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**INFORMATION CAPTURE
FROM PREVIOUSLY PUBLISHED MAPS**

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INFORMATION CAPTURE FROM PREVIOUSLY PUBLISHED MAPS

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Introduction

This paper addresses geologic map database development. The emphasis here is on the use of previously published maps as source documents. Although the perspective is significantly different, the principles which guide our procedures correspond to those which guide database development from new field mapping.

The Kansas Geologic Mapping and Database Development Project was initiated by the Kansas Geological Survey (KGS) in 1987 to update lower quality county maps and develop geologic maps for counties with no published map. The project has focused on new field work. Funding has come primarily from cost sharing in federal programs such as STATEMAP. Costs, generally funded over several years, tend to exceed \$100,000 per county. Development of digital geologic map databases for use in map publication has been an essential element of the project from the beginning.

In response to the National Geologic Mapping Act of 1992, the National Geologic Map Database Project was organized. The project seeks to promote development and access to earth science map information. Products may be paper or digital. This project is supported by the US Geological Survey and the American Association of State Geologists. The project is targeting efforts on nation-wide mapping at 1:100,000 or smaller.

The National Geologic Mapping Act and associated Database Project have been positive forces in support of the Kansas Mapping Project. However, with reduced federal funding for programs like STATEMAP, tight state budgets and rapidly increasing local demand for digital geologic map data, it is essential that state mapping programs maximize efficiency in digital geologic map database development.

Status of Geologic Mapping in Kansas

A detailed bibliography of county geologic maps in Kansas is found at the KGS web site (www.kgs.ukans.edu/General/Geology/geoMapIndex.html). Table 1 shows the types of published county maps available in Kansas. The counties which have no separate county-wide map available are represented on the Geologic Map of Kansas at 1:500,000. In many cases, maps listed as in print would be more accurately described as maps in stock with no plans to reprint. Maps in digital form do not go out of print. They can also be modified and updated within local study areas at low marginal cost.

Table 1: Summary of County Maps by Publication Format

85	Maps from non-digital proofs
	41 in print
	44 out of print
1	Maps for 80% of county from non-digital proofs (out of print)
12	Maps from digital map databases
7	Counties with no published map

These county maps actually occur in more than 25 different scales. Publication dates range from 1930 to the present. The wide range in published scales interferes with

the productive combined use of paper maps for adjacent counties. It also poses a significant problem for development of digital databases from the published maps. Techniques such as scanning or direct digitizing from the published map maintain variations in detail and appropriate scales for use of the source documents in the resulting data.

Back to the Future: An Integrated Response

In response to these problems and the increasing forces for change, the Kansas Geological Survey has implemented highly effective techniques for development of new geologic map databases from previously published maps. The testing and application of these techniques at the Kansas Geological Survey have occurred within the context of sedimentary stratigraphy typical of Kansas and the mid-continent. However, as noted by Collins (1997), there is no reason the same techniques could not be applied in any region lacking digital geologic map databases where high quality, larger scale, topographic maps are available in combination with reputable, smaller scale, geologic maps (provided the technique for database development is documented in the metadata). The basic steps involved in the process are outlined in Table 2.

Table 2: General Outline for Database Development from Published Maps

1. Transfer available geologic information from each source document to a common (1:24,000) topographic base
 - a. Identify critical points on published map for each mapped unit, for example:
 - extremes in outcrop geometry
 - proximity of outcrop to non-geologic map features
 - b. Locate these points on 1:24,000 topographic map
2. Derive 1:24,000 outcrop patterns
3. Digitize and edit outcrops and other geologic features
4. Create databases
 - a. Edge match quadrangles
 - b. Build and attribute polygons
5. Develop maps for publication (labels, legends, etc.)

The procedures in steps 3, 4, and 5 are identical, whether the geologic information was derived from previous publications or from new field investigations. As indicated by item 1, the process permits integration of map information from multiple sources, including different maps and field notes. When sources don't agree, an assessment must be made to determine the preferred source.

Critical points are locations in geologic outcrop patterns where the form of the outcrop or its proximity to non-geologic map features permit a reasonably accurate determination of its location. These characteristics enable us to locate the critical points on a topographic map, just as they would help to locate the formation in the field. The following examples will illustrate the concept of critical points on published maps.

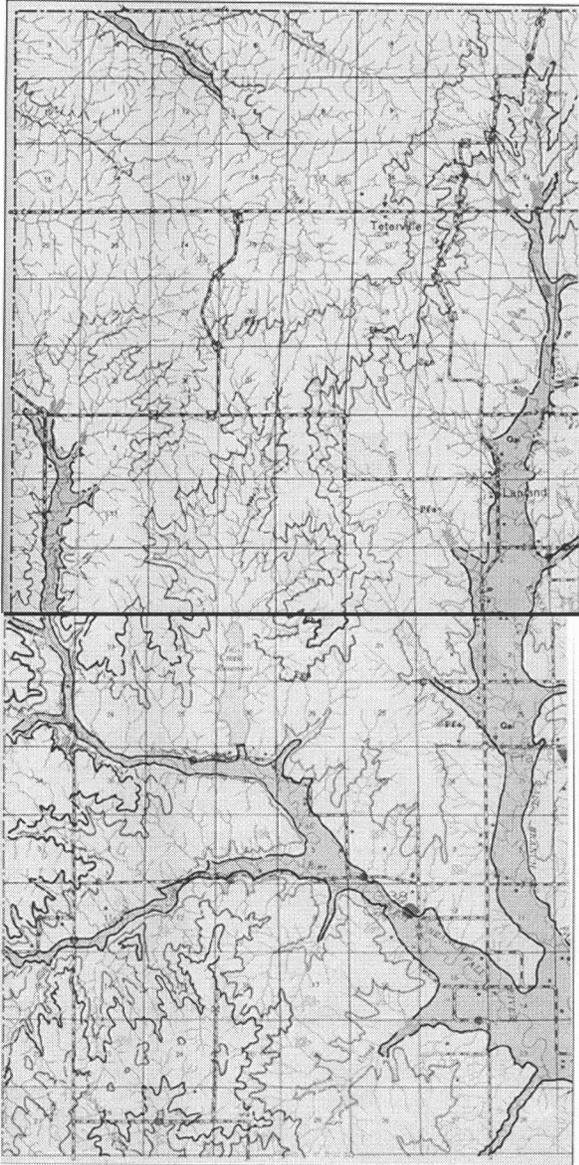


Figure 1: KDOT map of NW Greenwood County

Figure 1 is taken from Plate 3 (the north half of the figure) and Plate 6 (the south half) of the surface geology maps in the Kansas Department of Transportation (KDOT) "Construction Material Inventory of Greenwood Co.", published in 1982. The area represented is in the northwest corner of Greenwood County. The original plates are published at a scale of 1:64,000 with considerable generalization in the drafting of both base map features and geologic outcrops. The rock units in this area are Lower Permian and Upper Pennsylvanian.

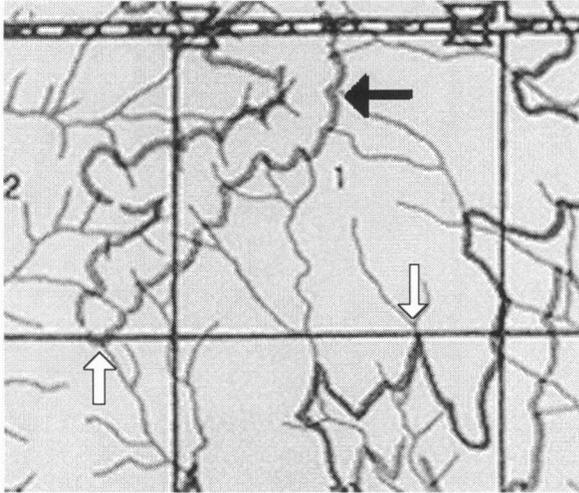


Figure 2a: Enlargement of ridge line from Figure 1

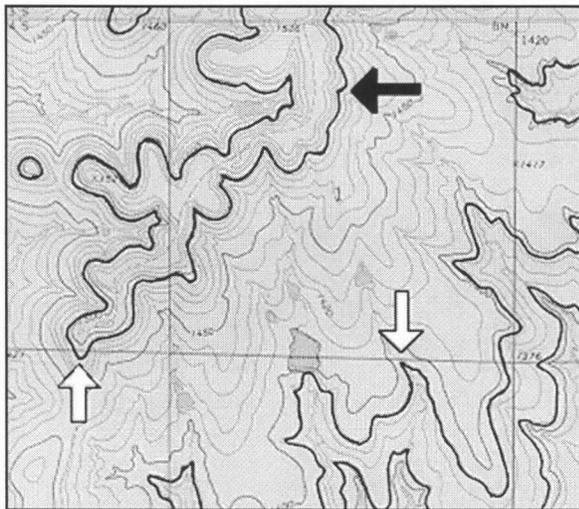


Figure 2b: Interpreted geology in the area of Figure 2a

Figure 2a is an enlarged area from the southwest part of KDOT's Plate 3. Figure 2b is the interpretation derived from 2a, using our procedures, as seen on the 1:24,000 Lapland, KS, quadrangle. Black arrows identify critical points determined by the geometry of the outcrop pattern. White arrows identify critical points determined by the proximity of outcrops to non-geologic map features.

The black arrows at the top of these images show an area where the land form almost causes a pinchout in the outcrop of the Threemile Limestone Member at the base of the Wreford Limestone along a ridge line. The geometry of the outcrop pattern, together with the actual land form, permit accurate determination of the location and elevation of the outcrop whether using the map in the real world or in our topographic model. The white arrows to the left on each map identify the southern extension of the Threemile Limestone Member along a ridge, to its limit at the south line of Section 2. To the right on both maps, white arrows identify the limit of northward erosion of the Cottonwood Limestone Member (therefore the northern

limit of its outcrop, at the base of the Beattie Limestone) extending up a stream valley, to the south line of Section 1. The proximity of these extremes, or critical points, to topographic or cultural features enables us to determine location and elevation of the outcrop.

Based on critical points identified on the KDOT map, it was determined that an isolated outcrop of the Threemile Limestone probably occurs near the top of the knoll on the west edge of the map area. Prior to confirmation by a field check, this would be flagged as 'probable' in the database and could be shown on a derived map by a different line style, to indicate the uncertain status of the outcrop, as is sometimes done on maps developed from new field mapping where outcrops are obscure.

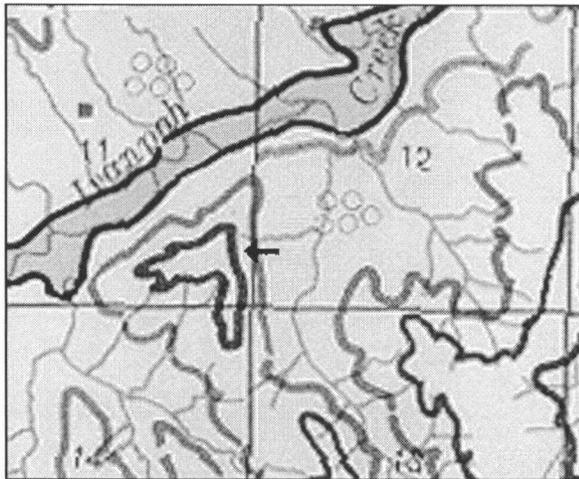


Figure 3a: Enlargement of isolated outcrop island from Figure 1

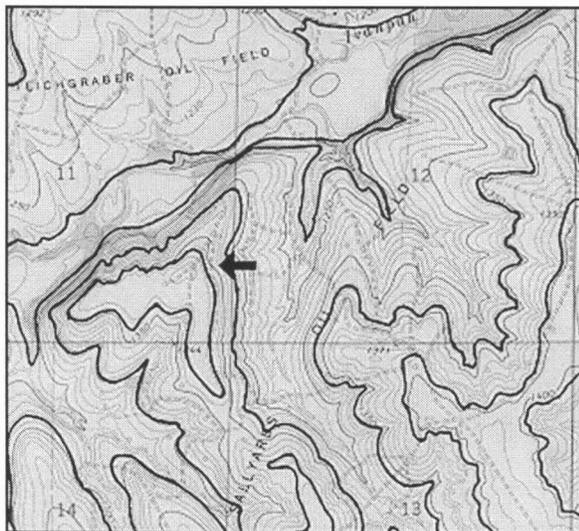


Figure 3b: Interpreted geology in the area of Figure 3a

To the south of the previous examples, black arrows in Figures 3a and 3b identify an isolated island in the outcrop of the Cottonwood Limestone. Figure 3a is enlarged from near the center of the west half of KDOT's Plate 6, while Figure 3b is the derived interpretation. Island features of this type are extremely useful for establishing

limits on the possible range of elevations where the outcrop could occur in the real world, permitting accurate location on our topographic model.

The idea of identifying critical points, for use in deriving a geologic outcrop, is consistent with situations often encountered by geologists doing new field mapping. Persistent, mappable units may be clearly identifiable only at scattered locations such as road cuts.

The process for deriving outcrop patterns from critical point locations is basically a problem in solid geometry. The surface geology occurs on a land form which can be represented by contours on a topographic map. Isolated outcrops or critical points are located on the map. Three such points in space determine an inclined plane which corresponds to the local trend of the geologic formation. The line of intersection between the plane representing the geologic formation and the irregular land form corresponds to the probable outcrop pattern of the formation.



Figure 4: Composite of geology in Butler County (left) obtained from new field mapping, with geology in Greenwood County (right) interpreted from the KDOT map in Figure 1

The ability of these procedures to develop results which can be merged with data from other sources is shown in the composite map of Figure 4. The work of James Aber in Butler County (on the left) is joined to our interpretation from KDOT's map of Greenwood County (on the right). While Aber mapped more geologic units than KDOT, the level of detail in outcrop patterns is comparable in Aber's map and our interpretation of KDOT's map, since both were developed from the common 1:24,000 base. Greenwood County is currently being mapped in the field by Dan Merriam, one

of the Survey's top senior geologists. Preliminary comparisons of new field mapping with our interpreted maps suggest a very high quality for our results.

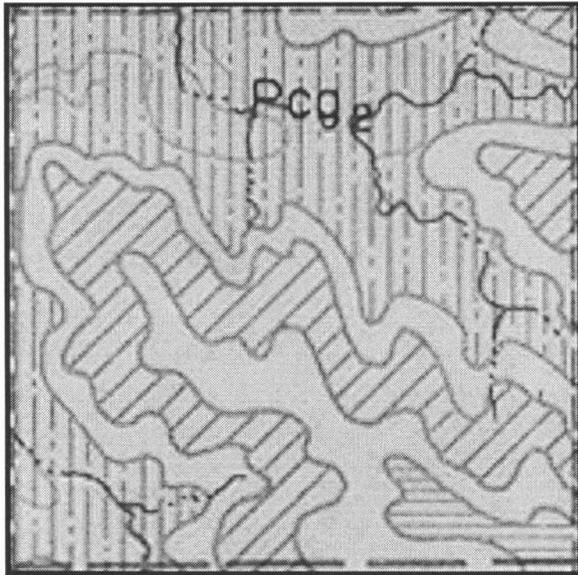


Figure 5a: Typical section from Geology of Chase County (R.C. Moore, 1952)

The superiority of this technique over direct scanning or digitizing of the source map is seen in a direct comparison. We will look at results within a typical area of Raymond C. Moore's map of Chase County, KS, published in 1951 at a scale of about 1:62,000. Figure 5a shows the area from Moore's map used for this example. Geology was digitized directly from R. C. Moore's map and registered to a topographic map. The results are shown in Figure 5b. Geology drafted according to our procedures for interpretation of Moore's map is shown on the 1:24,000 topographic map base in Figure 5c.

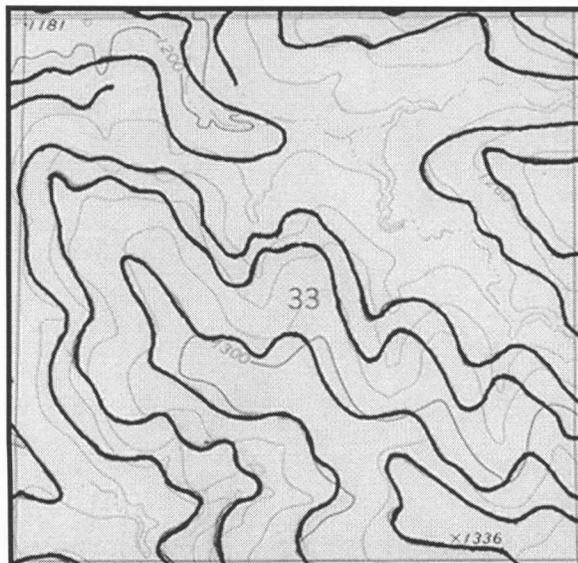


Figure 5b: Results of direct digitizing from Figure 5a superimposed on 1:24,000 topographic map

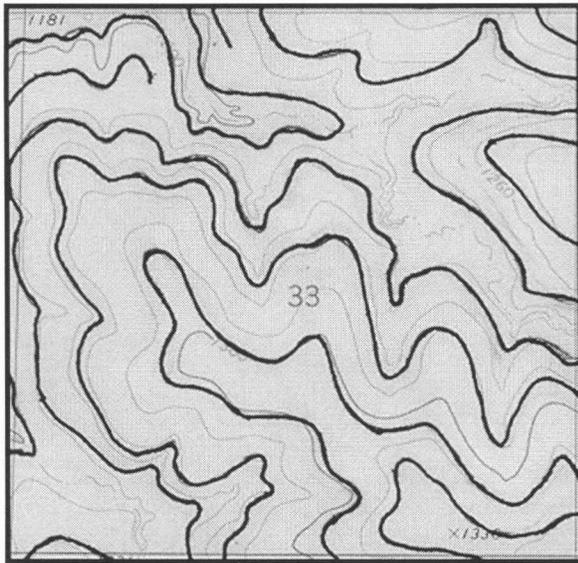


Figure 5c: Results, in the area of Figure 5a, from interpretation of R.C. Moore's map on a 1:24,000 topographic map

Errors in the precise location of outcrops in Figure 5b are the result of differences in the quality of base maps available at the time and the unavoidable process of cartographic generalization which becomes more pronounced with manual drafting at smaller scales. Direct enlargement of outcrop patterns from published maps maintains the distortions of form and location which were introduced with drafting of the original map.

As seen in Figure 5b, which is by no means a worst case example, cuts in the outcrop due to erosion are shifted to positions where they coincide with topographic highs, the outcrop pattern then drops into adjacent valleys. The improvement resulting from our method can be seen in Figure 5c, which eliminates the distortions found in the digital recreation (5b) of the original published map (5a). The result cannot eliminate mistakes in the original field mapping such as incorrect identification of a formation, but in any case it provides an improved representation of what the geologist intended to show on the map.

Once outcrop patterns are drafted on the base map, the remaining procedures for database development and map production are the same whether information was collected in the field or drawn from published maps. The outcrop patterns are digitized using point mode techniques on tables with 0.001" resolution and 0.003" repeatability. Using the Kansas Geological Survey's GIMMAP (Geodata Information Management, Mapping, and Production) system, databases are created and work proceeds to design maps for publication.

Resource Requirements

Cost estimates and extensive testing suggest that database development from previously published maps would average less than \$10,000 for a typical county in Kansas. A range of costs from \$1000 to \$16,000 would be expected. Time requirements to develop a finished geologic map for a single 1:24,000 quadrangle derived from a previously published, smaller scale map are summarized in Table 3. Using one staff

member, it would take two and one-half to three months to complete an interpreted map from the published map of an average county.

Table 3. Interpretation and map production for a single 1:24,000 quadrangle.

Task	Time (hours)
Identify and locate critical points	5.0
Derive outcrop patterns	8.2
Digitize and edit geologic features	11.6
Edge match quadrangles	4.0
Build and attribute polygons	2.7
<u>Add labels, etc.</u>	<u>3.6</u>
Total	35.1

Conclusion

To borrow from the poet Adrienne Rich, "What Is Found There" depends on how you look at it.

If the position of every point on every line of a published map is viewed as an absolute statement of ground truth, the results will be unsatisfactory; as seen in Figure 5b. But, if you use the available information -- contained in form and relative position of map features -- published maps can yield valuable data. Use of the procedures outlined here will yield other beneficial results beyond database development. Rather than diverting resources from field mapping, this process will prove to be a valuable tool for assessing the quality of existing geologic mapping and establishing priorities to target more expensive, but sometimes essential, field mapping on true problem areas.

Digitizing or scanning outcrops from published maps perpetuates errors introduced by cartographic license. Use of resulting data at scales larger than the scale of the source document would violate basic cartographic principles. Databases derived directly from maps published at different scales are likely to be unsuitable for use in combination. Rather than representing flagrant 'cartographic license', the map interpretation methods recommended here in the development of geologic map databases represents a redrafting of available information while eliminating much of the cartographic license taken in the process of generalization which occurred when data from field mapping were originally prepared for publication at a small scale. Databases developed through the use of these interpretation methods would have an inherent compatibility due to the common base used for development, even though the information may be derived from adjacent source maps originally published at different scales.

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