Kansas Geological Survey
Open File Report 96-58

Compilation of Digital Geologic Map Data at the Kansas Geological Survey

Report to the Working Group on Data Capture
Digital Geologic Map Standards Committee
American Association of State Geologists and
United States Geological Survey

prepared by

Jorgina A. Ross, Manager
Automated Cartography Group

October 29, 1996
Denver, Colorado

(with minor modification 10/31/96)

Kansas Geological Survey
The University of Kansas
Lawrence, Kansas

INTRODUCTION

This report will summarize the procedures used in capture of digital geologic map data at the Kansas Geological Survey (KGS), with particular emphasis on compilation of data from existing published maps.

The 'capture' of digital geologic map data by the Automated Cartography Group at the Kansas Geological Survey is currently carried out under two basic operational schemes, which are consistent with the two forms of geologic map data acquisition supported under the STATEMAP component of the National Cooperative Geologic Mapping Program. The first scheme involves capture of map data collected through intensive field investigations as part of the new mapping subprojects of the STATEMAP program or similar independent state initiatives. The second scheme involves capture of data derived from information presented in existing published (but commonly out-of-print) geologic maps as part of the compilation subproject of the STATEMAP program or similar independent state initiatives. Standards for data capture are intended to meet or exceed requirements for inclusion of data in the National Digital Geologic Map Database.

The objective of Automated Cartography's data capture procedures is the effective development of high quality digital databases representing the current state of knowledge regarding surface and near surface geology in Kansas.. Such information should be available as digital geographic information system (GIS) databases for easy display and analysis Improved accessibility to the resulting digital data and associated geologic information will encourage and support future research. It is increasingly imperative that these resources be made available to scientists, policy makers and the general public to achieve the Kansas Geological Survey's mission. A basic premise of our efforts is that the Kansas Geological Survey should be capable, at any time, of publishing the current state of information on mapped geologic features in Kansas for immediate distribution, with the ability to correct errors or add new information in an efficient, dynamic manner.

GENERAL ISSUES

Many excellent published geologic maps of Kansas counties are now out-of-print. Appendix A provides a list of references. Appendix B identifies out-of-print maps. While there is probably little that any geologist will ever do to improve significantly on R. C. Moore's interpretation of geology in Chase County (Moore, Jewett and O'Conner, 1951) the resulting publication is out-of-print and accessible only through libraries. Additional copies of the Chase County map can be made by photocopying or similar processes, including creation of raster image reproductions of the map through scanning. While the latter process provides a means of efficiently reproducing the original out-of-print map, it is inadequate (for reasons to be discussed later) as a method for producing input to the National Digital Geologic Map Database. The absence of digital databases is not unique to out-of-print maps. Many other high quality maps still in print have no corresponding database. Reproduction of these maps remains tied to traditional printing methods.

For counties where no geologic map has ever been published for the entire county, various portions of the county may have been studied and reported in a scattering of publications, with associated maps. The information in these maps can usefully be pulled together in the Kansas Geology Database.

In several instances, when critical maps went out of print and new sources of publication were required, it was demonstrated that the in-house process of transfer of geologic map information to a stable base, digitizing and database construction are not major time constraints in development of such a database. A geologic map of Kansas and maps of Sedgwick County geology and Douglas County geology were all produced in a timely fashion with a satisfactory level of quality maintained in the resulting product for general distribution.

The following is a summary of the current status of geologic maps and databases in the 105 counties in Kansas. See Appendix B for more detailed information:

> 44 counties for which the latest published map is out of print, with no digital database available (other than the Kansas 1:500,000 scale geologic map): Barton, Bourbon*, Chase, Coffey*, Crawford* Edwards, Elk, Ford, Geary, Gray, Greenwood*, Hamilton, Harvey, Haskell, Hodgeman, Kearny, Kiowa, Lane, Lyon, Marion, McPherson, Meade, Miami, Morris, Morton, Ness, Norton, Osage, Osborne, Pawnee, Pottawatomie, Reno, Republic*, Rooks, Scott, Seward, Shawnee, Smith, Stafford, Stevens, Thomas, Wabaunsee, Wilson and Wyandotte *(*KDOT Materials Inventory Report).*
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> 44 counties for which published, in-print maps exist, but no digital database is available (other than the Kansas 1:500,000 scale geologic map): Allen, Anderson, Atchison, Brown, Cherokee, Cheyenne, Clark*, Clay, Cloud, Cowley, Decatur, Doniphan, Ellsworth, Franklin, Gove, Graham, Grant, Greeley, Harper, Jackson, Jefferson, Jewell, Johnson, Kingman, Labette, Lincoln, Linn, Logan, Marshall, Mitchell, Nemaha, Neosho, Ottawa, Pratt, Rawlins, Rice, Rush, Sheridan, Sherman, Stanton, Sumner, Trego, Wallace and Wichita.
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> 7 counties with geology never published as county-wide geologic map, in traditional or digital form (other than the Kansas 1:500,000 scale geologic map): Barber, Comanche, Dickinson, Leavenworth, Saline, Washington and Woodson.
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> 10 counties with published geology in digital form: Butler, Chautauqua, Douglas, Ellis, Finney, Montgomery, Phillips, Riley, Russell, Sedgwick. Except for Montgomery County (KGS, GW-1), digital databases provide the only available source for in-print published geologic maps of these counties.

PLANS AND PROCEDURES FOR COMPILATION FROM NEW FIELD MAPPING

In the 95 counties which currently have no geologic map in publishable digital form, plans for development of geologic databases (using 1:24,000 scale base maps) under the new geologic mapping subprojects of STATEMAP or similar independent state initiatives are as follows:

> 4 county with digital geologic databases in the process of being produced: Elk, Ness, Stafford and Leavenworth.
>
> 2 counties with mapping near completion or completed and in the process of preparation of base maps for digitizing and construction of digital databases: Woodson and Coffey

10 counties currently being mapped or scheduled for mapping with the ultimate objective of digital database construction: Wyandotte, Bourbon, Labette, Greenwood, Ford, Republic, Wilson, Hamilton, Kearny and Comanche. The schedule for completion of digital databases for these counties is a multi-year effort under the geologic mapping program.

Digital data 'capture' for these projects begins with the geologist's completed field maps. These field maps are created on 1:24,000 scale USGS topographic maps. There are three basic steps in the database development process:

1) Transfer the geologic information from the field maps to mylar base maps using a color coding system which indicates to the digitizer the attribute code to associate with each arc as they are digitized. These code facilitate editing and subsequent cartographic display.

2) Digitize the geologic patterns developed in step 1.

3) Create GIS databases of surface geology for each 7.5 minutes quadrangle, subdivided as appropriate for selection by 7.5 minutes quadrangle or by county. This data structure is consistent with the data structure used for the Kansas Cartographic Database, which has proven effective in a wide range of Survey mapping applications.

Digitizing and initial data processing and database development are accomplished using in-house software. The results are then transported to a major commercial geographic information system (GIS) software product for final development of GIS databases. This system is then used to create export files in a variety of formats.

PLANS AND PROCEDURES FOR COMPILATION FROM PUBLISHED MAPS

As Appendix A indicates, there is great disparity in the scales at which county maps have been published. The Survey should be capable of producing, on demand, maps presenting the latest surface mapping information for any multi-county area in the state at a uniform scale. Compilation of digital data from existing published sources permits a significant increase in the rate at which geologic data is added to the Kansas Geology Database. Our procedures permit these additions to be made at relatively low cost, unconstrained by the time requirements for field investigations, original compilation of geologic field maps and subsequent reinterpretation and field work where inconsistencies are found between mapped quadrangles.

Four major steps are associated with each county map compilation project:

1) Create a GIS database inventory of all formations or other units represented on a published county map.

2) Transfer information from published geologic maps (many of which are out of print) to a common USGS base of 1:24,000 with the recognition that some interpretation is required. Results of preliminary experiments suggest that significant improvements in the representation of geologic outcrop patterns may be achieved by this process.

3) Digitize the geologic patterns developed in step 2.

4) Create GIS databases of surface geology for each 7.5 minutes quadrangle, subdivided as appropriate for selection by 7.5 minutes quadrangle or by county.

As in the new mapping procedures, digitizing and initial data processing and database development are accomplished using in-house software. The results are then transported to a major commercial geographic information system (GIS) software product for final development of GIS databases. This system is then used to create export files in a variety of formats.

The first step in our procedures for compilation of digital data from published sources is the development of an inventory database relating to geologic formations represented on the published maps to be used as source documents in the compilation process.

In general, geologic units (systems, series, stages, groups, subgroups or formations are represented on geologic maps in two explicit forms; arcs and zones. The inventory database will include, for each county, a listing of geologic units explicitly identified for zones or arcs in the map. In many cases the arc which forms the boundary of a zone will also be an explicit mapping of a particular formation or member at the top or base of the unit(s) represented by the zone. The database will also identify cases where the stratigraphic sequence represented in the legend of a county map makes specific reference to sub-units included within a zone of a mapped unit.

If a formation or member is identified on the map as the base unit within a zone the corresponding zone boundary arc will be identified as representing the "base" of that formation or member. Where a formation or member is identified on the map as the top unit within a zone the corresponding arc will be identified as representing the "top" of that formation or member. While recognizing that the width of the line drawn on a map as a zone boundary may be wider than the surface exposure of the formations at the top or base of the adjacent zones, no attempt will be made to determine whether this is the situation for any particular zone boundary.

If no formations or members are explicitly given as the top or base of a unit mapped by a zone, the arc boundary for that zone will identified as the top or base of the unit mapped by the zone.

Where specific formations or members are represented by arcs within a zone, the database will list the top of the unit or the base of the unit as the feature represented by the arc, depending upon how the map legend identifies the arc. In cases where the legend does not identify the arc as specifically mapping the top or base of the unit, the database will identify the arc as a representation of the entire unit outcrop, without regard to top or base.

Appendix C provides an example of the information collected in the inventory of mapped units from KGS Bulletin 106 for Marshall County. Thematic maps derived from these databases can be used to assess areas where further mapping is needed, areas which need to be remapped and areas where the nomenclature has changed since the original map was published.

The second step involves the transfer of information from published maps to a common USGS base of 1:24,000 "with the recognition that some interpretation is required." The tasks involved in this process, and the cartographic principles on which they are based, are described in the following paragraphs.

In general, the most reliable information on smaller scale geologic maps will be the locations; 1) at which mappable outcrops and contacts are exposed in road cuts, 2) where they are exposed in the drainage ditches of unpaved rural roads or cross those roads and 3) where they are exposed in stream beds. In addition, the shape or location of small isolated outcrop patterns (islands) on the small scale maps may define, within a very small tolerance, the location and associated elevation of the mapped unit outcrop on the larger scale (1:24,000) topographic maps. Similar location accuracy may be obtained where an outcrop pattern pinches in as it approaches a topographic saddle point in the terrain. These points are used as initial control points for transfer of geologic map information from smaller scale maps to 1:24,000 scale topographic base maps.

It is a basic principle in cartography that, while significant generalization in outcrop patterns takes place in the construction of arcs between critical points on small scale geologic maps, the locations of the critical points maintain fairly high position accuracy. In addition, critical aspects of topology (such as islands and saddle points) tend to maintain fidelity with the real world better than other features.

A working concept of the structure of a mapped unit is obtained from an evaluation of the general spatial trends in elevation associated with these critical points and areas. The rest of the map information transfer process consists of an interpolation of these identified trends between critical points and areas. This is basically a process of intersection of the mapped units structural surface with the topographic surface represented on the 1:24,000 scale base map. The interpolation process is the same as that used in completion of field maps in the new mapping programs, as described by Sawin (1996).

> "Geologic maps are compilations of data and inference. Because most bedrock is covered by soil and vegetation, the information gleaned from outcrops are pieced together to build a map. Because outcrops may be a mile or more apart, geologists must use their training and experience to connect the data points by extrapolating and interpreting what happens between the scattered points of information." (p. 3)

This process, used for transfer of data from a published map to a larger scale base map will generally result in a more complex representation of the outcrop pattern on the larger scale base map. The transfer process takes advantage of the more accurate representation which the larger scale map provides of the local topography.

Based on the transfer process described here, the cartographer may identify apparent anomalies in the structure of a formation. Where this occurs, some further interpretation of the information on the original map may be required or additional sources of information may be consulted. Where a clear resolution cannot be established, verification in the field may be required. Cartographers <u>will not</u> be trying to outguess geologists.

If the boundary of a mapped zone clearly represents an unconformity between the mapped unit and another older or younger mapped unit, the boundary pattern will be transferred to the larger scale base map without modification of shape, on the assumption that no improvement in the representation of the geomorphology of the outcrop can be inferred without field checking.

Quite simply, we are now capable of doing a better job of showing what the geologists have found in the field. When many of the county maps which are now out of print were drafted, cartographers did not have high quality, large scale, topographic maps available to guide their work. In addition, technology did not allow them the luxury of drafting at a large scale and immediately merging and reproducing map information with full fidelity at any desired smaller scale.

The idea of transferring the data to 1:24,000 topographic maps is not a matter of "trying" to make the data more accurate than the existing maps. We actually can make the data more accurately represent what the geologists intended to map than the existing maps. Obviously, if a geologist makes the wrong identification of a formation, there is no way a cartographer can correct the error and re-map the formation in its correct location. But, using the methods recommended in my proposal, the cartographer can more accurately describe where the geologist who was wrong thought the formation was located. This also holds for the geologist (presumably in the overwhelming majority) who was right!

Rather than representing flagrant 'cartographic license,' the process described here represent a redrafting of available information while eliminating much of the 'cartographic license' taken in the process of generalization which occurred when results of field mapping were prepared for publication at small scale. That process of generalization typically smoothes the outcrop pattern by cutting across small valleys or small protrusions in ridge lines. Cartographers are not the only ones who take this license. Many geologists, in the process of completing outcrop patterns on their field maps, will fail to follow the structure implied by their field observations (often made at sparse critical points) when interpolating between actual mapped locations of a formation. Digitizing or scanning the geologic formations boundaries and outcrop patterns directly from existing smaller scale maps or from bases prepared at a small scale such as 1:100,000 would simply perpetuate the errors introduced by this cartographic license. In reference to Kansas counties for which digital geologic map databases currently exist, the databases for Douglas, Ellis and Sedgwick counties were not derived from information transferred onto the desired 1:24,000 scale base.

Experience in the development of digital databases for Montgomery county (where base maps of both 1:50,000 and 1:24,000 scale were used as alternative source documents) has made clear the improvement in results associated with use of larger scale base maps.

The merits of this approach were tested by a comparison with results obtained from new field mapping efforts. Transfer of mapped information from selected plates in the KDOT Materials Inventory Report for Greenwood County have, without any effort in the field, produced base maps which match almost identically (for corresponding mapped units) the 1:24,000 field maps recently developed for the same area as part of the Survey's geologic mapping program.

Comparison of this approach with results obtained through direct digitization of a published map were made for the Gladstone quadrangle (USGS 1:24,000) in Chase County. The results highlight the problems associated with direct digitizing or scanning of published maps for development of databases for a state or national geologic map database. These problems are discussed in detail by Collins (1996). In general the problems center around the difference between the actual physical properties (location, etc.) of lines drafted for publication of maps at smaller scales (smaller than 1:24,000) and the information about local surface geology implied by the relations between lines and by various aspects of form of lines. The procedures used by Automated Cartography avoid these problems and take advantage, as completely as possible, of the actual information content of the published maps.

Large scale (1:24,000) base maps are essential for an accurate database representation of the geology implied by the information actually collected by geologists. Once the database has been properly created, the information can easily be rendered in cartographic form at any desired scale (from 1:24,000 to 1:5,000,000) with maximum possible fidelity to the original information.

Estimates have been made of time requirements for the various steps involved in data compilation:

Step 1)
An inventory of all formations currently mapped (in published county maps and in some cases sub-county maps) can be completed in one month.

Step 2)
The time required to complete the transfer of information from published maps to a common 1:24,000 scale base will vary significantly from county to county.

Where the publish map shows a conformable contact between geologic units, considerable care will be taken to incorporate the effect of topography on the outcrop pattern in ways that can be more accurately represented on the 1:24,000 scale base maps than may have been done on the smaller scale published maps.

In much of western Kansas, single mappable units are exposed in fairly random patterns through a cover of Tertiary of Quaternary deposits. Very little can be done through interpretation to enhance the information presented on a source map regarding the boundaries of such exposures when the information is transferred to the larger scale base. In this circumstance the transfer of map information will be much faster. Similar situations are associated with margins of alluvial valleys throughout Kansas and in areas of loess or glacial deposits in northeast Kansas.

The other primary factors controlling the speed at which geology from individual county maps could be transferred to 1:24,000 scale base maps, digitized and converted to a usable GIS database are; the quality and level of detail of the source map and the overall geographic size of the county. Poorer quality of the source map (implying a need for more interpretation and research of other possible information sources), greater detail, or larger county size would each imply a longer expected time for database construction (although greater detail may reflect greater care in mapping a county and therefore a higher quality map).

For an individual 7.5 minute quadrangle (USGS 1:24,000 scale series) in eastern Kansas, the average time required for a trained staff member (presumably a supervised student assistant) to transfer information from a source map would probably be on the order of one-half to one full working day. Again, this would depend upon the level of interpretation required and the quality and detail of the source map.

Steps 3 and 4)
Once map information has been transferred to a 1:24,000 scale base map and is ready for digitizing, the remaining process of construction of a GIS database is highly standardized. The total time requirement for this process would again depend upon

the level of detail in the map, but no further interpretation is required and the map quality is fixed at this point in the process. The process of digitizing and editing the information on a geologic map of a typical quadrangle (in eastern Kansas) by a trained staff member will probably require an average of one full working day with a slight additional time for building the associated GIS data structure. Once completed, scientists could add to the basic GIS database as desired.

Column 7 in Appendix B gives a 'time factor' for each county. This factor is a rough estimate of the average time required to transfer and digitize geologic information from quadrangles in each county in comparison to the time (2.5 days) required for the same process in a typical quadrangle in eastern Kansas. For reasons stated above, geologic maps from many areas of west, central and northeast Kansas could be transferred to digital databases at a far more rapid pace than typical counties in eastern Kansas (in some cases as much as ten times faster).

The total effort required to compile a digital geologic database for each county from existing published maps has been estimated by multiplying the time (2.5 days) required for the same process in a typical quadrangle in eastern Kansas by the time factor for each county and then multiplying by a quadrangle factor which is approximately the number of 7.5 minute (1:24,000 scale) quadrangles which completely cover the county. The results are given in the last two columns of Appendix B, where each map compilation project has been classified as priority 1 or priority 2. The division is very general, with priority 2 status associated with the availability of a better or more recent alternative published map or the inclusion of the county in current or planned new mapping projects.

Based on the estimates of staff effort, cost estimates have been made for compilation of digital geologic databases from a typical published county geologic map. These estimates include the cost of professional staff with general responsibility for management, review and evaluation of basic work done by student research assistants (KGS is a research unit within the University of Kansas), Preliminary estimates suggest that database compilation would be about $7,000 - $,8000 for a typical county when all costs are included. This compares quite favorably with the cost of new mapping projects which are commonly on the order of $100,000 per county and usually involve multiple years for completion. As discussed previously, the effort required to complete data compilation and map production for individual counties will vary significantly around the average cost figures estimated here. A range of actual costs from $1000 to $16,000 for individual counties would not be surprising.

These cost estimates do not include any expenses for field work by staff geologists. Little or no field work should be necessary to produce a satisfactory product from the best of the existing published maps. It is expected, however, that the necessary level of field work will range from this minimum of no field work to the other extreme in which field mapping of the entire county as a new mapping project provides the only acceptable means of database development.

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Appendix A

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Appendix B - County map status

County	Publication	Date	Scale factor	OoP	Digital	Inv	Time factor	Quad factor	Effort 1	Effort 2
									staff days	staff days
Allen	KGS B-195	1969	63360				1.0	10.0	25.0	
Anderson	USGS MG I-2302	1992	24000				0.7	11.0	19.3	
Anderson	USGS MG I-2303	1992	24000				0.7			
Anderson	USGS MG I-2273	1992	24000				0.7			
Anderson	USGS MG I-2377	1993	24000				0.7			
Anderson	USGS MG I-2378	1993	24000				0.7			
Anderson	USGS MG I-2379	1993	24000				0.7			
Atchison	USGS HA-467	1973	62500				1.0	9.0	22.5	
Barber								21.0	0.0	
Barton	KGS B-088	1950	126720	X			0.7	17.0	29.8	
Bourbon	KDOT IR-23	1976	64000	X			1.0	11.0		27.5
Brown	KGS B-186	1968	63360				0.7	11.0	19.3	
Butler	KGS M-30	1994	50000		X		0.0	26.0	0.0	
Chase*	USGS GA-folio 109	1904	125000	X						
Chase	KGS Vol-11	1951	61440	X		X	1.3	15.0	48.8	
Chautauqua	KGS M-43	1996	50000		X		0.0	13.0	0.0	
Cherokee	KGS GE-1	1975	125000				0.7	11.0	19.3	
Cheyenne	KGS B-100	1953	126720				0.3	19.0	14.3	
Clark	USGS OF 92-697	1992	24000				0.5	18.0	22.5	
Clark	USGS OF 92-698	1992	24000				0.5			
Clark	USGS OF 94-655	1994	24000				0.5			
Clark	USGS OF 94-656	1994	24000				0.5			
Clark	USGS OF 94-657	1994	24000				0.5			
Clark	USGS OF 94-658	1994	24000				0.5			
Clay	KGS B-136	1959	82300				1.1	12.0	33.0	
Cloud	KGS B-139	1959	84480				0.8	13.0	26.0	
Coffey	KDOT IR-02	1966	64000	X			1.0	13.0	32.5	
Comanche								14.0	0.0	
Cowley*	KGS B-012	1926	126720	X			1.2	20.0		60.0
Cowley	KGS B-158	1962	84480				1.0	20.0	50.0	
Crawford	KDOT IR-28	1975	64000	X			1.0	12.0	30.0	

Appendix B - County map status

County	Publication	Date	Scale factor	OoP	Digital	Inv	Time factor	Quad factor	Effort 1	Effort 2
									staff days	staff days
Decatur	KGS B-196	1969	84480				0.4	17.0	17.0	
Dickinson								16.0	0.0	
Doniphan	USGS HA-462	1973	62500				0.6	10.0	15.0	
Douglas*	KGS B-148	1960	64880	X			0.7	10.0		17.5
Douglas	KGS M-26	1992	64000		X		0.0	10.0		0.0
Edwards	KGS B-080	1949	126720	X			0.3	11.0	8.3	
Elk	KGS Vol-14	1958	64000	X			1.0	13.0		32.5
Ellis*	KGS B-011	1926	125000	X			0.7	17.0		29.8
Ellis	KGS M-19	1988	50000		X		0.0	17.0	0.0	
Ellsworth	KGS B-201	1971	62500				1.0	13.0	32.5	
Finney*	KGS B-055	1944	126720	X			0.1	22.0		5.5
Finney	KGS M-28	1993	50000		X		0.0	22.0	0.0	
Ford	KGS B-043	1942	126720	X			0.2	19.0		9.5
Franklin	KGS B-163	1963	63360				0.9	12.0	27.0	
Geary	KGS B-039	1941	126720	X			1.0	10.0	25.0	
Gove	KGS B-145	1960	129300				0.3	19.0	14.3	
Graham	KGS B-110	1955	101400				1.0	17.0	42.5	
Grant	KGS B-168	1964	126720				0.1	11.0	2.8	
Gray	KGS B-055	1944	126720	X			0.1	17.0	4.3	
Greeley	KGS B-108	1954	129000				0.2	15.0	7.5	
Greenwood	KDOT IR-36	1982	64000	X			1.0	20.0		50.0
Hamilton*	KGS B-011	1926	320000	X			0.2	17.0		8.5
Hamilton	KGS B-049	1943	126720	X			0.2	17.0		8.5
Harper	KGS B-143	1960	128000				0.4	16.0	16.0	
Harvey (W 4/5)	KGS B-079	1949	126720	X			0.3	9.0	6.8	
Haskell	KGS B-061	1946	138240	X			0.1	13.0	3.3	
Hodgeman	KGS B-019	1932	190080	X			0.6	16.0	24.0	
Jackson	KGS B-101	1953	84480				1.0	13.0	32.5	
Jefferson	KGS B-202	1972	62500				1.0	13.0	32.5	
Jewell	KGS B-115	1956	126720				0.9	17.0	38.3	
Johnson*	KGS B-021 pt1	1935	126720	X			1.2	10.0		30.0

County	Publication	Date	Scale factor	OoP	Digital	Inv	Time factor	Quad factor	Effort 1	Effort 2
									staff days	staff days
Johnson	KGS B-203	1971	48000				1.0	10.0	25.0	
Kearny	KGS B-049	1943	126720	X			0.2	17.0		8.5
Kingman	KGS B-144	1960	126000				0.3	17.0	12.8	
Kiowa	KGS B-065	1948	126720	X			0.3	14.0	10.5	
Labette	USGS HA-279	1968	63360				1.0	13.0		32.5
Lane	KGS B-093	1951	126720	X			0.3	14.0	10.5	
Leavenworth								11.0	0.0	
Lincoln	KGS B-095	1952	84480			X	0.8	13.0	26.0	
Linn	KGS B-193	1969	64000				1.0	12.0	30.0	
Logan	KGS B-129	1958	125000				1.2	19.0	57.0	
Lyon	KGS Vol-12	1953	63360	X			1.0	16.0	40.0	
Marion	USGS B-1060B	1959	64000	X			1.3	20.0	65.0	
Marshall	KGS B-106	1954	84480			X	1.0	19.0	47.5	
McPherson	KGS B-079	1949	126720	X			0.5	18.0	22.5	
Meade	KGS B-045	1942	143120	X			0.3	18.0	13.5	
Miami*	KGS B-021 pt 1	1935	126720	X			1.0	12.0		30.0
Miami	KGS B-181	1966	63360	X			1.0	12.0	30.0	
Mitchell	KGS B-140	1959	84480				0.7	13.0	22.8	
Montgomery*	KGS GW-1	1974	63360				1.0	13.0		32.5
Montgomery	KGS M-44	1996	50000		X		0.0	13.0	0.0	
Morris	USGS B-1060A	1958	63360	X			1.1	14.0	38.5	
Morton	KGS B-040	1942	126720	X			0.2	14.0	7.0	
Nemaha	KGS GW-2	1974	125000				0.4	14.0	14.0	
Neosho	KGS B-183	1966	63360				1.0	12.0	30.0	
Ness	KGS B-019	1932	190080	X			0.6	19.0	28.5	
Norton	KGS B-081	1949	84480	X			0.6	17.0	25.5	
Osage	KGS Vol-13	1953	63360	X			1.0	14.0	35.0	
Osborne	KGS B-016	1930	190080	X			0.8	17.0	34.0	
Ottawa	KGS B-154	1962	90000				0.3	13.0	9.8	
Pawnee	KGS B-080	1949	126720	X			0.3	13.0	9.8	
Phillips	KGS M-29	1993	50000		X		0.0	17.0	0.0	

County	Publication	Date	Scale factor	OoP	Digital	Inv	Time factor	Quad factor	Effort 1	Effort 2
									staff days	staff days
Pottawatomie	USGS B-1060C	1959	63360	X			1.4	16.0	56.0	
Pratt	KGS B-205	1973	84480				0.6	14.0	21.0	
Rawlins	KGS B-117	1956	107000				0.4	19.0	19.0	
Reno	KGS B-120	1958	122880	X			0.2	22.0	11.0	
Republic*	KGS B-073	1948	126720	X			0.6	13.0		19.5
Republic*	USGS Cir-79	1950	63360	X			0.9	13.0		29.3
Republic	KDOT IR-29	1976	64000	X			1.0	13.0		32.5
Rice*	KGS B-085	1950	126720	X			0.4	13.0		13.0
Rice	KGS B-206	1974	126720				0.4	13.0	13.0	
Riley*	KGS B-039	1941	126720	X			1.0	15.0		37.5
Riley	KGS M-36	1995	50000		X		0.0	15.0	0.0	
Rooks	USGS Cir-27	1949	63360	X			0.9	17.0	38.3	
Rush	KGS B-207	1974	84480				0.6	13.0	19.5	
Russell*	KGS B-010	1925	0	X			no map	17.0		
Russell	KGS M-37	1995	50000		X		0.0	17.0	0.0	
Saline								13.0	0.0	
Scott	KGS B-066	1947	126720	X			0.2	14.0	7.0	
Sedgwick*	KGS B-176	1965	126720	X			0.6	21.0		31.5
Sedgwick	KGS M-25	1991	125000		X		0.0	21.0		0.0
Seward	KGS B-069	1948	126720	X			0.3	13.0	9.8	
Shawnee (2 sheets)	USGS B-1215	1967	48000	X			1.5	12.0	45.0	
Sheridan	KGS B-116	1956	107000				0.4	17.0	17.0	
Sherman	KGS B-105	1953	126720				0.3	19.0	14.3	
Smith	USGS Cir-25	1948	63360	X			0.9	17.0	38.3	
Stafford	KGS B-088	1950	126720	X			0.3	16.0	12.0	
Stanton*	KGS B-037	1941	130000	X			0.1	14.0		3.5
Stanton	KGS B-168	1964	126720				0.1	14.0	3.5	
Stevens	KGS B-061	1946	138240	X			0.2	14.0	7.0	
Sumner	KGS B-151	1961	114000				0.6	22.0	33.0	
Thomas	KGS B-059	1945	126720	X			0.2	19.0	9.5	
Trego	KGS B-174	1965	63360				1.0	17.0	42.5	

County	Publication	Date	Scale factor	OoP	Digital	Inv	Time factor	Quad factor	Effort 1	Effort 2
									staff days	staff days
Wabaunsee	USGS B-1068	1959	63360	X			1.4	15.0	52.5	
Wallace	KGS B-161	1963	84480				0.4	17.0	17.0	
Washington								19.0	0.0	
Wichita	KGS B-108	1954	129000				0.3	14.0	10.5	
Wilson (SW 1/3)	USGS GQ-49	1954	62500				1.0	4.0		10.0
Wilson (SE 1/3)	USGS GQ-149	1661	62500				1.0	4.0		10.0
Wilson	KGS OF-67-6	1967	48700	X			1.0	12.0	30.0	
Woodson								10.0	0.0	
Wyandotte	KGS B-021 pt2	1935	126720	X			0.9	5.0		11.3

* Later published map also listed

Referenced Titles

KDOT IR- Kansas Department of Transportation Materials Inventory Report
KGS B- Kansas Geological Survey Bulletin
KGS OF- Kansas Geological Survey Open File Report
KGS GE- Kansas Geological Survey Geology Series
KGS GW- Kansas Geological Survey Groundwater Series
KGS M- Kansas Geological Survey M-series Map
KGS Vol- Kansas Geological Survey Volume
USGS B- US Geological Survey Bulletin
USGS Cir- US Geological Survey Circular
USGS GQ- US Geological Survey Geologic Quadrangle Map
USGS HA- US Geological Survey Hydrologic Atlas
USGS MG I- US Geological Survey Miscellaneous Geologic Investigation
USGS OF- US Geological Survey Open File Report
USGS GA- US Geological Survey Geologic Atlas of the United States

SUMMARY

Estimated staff effort for development of the Kansas Geology Database from published maps

Effort 1 and Effort 2 estimate staff days required for transfer and compilation of data from the corresponding published map. They relate to a preliminary separation of the listed maps into 1st and 2nd priority for data compilation.

Total effort	staff yrs	staff days
Priority 1 maps	12.75	1912.8
Priority 2 maps	3.87	580.8
Total: All listed maps	16.62	2493.5

code	name	system	f1	s1	series	f2	s2	group	f3	s3	formation	f4	s4	member	f5	s5
	Marshall	Quaternary			Pleistocene			alluvium	z							
	Marshall	Quaternary			Pleistocene						Sanborn	z				
	Marshall	Quaternary			Pleistocene			terrace deposits	z							
	Marshall	Quaternary			Pleistocene			glacial deposits	z							
	Marshall	Permian			Leonardian	za	b	Sumner	za	b	Wellington	za	b			
	Marshall	Permian			Wolfcampian			Chase	za	t	Nolans ls	a	t	Herrington ls	a	t
	Marshall	Permian			Wolfcampian			Chase			Nolans ls			Paddok shale		
	Marshall	Permian			Wolfcampian			Chase			Nolans ls			Krider ls		
	Marshall	Permian			Wolfcampian			Chase			Odell shale					
	Marshall	Permian			Wolfcampian			Chase			Winfield ls			Cresswell ls	a	b
	Marshall	Permian			Wolfcampian			Chase			Winfield ls			Grant shale	a	t
	Marshall	Permian			Wolfcampian			Chase			Winfield ls			Stovall ls		
	Marshall	Permian			Wolfcampian			Chase			Doyle shale			Gage shale		
	Marshall	Permian			Wolfcampian			Chase			Doyle shale			Towanda ls	a	b
	Marshall	Permian			Wolfcampian			Chase			Doyle shale			Holmesville shale	a	t
	Marshall	Permian			Wolfcampian			Chase			Barenston ls			Fort Riley ls	a	b
	Marshall	Permian			Wolfcampian			Chase			Barenston ls			Oketo shale	a	t
	Marshall	Permian			Wolfcampian			Chase			Barenston ls			Florence ls	a	b
	Marshall	Permian			Wolfcampian			Chase			Matfield shale			Blue Springs shale	a	t
	Marshall	Permian			Wolfcampian			Chase			Matfield shale			Kinney ls		
	Marshall	Permian			Wolfcampian			Chase			Matfield shale			Wymore shale		
	Marshall	Permian			Wolfcampian			Chase			Wreford ls			Schroyer ls	a	b
	Marshall	Permian			Wolfcampian			Chase			Wreford ls			Havensville shale	a	t
	Marshall	Permian			Wolfcampian			Chase	za	b	Wreford ls	a	b	Threemile ls	a	b
	Marshall	Permian			Wolfcampian			Council Grove	za	t	Speiser shale	a	t			
	Marshall	Permian			Wolfcampian			Council Grove			Funston ls					
	Marshall	Permian			Wolfcampian			Council Grove			Blue Rapids shale					
	Marshall	Permian			Wolfcampian			Council Grove			Crouse ls					
	Marshall	Permian			Wolfcampian			Council Grove			Easly creek shale					
	Marshall	Permian			Wolfcampian			Council Grove			Bader ls			Middleburg ls		
	Marshall	Permian			Wolfcampian			Council Grove			Bader ls			Hooser shale		

code	name	system	f1	s1	series	f2	s2	group	f3	s3	formation	f4	s4	member	f5	s5
	Marshall	Permian			Wolfcampian			Council Grove			Bader ls			Eiss ls		
	Marshall	Permian			Wolfcampian			Council Grove			Stearns shale					
	Marshall	Permian			Wolfcampian			Council Grove			Beattie ls			Morrill ls		
	Marshall	Permian			Wolfcampian			Council Grove			Beattie ls			Florena sh		
	Marshall	Permian			Wolfcampian			Council Grove			Beattie ls	a	b	Cottonwood ls	a	b
	Marshall	Permian			Wolfcampian			Council Grove			Eskridge shale	a	t			
	Marshall	Permian			Wolfcampian			Council Grove			Grenola ls			Neva ls	a	b
	Marshall	Permian			Wolfcampian			Council Grove			Grenola ls			Salem Point shale	a	t
	Marshall	Permian			Wolfcampian			Council Grove			Grenola ls			Burr ls		
	Marshall	Permian			Wolfcampian			Council Grove			Grenola ls			Legion shale		
	Marshall	Permian			Wolfcampian			Council Grove			Grenola ls			Sallyards ls		
	Marshall	Permian			Wolfcampian			Council Grove			Roca shale					
	Marshall	Permian			Wolfcampian			Council Grove			Red Eagle ls			Howe ls		
	Marshall	Permian			Wolfcampian			Council Grove			Red Eagle ls			Bennett shale		
	Marshall	Permian			Wolfcampian			Council Grove			Red Eagle ls			Glenrock ls		
	Marshall	Permian			Wolfcampian			Council Grove			Johnson shale					
	Marshall	Permian			Wolfcampian			Council Grove			Foraker ls			Long Creek ls		
	Marshall	Permian			Wolfcampian			Council Grove			Foraker ls			Hughes Creek shale		
	Marshall	Permian			Wolfcampian			Council Grove	za	b	Foraker ls	a	b	Americus ls	a	b
	Marshall	Permian			Wolfcampian			Admire	za	t	Hamlin shale*	a	t	Oaks shale**	a	t
	Marshall	Permian			Wolfcampian			Admire			Hamlin shale*			Houchen Creek ls**		
	Marshall	Permian			Wolfcampian			Admire			Hamlin shale*			Stine shale**		
	Marshall	Permian			Wolfcampian			Admire			Five Point ls*					
	Marshall	Permian			Wolfcampian			Admire			West Branch shale*					
	Marshall	Permian			Wolfcampian			Admire			Falls City ls					
	Marshall	Permian			Wolfcampian			Admire			Hawxby shale					
	Marshall	Permian			Wolfcampian			Admire			Aspinwall ls					
	Marshall	Permian			Wolfcampian			Admire	za	b	Towle shale	a	b			
	Marshall	Pennsylvanian			Virgilian	za	t	Wabaunsee	za	t	Brownville ls	a	t			
	Marshall	Pennsylvanian			Virgilian			Wabaunsee			Pony creek shale					
.																