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Preliminary Report on the Application of Computer Graphics to Generate Coal Resources of the Cache Coal Bed, Recluse Geologic Model Area, Campbell County, Wyoming

By

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ABSTRACT: Low-sulfur subbituminous coal resources have been calculated, using both manual and computer methods, for the Cache coal bed in the Recluse Model Area, which covers the White Tail Butte, Pitch Draw, Recluse, and Homestead Draw SW 7 1/2 minute quadrangles, Campbell County, Wyoming. Approximately 275 coal thickness measurements obtained from drill hole data are evenly distributed throughout the area. The Cache coal and associated beds are in the Paleocene Tongue River Member of the Fort Union Formation. The depth from the surface to the Cache bed ranges from 269 to 1,257 feet. The thickness of the coal is as much as 31 feet, but in places the Cache coal bed is absent. Comparisons between hand-drawn and computer-generated isopach maps show minimal differences. Total coal resources calculated by computer show the bed to contain 2,316 million short tons or about 6.7 percent more than the hand-calculated figure of 2,160 million short tons.

Introduction

In 1974, the U.S. Geological Survey initiated a project entitled, "Research on geologic analysis of selected coal model areas," to pioneer approaches to the acquisition, synthesis, evaluation, and dissemination of geologic information related in any manner to coal resource assessment activities in the United States. The Recluse Model Area in northeastern Wyoming (Fig. 1) is one of the selected areas. At 1:50,000 scale, it represents 15 minutes latitude and longitude. The White Tail Butte, Pitch Draw, Recluse, and Homestead Draw SW 7 1/2 minute quadrangles also cover the same 15 minute area.

The Recluse Model Area provides an opportunity to demonstrate the application of computer graphics to calculate coal resources. To make a proper evaluation of computer methods, they must be compared with the manual calculation methods, and both should yield similar products.

Stratigraphy

Rocks exposed in the Recluse Model Area comprise the lower part of the Eocene Wasatch Formation and the underlying Tongue River Member of the Paleocene Fort Union Formation. The rocks consist of sandstone, siltstone, mudstone, shale, carbonaceous shale, and coal. The contact between the formations is placed following the criteria used by Olive (1957, p.13-15) as shown in

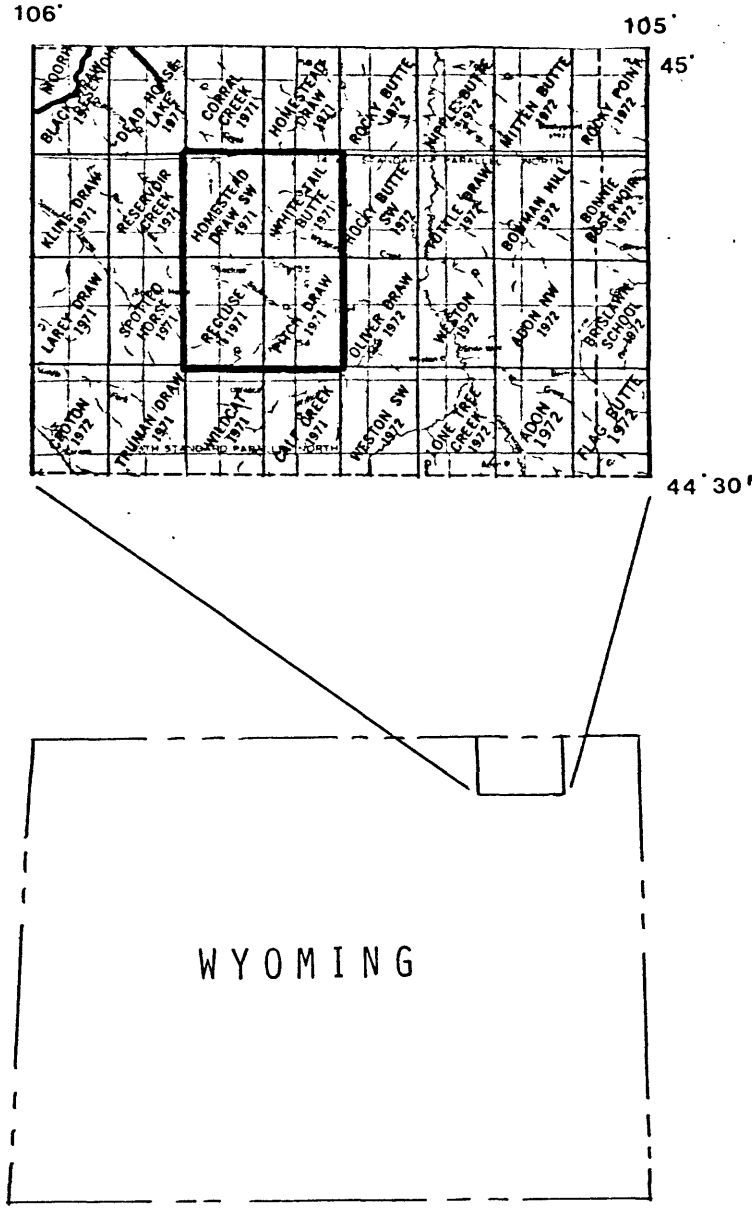

Figure 1. Index map showing the location of the Recluse Model Area outlined by heavy black square.

Figure 2. Seven major named coal beds (McKay, 1973) are contained in about 1300 feet of section (Fig. 2). The Cache coal bed dips generally westward and southwestward toward the Powder River Basin axis, which lies several tens of miles to the west. Total coal resources for the Cache bed within the model area, are approximately 2 billion short tons.

Within the model area the maximum thickness of the Cache coal bed is 31 feet, but in places it is absent. The Cache is completely subsurface within the four-quadrangle area. The coal is subbituminous and low in sulfur. Coals from two core samples (Hobbs, 1980) show a sulfur content of about 0.4 percent and an ash content of 11.3 percent on an as received basis with an unweighted mathematical average heating value calculated at about 6782 Btu.

Computer Calculation of Resources

The National Coal Resources Data System (NCRDS) of the U.S. Geological Survey supports three spatial data bases (in PACER) that interact with digitized data and the graphics display program, GARNET (Olson, 1980) to calculate resources. The Recluse Model Area data subset stored in the USTRAT data base consists of 279 drill hole locations with their respective stratigraphic sections, and 13 control points that lie outside the map boundary. Required digitized information includes X-Y locations (latitude and longitude) for each point, township-range

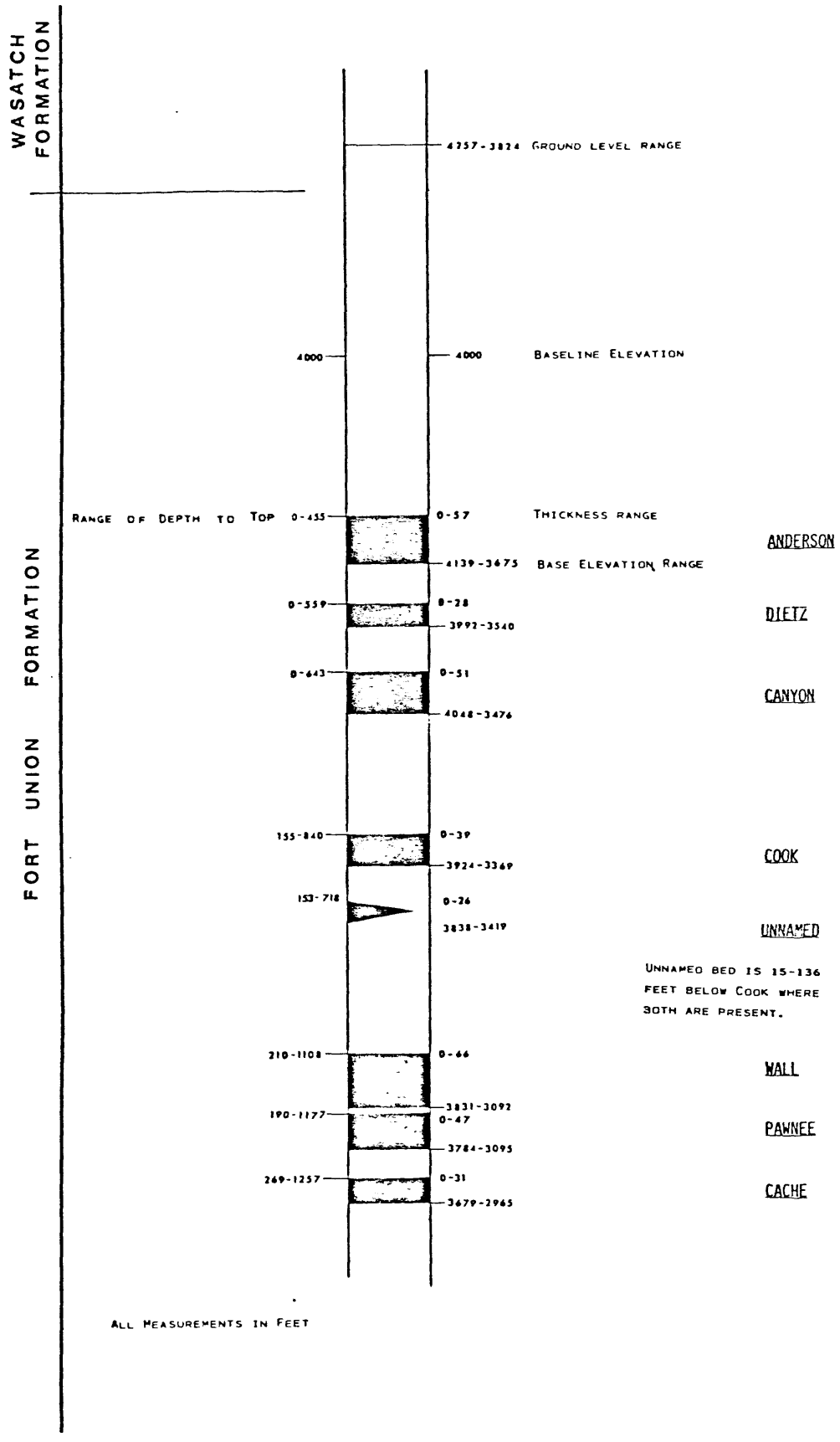

Figure 2. Generalized section of a part of the Tongue River Member of the Fort Union Formation and the Wasatch Formation in the Recluse Model Area, showing the relation of the Cache bed to other coal beds, and the range of thickness and elevation for all coal beds.

intersections from the base map, and the thickness-of-overburden categories determined by the geologist.

Generation of an isopach map in GARNET requires latitude, longitude, and a coal thickness for every point location in the map area to produce a gridded file for graphic display. Figure 3 is the geologist's hand-drawn isopach map for the Cache bed. Figure 4 is the result of using a planar gridding algorithm for the Cache coal bed data. A quadratic algorithm is also available, but due to the nature of the point distribution, the isopach is unsatisfactory for this set of data. The grid cell size of 1/2 inch for the 16" x 22", 1:50,000 scale map, equals 2,000 feet on the ground. It is the largest cell that can produce reliable resource figures and still remain cost-effective. Graphic display of the gridded file is possible at any requested contour interval.

The geologist evaluates the isopach maps and has the option to add, edit, or delete point data. Interpretive points are sometimes added to modify the isopach. Because the coal data for the Cache bed in the Recluse area have exceptionally even distribution, the addition of interpretive points was not necessary.

Standardized calculation of coal resources (USBM & USGS, 1976) requires that resource categories be delimited by coal thickness, overburden thickness, township-range, and the distance

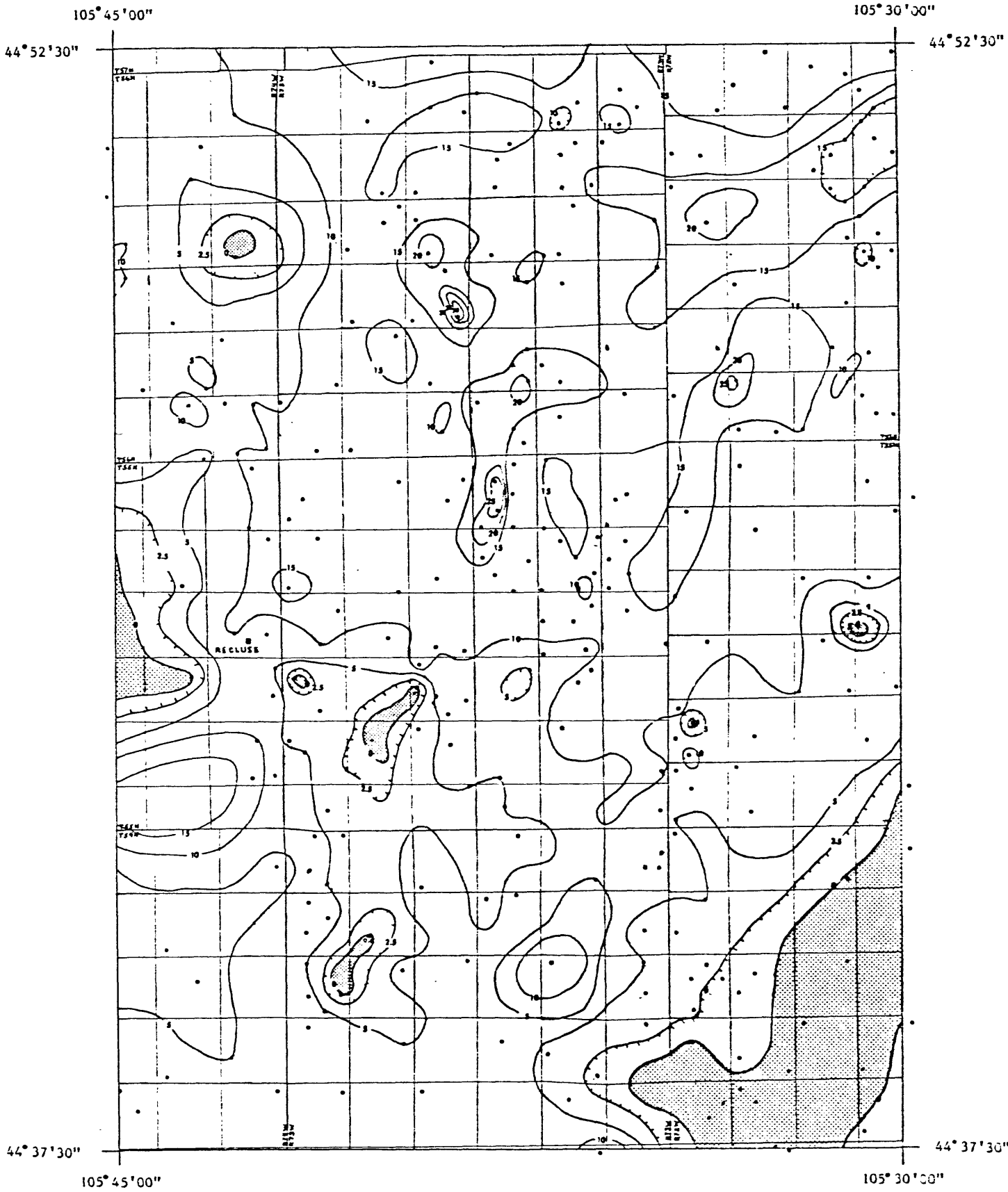

Figure 3. Hand-drawn isopach map of the Cache coal bed. Original scale at 1:50,000
• = drill hole location

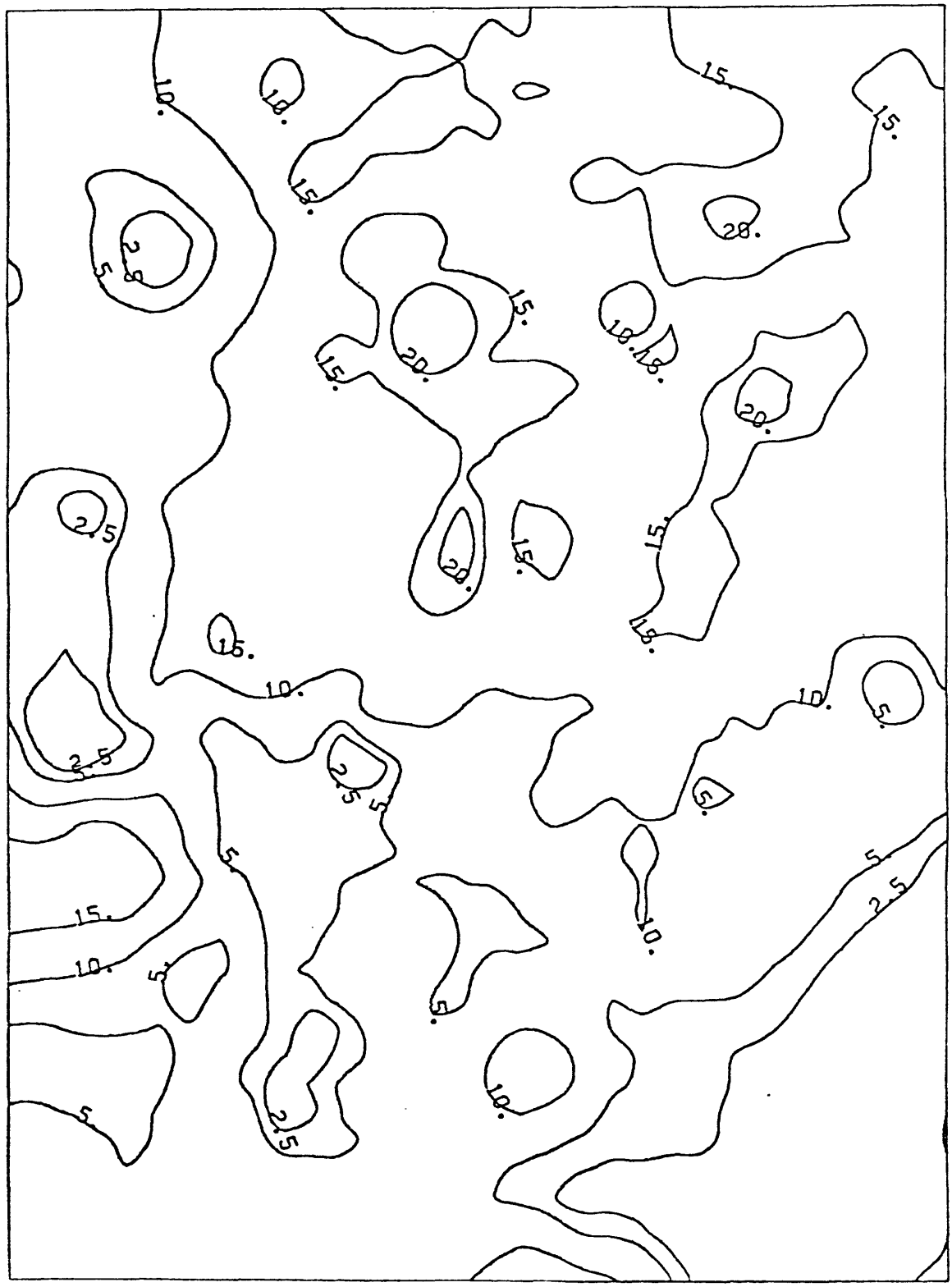

Figure 4. Computer-drawn isopach map of the Cache coal bed. Contours represent thicknesses of the Cache coal bed. Contour intervals equal 2.5, 5, 10, 15, and 20 ft. (latitude = 44 37'30" to 44 52'30" N, longitude = 105 30'00" to 105 45'00" W. Figure 3 covers the same lat/long). Original scale at 1:50,000

from the point of observation. GARNET allows interactive graphic combination of these digitized line data files to derive boundary lines of the required categories. These combinations produced 49 subfiles for the Recluse Model Area from which GARNET calculated measured (1/4 mile), indicated (1/4-3/4 mile), and inferred (3/4-3 miles) resources (tables 1, 2, & 3) represented by the respective circular areas on the resource map (Fig. 5).

Isopach and Resource Comparison

Initial visual comparison of the two isopachs (Figures 3 & 4) shows the geometry to be similar. Particularly note the 2.5 ft. and 5 ft. contours in the southeast, and the 10 ft. contour in the northwest extending southward to the middle of the map then continuing directly east. Upon closer inspection, there are two relationships to observe: 1) the hand-drawn isopach map (Fig. 3) in the upper central portion shows a clustering of contours from 10 ft. to 30 ft. whereas the computer-drawn isopach map (Fig. 4) displays the area as a collective relationship of 15 ft. and 20 ft. contours; and 2) the small areas within the 10 ft., 25 ft., and 30 ft. contours of the hand-drawn isopach in the same area are not present in the computer-drawn isopach. The explanation for their omission on the computer-drawn map is that the software assigns only one value to a given grid cell and draws contours between grid cells with differing values. The area absent in the computer isopach were smaller than the grid cell size (less than 1/2 inch); therefore, the value of the grid

Table 1.--Resources of subbituminous coal in the Cache bed for the Recluse Model Area, Campbell Co., Wyoming, as of Jan. 1, 1982 (in millions of short tons, thickness of coal and thickness of overburden categories in feet; Cache bed is in the Tongue River Member of the Paleocene Fort Union Formation, overburden 0 - 500'). Mode M = manual, C = computer; index = computer code for township-range designations.

			0 - 500 ft. of overburden											
			Measured				Indicated				Inferred			
Mode	Index	Township & Range	2 1/2-5	5-10	>10	Total	2 1/2-5	5-10	>10	Total	2 1/2-5	5-10	>10	Total
M	T.1	T. 54 N., R. 74 W.	---	---	---	---	---	---	---	---	---	---	---	---
C			---	---	---	---	---	---	---	---	---	---	---	---
M	T.2	T. 55 N., R. 74 W.	---	---	---	---	---	---	---	---	---	---	---	---
C			---	---	---	---	---	---	---	---	---	---	---	---
M	T.3	T. 56 N., R. 74 W.	---	---	---	---	---	---	---	---	---	---	---	---
C			---	---	---	---	---	---	---	---	---	---	---	---
M	T.4	T. 57 N., R. 74 W.	---	---	---	---	---	---	---	---	---	---	---	---
C			---	---	---	---	---	---	---	---	---	---	---	---
M	T.5	T. 57 N., R. 73 W.	---	---	---	---	---	---	---	---	---	---	---	---
C			---	---	---	---	---	---	---	---	---	---	---	---
M	T.6	T. 56 N., R. 73 W.	---	---	---	---	---	---	---	---	---	---	---	---
C			---	---	---	---	---	---	---	---	---	---	---	---
M	T.7	T. 55 N., R. 73 W.	---	.337	.538	.875	---	.344	.671	1.015	---	---	---	---
C			---	---	.232	.232	---	---	1.359	1.359	---	---	---	---
M	T.8	T. 54 N., R. 73 W.	1.51	3.072	---	4.582	3.19	3.030	---	6.220	---	.340	---	.340
C			1.167	1.169	1.894	4.230	1.150	3.815	2.058	7.023	---	.309	---	.309
M	T.9	T. 54 N., R. 72 W.	.929	.865	---	1.794	3.519	4.49	---	8.009	.440	.097	---	.537
C			1.32	.748	---	2.068	2.16	8.23	---	10.39	---	.455	---	1.273
M	T.10	T. 55 N., R. 72 W.	---	12.922	14.838	27.760	---	20.059	36.550	56.609	---	.359	6.010	6.369
C			.476	9.358	12.886	22.720	.218	15.662	38.659	54.539	---	---	6.390	6.390
M	T.11	T. 56 N., R. 72 W.	---	---	48.695	48.695	---	---	43.872	43.872	---	---	.009	.009
C			---	---	47.786	47.786	---	---	44.649	44.649	---	---	---	---
M			2.439	17.196	64.071	83.706	6.709	27.923	81.093	115.725	.440	.796	6.019	7.255
C			2.963	11.275	62.798	77.036	3.528	27.707	86.725	131.715	---	.764	6.390	7.972

Table 2.--Resources of subbituminous coal in the Cache bed for the Recluse Model Area, Campbell Co., Wyoming, as of Jan. 1, 1982 (in millions of short tons, thickness of coal and thickness of overburden categories in feet; Cache bed is in the Tongue River Member of the Paleocene Fort Union Formation, overburden 500 - 1000'). Mode M = manual, C = computer; index = computer code for township-range designations.

500 - 1000 ft. of overburden														
			Measured				Indicated				Inferred			
Mode	Index	Township & Range	2 1/2-5	5-10	>10	Total	2 1/2-5	5-10	>10	Total	2 1/2-5	5-10	>10	Total
M	T. 1	T. 54 N., R. 74 W.	.893	---	---	.893	2.118	.068	---	2.186	---	---	---	---
C			.772	---	---	.772	1.057	1.666	---	2.723	---	---	---	---
M	T. 2	T. 55 N., R. 74 W.	2.741	3.953	4.047	10.741	5.448	15.591	8.01	29.049	3.310	.409	2.291	6.010
C			1.091	5.222	1.685	7.998	4.119	14.456	8.181	26.756	6.817	.621	---	7.438
M	T. 3	T. 56 N., R. 74 W.	1.68	16.576	3.68	21.936	1.943	46.185	12.9	61.028	1.794	13.279	.761	15.834
C			.542	17.032	1.811	19.385	6.584	53.368	5.469	65.421	1.270	14.636	.467	16.373
M	T. 4	T. 57 N., R. 74 W.	---	---	---	---	---	---	.269	.269	---	7.09	4.290	11.380
C			---	---	---	---	---	---	---	---	---	7.101	2.826	9.927
M	T. 5	T. 57 N., R. 73 W.	---	---	.940	.940	---	---	5.577	5.577	---	---	11.556	11.556
C			---	---	.840	.840	---	---	5.632	5.632	---	---	10.632	10.632
M	T. 6	T. 56 N., R. 73 W.	---	.668	193.089	193.757	---	9.350	357.147	366.497	---	8.630	31.891	40.521
C			---	3.358	170.340	173.698	.199	9.260	358.789	368.248	.069	10.969	27.334	38.372
M	T. 7	T. 55 N., R. 73 W.	11.567	25.515	118.055	155.137	12.472	54.105	150.723	217.300	2.372	10.320	6.519	19.211
C			5.878	21.887	113.271	141.036	13.075	54.233	143.402	210.710	3.043	5.256	4.752	13.051
M	T. 8	T. 54 N., R. 73 W.	16.221	15.477	---	31.698	41.265	72.835	---	114.100	6.765	9.612	---	16.377
C			6.602	21.917	1.686	30.205	16.751	99.074	10.095	125.924	.645	19.653	3.645	23.943
M	T. 9	T. 54 N., R. 72 W.	2.176	.630	---	2.806	5.009	.304	---	5.313	4.188	---	---	4.188
C			2.773	.835	---	3.608	4.16	.870	---	4.990	3.132	.080	---	3.212
M	T. 10	T. 55 N., R. 72 W.	---	14.463	25.150	39.613	1.26	44.746	63.930	109.936	.236	1.955	8.936	11.127
C			.730	10.587	15.197	26.514	2.910	37.063	77.093	117.066	1.876	5.967	9.761	17.604
M	T. 11	T. 56 N., R. 72 W.	---	---	72.537	72.537	---	---	188.119	188.119	---	---	29.106	29.106
C			---	---	67.342	67.342	---	---	191.883	191.883	---	---	29.131	29.131
M			35.278	77.282	417.498	530.058	69.515	243.184	786.675	1099.374	18.665	51.295	95.350	165.310
C			18.388	80.838	372.172	471.398	48.815	269.99	800.544	1119.349	16.852	64.283	88.548	169.683

Table 3.--Resources of subbituminous coal in the Cache bed for the Recluse Model Area, Campbell Co., Wyoming, as of Jan. 1, 1982 (in millions of short tons, thickness of coal and thickness of overburden categories in feet; Cache bed is in the Tongue River Member of the Paleocene Fort Union Formation, overburden 1000 - 2000'). Mode M = manual, C = computer; Index = computer code for township-range designations.

			1000 - 2000 ft. of overburden											
			Measured				Indicated				Inferred			
Mode	Index	Township & Range	2 1/2-5	5-10	>10	Total	2 1/2-5	5-10	>10	Total	2 1/2-5	5-10	>10	Total
M	T. 1	T. 54 N., R. 74 W.	2.09	7.346	---	9.436	14.49	32.345	---	46.835	8.86	17.30	12.8	38.960
C			1.867	6.789	---	8.656	13.427	33.326	---	46.753	7.219	22.258	1.937	31.414
M	T. 2	T. 55 N., R. 74 W.	.308	5.68	6.47	12.458	2.325	13.380	41.40	57.105	.468	.230	2.267	2.965
C			---	3.841	6.917	10.758	1.952	6.385	18.842	27.179	2.526	5.786	13.259	21.571
M	T. 3	T. 56 N., R. 74 W.	---	5.579	---	5.579	---	15.152	---	15.152	---	.989	---	.989
C			---	6.103	.376	6.479	---	15.080	.123	15.203	---	.586	---	.586
M	T. 4	T. 57 N., R. 74 W.	---	---	---	---	---	---	---	---	---	---	---	---
C			---	---	---	---	---	---	---	---	---	---	---	---
M	T. 5	T. 57 N., R. 73 W.	---	---	---	---	---	---	---	---	---	---	---	---
C			---	---	---	---	---	---	---	---	---	---	---	---
M	T. 6	T. 56 N., R. 73 W.	---	---	---	---	---	---	---	---	---	---	---	---
C			---	---	---	---	---	---	---	---	---	---	---	---
M	T. 7	T. 55 N., R. 73 W.	---	.794	10.880	11.674	.054	1.08	14.046	15.180	---	---	.031	.031
C			.748	.427	9.724	10.899	.417	2.012	14.535	16.964	---	---	---	---
M	T. 8	T. 54 N., R. 73 W.	3.086	.345	---	3.431	2.169	4.420	---	6.589	---	.524	---	.524
C			.685	2.584	---	3.269	.870	4.853	---	5.723	---	.453	---	.453
M	T. 9	T. 54 N., R. 72 W.	---	---	---	---	---	---	---	---	---	---	---	---
C			---	---	---	---	---	---	---	---	---	---	---	---
M	T. 10	T. 55 N., R. 72 W.	---	---	---	---	---	---	---	---	---	---	---	---
C			---	---	---	---	---	---	---	---	---	---	---	---
M	T. 11	T. 56 N., R. 72 W.	---	---	---	---	---	---	---	---	---	---	---	---
C			---	---	---	---	---	---	---	---	---	---	---	---
M			5.484	19.744	17.350	42.578	19.038	66.377	55.446	140.861	9.328	19.043	15.098	43.469
C			3.300	19.744	17.017	40.061	16.666	61.656	33.500	111.822	9.745	29.083	15.196	54.024

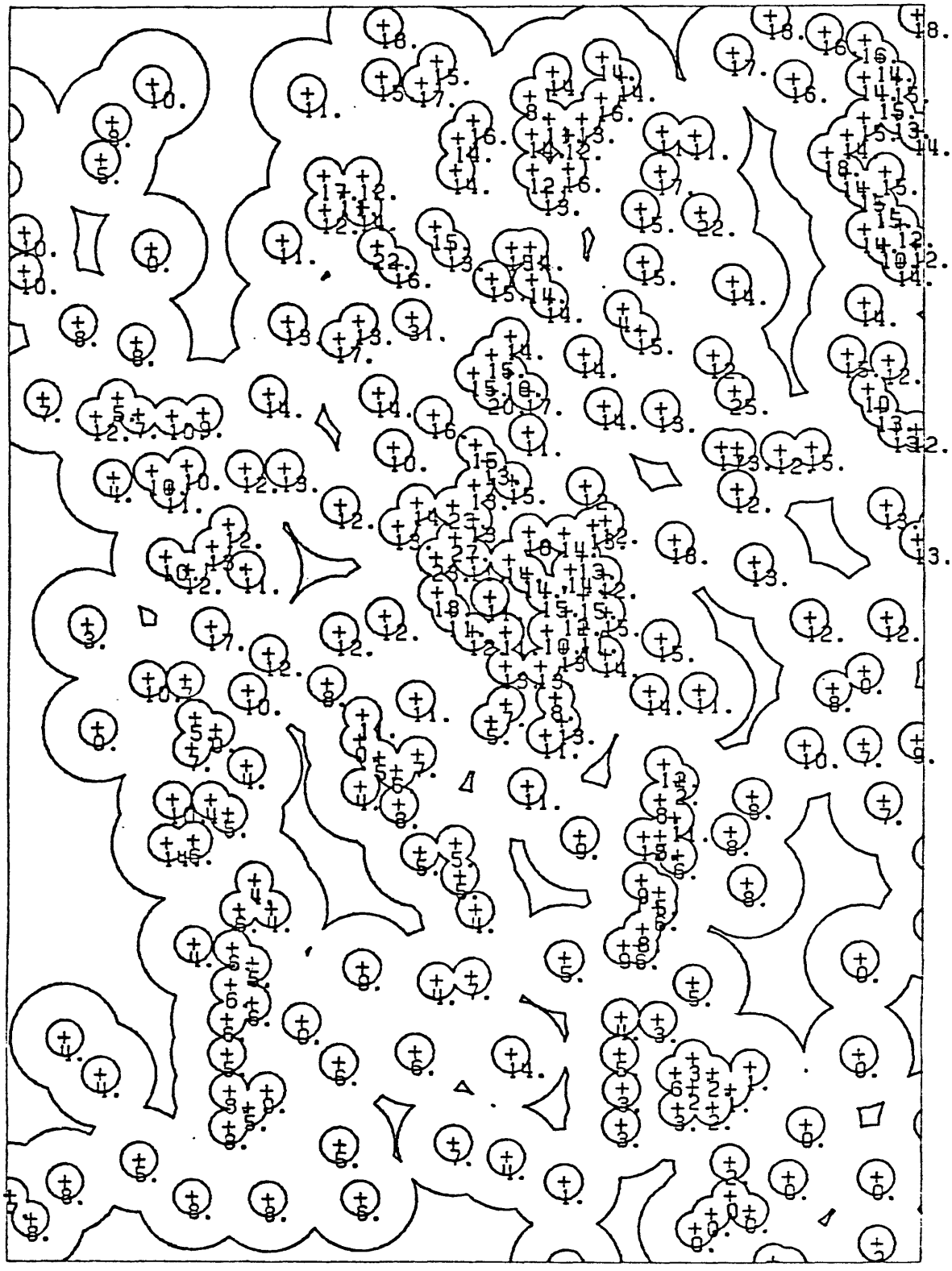

Figure 5. Computer resource map showing location and Cache coal thickness at that point. Circular areas represent ¼, 3/4, and 3 mile radii. (latitude = 44° 37'30" to 44° 52'30" N, longitude = 105°30'00" to 105°45' 00" W. Figure 3 covers the same lat/long). Original scale at 1:50,000

cell remained the same and contours were not drawn. This lack of contouring explains other omissions of small contour area from the computer-drawn map. When comparing the overall appearance of the two maps, the 2.5 ft. and 10 ft. contours demonstrate this situation. An isopach map more closely approximating the hand-drawn map may have been obtained by using a smaller grid cell size (less than 1/2 inch).

The standardized USGS-USBM resource classification system requires that resources be presented by overburden category as defined by the geologist; township-range limits; specified coal thickness categories for coal of subbituminous rank; and measured, indicated, and inferred categories determined by 1/4, 3/4, and 3 mile radii respectively.

Total tonnage comparison of 2,160 million short tons (manual) and 2,316 million short tons (computer) shows a 6.7 percent difference. Point data coal thickness, overburden trace, category radii, and township-range limits are constants. The only real variable to explain this difference is the isopach area. Because isopach lines were combined with overburden trace and township-range limits, differences for some categories can be explained. Another factor is the difference in the thickness value used in the calculation: the geologist assigns an average thickness to each area planimetered; the computer integrates areas represented by isopachs on a cell-by-cell basis, reflecting the thickness changes.

Conclusion

The NCRDS method for calculating coal resources by computer applies the rules defined by the U.S. Bureau of Mines and U.S. Geological Survey (1976) to produce reliable maps and resource numbers. The computer isopach configuration can be debated as can the manual isopach configuration. Both are subject to interpretation and both can be edited to satisfy the preconceived ideas of the geologist. However, the computer has no preconceptions or biases of its own about how the isopach map should look. It can only apply mathematical relationships to data that the user submits.

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