U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Digital representation of the Montana state geologic map: a contribution to the Interior Columbia River Basin Ecosystem Management Project

by

Gary L. Raines and Bruce R. Johnson

Open File Report 95-691

Prepared in cooperation with the U.S. Forest Service and Bureau of Land Management.

1996

CONTENTS

Acknowledgments

Digital products such as this map would not exist without the geologic mapping of generations of geologists whose work contributed to the small-scale state geologic maps that have been published by most states. We gratefully acknowledge the work of the geologists and agencies that supported compilation of this map. Those agencies include the U.S. Geological Survey and the Washington State Department of Natural Resources.

We particularly wish to acknowledge Patrick Geehan, the Bureau of Land Management Project coordinator for the Interior Columbia River Basin Ecosystem Management Project, for recognizing the importance of geology to ecosystem management and for supplying funds to digitize the Washington map.

Introduction

This report provides the digital representation of the Montana state geologic map (Ross, Andres and Witkind, 1955). This report contains an explanation of why the data were prepared, a description of the digital data, and information on obtaining the digital files. This report is one in a series of digital maps, data files, and reports generated by the U.S. Geological Survey to provide geologic process and mineral resource information to the Interior Columbia Basin Ecosystem Management Project (ICBEMP). The various digital maps and data files are being used in a geographic information system (GIS)-based ecosystem assessment including an analysis of diverse questions relating to past, present, and future conditions within the general area of the Columbia River Basin east of the Cascade Mountains.

The Interior Columbia Basin Ecosystem Management Project

In July of 1993, President Clinton directed the Forest Service (USFS) to “develop a scientifically sound and ecosystem-based strategy for management of eastside forests.” (SIT, 1994) What was first called the Eastside Ecosystem Management Project was chartered in January, 1994, by the Chief of the Forest Service and Director of the Bureau of Land Management (BLM) in response to the President's directive and charged to “develop an ecosystem management framework and assessment for land administered by the Forest Service and the Bureau of Land Management on those lands east of the Cascade crest in Washington and Oregon and within the interior Columbia River Basin.” (SIT, 1994) The driving force behind the project was the need to develop a strategy for dealing with anadromous fish habitat and watershed conservation and to develop overall land management policy in eastern Oregon and Washington. When it subsequently became clear that similar strategies were needed for anadromous fish in the remainder of the Columbia River Basin (particularly in Idaho and Montana), the project was extended to include all of the Columbia River drainage basin in the United States, east of the Cascade Mountain divide plus the remainder of southeastern Oregon, which is not within the drainage basin (fig. 1). At that time, the project was renamed the Interior Columbia Basin Ecosystem Management Project (ICBEMP).

The ICBEMP is producing scientific assessments of current and historic landscape conditions; aquatic and terrestrial habitat, species distributions, and populations; and economic and social conditions as well as the potential future conditions and possible tradeoffs likely to result from a range of possible disturbances and management practices on public lands in the basin. Although the scientific assessment is being conducted for the entire basin, the management decisions that will result from the assessments will be for public lands (USFS and BLM) only.

The goal of the ICBEMP management strategy is to provide management tools to sustain or restore ecosystem integrity and produce desired conditions, uses, products, values, and services over the long term. The intent of the project is to understand the ramifications of management practices or disturbances both in the area subject to the practice or disturbance as well as effects which may be removed, in time and space, from the area.

The project objectives are to:

- Conduct a broad integrated scientific assessment of the resources within the interior Columbia River basin to characterize and assess landscape, ecosystem, social, and economic processes and functions and describe probable outcomes of various management practices and trends.
- Develop an ecosystem management framework that includes principles and processes which may be used in a National Environmental Protection Act (NEPA) process to develop management direction for federal agencies at all levels with the basin.
- Write an Eastside Environmental Impact Statement (EIS) proposing a broad array of management alternatives for an area that encompasses ten national forests and portions of four BLM districts in eastern Washington and Oregon (fig. 1).
- Write an Upper Columbia River Basin EIS with a similar array of management alternatives for an area that encompasses lands administered by the BLM and USFS in Idaho, western Montana, Wyoming, Utah, and Nevada within the Columbia River Basin (fig. 1).
- Conduct a scientific evaluation of issues and alternatives identified through the NEPA scoping process for the Eastside EIS.

The ICBEMP is an intense, short term assessment and planning activity used to develop a set of regional implementation management alternatives. These alternatives, derived from basin-wide analyses of regional (1:500,000 and 1:1,000,000 scales) and locally more detailed (1:100,000 scale) data, will form a framework for implementation decisions at the local level. This framework will then be adapted as better data and understanding of the basin are developed. The project will provide a basin-wide, digital data framework that will evolve and improve as higher resolution data become available. All data are being collected in a GIS-compatible format for digital display, analysis, and distribution. Information on the availability of all digital data sets, paper maps, and other reports generated by the ICBEMP can be obtained from:

Interior Columbia Basin Ecosystem Management Project
ATTN: Cindy Dean
112 E. Poplar Street
Walla Walla, WA 99362
(509) 522-4030

or from:

Bureau of Land Management
ATTN: Becky Gravenmeier, OR99.2
Oregon - Washington State Office
P.O. Box 2965
Portland, OR 97208
(503) 952-6273

Project extent and scale

The scope and extent of the project area varies depending on the objective. The broad scientific assessment considers all lands, not just those that are federally managed. It is focused on the Columbia River Basin but is not strictly limited to the actual drainage basin boundaries. Some scientific assessment staff areas have extended their work beyond the formal project area because factors such as wildfires and wildlife migration are not limited to drainage divides or political boundaries. Most staff areas use the Landscape Characterization boundary developed by the Landscape Ecology group (fig. 1). The broad assessment uses information suitable for compilation at a scale of 1:1,000,000.

U.S. Geological Survey involvement

In May, 1994, the USGS approached ICBEMP staff about providing estimates of undiscovered mineral resources to the economic, landscape ecology, and aquatic-riparian assessment staff. In discussions with members of various staff areas, it became apparent that the USGS could also provide geoscientific background information relevant to the assessment of historic, current, and future ecological, economic, and social systems. Within the ICBEMP's tight schedule (7 months from the USGS start date until the information had to be available to the rest of the Science Integration Team), the USGS was able to provide basin-wide, integrated, digital information about bedrock lithology, compositional classifications of lithology, potential animal habitat, stream sediment geochemistry, volcanic and earthquake hazards, and mineral resources. The bedrock lithology information is summarized in Johnson and Raines (1995). The potential animal habitat information is summarized in Frost, Raines, Almquist, and Johnson (1996). The stream sediment geochemistry is summarized in Raines and Smith (1996). The digital hazards information was derived from Algermissen, et al (1990) and Hoblitt, Miller, and Scott (1987). The mineral resources information is summarized in Box and others (1996); Bookstrom, Zientek, and others (1996); Zientek and others (1996); and Bookstrom, Raines, and Johnson (1996). The compositionally classified lithology information is reported Raines and others (1996). The bedrock lithology, compositionally classified lithology, and potential animal habitat maps were all derived from interpretation of state geologic maps at scales of 1:500,000 to 1:750,000. Johnson and Raines (1995) summarizes the strategy that was used for the rapid analysis of geologic map data using GIS techniques. Considerably more information was identified as potentially useful to the ICBEMP, but integrated digital products could not be provided for the entire study area within the time frame of the assessment.

Data Sources, Processing, and Accuracy

The starting point for the digital geology map of Montana (Ross, Andres and Witkind, 1955) was a paper copy of the published geologic map. The characteristics of the source material are summarized in Table 1. The map was processed in the ARC/INFO GIS of ESRI and based on the results presented in Table 1 is considered an accurate geographic representations of the original map.

State	Date	Scale	Source Material	Registration Error (RMS) input (inches), output (meters)
Eastern Montana	1955	1:500,000	Paper	0.011, 133.434
Western Montana	1955	1:500,000	Paper	0.076, 965.561

Table 1. Source of materials and registration errors for the digital geologic map of Montana. The registration root-mean-square (RMS) errors are obtained while transforming from scanner units of inches (input in table) to real world coordinates of meters (output in table). These errors are the RMS difference between the scanned latitude-longitude location points from the source material and the calculated locations of these points. The error for western Montana is significant and was corrected with a rubber-sheet stretch as described in the text.

The map was processed digitally, as follows: the source material was scanned, the scanned image was vectorized and topologically structured, the lines and polygons were edited and proofed, attributes were added and proofed, the map was transformed from scanner units to geographic coordinates, and finally, map distortions were removed by rubber-sheeting. The initial objective was to obtain a digital representation that, when plotted, would overlay the source material within a line width; the digital version of the map meets this test.

A measure of the geometric accuracy of the source materials (as represented digitally) was obtained by comparing 25 points with known latitudes and longitudes from the source material with calculated locations of these points. The results of this comparison as the registration root-mean-square error (RMS error in Table 1). Appendix B contains a detailed breakdown of registration errors for each point. The RMS error on these map (133 m for eastern Montana and 966 m for western Montana) is excellent for eastern Montana but significantly larger than the national standard for 1:500,000-scale topographic base maps (plus or minus 140 meters horizontally) for western Montana. This is probably due to the paper base and possibly the source materials used to make the original base. The rubber sheeting that was preformed after this processing made the best correction possible with the data as it exists.

Each polygon and line on the digital map was assigned attribute information based on the original map explanation. Details of the attributes used and the values which those attributes can contain are given in Appendix A. At least two GIS coverages are required to efficiently represent a geologic map. One set of coverages (wmtgeol and emtgeol) contains all of the polygon data and all of the contacts between polygons. To prevent polygons from being dissected by cross-cutting lines, a second set of coverages (wmtarc and emtarc) is used to contain all of the linework other than contacts (faults, fold axes, etc.) Where the contact between polygons (lithologic units) is made up of a fault, the identical line (fault/contact) will exist in both coverages. Appendix B contains detailed documentation of the three coverages which were used to represent the map digitally. There were approximately 100 to 200 tiny polygons on the original map that were either ambiguously attributed or un-attributed on the original published map. These polygons were assigned map-unit attributes by consultation with regional experts and inspection of more detailed maps.

Obtaining Digital Data
To obtain copies of the digital data, do one of the following:

1. Download the digital files from the USGS public access World Wide Web site on the Internet.
URL = http://wrgis.wr.usgs.gov/docs/geologic/mt/montana.html
The World Wide Web site contains the geologic GIS coverage in Arc/Info Export file format as well as the associated data files and Arc/Info macro programs which are used to plot the map at 1:1,000,000 and 1:2,000,000 scales. Use of this data requires a GIS that is capable of reading Arc/Info Export formatted files and a computer capable of reading UNIX ASCII files. To use these files on a DOS computer, they must be put through a unix-to-dos filter. Or,

2. Obtain the digital files from the ICBEMP project office. Contact information is given in the section, **U.S. Geological Survey involvement** , above.

Digital versions of other state geologic maps in the Northwest are available as follows:

Arizona	Data files are available via anonymous FTP from a USGS public access site, **greenwood.cr.usgs.gov** in the following subdirectory: **/pub/arizona**
California:	Contact the California Division of Mines and Geology, 1416 Ninth Street, Room 1341, Sacramento, CA 95814
Idaho:	Johnson and Raines (1996b)
Nevada:	Turner and Bawiec (1991) — CD-ROM
Oregon:	Data files are available via anonymous FTP from a USGS public access site, **greenwood.cr.usgs.gov** in the following subdirectory: **/pub/oregon**
Utah:	Data files are available via anonymous FTP from a USGS public access site, **greenwood.cr.usgs.gov** in the following subdirectory: **/pub/utah**
Washington:	Raines and Johnson (1996)
Wyoming:	Green and Drouillard (1994) This report is a description of the digital data files only. The data files are available via anonymous FTP from a USGS public access site, **greenwood.cr.usgs.gov** in the following subdirectory: **/pub/open-file-reports/ofr-94-0425**)

Obtaining Paper Maps
Paper copies of the Montana state geologic map are not available from the USGS. The original published geologic map may be available from the Montana Bureau of Mines and Geology. Paper copies of the map can also be created by obtaining the digital files as described above, and then creating a plot file in a GIS.

References Cited

Algermissen, S. T., Perkins, D. M., Thenhaus, P. C., Hanson, S. L., and Bender, B. L., 1990, Probabilistic earthquake acceleration and velocity maps for the United States and Puerto Rico: U.S. Geological Survey Miscellaneous Field Studies Map, MF-2120, scale 1:7,500,000.

Bookstrom, A. A., Raines, G. L., and Johnson, B. R., 1996, Digital mineral resource maps of phosphate and natural aggregate in the Pacific Northwest: a contribution to the Interior Columbia Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-681, 31 pp.

Bookstrom, A. A., Zientek, M. L., Box, S. E., Derkey, P. D., Elliott, J. E., Frishman, David, Evarts, R. C., Ashley, R. P., Moyer, L. A., Cox, D. P., and Ludington, S. D., 1996, Status and contained metal content of significant base and precious metal deposits in the Pacific Northwest: a contribution to the Interior Columbia Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-688, 93 pp.

Box, S. E., Bookstrom, A. A., Zientek, M. L., Derkey, P. D., Ashley, R. P., Elliott, J. E., and Peters, S. G., 1996, Assessment of undiscovered mineral resources in the Pacific Northwest: a contribution to the Interior Columbia Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-682, 415 pp.

Green, G.N. and Drouillard, P.H., 1994, The digital geologic map of Wyoming in ARC/INFO format: U.S. Geological Survey Open-File Report 94-0425, 10 p.

Hoblitt, R. P., Miller, C. D., and Scott, W. E., 1987, Volcanic hazards with regard to siting nuclear power plants in the Pacific Northwest: U.S. Geological Survey Open-File Report 87-297, 196 pp.

Johnson, B.R. and Raines, G.L., 1995, Digital map of major lithologic bedrock units for the Pacific Northwest: a contribution to the Interior Columbia River Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report-680, 36 p. plus 2 plates.

Johnson, B. R. and Raines, G. L., 1996, Digital representation of the Idaho state geologic map: a contribution to the Interior Columbia River Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-690, 22 pp.

Raines, G.L., and Johnson, B.R., 1996b, Digital representation of the Washington state geologic map: a contribution to the Interior Columbia River Basin Ecosystem Management Project:, U.S. Geological Survey Open-File Report 95-648, 20 pp.

Raines, G. L., Johnson, B. R., Frost, T. P., and Zientek, M. L., 1996, Digital maps of compositionally classified lithologies derived from 1:500,000 scale geologic mapping for the Pacific Northwest: a contribution to the Interior Columbia Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-685, 28 pp.

Raines, G. L. and Smith, C. L., 1996, Digital maps of National Uranium Resource Evaluation (NURE) geochemistry for the Pacific Northwest: a contribution to the Interior Columbia Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-686, 22 pp.

Ross, C. P., Andres, D. A., and Witkind, I. J., 1955, Geologic map of Montana: U.S. Geological Survey, plate 2, Scale 1:500,000.

SIT (Science Integration Team), 1994, Framework for ecosystem management in the Interior Columbia River Basin - version 1: eastside Ecosystem Management Project, USFS, Walla Walla, Washington, 48 p.

Turner, R.M., and Bawiec, W.J., 1991, Geology of Nevada - a digital representation of the 1978 geologic map of Nevada: U.S. Geological Survey Digital Data Series, DDS-2, 1 CD-ROM.

Zientek, M. L., Bookstrom, A. A., Box, S. E., and Johnson, B. R., 1996, Future minerals related activity, Interior Columbia Basin Ecosystem Management Project area: an overview: U.S. Geological Survey Open-File Report 95-687, xx pp.

Appendix A: Geologic Map Attributes.

Attributes Compiled for Classification

The table below is a list of the ARC/INFO attributes that were compiled for each geologic map unit.

Attribute	Description
FORMATION	The map unit symbol used on the published map. This is the item that is related to the map coverage. This is not necessary a formation in the normal usage. It is a map unit.
UNIT_NAME	The map unit name from the map explanation.
ROCK_TYPE	The general rock category from the map explanation. Generally this is something like sedimentary, igneous, or metamorphic.
ERA, SYSTEM, SERIES	Age information from the map explanation.
LITH1, LITH2, etc.	Lithology from the map explanation. LITH1 is the first described lithology, LITH2 is the next, etc.
LOCATION1, LOCATION2	Notes on location of this particular map unit within the state. Some state maps have differing lithologic descriptions for a single geologic unit in different geographic portions of the state.
COMMENTS	Other comments from map explanation that do not fit in previous attributes

Example of Complete Data for One Stratigraphic Unit

Description from map explanation:

Sedimentary and Metasedimentary Rocks

Ordovician rocks — Mainly black to gray slate or slatey argillite, argillite, black to dark-gray limestone, and some black to gray quartzite. Includes dark gray siltstone in north-central Stevens County and grayish olive-green silty argillite in west-central Stevens County. Many occurrences of Early and Middle Ordovician graptolites; also rare conodonts.

GIS attributes derived from map explanation:

Attribute Name	Contents
FORMATION	O
UNIT_NAME	Ordovician rocks
ROCK_TYPE	Marine sedimentary and metasedimentary rocks
ERA	Paleozoic
SYSTEM	Ordovician
SERIES	
LITH1	slate
LITH2	argillite
LITH3	limestone
LITH4	quartzite
LITH5	siltstone
LITH6	
LITH7	
LITH8	
LOCATION1	
LOCATION2	
COMMENTS	Many occurrences of Early and Middle Ordovician graptolites; also rare conodonts.

Time Stratigraphic Symbols used for Formation Names

Because the database tables that are used with the GIS are confined to ASCII characters, the following ASCII character substitutions were used for representing geologic time designators in formation names:

Geologic Time	Map Symbols	ASCII Equivalent
Quaternary	Q	Q
Tertiary	T	T
Pliocene	P	PL
Miocene	M	MI
Oligocene	OI	OL
Eocene	E	E
Paleocene	pE	EP
Mesozoic	Mz	MZ
Cretaceous	K	K
Jurassic	J	J
Triassic	TR	TR
Permian	PM	P
Carboniferous	C	PNM
Devonian	D	D
Silurian	S	S
Ordovician	O	O
Cambrian	C̄	C
Precambrian	p C̄	pC

Appendix B: GIS Coverage Documentation

Registration Tics and Registration Errors

Latitude and longitude tics that could be identified on the original map were used to rubber sheet the coverage to calculated latitude-longitude points to reduce the distortion of the paper. The latitude and longitude and the adjustment report for the points are listed below.

Results of coordinate transformation of Montana registration points:
Eastern Montana
Scale (X, Y) = (12693.492, 12697.491)
RMS Error (input, output) = (0.011, 133.434)

Western Montana
Scale (X,Y) = (12673.625, 12652.242)
RMS Error (input, output) = (0.076, 965.561)
The RMS error measures the errors between the output coverages tics and the transformed location of the input coverages tics. It indicates how good the derived transformation is and is foremost a measure of the quality of the original materials used for scanning.. The first number is the error in digitizer units and the second is the error in meters. Scale has to do with the scanning parameters, i.e. how the original map was placed on the scanner.

The following table lists the tics and their associated longitude, latitude, input and output locations, and location errors for western Montana.

id	Long	Lat	input X (in)	input Y (in)	output X (m)	output Y (m)	error X (m)	error Y (m)
1	114	46	14.746	17.652	-310399.438	5405446.500	-59.772	321.436
2	113	46	20.870	17.554	-232832.469	5402457.500	-55.652	317.785
3	115	47	8.913	26.611	-381795.969	5520639.500	-44.520	107.592
4	116	49	3.655	44.499	-443274.375	5748774.000	-141.501	-252.985
5	115	49	9.498	44.262	-369477.344	5744302.000	35.065	-454.697
6	114	47	14.941	26.513	-305492.250	5516858.000	8.675	930.828
7	114	48	15.128	35.255	-300571.562	5628576.500	-78.087	-255.793
8	113	47	20.969	26.351	-229151.562	5513916.000	2.123	115.136
9	113	48	21.063	35.162	-225460.531	5625682.000	-19.857	-226.627
10	114	49	15.334	44.114	-295635.594	5740642.500	94.465	-328.101
11	113	49	21.161	44.007	-221758.016	5737795.500	21.749	-493.157
13	112	45	26.999	8.755	-157685.594	5289097.000	-22.215	635.384
14	111	45	33.205	8.787	-78847.570	5287796.000	-217.443	574.515
15	112	46	26.989	17.505	-155237.312	5400322.000	-131.614	90.505
16	111	46	33.125	17.575	-77623.352	5399041.000	13.506	515.539
17	110	46	39.254	17.677	0.000	5398614.000	75.785	483.827
18	109	45	45.662	9.094	78847.570	5287796.000	7.628	903.705
19	109	46	45.374	17.851	77623.352	5399041.000	52.598	506.282
20	108	45	51.915	8.939	157685.594	5289097.000	348.747	-4139.696
21	112	47	26.993	26.310	-152783.125	5511814.500	-48.534	-29.008
22	111	47	33.029	26.365	-76396.188	5510553.500	52.074	209.981
23	112	48	27.002	35.138	-150322.188	5623614.500	85.866	-164.603
24	111	48	32.926	35.159	-75165.648	5622373.500	-7.359	-348.303
25	110	47	39.055	26.465	0.000	5510133.500	38.843	182.229
26	110	48	38.842	35.265	0.000	5621960.000	-173.657	-270.927

27	112	49	26.995	44.000	-147853.594	5735762.000	27.005	-205.415
28	111	49	32.841	44.026	-73931.273	5734541.500	189.041	-326.811
29	110	49	38.642	44.103	0.000	5734135.000	-226.395	-600.341
30	109	47	45.069	26.633	76396.188	5510553.500	-115.084	168.201
31	109	48	44.777	35.442	75165.648	5622373.500	-99.282	-137.969
32	109	49	44.472	44.283	73931.273	5734541.500	-232.993	-397.530
33	108	49	50.333	44.776	147853.594	5735762.000	241.895	2949.166
34	115	48	9.210	35.414	-375646.219	5632297.000	62.685	-276.582
35	116	48	3.304	35.654	-450675.375	5636843.500	316.212	-103.567

The following table lists the tics and their associated longitude, latitude, input and output locations, and location errors for eastern Montana.

id	Long	Lat	Input X (in)	Input Y (in)	Output X (m)	Output Y (m)	X error (m)	Y error (m)
1	108	45	1.590	1.932	157685.594	5289097.000	95.150	91.445
2	108	46	1.586	10.693	155237.313	5400322.000	-18.855	80.270
3	107	45	7.802	1.958	236504.516	5291266.000	91.232	-17.481
4	106	45	14.004	2.067	315294.813	5294302.000	-26.216	50.358
5	107	46	7.707	10.723	232832.469	5402457.500	52.268	34.020
6	106	46	13.819	10.819	310399.438	5405446.500	25.855	-34.443
7	108	47	1.593	19.461	152783.125	5511814.500	27.551	-106.487
8	108	48	1.608	28.277	150322.188	5623614.500	154.223	20.777
9	108	49	1.599	37.119	147853.594	5735762.000	-12.466	113.876
10	107	47	7.607	19.490	229151.563	5513916.000	-37.665	-162.868
11	107	48	7.498	28.300	225460.531	5625682.000	-241.806	-122.673
12	106	47	13.631	19.594	305492.250	5516858.000	45.197	-111.015
13	106	48	13.431	28.405	300571.563	5628576.500	-93.659	-35.647
14	107	49	7.412	37.146	221758.016	5737795.500	-167.971	34.050
15	106	49	13.246	37.241	295635.594	5740642.500	-36.065	14.311
16	105	45	20.217	2.236	394046.938	5298205.000	18.482	30.525
17	104	45	26.402	2.478	472751.313	5302974.500	-266.468	55.167
18	105	46	19.929	10.994	387928.813	5409288.500	-18.014	41.428
19	104	46	26.037	11.219	465411.188	5413984.000	-46.399	-102.617
20	105	47	19.652	19.767	381795.969	5520639.500	97.274	-20.355
21	105	48	19.361	28.574	375646.219	5632297.000	28.786	48.044
22	104	47	25.668	19.998	458053.438	5525260.500	114.797	-34.732
23	104	48	25.278	28.805	450675.375	5636843.500	28.036	70.806
24	105	49	19.065	37.403	369477.344	5744302.000	-71.598	33.521
25	104	49	24.912	37.627	443274.375	5748774.000	258.331	29.720

Details of Lithology Coverage

Coverage Name: wmtgeol and emtgeol
Descriptive Location: Montana split into two coverages at 108°.
Brief Description: Geologic map of Montana

SOURCE

Data Source: Ross, C.P., Andres, D.A., and Witkind, I.J., 1955, Geologic map of Montana: U.S. Geological Survey, 1 Plate, Scale 1:500,000.
Point of Contact: Montana Bureau of Mines and Geology
Telephone: (406) 496-4180
Source Material: paper
Source Scale: 1:500,000
Source Projection:
PROJECTION lambert, North American datum, 1927
UNITS METERS
PARAMETERS
33 00 00 /* 1ST STANDARD PARALLEL
45 00 00 /* 2ND STANDARD PARALLEL
-110 00 00 /* CENTRAL MERIDIAN
0 0 0 /* LATITUDE OF PROJECTIONS ORIGIN
0.0 /* FALSE EASTING
0.0 /* FALSE NORTHING
Source Date (Publication date): 1955
General Comments (disclaimers, qualifications): Digitized on contract from a flat paper copy. The contractor, Optronics Specialty Co., Inc., used scanning technology and delivered the coverage in digitizer coordinates. The latitude and longitude tics that could be identified on the original were digitized. These tic points were used to transform and rubber sheet the coverage to calculated latitude-longitude points to reduce the distortion of the paper. The latitude and longitude and the adjustment report for the points are listed above. Note the large RMS error for western Montana. The rubber sheeting should have removed much of this error.

Date Received: November, 1994

DIGITAL COMPILER

Responsible Organization/Agency: Spokane and Reno Office, USGS
Project Name: Interior Columbia River Basin Project
Point of Contact: Gary Raines and Bruce Johnson
Telephone: 702/784-5591 or 509/359-3176

ATTRIBUTES

Creation Date: November, 1994
GIS ARC/INFO
Feature Types: polygons, arcs
Topology Present: poly, arc
Precision: Single Precision

DATAFILE NAME: WMTGEOL.PAT 5 ITEMS: STARTING IN POSITION 1

COL	ITEM NAME	WDTH	OPUT	TYP	N.DEC	Description
1	AREA	4	12	F	3	
5	PERIMETER	4	12	F	3	
9	WMTGEOL#	4	5	B	-	
13	WMTGEOL-ID	4	5	B	-	
17	FORMATION	11	11	C	-	Map unit name

DATAFILE NAME: EMTGEOL.PAT 5 ITEMS: STARTING IN POSITION 1

COL	ITEM NAME	WDTH	OPUT	TYP	N.DEC	Description
1	AREA	4	12	F	3	
5	PERIMETER	4	12	F	3	
9	EMTGEOL#	4	5	B	-	
13	EMTGEOL-ID	4	5	B	-	
17	FORMATION	11	11	C	-	Map unit name

DATAFILE NAME: WMTGEOL.AAT 12 ITEMS: STARTING IN POSITION 1

COL	ITEM NAME	WDTH	OPUT	TYP	N.DEC	Description
1	FNODE#	4	5	B	-	
5	TNODE#	4	5	B	-	
9	LPOLY#	4	5	B	-	
13	RPOLY#	4	5	B	-	
17	LENGTH	4	12	F	3	
21	WMTGEOL#	4	5	B	-	
25	WMTGEOL-ID	4	5	B	-	
29	ARC_TYPE	8	8	C	-	Short name for line type. Examples CON, FLTC.
37	LTYPE	31	31	C	-	Contact, fault, fold or other the of line
68	MODIFIER	21	21	C	-	Type of contact, fault, fold or other.
89	ACCURACY	16	16	C	-	Positional accuracy.
105	FAULT_CONT	3	3	C	-	Denotes that arc is both a fault and a contact. Values can be yes or no.
	** REDEFINED ITEMS **					
37	LINE_DESCRIP	68	68	C	-	ltype, modifier, and accuracy combined as one attribute

DATAFILE NAME: EMTGEOL.AAT 12 ITEMS: STARTING IN POSITION 1

COL	ITEM NAME	WDTH	OPUT	TYP	N.DEC	Description
1	FNODE#	4	5	B	-	
5	TNODE#	4	5	B	-	
9	LPOLY#	4	5	B	-	
13	RPOLY#	4	5	B	-	
17	LENGTH	4	12	F	3	
21	EMTGEOL#	4	5	B	-	
25	EMTGEOL-ID	4	5	B	-	
29	ARC_TYPE	8	8	C	-	Short name for line type. Examples CON, FLTC.
37	LTYPE	31	31	C	-	Contact, fault, fold or other the of line
68	MODIFIER	21	21	C	-	Type of contact, fault, fold or other.
89	ACCURACY	16	16	C	-	Positional accuracy.
105	FAULT_CONT	3	3	C	-	Denotes that arc is both a fault and a contact. Values can be yes or no.
	** REDEFINED ITEMS **					
37	LINE_DESCRIP	68	68	C	-	ltype, modifier, and accuracy combined as one attribute

List of unique values for the arc attributes.

ARC_TYPE	LTYPE	MODIFIER	ACCURACY
CON	contact	normal	certain
CONAPPQ	contact	normal	approx. located
CONAPPX	contact	normal	approx. located
CONQ	contact	normal	certain ?
DIKEPCBC	dike	pCb	certain
DIKEPUC	dike	Pu	certain
FLTC	fault	normal	certain
FLTCNCLC	fault	normal	concealed
FLTINFC	fault	normal	inferred
FLTINFQC	fault	normal	inferred ?
FLTQC	fault	normal	certain ?
FLTTHRC	fault	thrust	certain
FLTTHRIC	fault	thrust	inferred
POLYBRK	polybrk	polygon break	N/A

The following table is derived from the explanation that accompanies the map. All the data in the table is explicitly stated in the map explanation. The values in lith are ordered as they appeared in the explanation.

DATAFILE NAME: MONTANA.TBL 23 ITEMS: STARTING IN POSITION 1

COL	ITEM NAME	WDTH	OPUT	TYP	N.DEC	Description
1	FORMATION	11	11	C	-	Map unit name
12	UNIT_NAME	75	76	C	-	Descriptive name

87	ROCK_TYPE	50	51	C	-	General rock group
137	ERA	24	25	C	-	Geologic era
161	SYSTEM	24	25	C	-	Geologic system
185	SERIES	24	25	C	-	Geologic series
209	LITH1	40	41	C	-	First lithology listed in the map explanation.
249	LITH2	40	41	C	-	second lithology
289	LITH3	40	41	C	-	third lithology
329	LITH4	40	41	C	-	etc.
369	LITH5	40	41	C	-	
409	LITH6	40	41	C	-	
449	LITH7	40	41	C	-	
489	LITH8	40	41	C	-	
529	LOCATION1	60	61	C	-	
589	LOCATION2	60	61	C	-	
649	COMMENTS	70	71	C	-	
	** REDEFINED ITEMS **					
209	LITH_MAJOR	120	123	C	-	Grouping of lith1, 2, and 3. This is assumed to be the major lithology of the map unit.
329	LITH_MINOR	200	205	C	-	Grouping of remaining map units. This is assumed to be the minor lithologic components of the map unit.
209	LITHOLOGY	320	328	C	-	
137	AGE	72	75	C	-	

Details for the fault coverage .

Coverage Name: wmtarcs and emtarcs
Descriptive Location: Montana split into two coverages at 108°.
Brief Description: Arcs of Montana, such as faults, folds, and other ars to complete the geologic.

SOURCE

Data Source: Ross, C.P., Andres, D.A., and Witkind, I.J., 1955, Geologic map of Montana: U.S. Geological Survey, 1 Plate, Scale 1:500,000.
Point of Contact: Montana Bureau of Mines and Geology
Telephone: (406) 496-4180
Source Material: paper
Source Scale: 1:500,000
Source Projection:
PROJECTION lambert, North American datum, 1927
UNITS METERS
PARAMETERS
33 00 00 /* 1ST STANDARD PARALLEL
45 00 00 /* 2ND STANDARD PARALLEL
-110 00 00 /* CENTRAL MERIDIAN
0 0 0 /* LATITUDE OF PROJECTIONS ORIGIN
0.0 /* FALSE EASTING
0.0 /* FALSE NORTHING
Source Date (Publication date): 1955
General Comments (disclaimers, qualifications): Digitized on contract from a flat paper copy. The contractor, Optronics Specialty Co., Inc., used scanning technology and delivered the coverage in digitizer coordinates. The latitude and longitude tics that could be identified on the original were digitized. These tic points were used to transform and rubber sheet the coverage to calculated latitude-longitude points to reduce the distortion of the paper. The latitude and longitude and the adjustment report for the points are listed below. Note the large RMS error. The rubber sheeting should have removed much of this error.

Date Received: November, 1994

DIGITAL COMPILER

Responsible Organization/Agency: Spokane and Reno Office, USGS
Project Name: Interior Columbia River Basin Project
Point of Contact: Gary Raines and Bruce Johnson
Telephone: 702/784-5591 or 509/359-3176

ATTRIBUTES

Creation Date: November, 1994
GIS ARC/INFO
Feature Types: arcs
Topology Present: arc
Precision: Single Precision

DATAFILE NAME: WMTARCS.AAT 12 ITEMS: STARTING IN POSITION 1

COL	ITEM NAME	WDTH		OPUT	TYP	N.DEC	Description
1	FNODE#	4	5	B	-		
5	TNODE#	4	5	B	-		
9	LPOLY#	4	5	B	-		
13	RPOLY#	4	5	B	-		
17	LENGTH	4	12	F	3		
21	WMTARCS#	4	5	B	-		
25	WMTARCS-ID	4	5	B	-		
29	ARC_TYPE	8	8	C	-	Short name for line type. Example: CON, FLTC.	
37	LTYPE		31	31	C	-	Contact, fault, fold or other the of line
68	MODIFIER	21	21	C	-	Type of contact, fault, fold or other.	
89	ACCURACY	16	16	C	-	Positional accuracy.	
105	FAULT_CONT	3	3	C	-	Denotes that arc is both a fault and contact. Value can be yes or no.	
	** REDEFINED ITEMS **						
37	LINE_DESCRIP	68	68	C	-	ltype, modifier, and accuracy combined as one attribute	

DATAFILE NAME: EMTARCS.AAT 12 ITEMS: STARTING IN POSITION 1

COL	ITEM NAME	WDTH		OPUT	TYP	N.DEC	Description
1	FNODE#	4	5	B	-		
5	TNODE#	4	5	B	-		
9	LPOLY#	4	5	B	-		
13	RPOLY#	4	5	B	-		
17	LENGTH	4	12	F	3		
21	EMTARCS#	4	5	B	-		
25	EMTARCS-ID	4	5	B	-		
29	ARC_TYPE	8	8	C	-	Short name for line type. Example: CON, FLTC.	
37	LTYPE		31	31	C	-	Contact, fault, fold or other the of line
68	MODIFIER	21	21	C	-	Type of contact, fault, fold or other.	
89	ACCURACY	16	16	C	-	Positional accuracy.	
105	FAULT_CONT	3	3	C	-	Denotes that arc is both a fault and contact. Value can be yes or no.	
	** REDEFINED ITEMS **						
37	LINE_DESCRIP	68	68	C	-	ltype, modifier, and accuracy combined as one attribute	

List of unique values for the arc attributes. The apparent duplication, such as FLT and FLTC, differentiate those lines that are contacts between polygons (FLTC) and not contacts (FLT).

ARC_TYPE	LTYPE	MODIFIER	ACCURACY
DIKEPCB	dike	pCb	certain
DIKEPCBC	dike	pCb	certain
DIKEPCD	dike	pCd	certain

DIKEPU	dike	Pu	certain
DIKEPUC	dike	Pu	certain
FLT	fault	normal	certain
FLTC	fault	normal	certain
FLTCNCL	fault	normal	concealed
FLTCNCLC	fault	normal	concealed
FLTINF	fault	normal	inferred
FLTINFC	fault	normal	inferred
FLTINFQC	fault	normal	inferred ?
FLTQC	fault	normal	certain ?
FLTTHR	fault	thrust	certain
FLTTHRC	fault	thrust	certain
FLTTHRI	fault	thrust	inferred
FLTTHRIC	fault	thrust	inferred
ICESHEET	other	continental ice sheet	certain
TERDIKE	other	tertiary dikes	certain