CROSSING	78	MOTT NW

Table WN-4. Key to 7.5-minute quadrangle maps, Harmon study limit—continued

Number	7.5-minute quadrangle map	Number	7.5-minute quadrangle map
79	NOTT NORTH	103	SCRANTON NE
80	BURT NW	104	WHETSTONE BUTTES
81	NORTH STAR BUTTE	105	WOLF BUTTE
82	MARMARTH SE	106	EHLAER LAKE
83	IVES	107	TAYLOR BUTTE
84	WEST FORK DEEP CREEK	108	PEARL BUTTE NW
85	STEWART LAKE	109	LONG BUTTE
86	AMIDON SE	110	PLUM BUTTE
87	MINERAL SPRINGS	111	PLUM BUTTE NE
88	WARNKE HILL	112	COFFIN BUTTES
89	CEDAR LAKE	113	BOWMAN SE
90	ENTERPRISE SCHOOL	114	SCRANTON SW
91	LIENS DAMS	115	GASCOYNE
92	ABBEY HILL	116	REEDER
93	MOTT SW	117	BUCYRUS
94	MOTT SOUTH	118	HETTINGER NORTH
95	BURT	119	TAYLOR BUTTE SE
96	BENTLEY	120	PEARL BUTTE
97	NEW LEIPZIG SOUTH	121	BARTHS BUTTE
98	RHAME	122	CEDAR BUTTE
99	GRIFFIN	123	NASON HILL
100	BOWMAN	124	KID RICH BUTTE
101	TALBOT BUTTE	125	HAYNES
102	SCRANTON		

Table WN-5. Data used for computation of confidence intervals within reliability categories for Harmon coal resources in the Bowman-Dickinson coalfield, Williston Basin, North Dakota. Volume refers to the calculated resource in millions of short tons (MST). NA, not applicable

Parameter	Reliability category				Entire area
	Measured	Indicated	Inferred	Hypothetical	
Area (in square meters)	177,067,168	868,859,831	4,352,969,100	5,065,252,495	10,464,148,594
Percent of area	2	8	42	48	100
Acres (area x 0.0002471)	43,754	214,700	1,075,642	1,251,651	2,585,747
SD (standard deviation (in ft) from semivariogram model)	2.174	2.59	3.727	5.507	NA
Acre feet (acres x SD)	95,125	556,065	4,008,751	6,892,834	NA
Volume standard deviation (MST)	9	71	920	12,200	13,201
Pseudo *n*	348	190	59	1	NA

Table WN-6. Estimates of uncertainty (calculated with measurement error) for Harmon coal resources in the Bowman-Dickinson coalfield, Williston Basin, North Dakota. To show detail, resources are reported in millions of short tons (MST) with four significant figures

Parameter	Reliability category				Entire area
	Measured	Indicated	Inferred	Hypothetical	
Total calculated resource (MST)	847.0	4,596	20,230	19,000	44,670
Lower 90% confidence limit (MST)	832.0	4,479	18,720	0.0	22,960
Upper 90% confidence limit (MST)	862.0	4,714	21,750	39,070	66,390

Table WN-7. Coal resources of the Hansen coal zone in the Bowman-Dickinson coalfield, Williston Basin, North Dakota, reported by county (fig. WN-5), overburden (fig. WN-8), coal thickness (fig. WN-7), and reliability categories. Zeros (0) indicate areas where no resources were calculated. The table does not include resources for coal less than 2.5 ft thick or coal in mine areas (fig. WN-7). Resources are reported in millions of short tons (MST) with two significant figures. Resource numbers will not sum to match totals due to independent rounding

County	Overburden thickness	Net coal thickness	Reliability category (distance from data point)				Grand total (MST)
			Measured (<1/4 mi)	Indicated (1/4-3/4 mi)	Inferred (3/4-3 mi)	Hypothetical (>3 mi)	
ADAMS	0-100 ft	2.5-5 ft	0	0	19	1.0	20
		5-10 ft	6.2	49	520	1,200	1,700
		10-20 ft	6.2	48	470	200	730
	0-100 ft total		12	98	1,000	1,400	2,500
	100-200 ft	2.5-5 ft	0.083	3.9	16	5.7	25
		5-10 ft	1.5	8.8	24	12	46
		10-20 ft	1.1	0	0	0	1.1
	100-200 ft total		2.7	13	40	18	73
	200-500 ft	2.5-5 ft	5.7	33	110	10	160
		5-10 ft	42	120	220	17	390
		10-20 ft	31	16	0	0	46
	200-500 ft total		79	170	320	27	600
	>500 ft	5-10 ft	1.6	0.39	0	0	2.0
		10-20 ft	2.2	0.42	0	0	2.6
	>500 ft total		3.8	0.81	0	0	4.6
ADAMS total			97	280	1,400	1,400	3,200
BILLINGS	0-100 ft	2.5-5 ft	0	0.013	5.8	0.13	5.9
		5-10 ft	0	0	6.4	6.5	13
		10-20 ft	0.11	3.4	2.1	18	24
	0-100 ft total		0.11	3.4	14	25	43
	100-200 ft	2.5-5 ft	0	0	2.8	0	2.8
		5-10 ft	0	0	0.74	0	0.74

Table WN-7. Hansen coal resources—continued

County	Overburden thickness	Net coal thickness	Reliability category (distance from data point)				Grand total (MST)
			Measured (<1/4 mi)	Indicated (1/4-3/4 mi)	Inferred (3/4-3 mi)	Hypothetical (>3 mi)	
BILLINGS	100-200 ft	10-20 ft	0	0	0	5.4	5.4
		20-40 ft	0	0	0	21	21
	100-200 ft total		0	0	3.5	27	30
	200-500 ft	2.5-5 ft	0.89	4.0	38	6.1	49
		5-10 ft	0	6.6	59	17	82
		10-20 ft	3.1	11	110	160	280
		20-40 ft	0	0	0	630	630
	200-500 ft total		4	21	210	810	1,000
	>500 ft	2.5-5 ft	0	0	6.3	35	41
		5-10 ft	0	0	43	85	130
		10-20 ft	6.2	24	110	330	470
		20-40 ft	0	0	0	460	460
	>500 ft total		6.2	24	160	910	1,100
BILLINGS total			10.0	48	390	1,800	2,200
BOWMAN	0-100 ft	2.5-5 ft	4.7	16	70	73	160
		5-10 ft	8.7	42	240	270	560
		10-20 ft	3.5	9.5	33	16	62
		20-40 ft	0	0	0.24	0	0.24
	0-100 ft total		17	67	340	360	790
	100-200 ft	2.5-5 ft	4.2	13	14	2.2	33
		5-10 ft	11	40	100	25	180
		10-20 ft	0.83	2.8	8.2	0	12
		20-40 ft	2.2	2.5	0	0	4.7
	100-200 ft total		19	59	120	27	230

Table WN-7. Hansen coal resources—continued

County	Overburden thickness	Net coal thickness	Reliability category (distance from data point)				Grand total (MST)
			Measured (<1/4 mi)	Indicated (1/4-3/4 mi)	Inferred (3/4-3 mi)	Hypothetical (>3 mi)	
BOWMAN	200-500 ft	2.5-5 ft	28	60	33	0.13	120
		5-10 ft	38	120	210	0.91	380
		10-20 ft	10	79	190	0.86	280
		20-40 ft	7.9	36	21	0	65
	200-500 ft total		84	300	460	1.9	840
BOWMAN total			120	420	920	390	1,900
GOLDEN VALLEY	0-100 ft	2.5-5 ft	0.88	6.6	12	2.4	22
		5-10 ft	0	0.055	1.8	2.3	4.2
		10-20 ft	0	0	0	5.6	5.6
	0-100 ft total		0.88	6.7	14	10	32
	100-200 ft	2.5-5 ft	0.079	2.6	14	0.75	18
		5-10 ft	0.14	12	88	3.4	100
		10-20 ft	0	1.5	11	32	44
		20-40 ft	0	0	0	32	32
	100-200 ft total		0.22	16	110	68	200
	200-500 ft	2.5-5 ft	3.2	17	120	44	190
		5-10 ft	6.3	58	460	250	770
		10-20 ft	11	64	500	1,100	1,700
		20-40 ft	0	0	0	880	880
	200-500 ft total		20	140	1,100	2,300	3,500
	>500 ft	2.5-5 ft	0	0.90	32	67	100
		5-10 ft	0	0	14	140	150
		10-20 ft	0	0	0	300	300
		20-40 ft	0	0	0	470	470
	>500 ft total		0	0.90	46	970	1,000
GOLDEN VALLEY total			21	160	1,200	3,300	4,800

Table WN-7. Hansen coal resources—continued

County	Overburden thickness	Net coal thickness	Reliability category (distance from data point)				Grand total (MST)
			Measured (<1/4 mi)	Indicated (1/4-3/4 mi)	Inferred (3/4-3 mi)	Hypothetical (>3 mi)	
HETTINGER	0-100 ft	5-10 ft	0	0	0.015	0.99	1.0
	0-100 ft total		0	0	0.015	0.99	1.0
	100-200 ft	2.5-5 ft	0	0	6.5	27	33
		5-10 ft	0	0.31	61	110	170
		10-20 ft	0	9.2	19	0	28
	100-200 ft total		0	9.5	86	130	230
	200-500 ft	2.5-5 ft	0.64	3.5	77	110	190
		5-10 ft	3.5	32	410	550	1,000
		10-20 ft	2.4	5.2	16	0	24
	200-500 ft total		6.5	40	500	660	1,200
	>500 ft	5-10 ft	0	0	0	42	42
	>500 ft total		0	0	0	42	42
HETTINGER total			6.5	50	590	840	1,500
SLOPE	0-100 ft	2.5-5 ft	4.1	34	260	110	400
		5-10 ft	18	120	610	420	1,200
		10-20 ft	7.9	70	410	130	620
	0-100 ft total		30	220	1,300	660	2,200
	100-200 ft	2.5-5 ft	0.78	14	38	0.66	53
		5-10 ft	10	67	260	68	410
		10-20 ft	5.1	17	81	77	180
	100-200 ft total		16	98	380	150	640
	200-500 ft	2.5-5 ft	9.1	50	380	140	570
		5-10 ft	18	130	920	410	1,500
		10-20 ft	29	220	1300	130	1,700
		20-40 ft	4.8	28	140	0	180
	200-500 ft total		61	420	2,800	670	3,900
SLOPE total			130	860	5,000	1,700	7,600

Table WN-7. Hansen coal resources—continued

County	Overburden thickness	Net coal thickness	Reliability category (distance from data point)				Grand total (MST)
			Measured (<1/4 mi)	Indicated (1/4-3/4 mi)	Inferred (3/4-3 mi)	Hypothetical (>3 mi)	
STARK	>500 ft	2.5-5 ft	0	0	1.1	61	62
		5-10 ft	0	0	25	170	190
		10-20 ft	0.64	22	220	5.6	250
	>500 ft total		0.64	22	250	230	500
STARK total			0.64	22	250	230	500
Grand total (MST)			380	1,800	9,700	9,700	22,000

Table WN-8. Coal resources of the Hansen coal zone in the Bowman-Dickinson coalfield, Williston Basin, North Dakota, reported by 7.5-minute quadrangle map area (see figure WN-5 and table WN-10). Resources are reported in millions of short tons (MST) with two significant figures. Table does not include resources for coal less than 2.5 ft thick or coal in mine areas (fig. WN-7). Resource numbers will not sum to match total due to independent rounding

7.5-minute quadrangle map	Index map number	Total (MST)	7.5-minute quadrangle map	Index map number	Total (MST)
ABBEY HILL	63	150	DEEP CREEK SOUTH	41	170
ALPHA	20	48	DRY BULLION CREEK	21	100
AMIDON	43	170	DUCK CREEK	11	59
AMIDON SE	57	610	EAST RAINY BUTTE	46	260
BARTHS BUTTE	85	300	EHLER LAKE	74	14
BEACH EAST	7	450	ENTERPRISE SCHOOL	61	2.3
BEACH WEST	6	280	FRYBURG	17	170
BLACK BUTTE	42	260	GASCOYNE	79	96
BOWMAN	68	90	GOLVA	19	13
BOYCE CREEK EAST	40	320	GRIFFIN	67	16
BOYCE CREEK WEST	39	160	HAVELOCK	48	45
BUCYRUS	81	44	HAYNES	90	140
BUFFALO GAP CAMPGROUND	9	250	HETTINGER NORTH	82	110
BULLION BUTTE	22	48	HETTINGER SOUTH	88	98
CARLYLE	18	11	HOOTOWL CREEK SW	4	250
CEDAR BUTTE	86	70	HOOTOWL CREEK WEST	1	0.08
CEDAR HILLS	65	110	IVES	54	500
CEDAR LAKE	60	190	JUNG LAKE	47	180
CHIMNEY BUTTE	15	1000	JUNIPER SPUR	31	670
CLIFFS PLATEAU	23	110	KID RICH BUTTE	89	230
COW BUTTE NE	87	0.14	LEFOR SW	37	0.15
DAGLUM	26	230	LEMMON	92	180
DAGLUM NW	25	350	LEMMON NE	93	2.7
DAGLUM SE	34	460	LIENS DAMS	62	200
DAGLUM SW	33	630	LONG BUTTE	77	0.79
DEEP CREEK NORTH	30	460	MARMARTH	52	41

Table WN-8. Hansen coal resources—continued

7.5-minute quadrangle map	Index map number	Total (MST)	7.5-minute quadrangle map	Index map number	Total (MST)
MARMARTH SE	53	530	SCRANTON SW	78	9.6
MEDORA	10	0.83	SENTINEL BUTTE	8	710
MINERAL SPRINGS	58	250	SENTINEL BUTTE SE	13	700
MOTT NORTH	51	6.8	SPRING CREEK	29	390
MOTT NW	50	190	SQUARE BUTTE	14	1,100
MOTT SW	64	6.5	STEWART LAKE	56	480
NEW ENGLAND	36	160	TALBOT BUTTE	69	230
NEW ENGLAND NW	27	49	TAYLOR BUTTE	75	0.094
NEW ENGLAND SW	35	400	TAYLOR BUTTE SE	83	450
ODLAND DAM	3	220	THELAN	12	350
ODLAND DAM NE	1	10	THREE V CROSSING	28	45
PEARL BUTTE	84	520	TRACY MOUNTAIN	16	810
PEARL BUTTE NW	76	11	WARNKE HILL	59	240
PRETTY BUTTE	38	9.0	WEST FORK DEEP CREEK	55	120
REEDER	80	260	WEST RAINY BUTTE	45	180
REGENT	49	260	WEST TWIN BUTTE	5	11
RHAME	66	140	WHETSTONE BUTTES	72	390
ROCKY RIDGE NORTH	24	250	WHITE BUTTE	91	180
ROCKY RIDGE SOUTH	32	740	WHITE LAKE	44	120
SCRANTON	70	200	WOLF BUTTE	73	120
SCRANTON NE	71	380	Grand total (MST)		22,000

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Table WN-9. Hansen coal resources in the Bowman-Dickinsen coalfield, Williston Basin, North Dakota, reported by Federal coal and surface ownership (fig. WN-6). Resources are shown in millions of short tons (MST) with 2 significant figures. The table does not include resources in mine areas or areas containing less than 2.5 ft of coal (fig. WN-7). Resource numbers will not sum to match total due to independent rounding

Federal ownership	Total (MST)
No Federal coal or surface ownership	13,000
No Federal coal, but Federal surface ownership	530
Federal coal, but no Federal surface ownership	5,800
Federal coal and surface ownership	2,000
Grand total (MST)	22,000

Table WN-10. Key to 7.5-minute quadrangle maps in the Hansen study limit (see figure WN-5 and table WN-8)

Number	7.5-minute quadrangle map	Number	7.5-minute quadrangle map	Number	7.5-minute quadrangle map
1	ODLAND DAM NE	32	ROCKY RIDGE SOUTH	63	ABBEY HILL
2	HOOTOWL CREEK WEST	33	DAGLUM SW	64	MOTT SW
3	ODLAND DAM	34	DAGLUM SE	65	CEDAR HILLS
4	HOOTOWL CREEK SW	35	NEW ENGLAND SW	66	RHAME
5	WEST TWIN BUTTE	36	NEW ENGLAND	67	GRIFFIN
6	BEACH WEST	37	LEFOR SW	68	BOWMAN
7	BEACH EAST	38	PRETTY BUTTE	69	TALBOT BUTTE
8	SENTINEL BUTTE	39	BOYCE CREEK WEST	70	SCRANTON
9	BUFFALO GAP CAMPGROUND	40	BOYCE CREEK EAST	71	SCRANTON NE
10	MEDORA	41	DEEP CREEK SOUTH	72	WHETSTONE BUTTES
11	DUCK CREEK	42	BLACK BUTTE	73	WOLF BUTTE
12	THELAN	43	AMIDON	74	EHLER LAKE
13	SENTINEL BUTTE SE	44	WHITE LAKE	75	TAYLOR BUTTE
14	SQUARE BUTTE	45	WEST RAINY BUTTE	76	PEARL BUTTE NW
15	CHIMNEY BUTTE	46	EAST RAINY BUTTE	77	LONG BUTTE
16	TRACY MOUNTAIN	47	JUNG LAKE	78	SCRANTON SW
17	FRYBURG	48	HAVELOCK	79	GASCOYNE
18	CARLYLE	49	REGENT	80	REEDER
19	GOLVA	50	MOTT NW	81	BUCYRUS
20	ALPHA	51	MOTT NORTH	82	HETTINGER NORTH
21	DRY BULLION CREEK	52	MARMARTH	83	TAYLOR BUTTE SE
22	BULLION BUTTE	53	MARMARTH SE	84	PEARL BUTTE
23	CLIFFS PLATEAU	54	IVES	85	BARTHS BUTTE
24	ROCKY RIDGE NORTH	55	WEST FORK DEEP CREEK	86	CEDAR BUTTE
25	DAGLUM NW	56	STEWART LAKE	87	COW BUTTE NE
26	DAGLUM	57	AMIDON SE	88	HETTINGER SOUTH
27	NEW ENGLAND NW	58	MINERAL SPRINGS	89	KID RICH BUTTE
28	THREE V CROSSING	59	WARNKE HILL	90	HAYNES
29	SPRING CREEK	60	CEDAR LAKE	91	WHITE BUTTE
30	DEEP CREEK NORTH	61	ENTERPRIZE SCHOOL	92	LEMMON
31	JUNIPER SPUR	62	LIENS DAMS	93	LEMMON NE

Table WN-11. Data used for computation of confidence intervals within reliability categories for Hansen coal resources in the Bowman-Dickinson coalfield, Williston Basin, North Dakota. Volume refers to the calculated resource in millions of short tons (MST). NA, not applicable

Parameter	Reliability category				Entire area
	Measured	Indicated	Inferred	Hypothetical	
Area (in square meters)	123,667,036	593,688,851	3,286,461,611	2,693,673,550	6,697,491,047
Percent of area	2	9	49	40	100
Acres (area x 0.0002471)	30,559	146,704	812,102	665,621	1,654,986
SD (standard deviation (in ft) from semivariogram model)	2.16	2.45	3.41	4.01	NA
Acre feet (Acres x SD)	65,844	359,567	2,769,859	2,670,629	NA
Volume standard deviation (MST)	7	56	732	4,727	5,522
Pseudo *n*	243	130	45	1	NA

Table WN-12. Estimates of uncertainty (calculated with measurement error) for Hansen coal resources in the Bowman-Dickinson coalfield, Williston Basin, North Dakota. To show detail, resources are reported in millions of short tons (MST) with four significant figures

Parameter	Reliability category				Entire area
	Measured	Indicated	Inferred	Hypothetical	
Total calculated resource (MST)	382.6	1,846	9,743	9,669	21,640
Lower 90% confidence limit (MST)	370.0	1,754	8,539	1,893	12,560
Upper 90% confidence limit (MST)	395.0	1,938	10,950	17,450	30,730

Table WN-13. Coal resources of the Beulah-Zap coal zone in the Beulah coalfield, Williston Basin, North Dakota, reported by overburden (fig. WN-12), net coal thickness (fig. WN-11), and reliability categories. Zeros (0) indicate areas where no resources were calculated. Table does not include resources for coal less than 2.5 ft, in mine areas, or in areas containing Beulah-Zap clinker (fig. WN-11). Resources are reported in millions of short tons (MST) with two significant figures. Resource numbers will not sum to match totals due to independent rounding

County	Overburden thickness	Net coal thickness	Reliability category (distance from data point)				Grand total (MST)
			Measured (<1/4 mi)	Indicated (1/4-3/4 mi)	Inferred (3/4-3 mi)	Hypothetical (>3 mi)	
MCLEAN	0-100 ft	2.5-5 ft	8.3	18	6.5	0	33
		5-10 ft	40	100	23	0	170
		10-20 ft	87	180	28	0	290
	0-100 ft total		130	300	58	0	490
	100-200 ft	2.5-5 ft	2.8	13	3.9	0	20
		5-10 ft	22	76	35	0	130
		10-20 ft	23	74	31	0	130
	100-200 ft total		48	160	69	0	280
	200-500 ft	2.5-5 ft	0.83	0.31	0	0	1.1
		5-10 ft	1.2	6.2	7.7	0	15
		10-20 ft	0.24	0.49	0	0	0.73
	200-500 ft total		2.2	7	7.7	0	17
MCLEAN total			180	470	130	0	790
MERCER	0-100 ft	2.5-5 ft	13	26	27	3.8	70
		5-10 ft	110	110	130	63	410
		10-20 ft	310	210	390	310	1,200
		20-40 ft	75	35	18	0	130
		>40 ft	0.31	0	0	0	0.31
	0-100 ft total		510	380	560	380	1,800
	100-200 ft	2.5-5 ft	3.4	2.3	28	2.4	36
		5-10 ft	31	50	18	15	110
		10-20 ft	220	190	320	130	870

Table WN-13. Beulah-Zap coal resources—continued

County	Overburden thickness	Net coal thickness	Reliability category (distance from data point)				Grand total (MST)
			Measured (<1/4 mi)	Indicated (1/4-3/4 mi)	Inferred (3/4-3 mi)	Hypothetical (>3 mi)	
MERCER	100-200 ft	20-40 ft	62	72	150	0	280
	100-200 ft total		320	320	510	150	1,300
	200-500 ft	2.5-5 ft	0.15	0.24	2.4	0	2.8
		5-10 ft	5.1	4.3	11	0	20.0
		10-20 ft	19	37	41	24	120
		20-40 ft	6.4	34	94	0	130
	200-500 ft total		31	75	150	24	280
MERCER total			860	770	1,200	550	3,400
MORTON	0-100 ft	5-10 ft	0.38	0.26	0	0	0.64
	0-100 ft total		0.38	0.26	0	0	0.64
	100-200 ft	5-10 ft	0.40	1.7	0	0	2.1
	100-200 ft total		0.40	1.7	0	0	2.1
	200-500 ft	5-10 ft	0	0.13	0	0	0.13
	200-500 ft total		0	0.13	0	0	0.13
MORTON total			0.78	2.1	0	0	2.8
OLIVER	0-100 ft	2.5-5 ft	7.5	4.9	3.4	0	16
		5-10 ft	28	47	42	0	120
		10-20 ft	31	7.2	0.37	0	39
		20-40 ft	0.79	0.39	0	0	1.2
	0-100 ft total		67	59	46	0	170
	100-200 ft	2.5-5 ft	3.0	5.9	11	0	20
		5-10 ft	25	110	68	0	210
		10-20 ft	20.0	69	36	0	120
	100-200 ft total		48	190	110	0	350
	200-500 ft	2.5-5 ft	1.1	4.7	0.69	0	6.5
		5-10 ft	7.3	47	20	0	75

Table WN-13. Beulah-Zap coal resources—continued

County	Overburden thickness	Net coal thickness	Reliability category (distance from data point)				Grand total (MST)
			Measured (<1/4 mi)	Indicated (1/4-3/4 mi)	Inferred (3/4-3 mi)	Hypothetical (>3 mi)	
OLIVER	200-500 ft	10-20 ft	5.7	21	6.4	0	34
	200-500 ft total		14	73	27	0	110
OLIVER total			130	320	190	0	640
Grand total (MST)			1,200	1,600	1,500	550	4,800

Table WN-14. Coal resources of the Beulah-Zap coal zone in the Beulah coalfield, Williston Basin, North Dakota, reported by 7.5-minute quadrangle (fig. WN-9) map area. Resources are reported in millions of short tons (MST) with two significant figures. The table does not include resources for coal less than 2.5 ft thick, in mine areas, or in areas containing Beulah-Zap clinker (fig. WN-11). Resource numbers will not sum to match total due to independent rounding

7.5-minute quadrangle map	Total (MST)	7.5-minute quadrangle map	Total (MST)	7.5-minute quadrangle map	Total (MST)
BEULAH	330	GLEN ULLIN NE	34	MEDICINE BUTTE NE	79
BEULAH NE	240	GLEN ULLIN NW	22	MEDICINE BUTTE SE	300
BEULAH NW	590	GOLDEN VALLEY	180	MEDICINE BUTTE SW	210
BLACKWATER LAKE	6.0	GOLDEN VALLEY NE	230	OTTER CREEK	74
BLUE HILL	42	HAILSTONE BUTTE	29	RED BUTTE	48
DOUGLAS EAST	92	HANNOVER NW	3.5	RED BUTTE NW	30
DOUGLAS WEST	120	HANNOVER NW	3.5	RED BUTTE SW	400
EMMET	14	HAZEN EAST	22	ROSEGLEN	41
EMMET NE	120	HAZEN NE	140	SCHAFFNER CREEK NE	15
EMMET SE	35	HAZEN NW	190	WILLOW CREEK EAST	46
GARRISON	280	HAZEN WEST	140	ZAP	560
GARRISON DAM NORTH	44	MEDICINE BUTTE	130	Grand total (MST)	4,800

Table WN-15. Beulah-Zap coal resources in the Beulah coalfield, Williston Basin, North Dakota, reported by Federal coal and surface ownership (fig. WN-10). Resources are shown in millions of short tons (MST) with two significant figures. The table does not include resources for coal less than 2.5 ft thick, in mine areas, or in areas containing Beulah-Zap clinker (fig. WN-11). Resource numbers will not sum to match total due to independent rounding

Federal ownership	Total (MST)
No Federal coal or surface ownership	3,400
Federal coal ownership, but no Federal surface ownership	1,400
Grand total (MST)	4,800

Table WN-16. Data used for computation of confidence intervals within reliability categories for Beulah-Zap coal resources in the Beulah coalfield, Williston Basin, North Dakota. Volume refers to the calculated resource in millions of short tons (MST). NA, not applicable

Parameter	Reliability category				Entire area
	Measured	Indicated	Inferred	Hypothetical	
Area (in square meters)	237,120,736	368,807,104	314,035,128	120,633,512	1,040,596,479
Percent of area	23	35	30	12	100
Acres (area x 0.0002471)	58,594	91,134	77,600	29,809	257,137
SD (standard deviation (in ft) from residual thickness)	4.132	4.132	4.132	4.132	NA
Acre feet (acres x SD)	242,110	376,567	320,642	123,172	NA
Volume standard deviation (MST)	20	74	274	218	586
Pseudo *n*	466	81	4	1	NA

Table WN-17. Estimates of uncertainty (calculated with measurement error) for Beulah-Zap coal resources in the Beulah coalfield, Williston Basin, North Dakota. To show detail, resources calculations are in millions of short tons (MST) with four significant figures

Parameter	Reliability category				Entire area
	Measured	Indicated	Inferred	Hypothetical	
Total calculated resource (MST)	1,172	1,561	1,546	551.4	4,830
Lower 90% confidence limit (MST)	1,139	1,439	1,095	193.0	3,866
Upper 90% confidence limit (MST)	1,205	1,683	1,997	910.0	5,794

Table WN-18. Coal resources of the Hagel coal zone in the Center-Falkirk coalfield, Williston Basin, North Dakota, reported by overburden (fig. WN-16), net coal thickness (fig. WN-15), and reliability categories. Zeros (0) indicate areas where no resources were calculated. Table does not include resources for coal less than 2.5 ft thick or coal in mine areas (fig. WN-15). Resources are reported in millions of short tons (MST) with two significant figures. Resource numbers will not sum to match totals due to independent rounding

County	Overburden thickness	Net coal thickness	Reliability category (distance from data point)				Grand total (MST)
			Measured (<1/4 mi)	Indicated (1/4-3/4 mi)	Inferred (3/4-3 mi)	Hypothetical (>3 mi)	
MCLEAN	0-100 ft	2.5-5 ft	21	25	4.7	0	50.0
		5-10 ft	130	120	25	0	270
		10-20 ft	120	69	5.7	0	190
	0-100 ft total		270	210	35	0	510
	100-200 ft	2.5-5 ft	7.3	10.0	5.8	0	23
		5-10 ft	29	47	13	0	89
		10-20 ft	23	57	15	0	95
	100-200 ft total		59	110	35	0	210
MCLEAN total			330	320	70.0	0	720
MERCER	0-100 ft	2.5-5 ft	4.5	15	5.1	0	25
		5-10 ft	9.7	10.0	23	0	43
		10-20 ft	56	30.0	28	0.29	110
		20-40 ft	14	35	17	0	66
	0-100 ft total		84	90.0	74	0.29	250
	100-200 ft	2.5-5 ft	10	25	39	1.8	77
		5-10 ft	12	41	66	0	120
		10-20 ft	51	23	94	0	170
		20-40 ft	6.4	26	25	0	57
	100-200 ft total		80	120	220	1.8	420

Table WN-18. Hagel coal resources—continued

County	Overburden thickness	Net coal thickness	Reliability category (distance from data point)				Grand total (MST)
			Measured (<1/4 mi)	Indicated (1/4-3/4 mi)	Inferred (3/4-3 mi)	Hypothetical (>3 mi)	
MERCER	200-500 ft	2.5-5 ft	4.5	22	89	9.7	130
		5-10 ft	2.9	14	98	0	110
		10-20 ft	4.6	2.6	42	0	49
		20-40 ft	3.4	5.0	3.0	0	12
	200-500 ft total		15	43	230	9.7	300
MERCER total			180	250	530	12	970
OLIVER	0-100 ft	2.5-5 ft	16	4.4	0	0	20.0
		5-10 ft	100	46	1.0	0	150
		10-20 ft	430	260	22	0	710
		20-40 ft	56	40	2.1	0	98
	0-100 ft total		600	350	25	0	970
	100-200 ft	2.5-5 ft	4.1	4.3	3.8	0	12
		5-10 ft	23	52	28	0	100
		10-20 ft	310	380	110	0	800
		20-40 ft	53	89	18	0	160
	100-200 ft total		390	520	160	0	1,100
	200-500 ft	2.5-5 ft	7.1	22	17	0	47
		5-10 ft	32	71	93	0	200
		10-20 ft	34	140	120	0	300
		20-40 ft	6.4	71	45	0	120
		>40 ft	1.7	0	0	0	1.7
	200-500 ft total		81	300	280	0	660
OLIVER total			1,100	1,200	460	0	2,700
Grand total (MST)			1,600	1,700	1,100	12	4,400

Table WN-19. Coal resources of the Hagel coal zone in the Center-Falkirk coalfield, Williston Basin, North Dakota, reported by 7.5-minute quadrangle (fig. WN-13). Resources are reported in millions of short tons (MST) with two significant figures. Table does not include resources for coal less than 2.5 ft thick or coal in mine areas (fig. WN-15). Resource numbers will not sum to match total due to independent rounding

7.5-minute quadrangle map	Total (MST)	7.5-minute quadrangle map	Total (MST)	7.5-minute quadrangle map	Total (MST)
BEULAH	3.3	HAZEN EAST	41	RIVERDALE NORTH	7.3
BEULAH NE	65	HAZEN NE	130	RIVERDALE SOUTH	44
CENTER	210	HAZEN NW	350	STANTON	180
COLEHARBOR	85	HAZEN WEST	71	STANTON SE	69
EMMET SW	17	LAKE NETTIE	100	TURTLE CREEK NW	27
FORT CLARK	260	NELSON LAKE	67	UNDERWOOD	120
GARRISON DAM SOUTH	24	OTTER CREEK	190	WASHBURN	0.22
HANNOVER	380	RED BUTTE	290	WASHBURN NE	220
HANNOVER NE	430	RED BUTTE NW	34	WASHBURN SW	42
HANNOVER NW	940	RED BUTTE SW	2.0	Grand total (MST)	4,400

Table WN-20. Hagel coal resources in the Center-Falkirk coalfield, Williston Basin, North Dakota, reported by Federal coal and surface ownership (fig. WN-14). Resources are shown in millions of short tons (MST) with 2 significant figures. The table does not include resources in mine areas or areas containing less than 2.5 ft of coal. Resource numbers will not sum to match total due to independent rounding

Federal ownership	Total (MST)
No Federal coal or surface ownership	3,600
Federal coal, but no Federal surface ownership	760
Grand total (MST)	4,400

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Table WN-21. Data used for computation of confidence intervals within reliability categories for Hagel coal resources in the Center-Falkirk coalfield, Williston Basin, North Dakota. Volume refers to the calculated resource in millions of short tons (MST). NA, not applicable

Parameter	Reliability Category				Entire Area
	Measured	Indicated	Inferred	Hypothetical	
Area (in square meters)	335,432,395	389,435,954	303,702,006	6,609,852	1,035,180,207
Percent of area	32	38	29	1	100
Acres (area x 0.0002471)	82,887	96,232	75,046	1,633	255,799
SD (standard deviation (in ft) from semivariogram model)	4.295	5.088	6.403	6.762	NA
Acre feet (acres x SD)	355,982	489,643	480,516	11,045	NA
Volume standard deviation (MST)	25	94	418	20	556
Pseudo *n*	660	85	4	1	NA

Table WN-22. Estimates of uncertainty (calculated with measurement error) for the Hagel coal resources in the Center-Falkirk coalfield, Williston Basin, North Dakota with measurement error. To show detail, resources are reported in millions of short tons (MST) with four significant figures

Parameter	Reliability category				Entire area
	Measured	Indicated	Inferred	Hypothetical	
Total calculated resource (MST)	1,585	1,746	1,057	11.77	4,401
Lower 90% confidence limit (MST)	1,544	1,592	371.0	0.000	3,487
Upper 90% confidence limit (MST)	1,625	1,901	1,745	44.00	5,315