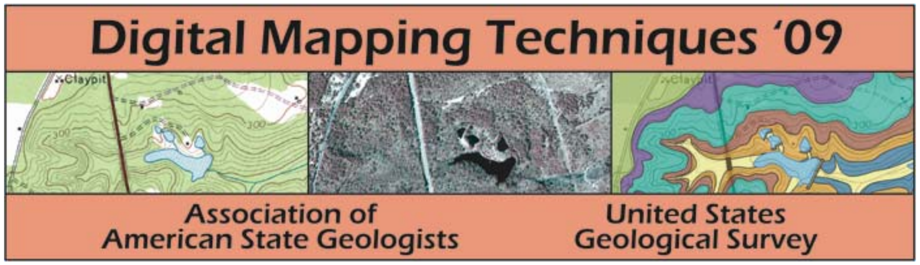


The following was presented at DMT'09
(May 10-13, 2009).

The contents are provisional and will be
superseded by a paper in the
DMT'09 Proceedings.

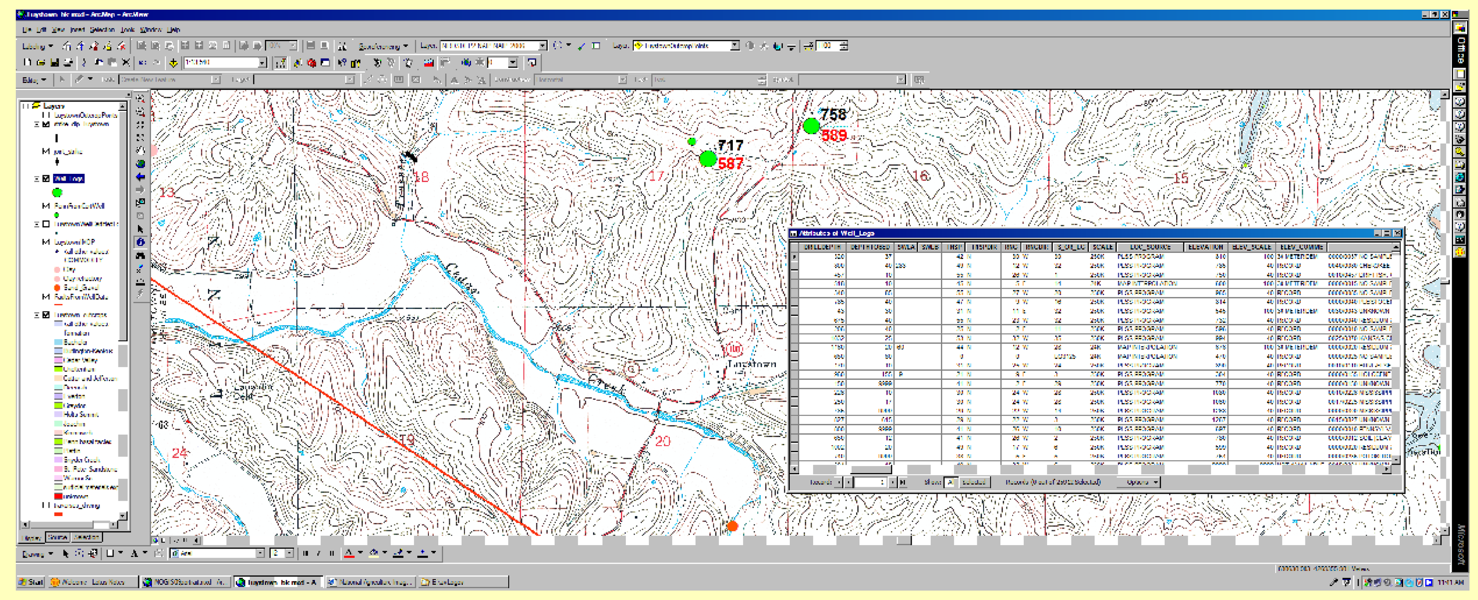
See also earlier Proceedings (1997-2008)
http://ngmdb.usgs.gov/info/dmt/

Surficial Material and Bedrock Geologic Mapping at the Missouri Department of Natural Resources, Division of Geology and Land Survey

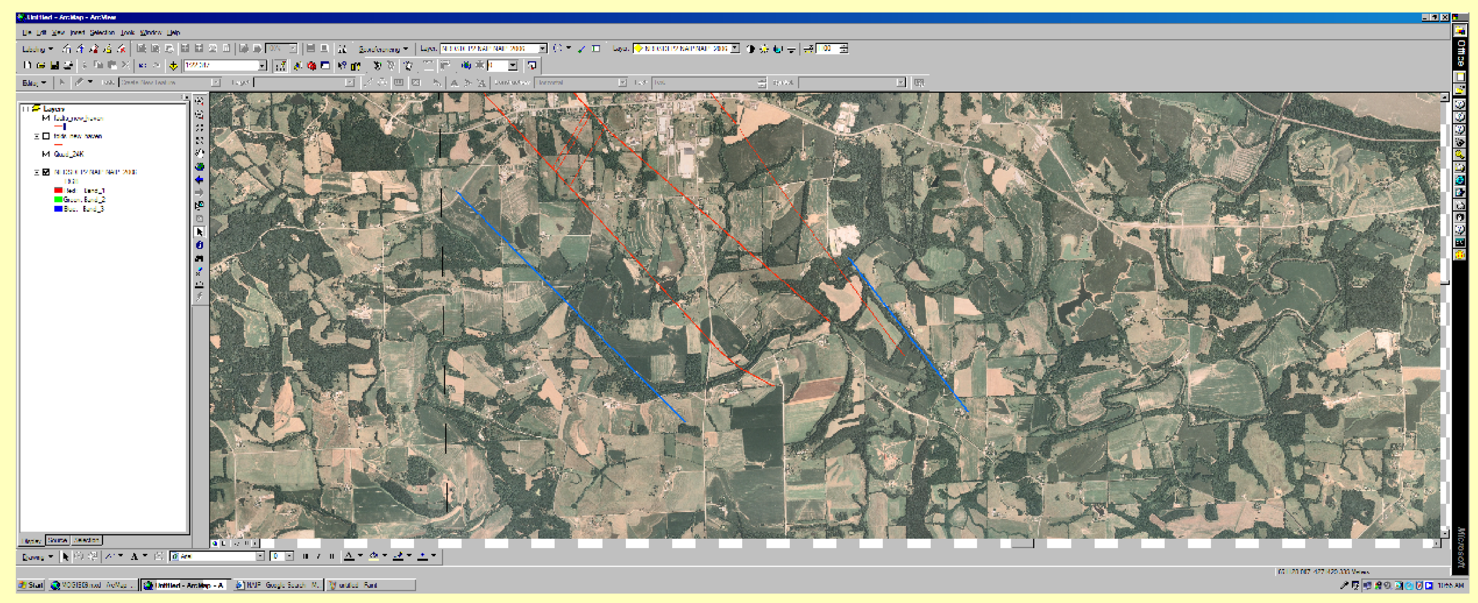
Edith Starbuck
Missouri Department of Natural Resources
Division of Geology and Land Survey
February 2009

DNR photo by Mike Siemens

Most of the information that geologists use to make a new geologic map comes from field work. Geologists collect information about exposures of bedrock and surficial materials and record the locations where the data was collected. U. S. Geological Survey (USGS) 1:24,000 scale topographic maps have traditionally been used for data collection and as the base map for the hard copy version of the geologic map. Digital raster graphic (DRG) images of these maps currently serve as base maps for geologic maps. Field data are collected on Panasonic Toughbook™ notebook computers loaded with DRGs and ArcPad.™ A Garmin™ global positioning system (GPS) receiver communicates with the Toughbook via Bluetooth technology. The small GPS receiver is easily held in the hand as the computer is cradled in the crook of an arm, just as any notebook would be held. Ease of carrying is important since long traverses are required to collect required information for the geologic map. This equipment allows the geologist to enter data directly into a geographic information system (GIS).



Data from files of well logs and measured sections are maintained and stored in databases at the Division of Geology and Land Survey (DGLS). This information is added to the ArcMap™ project. Information from published references relating to the study area are also included. Aerial imagery, stored on the department's digital data server, may reveal lineaments related to geologic structures.

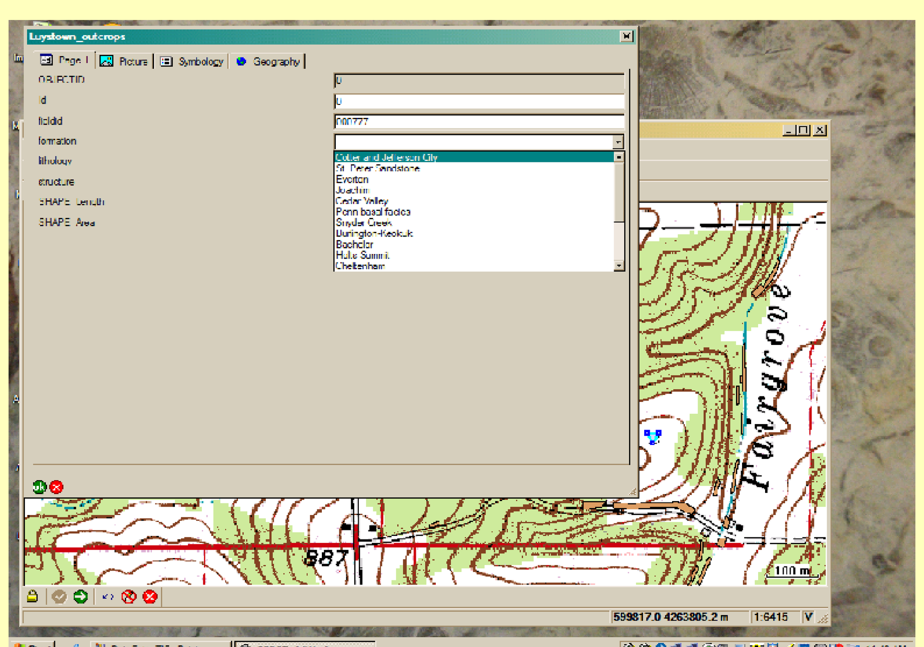


DNR photo by Edith Starbuck

In the office, the data is transferred to the ArcMap™ project that the geologist uses for data collection, interpretation, map creation and layout.

DNR photo by Mark Gordon

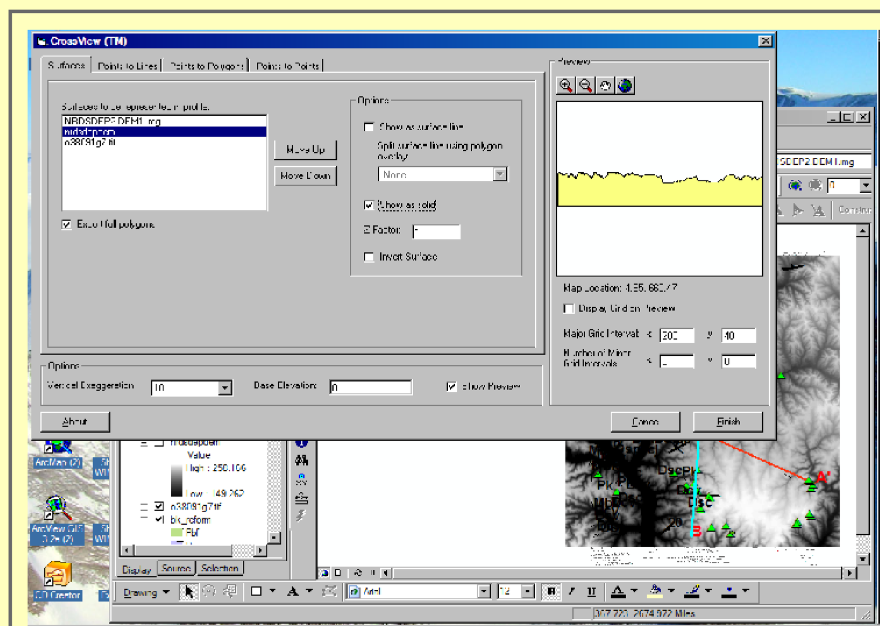
Field data entry into ArcPad.™



ArcPad™ data entry dialog box.

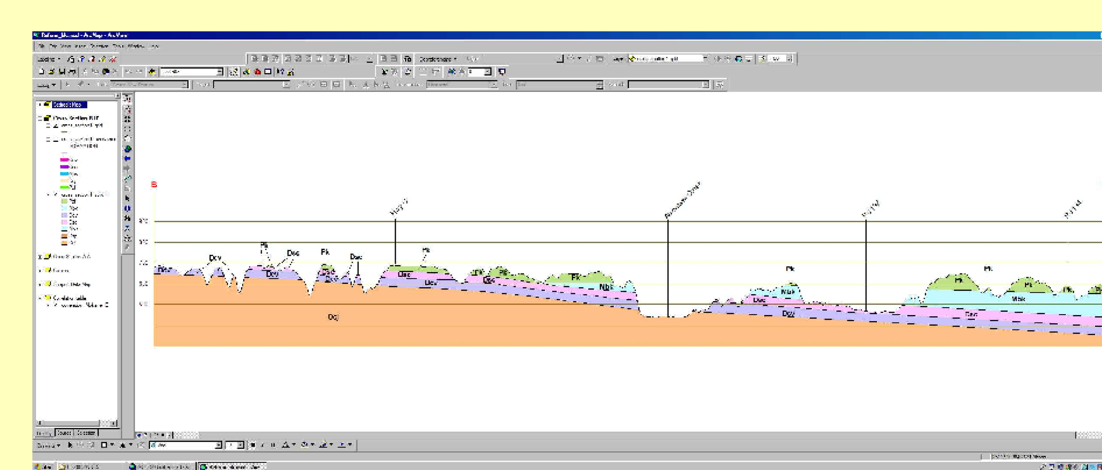
The Division of Geology and Land Survey (DGLS) produces maps showing the distribution of surficial material and bedrock types. At right is an example of a bedrock map (at reduced size) to demonstrate a typical map layout. The maps are produced for distribution at a scale of 1:24,000. Regional maps are published at smaller scales, such as 1:100,000. These are compiled from the larger scale maps.

DGLS began using GIS to produce geologic maps in 1997 by using Arc View™ to recreate maps that had previously been drawn on paper. Data collection and map development methods have changed significantly since that time. Today, notebook computers with ArcPad™ software and a GPS receiver allow geologists to enter data in the field. The geologist then uses ArcMap™ in the office to help with data interpretation, map creation and layout. The process evolves each year. DGLS is currently in the process of transitioning from paper to electronic field notes.



CrossView™ dialog box.

In 2008, DGLS began using an ArcMap™ plug-in called CrossView™ (A-Prime Software) to construct the geologic cross sections included in the layout. CrossView™ significantly reduces the amount of time necessary to create a cross section. With this plug-in, the geologist can display information from well logs and even drape the newly created geologic map across the topographic profile.



Geologic cross sections are developed within an ArcMap™ Data View.

DNR photo by Edith Starbuck

DNR photo by Edith Starbuck

In the field, geologists collect data used to construct bedrock geologic maps. At left, a rock sample is examined with a hand lens to determine texture and crystallinity. In the photo at right, a geologist measures the dip (degree of inclination or slope) of a bedrock surface.

Base maps have been improved in two ways. The appearance has been muted by representing contour lines and text as a dark gray color. This allows the geology to be more prominently displayed. In addition, DGLS has begun using DRGs that are produced in-house at higher resolution than the standard USGS DRGs. In the example below, a paper topographic map was scanned at 400 dots per inch. The higher resolution base maps will improve the legibility of the paper product and the appearance of the digital image.

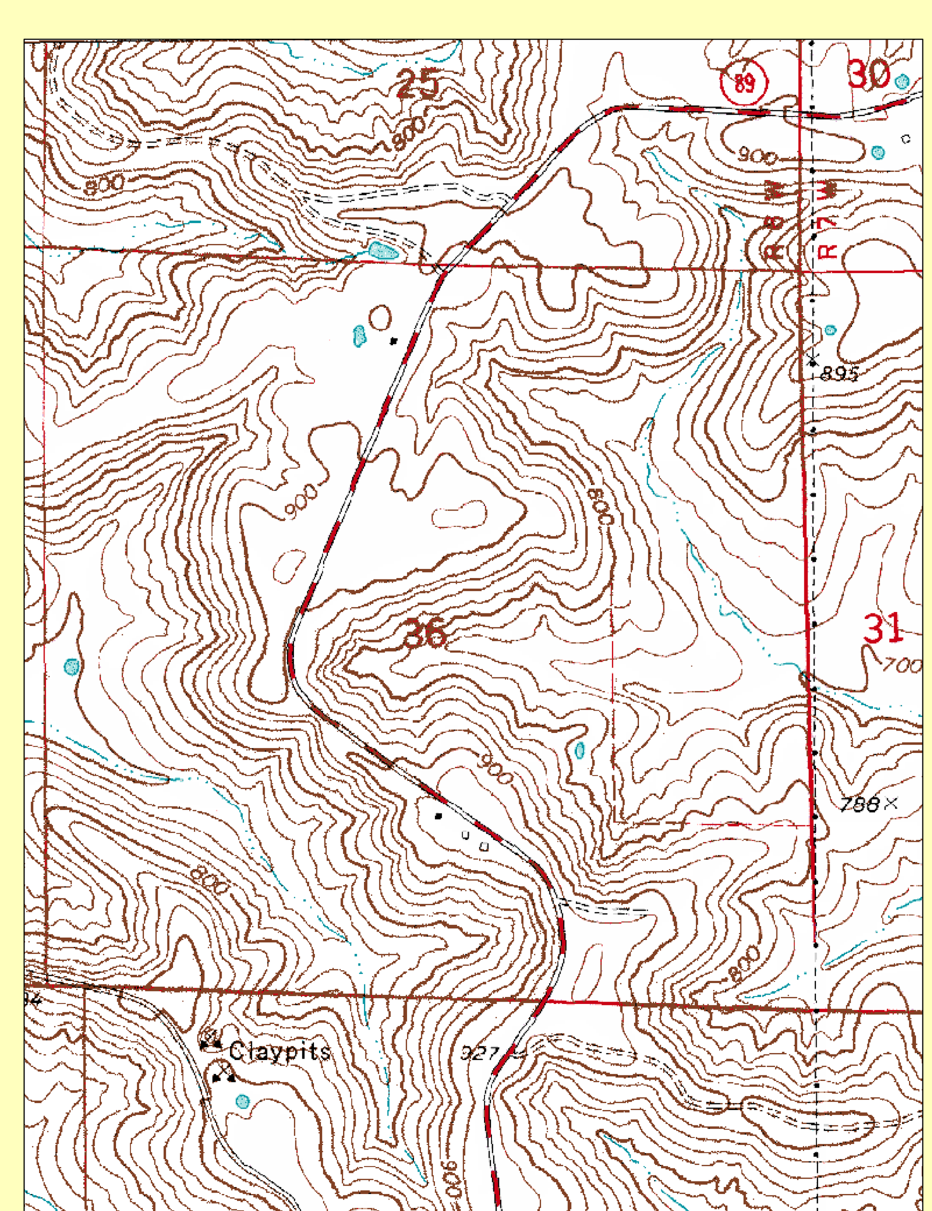
Additional information about surficial materials is obtained by drilling and coring. This is a cooperative effort between the Missouri Departments of Natural Resources and Transportation. Surficial materials include all unconsolidated material between the top of bedrock and the ground surface. Residuum (formed in place by the decomposition of bedrock) and alluvium (stream deposited material) are examples of surficial materials.

DNR photo by Mike Siemens

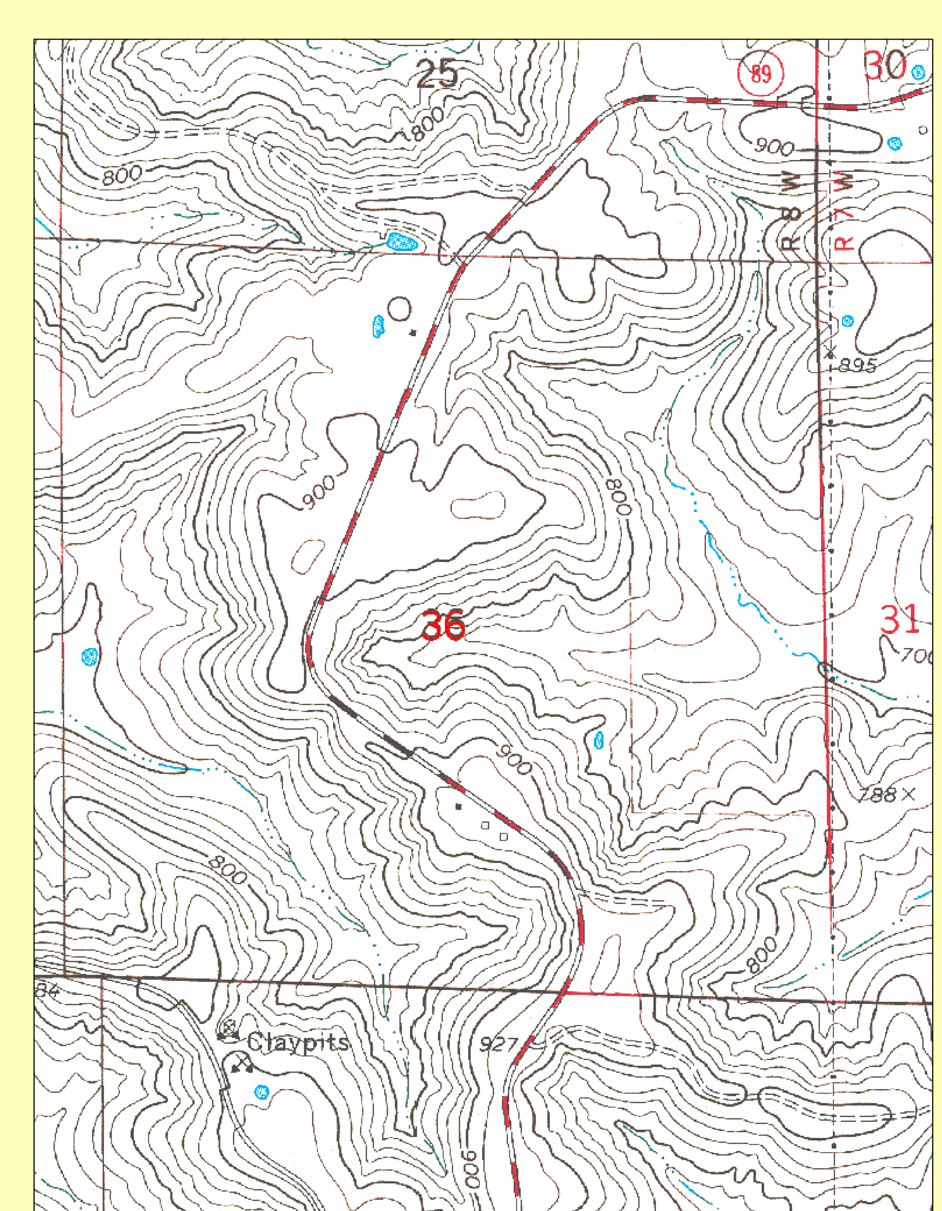
Collecting surficial material cores.

DNR photo by Mike Siemens

Cores of glacially deposited till and loess, two more examples of surficial materials.



USGS digital raster graphic plotted at 1:10,000 scale.
The resolution of most USGS DRGs is 250 dots per inch.



Digital raster graphic created at DGLS and plotted at 1:10,000 scale.
The DGLS scans paper topographic maps at a resolution of 400 dots per inch.

Map size reduced to fit poster

BEDROCK GEOLOGIC MAP OF THE REFORM 7.5' QUADRANGLE CALLAWAY COUNTY, MISSOURI

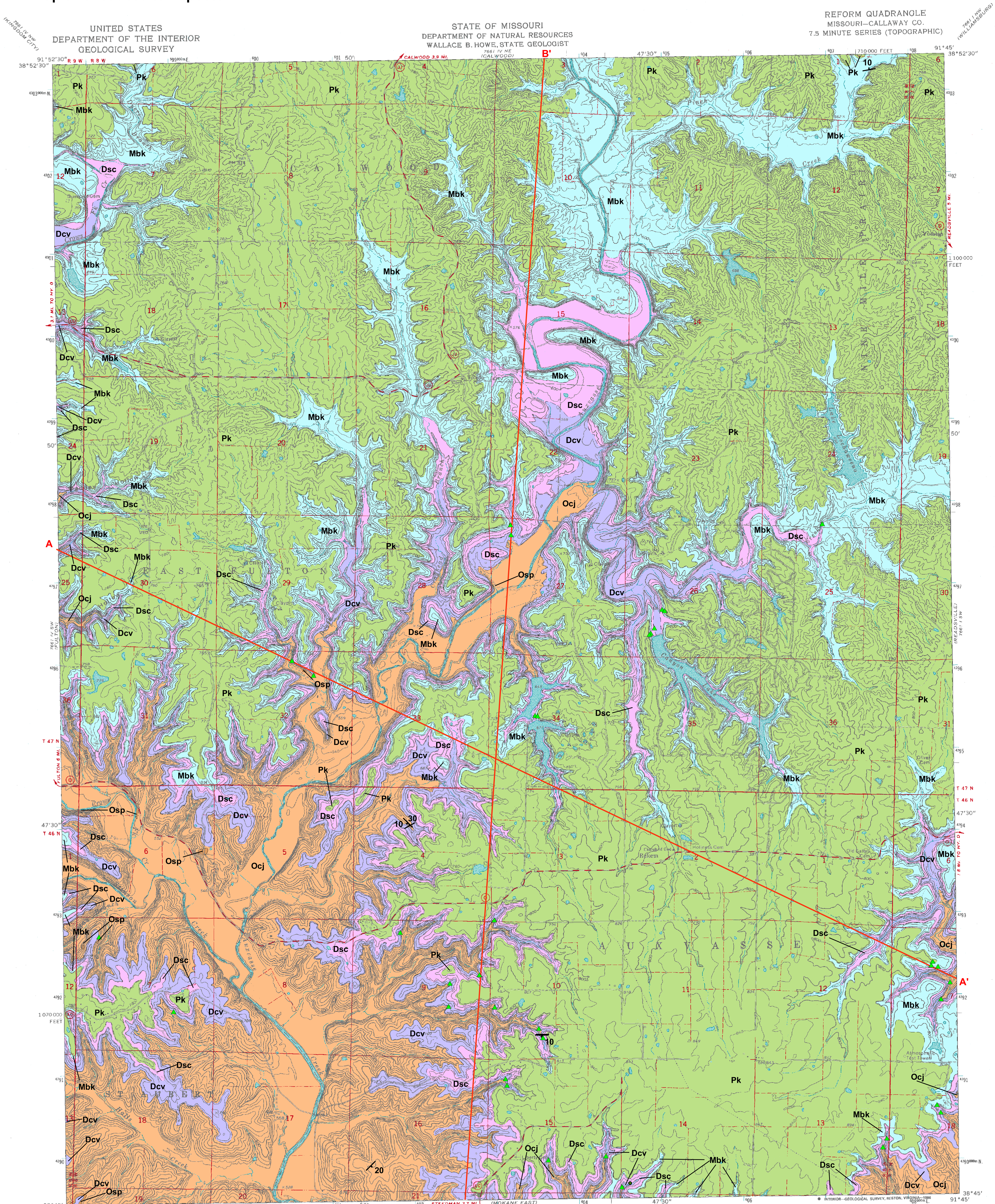
Geology and Digital Compilation by
Edith A. Starbuck

2008

OFM-08-537-GS

MISSOURI DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGY AND LAND SURVEY

THIS GEOLOGIC MAP WAS FUNDED IN PART BY THE U.S. GEOLOGICAL SURVEY
NATIONAL COOPERATIVE GEOLOGIC MAPPING PROGRAM



Mapped, edited, and published by the Geological Survey
Control by USGS and NOS/NOAA

Topography by photogrammetric methods from aerial photographs taken 1970. Field checked 1975

Projection and 10,000-foot grid ticks: Missouri coordinate system, central zone (transverse Mercator)
1000-meter Universal Transverse Mercator grid ticks, zone 15, shown in blue. 1927 North American Datum
To place on the predicted North American Datum 1983, move the projection lines 1 meter south and 13 meters east as shown by dashed corner ticks

Fine red dashed lines indicate selected fence and field lines where generally visible on aerial photographs. This information is unchecked

UTM GRID AND 1985 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

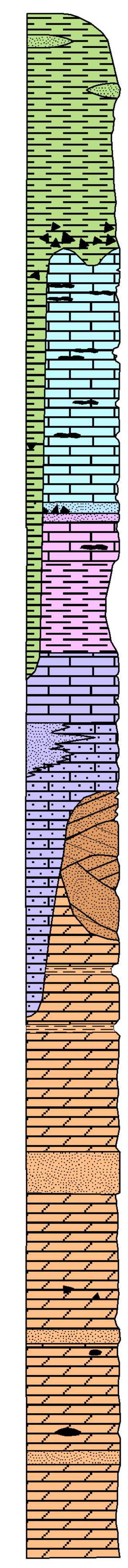
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
AND DIVISION OF GEOLOGY AND LAND SURVEY
MISSOURI DEPARTMENT OF NATURAL RESOURCES, ROLLA, MISSOURI 65401
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

QUADRANGLE LOCATION

ROAD CLASSIFICATION
Primary highway, hard surface
Light-duty road, hard or improved surface
Secondary highway, hard surface
Unimproved road
Interstate Route
U. S. Route
State Route

REFORM, MO.
38091-G7-TF-024
1975
DMA 7661 IV SE–SERIES V879

STRATIGRAPHIC COLUMN



Approximate vertical scale
1:300
(1 inch = 25 feet)

Access permission needs to be granted to visit any privately owned land.

DESCRIPTION OF MAP UNITS

Pk

KREBS SUBGROUP (PENNSYLVANIAN SUBSYSTEM, DESMOINESIAN STAGE, CHEROKEE GROUP) - The Warner Sandstone, Graydon Conglomerate and Cheltenham Formation are poorly exposed on the Reform quadrangle. The variable thickness of these formations along with poor exposures and scant well log data makes it difficult to map them as separate units, so they are combined on this map. The Graydon Conglomerate is the basal Pennsylvanian unit and is time-transgressive across the state. Though it is indicated to be Desmoinesian, it is Atokan in some parts of the state. The Graydon is typically a chert conglomerate to breccia, but has a variable lithology, and includes sandstone ledges, maroon-red and gray or tan clays and claystone. The conglomerate is composed primarily of reworked crinoidal Mississippian chert. The sandstone ledges are typically one to four feet thick with variable grain sizes, but are generally very fine to fine grained and are iron or silica cemented. Iron nodules and staining are common in the sandstone. Sandstone may also be friable and clayey and be the same tan and maroon-red color as much of the clay. The conglomerate may be cemented with iron oxide, but is more often poorly consolidated with a matrix of tan or maroon clay. Cherts of residual Graydon are widely scattered across the quadrangle.

The Cheltenham is composed of high-alumina clays that are buff, white, gray or maroon-red. The Cheltenham may overlie Graydon, or it may directly overlie Mississippian or Devonian carbonates. Solutioning on the pre-Pennsylvanian surface has caused the lower contact to be quite irregular. Refractory clay mining operations scattered across the southern half of the mapped area were developed in pockets of clay that fill depressions in this irregular surface. The absence of old clay pits in the northern part of the quadrangle is probably due to burial of the Cheltenham beneath a considerable thickness of glacial till.

Total thickness of the Pennsylvanian on the Reform quadrangle is estimated to be up to 40 feet, though it may exceed 100 feet in "paleo sink" structures. The Pennsylvanian/Mississippian contact is concealed by a thick cover of glacial till in the northeastern and north central part of the quadrangle. The Pennsylvanian/Mississippian contact is less reliable here than in other parts of the map area. The Pennsylvanian unconformably overlies the Mississippian Burlington-Keokuk throughout most of the map area, but in the southwestern quarter of the quadrangle the Pennsylvanian directly overlies Devonian bedrock.

Mbk

BURLINGTON-KEOKUK LIMESTONE (MISSISSIPPIAN SUBSYSTEM, OSAGEAN SERIES) – The Burlington and Keokuk limestones cannot be distinguished from each other throughout much of Missouri and are usually mapped together as one unit, the Burlington-Keokuk Limestone. The Burlington-Keokuk is present throughout the map area except in much of the southwestern quarter of the quadrangle where it appears to have been eroded prior to deposition of the Pennsylvanian. It is typically a gray, medium- to coarse-crystalline, fossiliferous lime packstone. Crinoids are the dominant fossil, followed by brachiopods and bryozoans. Bed thickness varies from a few inches to greater than two feet. Nodular chert is scattered between the limestone beds. The chert that was observed in Burlington-Keokuk outcrops is pale-gray and crinoidal with a smooth, conchoidal fracture. The chert often contains molds of crinoid columnals. Fossiliferous chert is abundant in the overlying residuum, but in many cases this may actually be residual Graydon Conglomerate. The basal two to twelve feet of the Burlington is generally orange-tan, massive, fine to medium crystalline or even earthy and may be sandy. The Burlington-Keokuk is generally easily solutioned. Where it is thin, the formation is comprised mainly of large boulders of crinoidal limestone floating in residual clay and chert. The maximum thickness of the Burlington-Keokuk Limestone on the Reform quadrangle is about 110 feet in the north half of the quadrangle.

BACHELOR SANDSTONE (MISSISSIPPIAN SUBSYSTEM, KINDERHOOKIAN SERIES) and HOLTS SUMMIT SANDSTONE (DEVONIAN SYSTEM, UPPER DEVONIAN SERIES) - Sandstone is present above the Snyder Creek Shale in several locations throughout the quadrangle. These sandstones are too thin to constitute a mappable unit. At an exposure on the adjacent Readsville quadrangle in the SW ¼ of Section 5, T46N, R07W, both the Holts Summit and Bachelor Sandstones are both present. The Holts Summit Sandstone is approximately one foot thick, gray and very well cemented. The Bachelor Sandstone is also about one foot thick, but is pale gray, and less well cemented. The top and base of this sandstone are softer and include some blue-green shale. Small black phosphatic nodules are also found in the Bachelor. Weathered surfaces of both sandstones oxidize to reddish tan or yellowish tan. Thickness and characteristics of both sandstones vary. The sandstones are generally one to three feet thick. No location was found on the Reform quadrangle where the two beds occur in sequence. The two beds are very difficult to tell apart, but the presence of a sandstone bed distinguishes the contact between the limestone of the Snyder Creek Shale and the basal Burlington Limestone where these two limestone have a very similar appearance.

Dsc

SNYDER CREEK SHALE – The Snyder Creek Shale is generally poorly exposed. It consists of shale, tan to blue gray that is overlain by about six to 12 feet of dolomitic limestone, orange-tan, fine, argillaceous, massively bedded. Brachiopods of the genus *Atrypa* locally weather from the shale beneath the limestone, but the brachiopod fauna may vary. Brown, nodular chert may be present in the limestone, though it is never abundant. In some locations, the limestone appears to be absent. The limestone generally thickens toward the North, but is not more than 10 feet thick. The shale is orange tan to blue gray and may be silty. Thin, one to four inch thick beds of fine sandstone or siltstone may be present. The shale within three feet of the base of the limestone is calcareous in most locations. The total thickness of the Snyder Creek ranges from about 20 to 50 feet. An excellent natural exposure of Snyder Creek is found at the head of the drainage in SE ¼ of SE ¼ of SW ¼ of section 10, T. 46 N., R. 8 W.

Dcv

CEDAR VALLEY LIMESTONE – The Cedar Valley Limestone consists of the Mineola and the Callaway facies. The Mineola facies is limestone, pale-gray, medium- to coarse-crystalline, fossiliferous grainstone to packstone. It is often crinoidal, with a strong resemblance to the Burlington Limestone. The Mineola, however, lacks chert and is often sandy. This allows differentiation from the Burlington. Sandy limestones in the Cedar Valley often grade laterally into calcareous sandstones. The basal five feet of the Cedar Valley is sandy, grading to sandstone across much of the quadrangle. A sandstone in the Cedar Valley has previously been identified as the Hoing (Thompson, 1993). The Callaway facies is limestone, gray to tan or brown, fine- to medium-crystalline, fossiliferous to unfossiliferous, wackestone to mudstone. Fossils include colonial coral fragments, horn corals, crinoid columnals, brachiopods and bryozoans. The top of the Cedar Valley Limestone is usually marked by very fossiliferous limestone made up primarily of bryozoans. In many places, it is a bryozoan coquina. The maximum thickness of the Cedar Valley Limestone is about 60 feet, though it thins to the south and is absent in local areas. The contact with the overlying Snyder Creek Shale is abrupt but conformable.

PLATTIN LIMESTONE – Isolated lenses of Plattin Limestone have been reported on the Reform quadrangle. DGLS well log files provided an outcrop description indicating the presence of Plattin in the NW ¼ of section 6, T. 46 N., R. 8 W. This property could not be accessed during the field study. Plattin Limestone was also reported at a pit in the quarry located in the NW ¼ of section 27, T. 47 N., R. 7 W. This stratigraphic horizon was not accessible during the investigation. No Plattin Limestone was observed during the investigation.

Osp

ST. PETER SANDSTONE - The St. Peter consists of massive beds of pale gray to pale tan quartz sandstone, medium-grained, generally well-sorted, rounded and frosted. The rock varies from poorly to moderately cemented and is commonly friable. Large-scale crossbeds are common. It is generally less than five feet thick on the Reform quadrangle but may occur as large sandstone masses in the irregular surface of the Cotter Dolomite. The contact between the St. Peter and the underlying dolomite is very irregular, and has over 80 feet of relief in the south half of the NW of section 6, T. 46 N., R. 8 W. The total thickness of the St. Peter Sandstone is quite variable and ranges from 0 to over 80 feet. This dramatic variation in thickness can occur over a relatively short distance. The St. Peter is absent across much of the quadrangle. It is bounded both above and below by unconformities.

Ocj

COTTER AND JEFFERSON CITY DOLOMITES (UNDIVIDED) -This map unit is comprised primarily of dolomite, but also includes chert, sandstone and numerous thin shales. The dolomite is generally a tan, fine-crystalline, silty to sandy dolomudstone, but includes scattered beds of algal dolomite, conglomeratic beds of dolomite and chert pebbles, and cherty dolomite. Chert is most often porous and white, occurring in thin seams; nodular zones of smooth gray and white or quartzose sandy and oolitic chert also occur. Thin, greenish-gray shale seams are also found in the upper part of the map unit. Sandstones are dark-reddish-brown, medium- to thin-bedded, well-cemented, often ripple-marked with small-scale cross bedding. Individual grains are fine and angular. Sandstone beds are up to five feet thick. The total exposed thickness is approximately 200 feet.

STRUCTURAL FEATURES

Regional dip is to the north-northwest. This dip is more pronounced in the pre-Pennsylvanian part of the section. The Mississippian and part of the Devonian section was removed prior to deposition of the Pennsylvanian on the southern portion of the mapped area. Irregularities, such as paleo-sinkholes, are also present at this unconformity. Deposition on an irregular surface is probably also responsible for the variability in thickness of the Devonian section, particularly across the southern part of the quadrangle. Evidence of pre-Devonian folding is present to the south, on the adjacent Mokane East quadrangle (Starbuck, 2008). It appears that uplift centered somewhere to the south-southeast (Ozark Dome) affected this area during at least these two periods. Minor folding of Devonian Snyder Creek and Cedar Valley formations is not expressed in the overlying Mississippian Burlington Limestone at the quarry exposures in NW ¼ section 27, T. 47 N., R. 8 W. This suggests that another period of deformation prior to deposition of the Mississippian probably also occurred.

ECONOMIC GEOLOGY

The Burlington-Keokuk and Cedar Valley limestones are used as sources of crushed and broken limestone on the Reform quadrangle. Though they have been used primarily as road base and rip rap, these formations are sources of high quality limestone and have a variety of uses. No quarries are known to exist in the Cotter and Jefferson City formations on the Reform quadrangle, however, several small quarries have been operated in the past in this unit just a few miles to the south, on the Mokane East quadrangle. The dolomite was reported to have been crushed and broken, and was probably used primarily for road construction. Refractory clay has been mined from deposits of Cheltenham Formation in scattered locations on the southern half of the quadrangle. These deposits are located in paleo-sink structures where the clay thickness may exceed 100 feet, but is generally several tens of feet. Similar deposits are probably also present on the northern half of the quadrangle buried beneath a cover of thick glacial till.

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LEGEND

Bedrock Map

Stratigraphic contact - triangle on line indicates observed field location; dashed line where location is probable

45 Strike and dip of bedding

A — A' Line of cross section

Stratigraphic Column Lithologies

Limestone | Limestone with chert | Dolomite | Sandy dolomite | Claystone and shale | Claystone with angular chert fragments | Lateral transition from sandstone to sandy limestone | Sandstone with cross-beddding

Support Data Map

- Well with detailed bedrock description
- Cheltenham or Graydon outcrop
- Burlington-Keokuk outcrop
- Bachelor outcrop
- Holts Summit outcrop
- Snyder Creek outcrop
- Cedar Valley outcrop
- St. Peter outcrop
- Cotter-Jefferson City outcrop
- Roads
- Streams
- Topographic contours
- Section lines

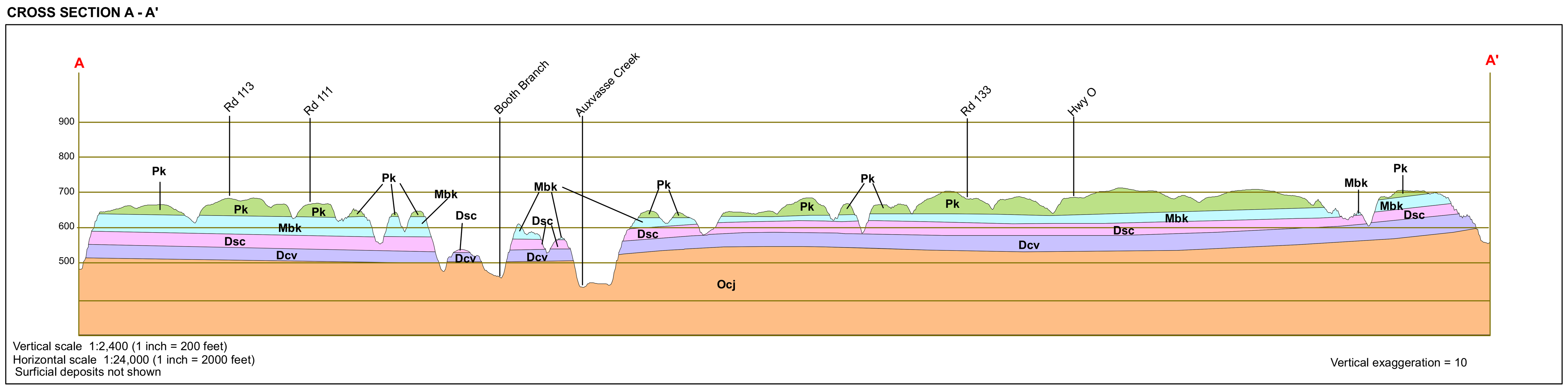
CORRELATION OF MAP UNITS

MAP UNIT SYMBOL	SYSTEM/ *SUBSYSTEM*	SERIES or *STAGE*	FORMATION(S)/MAPPABLE UNIT	THICKNESS IN FEET
Pk	Carboniferous *Pennsylvanian*	*Desmoinesian*	Krebs Subgroup (Graydon Conglomerate and Cheltenham Formation)	0 - 100
~~ unconformity~~				
Mbk	Carboniferous *Mississippian*	Osagean	Burlington-Keokuk Limestone	0 - 110
Dsc	Devonian	Kinderhookian, Upper Devonian	Holts Summit Sandstone, Snyder Creek Shale	20 - 50
Dcv	Devonian	Middle Devonian	Cedar Valley Limestone	0 - 60
~~ unconformity~~				
Osp	Ordovician	Mohawkian	St. Peter Sandstone	0 - 80
~~ unconformity~~				
Ocj	Ordovician	Ibexian	Cotter and Jefferson City Dolomites undivided	200+*

* Complete thickness is not exposed on the Reform quadrangle

Folding of Devonian Cedar Valley and Snyder Creek formations in NW, section 27, T. 47 N., R. 8 W.

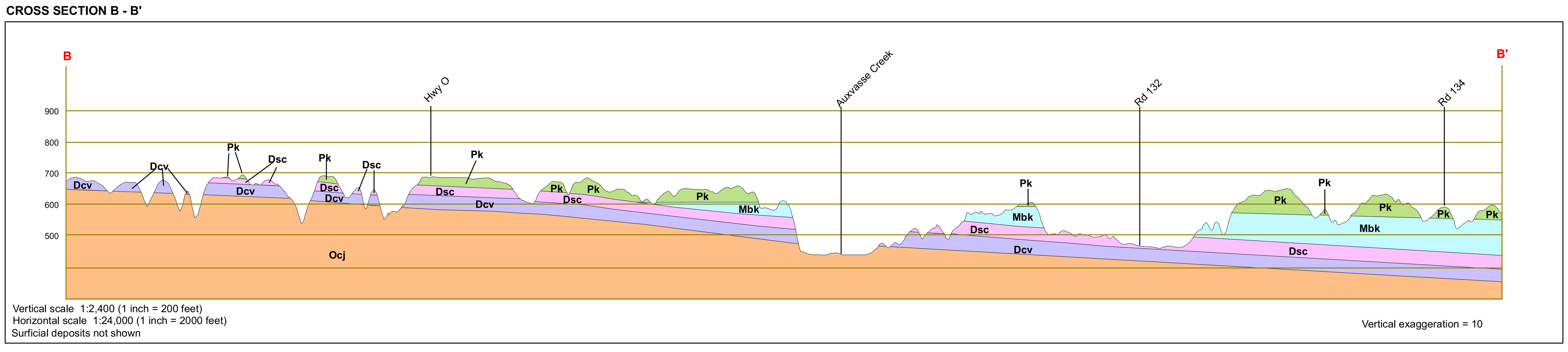
CROSS SECTION A - A'



Vertical scale 1:2,400 (1 inch = 200 feet)
Horizontal scale 1:24,000 (1 inch = 2000 feet)
Surficial deposits not shown

Vertical exaggeration = 10

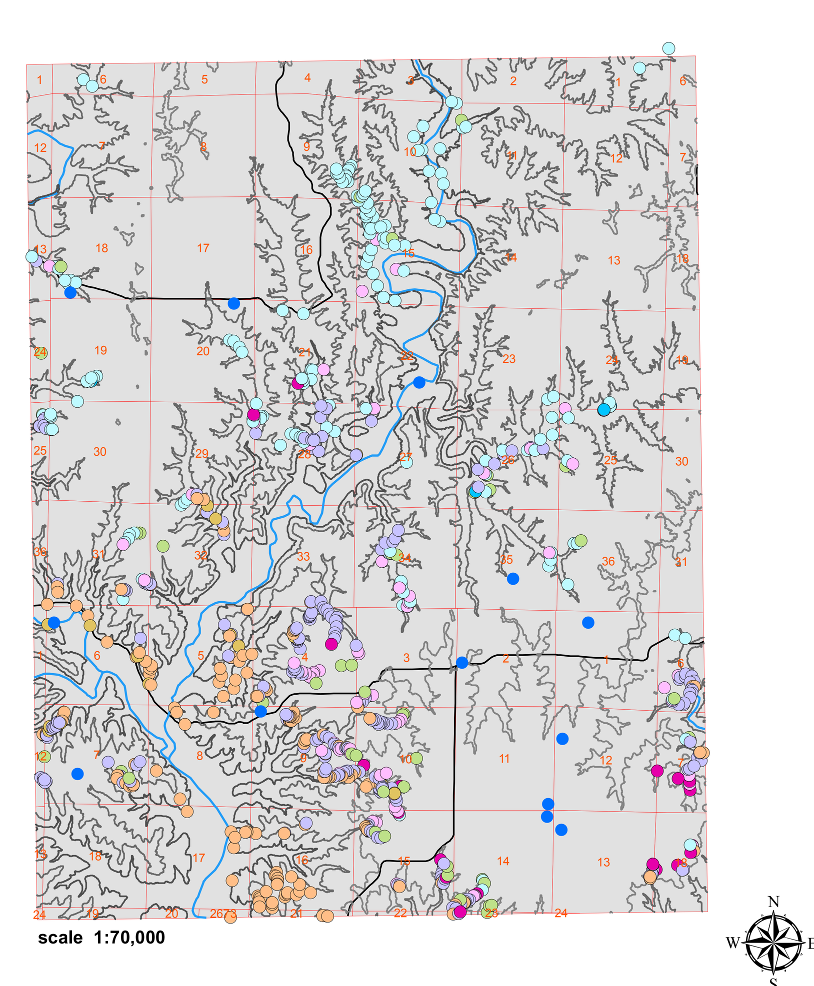
CROSS SECTION B - B'



Vertical scale 1:2,400 (1 inch = 200 feet)
Horizontal scale 1:24,000 (1 inch = 2000 feet)
Surficial deposits not shown

Vertical exaggeration = 10

SUPPORT DATA MAP



scale 1:70,000

Map size reduced to fit poster