U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Digital map of Possible Bat Habitats for the Pacific Northwest: a contribution to the Interior Columbia River Basin Ecosystem Management Project

by

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Open File Report 95-683

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

1996

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Acknowledgments

Digital compilation 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. Those agencies that supported the creation of the state maps include the U.S. Geological Survey, the California Division of Mines and Geology, the Idaho Bureau of Mines and Geology, the Montana Bureau of Mines and Geology, the Nevada Bureau of Mines and Geology, the Oregon Department of Geology and Mineral Industries, the Utah Geological and Mineral Survey, the Washington State Department of Natural Resources, and the Geological Survey of Wyoming.

We particularly wish to acknowledge Patrick Geehan, the Bureau of Land Management Deputy 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, Idaho, and Montana state geologic maps.

Introduction

This report provides background information on the bat habitat map provided by the U.S. Geological Survey to the Interior Columbia Basin Ecosystem Management Project (ICBEMP). A page-size copy of the map is shown in Figures 1 and 2 to illustrate the information content. This report is one in a series of digital maps, data files, and reports generated by the U.S. Geological Survey (USGS) to provide geologic process and mineral resource information for the Interior Columbia Basin Ecosystem Management Project (ICBEMP), a U.S. Forest Service and Bureau of Land Management interagency project. The various digital maps and data files which were provided by the USGS, and which are available in this and other reports, are being used in a geographic information system (GIS)-based ecosystem assessment which includes a comprehensive analysis of past, present, and future ecosystem conditions within the general area of the Columbia River Basin east of the Cascade Mountains.

The Interior Columbia Basin Ecosystem Management

In January of 1994, the Chief of the U.S. Forest Service (USFS) and the Director of the Bureau of Land Management (BLM), under direction of the President of the United States, initiated what was then called the Eastside Ecosystem Management Project to “develop a scientifically sound and ecosystem-based strategy for management of eastside forests.” The project was further directed 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.” The driving force behind the project was the need to develop a strategy for dealing with anadromous fish habitat and watershed conservation in eastern Oregon and Washington. Subsequently, when it 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; of aquatic and terrestrial habitat, species distributions, and populations; and of economic and social conditions. The project is also producing scientific assessments of the potential future conditions and possible tradeoffs likely to result from a range of possible

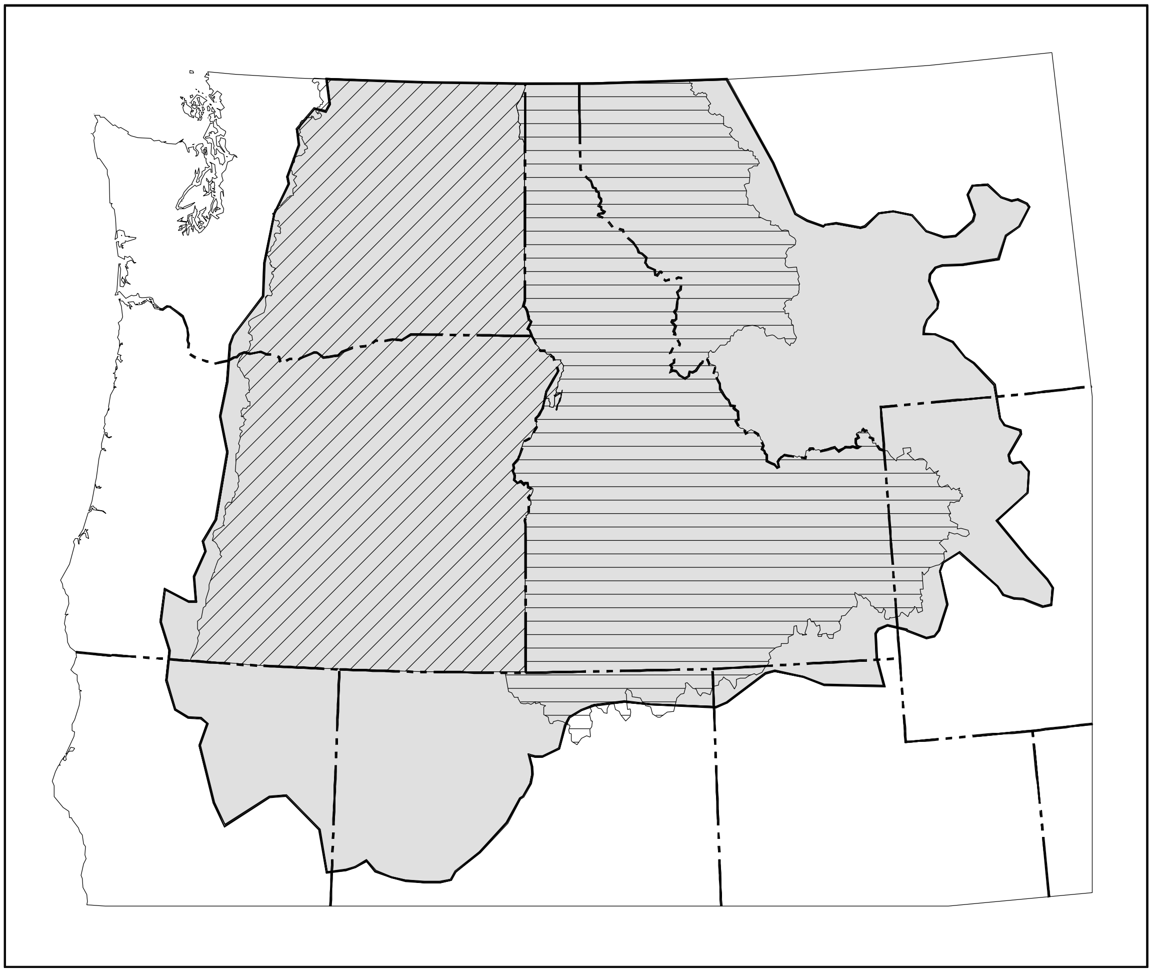

Figure 1. Index map showing the geographic extent of the Interior Columbia Basin Ecosystem Management Project. Shown on the map are the Landscape Characterization Area (grey shading) which is the study area used by most Science Integration Team staff areas, the Eastside EIS area (diagonal hatching), and the Upper Columbia EIS area (horizontal hatching).

disturbances and management practices on public lands in the basin. Although scientific assessments are being conducted for the entire basin, management decisions that are based on the assessments will apply to public lands (USFS and BLM) only.

The goal of the ICBEMP management strategy is to provide management tools which can be used to sustain or restore ecosystem integrity and to promote products and services desired by society over the long term. The management strategy is intended to provide tools to balance ecosystem conditions, resource uses, and competing values of ecosystem users. The intent of the project is to understand the ramifications of past, present, and future management practices and man-made or natural disturbances both in the area subject to the management practice or disturbance and in areas which may be remote, in time and/or space.

The project is organized around two teams, the Science Integration Team and the Environmental Impact Statement Team, with overlapping membership. Both teams are further sub-divided into staff areas (sub-teams of subject experts) including: landscape ecology, aquatic/riparian, terrestrial, forest policy and economics, and social sciences. Many staff scientists work on both the Science Integration Team and the Environmental Impact Statement Team.

Specific objectives of the project are:

To conduct a broad 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.

To 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 within the basin.

To write an Eastside Environmental Impact Statement (EIS) proposing a broad array of alternative strategies for an area that encompasses ten national forests and portions of four BLM districts in eastern Washington and Oregon (fig. 1).

To write an Upper Columbia River Basin EIS with a similar array of alternative strategies 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).

To 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 project to develop several regionally-consistent, land-management alternatives. These alternatives, derived from basin-wide analyses of highly generalized data, will form a framework for land-management decisions at the local level. This framework will be modified as better data and understanding of the basin are developed. Under the project, a flexible, basin-wide, digital database will be developed 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 as a function of the objective. The scientific assessment, for example, includes all lands, not just those that are federally managed. This objective is focused on the Columbia River Basin but is not strictly limited to the actual drainage basin boundaries. Moreover, some scientific assessment subject sub-teams, by necessity, have extended their work beyond the limits of the formal project because factors such as wildfires and wildlife migration are not limited by drainage divides or political boundaries. Most subject sub-team project areas are restricted to the Landscape Characterization boundary developed by the Landscape Ecology group (fig. 1). The scientific assessment is primarily based on information suitable for compilation at a scale of 1:1,000,000.

U.S. Geological Survey involvement

In June, 1994, the USGS was asked to provide estimates on the value of undiscovered mineral resources for the Columbia basin. In the course of discussions with members of various sub-teams from both project teams, it became apparent that additional earth science information also was highly relevant to the assessment of historic, current, and future ecological, economic, and social systems, and that the USGS could provide this information in a digital format. 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, rock chemistry, potential animal habitat, stream sediment geochemistry, volcanic and earthquake hazards, and mineral resources. The bedrock lithology information is summarized in Johnson and Raines (1995a). The bedrock chemistry information is summarized in Raines, Johnson, Frost, and Zientek (1996). Potential animal habitat information is summarized in this report, and regional geochemistry is summarized in Raines and Smith (1996). Digital hazards information was derived from Algermissen, et al (1990) and Hoblitt, Miller, and Scott (1987). Mineral resources information is summarized in Box, et al (1996); Bookstrom, Zientek, et al (1996); Zientek, Bookstrom, Box, and Johnson (1996); Bookstrom, Raines, and Johnson (1996); and Zientek, Bookstrom, Johnson, and Frost (1996).

Information on the bat habitat portion of the study is covered by this report. This report also summarizes the strategy that was used for rapid analyses of regional geologic map data using GIS techniques to produce the bedrock lithology, rock chemistry, and potential animal habitat maps, which were all derived from the state geologic maps. 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 points for the bat habitat map and other derivative maps were the geologic maps of California (Jennings, 1977), scale, 1:750,000; Idaho (Bond and Wood, 1978), scale, 1:500,000; Montana (Ross, Andres and Witkind, 1955), scale, 1:500,000; Nevada (Stewart and Carlson, 1978), scale, 1:500,000; Oregon (Walker, MacLeod, 1991), scale, 1:500,000; Utah (Hintze, 1980), scale, 1:500,000; Washington (Hunting and others, 1961), scale, 1:500,000; and Wyoming (Love and Christiansen, 1985) scale, 1:500,000. Characteristics of the source materials of each of these maps are summarized in Table 1. All of the maps were processed using the GIS package, ARC/INFO (ESRI), and based on the results presented in Table 1 are considered accurate geographic representations of the original maps for the purposes of regional assessments.

Table 1. Source of materials and registration errors for the digital, state geologic maps. 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. Where the registration error is queried the data are not available; however, these maps were all digitized by scanning mylar copies of original publication material. These normally have an input RMS error of approximately 0.003, much smaller than the errors obtained from the paper sources used here. The Oregon geologic map was created using digital techniques so no additional processing was required. The large transform error for the western Montana sheet was caused by distortion in the southeastern corner of the paper map sheet.

State	Date	Scale	Source Material	Registration Error (RMS)
California	1977	1:750,000	Mylar	?
Idaho	1978	1:500,000	Paper	0.011, 145.720
Montana	1955	1:500,000	Paper	Western Montana: 0.076, 965.561 Eastern Montana: 0.011, 133.434
Nevada	1978	1:500,000	Mylar	?
Oregon	1991	1:500,000	Digital	N.A.
Utah	1980	1:500,000	Mylar	?
Washington	1961	1:500,000	Mylar	0.015, 189.092
Wyoming	1985	1:500,000	Mylar	?

State geologic maps were selected as the basis for the bat habitat map because their scale provides an appropriate level of information to satisfy project objectives, and because they cover large areas, thereby reducing errors inherent in resolving correlation differences between maps. In addition, several state maps were available in digital form, and the others could be quickly digitized. The state maps provide considerably more detail and, in some areas, more current interpretations of the geology than the 1:2,500,000-scale geologic map of the United States (King and Beikman, 1974), even though some of the state maps are relatively old and, in places, do not represent the most current geologic understanding.

Digital processing of the state geologic maps was accomplished by scanning the source materials; the scanned images were then vectorized and topologically structured, the lines and polygons were edited and proofed, attributes were added and proofed, the maps were 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 materials within a line width. Each of the digital state maps meet this test.

In each state map used, approximately 100 to 200 extremely small polygons were found that were either ambiguously attributed or un-attributed. These polygons were assigned map-unit attributes by consultation with regional experts and inspection of more detailed maps.

Geometric accuracy of the digitized source materials was determined by comparing the calculated locations of 15-25 points with known latitudes and longitudes with the locations of the same points on the source materials. Table 1 contains the results of this comparison as the registration root-mean-square error. Except for the western Montana sheet, these errors range from much less than to slightly larger than the national standard for 1:500,000-scale topographic base maps which is plus or minus 140 meters horizontally. The Montana maps (2 sheets) were scanned from old paper versions of the published map because the map is out of print and original materials are no longer available. The large transform error for the western Montana sheet was caused by distortion in the southeastern corner of the paper map sheet. To correct for the geographic distortion of the source maps, the digital maps were then rubber-sheeted to move the scanned latitude-longitude points to the correct calculated locations. This rubber-sheet correction provides the most accurate representation of the individual state geologic maps.

Digital versions of individual state geologic maps are available as follows:

California: California Division of Mines and Geology, 1416 Ninth Street, Room 1341, Sacramento, CA 95814

Idaho: Descriptive report: Johnson and Raines (1996b); digital files can be downloaded from the USGS public access World Wide Web site on the Internet:

URL = http://wrgis.wr.usgs.gov/docs/geologic/id/idaho.html

Montana: Descriptive report: Raines and Johnson (1996a); digital files can be downloaded via anonymous FTP from the USGS publicaccess site:

greenwood.cr.usgs.gov in the directory: **/pub/open-file-report/ofr-95-0691**

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: Descriptive report: Raines and Johnson (1996b) ; digital files can be

URL = http://wrgis.wr.usgs.gov/docs/geologic/wa/washington.html

Wyoming: Descriptive report: Green and Drouillard (1994); the data files are available via anonymous FTP from a USGS public access site:

greenwood.cr.usgs.gov in the directory: **/pub/open-file-reports/ofr-94-0425**

As a final step, the individual state maps were edge-matched by rubber-sheeting along their boundaries to fit the adjacent state maps. Because of the differences in how the digital maps had been prepared, there are differences in geometric accuracy from state to state. The Oregon state map was originally prepared digitally; so the published and digital version are identical. The Wyoming map was digitized from original source materials, and the California, Nevada, and Utah maps were prepared from base-stable copies of original source materials. These four maps have an root-mean-square error of registration near 0.003 inches. Because these maps have higher geometric accuracy than the Idaho, Montana, and Washington maps, the later three maps were rubber-sheeted to fit the more accurate California, Oregon, Nevada, Utah, and Wyoming maps along their common boundaries. The maximum translation needed to match boundaries was approximately 400 meters; in most areas 200 meters or less were needed. The remaining borders were then rubber-sheeted to a compromise boundary to make a composite of all of the states. Because the Idaho-Montana border is very irregular and the two state maps used different base materials, many adjustments were required. Consequently this is the area of largest residual geometric error. Because of the differences in geologic representation between the state maps, the state boundaries were maintained in the bedrock lithology digital composite and were only eliminated in derivative maps.

As a partial test of the digitizing and attributing of the individual state maps, all derivative maps were checked for differences at the state boundaries. A few incorrectly labeled map units and areas where the map units were defined differently across state boundaries were identified. Examples include a rock unit mapped as granitic gneiss in one state and granite in the adjacent state, and several sedimentary facies changes that occur in the vicinity of state boundaries. To evaluate these problems and refine some of the interpretive maps, newer, larger-scale, geologic maps were examined and regional geology experts were consulted. National Uranium Resource Evaluation stream sediment geochemistry was also used where available to test the geochemical interpretations of the lithologic information (Raines and Smith, 1995).

Bat Habitat Maps

Wild animals are dependent on physical characteristics of the landscape to provide their homes. Cave-dwelling bats make their homes in limestone caves, lava tubes, and mines. These animals will also live in openings in buildings, under bridges, and natural pockets, ledges, or cracks in any available rock, that is any type of protected dark space. This bat-habitat map is not, therefore, a comprehensive map of cave dwelling bat habitats, but does show areas known or suspected to contain prime habitat considering only the dwelling requirements that can be addressed through readily derived geological data. It shows areas that are geologically favorable to host caves and caverns, given the scale and level of information inherent in the original state geologic mapping.

The bat habitat map identifies areas where limestone caves or lava tubes can occur and where they are known to occur. It also shows locations of known underground mines. Areas on the map that are identified as having potential for limestone caves are areas where formations of thick limestone and dolomite are found, defined as the high areas on the calcium map (Raines, Johnson, Frost, and Zientek, 1995). A second category is identified that is characterized by lithologies with significant, but thinner or discontinuous beds of limestone or dolomite. Areas assigned to this category generally correspond to medium areas from the calcium map (Raines, Johnson, Frost, and Zientek, 1995). Lava tubes generally form in basaltic lava flows and are known especially to exist in many young basalt units. Because these features form at the earth's surface and are physically unstable, only the youngest ones are preserved. Included are areas of known lava tubes such as Crater's of the Moon in Idaho and Lava Tubes National Monument in California, and extensive lava tubes around Bend, Oregon. The underground mines are taken from the U.S. Bureau of Mines MILS data base. These mine locations are noted as points in the data base and are represented here as small areas having a 1 kilometer radius around the mines because it is very common to find clusters of mine openings where only one point is noted in the data base. This map represents one geologic factor of many factors defining the habitat of cave dwelling bats. Table 2 describes specific map units from the state maps that were classified as potential bat habitats.

The bat habitat map should be considered a model exploring the geologic characteristics which a specific species finds suitable as habitat. Other similar maps can be derived from digital geologic coverages that would identify any other known factor, or combination of factors, that a species of plant or animal finds attractive or necessary. Such maps will become especially powerful tools when geologic factors are combined with topographic, climatic, geographic, slope-aspect, vegetation, or other map coverages.

Table 2: Map units classified as having potential for underground openings suitable bat habitat. Listed are the map units for each state map, a brief lithologic description from those map legends, and the bat-habitat categories. Carbonate habitat indicates map units having thick carbonate rocks which, could form caves. Habitat classified as some carbonate indicates map units with thin carbonate beds that may form some caves or other small openings. Lava tubes indicates map units known to have lava tubes. The lithologic descriptions are sometimes truncated due to field length limitations. Note that the map units use the following substitutions: C, Cambrian; TR, Triassic; PN or P, Pennsylvania: PP, Permian-Pennsylvanian; M, Mississippian.

Map Unit	Lithologic Description	Habitat
Washington:		
Cls	Cambrian limestone and dolomite	carbonate
Pcd	Precambrian rocks, undivided	some carb
Qv	Pleistocene-Recent volcanic rocks	lava tube
TR	Triassic sedimentary rocks, undivided	carbonate
pTm		

Pre-Tertiary metamorphic rocks, undivided
some carb

Idaho:

C
Cambrian marine dolomite, limestone, claystone, and quartzite
carbonate

Cun
Upper Cambrian dolomitic limestone and claystone of northern Idaho
carbonate

D
Devonian bedded dolomite and limestone interval of eastern and southern Idaho
carbonate

DO
Devonian to Ordovician marine calcareous sediments north of the Snake Plain
some carb

DS
Devonian and Silurian shallow-water marine carbonate units of east-central
carbonate

Jl
Lower Jurassic shaley, sandy limestone overlaying red, crossbedded sandstone
carbonate

Ku
Upper Cretaceous thick detrital and fresh-water limestone
carbonate

M
Mississippian shallow-water carbonates-to-clastic sequence of east-central
carbonate

MD
Lower Mississippian and Devonian marine dolomite and limestone of eastern Idaho
carbonate

Ms
Mississippian shallow-water coralline limestone interval of southern Idaho
carbonate

O
Ordovician marine dolomite, quartzite, and limestone
carbonate

Occ

	Ordovician and Cambrian thrusted dolomite, siltstone, and quartzite of central Idaho carbonate
Ol	Lower Ordovician dolomite, nodular cherty limestone, and intraformational carbonate
Ou	Upper and Middle Ordovician dolomite and quartzite carbonate
PNM	Pennsylvanian and Mississippian shallow-water carbonates of eastern Idaho carbonate
PPNs	Lower Permian to Middle Pennsylvanian chert, limestone, and sandstone of southern Idaho some carb
Pzl	Lower Paleozoic marine carbonate and clastic units southeast of the Snake Plain carbonate
Pzu	Upper Paleozoic marine sediments in southern Idaho some carb
Ps	Lower Permian beds; uppermost portion of southern Idaho sequence some carb
Qtb	Lower Pleistocene to Pliocene basalts with associated tuffs and volcanic detritus lava tube
Qpmb	Middle Pleistocene canyon-filling basalt in and near Snake Plain lava tube
Qpu1b	Upper Pleistocene Snake Plain lava flows lava tube
Qpu2b	Upper Pleistocene Snake Plain lava flows lava tube
Qpu3b	Upper Pleistocene Snake Plain lava flows lava tube
Qpu4b	Upper Pleistocene Snake Plain lava flows lava tube

Qpu?b
Upper Pleistocene Snake Plain lava flows
lava tube
Qpub
Upper Pleistocene Snake Plain lava flows
lava tube
Qrb
Recent, relatively unweathered Snake Plain basalt flows and cinder cones
lava tube
S
Upper and Middle Silurian fossiliferous dolomite
carbonate
SO
Silurian to Middle Ordovician marine carbonate-to-clastic strata of east-central Idaho
carbonate
Trl
Lower Triassic limestone and chert above shaley sandstone, siltstone, and limestone
carbonate
Y3n
Precambrian dark-colored calcareous and dolomitic argillite and siltite
some carb

Montana:

Cu
Cambrian, undifferentiated
some carb
Du
Devonian, undifferentiated
some carb
Kg
Greenhorn formation
some carb
Kn
Niobrara formation
some carb
Mu
Mississippian, undifferentiated
carbonate
Ou
Ordovician, undifferentiated
some carb
Pu
Permian, undifferentiated
some carb

pCa
Belt Series - Altyn limestone
carbonate
pCh
Belt Series - Helena limestone
carbonate
pCn
Belt Series - Newland limestone
carbonate
pCpi
Belt Series - Piegan group
some carb
pCpi?
Belt Series - Piegan group, queried
some carb
pCsi
Belt Series - Siyeh limestone
carbonate
pCw
Belt Series - Wallace formation
some carb
pCwc
Belt Series - Wallace formation
carbonate

Wyoming:

TRad
Ankareh Formation, Thaynes Limestone, Woodside Shale and Dinwoody Formation
some carb
TRcd
Chugwater and Dinwoody Formations
some carb
TRcd
Chugwater and Dinwoody Formations
some carb
Kg
Gannett Group--Includes Smoot Formation, Draney Limestone, Bechler Conglomerate, Peterson Limestone, and Ephraim
some carb
Kgb
Greenhorn Formation and Belle Fourche Shale
carbonate
Kgbm
Greenhorn Formation and Belle Fourche and Mowry Shales
carbonate

Kn
Niobrara Formation
carbonate
Knc
Niobrara Formation and Carlile Shale
carbonate
Knt
Niobrara and Frontier Formations, and Mowry and Thermopolis Shales
carbonate
MD
Madison Limestone and Darby Formation
carbonate
MD
Madison Group and Three Forks and Jefferson Formations
carbonate
MD
Madison Group and Darby Formation
carbonate
MDO
Madison Limestone, Darby or Three Forks, Jefferson, and Beartooth Butte Formations, and Bighorn Dolomite
carbonate
MDe
Pahasapa and Englewood Limestones
carbonate
MDg
Guernsey Formation--Locally Includes Dolomite and Sandstone of Devonian and Cambrian(?) Age
carbonate
MO
Madison Limestone and Bighorn Dolomite--East Side of Bighorn Mountains
carbonate
Mm
Madison Limestone
carbonate
Mm
Madison Limestone or Group--Includes Wedge Edge of Bighorn Dolomite in Tps. 43 and 44 N., Rgs. 85 and 86 w.
carbonate
Mm
Madison Group
carbonate
OC
Bighorn Dolomite, Gallatin Limestone, and Gros Ventre Formation

some carb
OC
Bighorn Dolomite, Snowy Range Formation, Pilgrim Limestone, Park Shale, Meager Limestone, Wolsey Shale, and Flathead
some carb
OC
Whitewood Dolomite, and Winnipeg and Deadwood Formations
some carb
O C
Bighorn Dolomite, Gallatin Limestone, Gros Ventre Formation, and Flathead Sandstone Gallatin Limestone, Gros Ventre
some carb
Ob
Bighorn Dolomite
carbonate
P&M
Casper Formation and Madison Limestone
carbonate
P&M
Casper Formation and Madison Limestone
carbonate
P&M
Wells and Amsden Formations
carbonate
P&Ma
Phosphoria Formation and Related Rocks, Quadrant Sandstone, and Amsden Formation
carbonate
P&Ma
Phosphoria, Wells, and Amsden Formations
carbonate
P&Ma
Phosphoria Formation and Related Rocks, Tensleep Sandstone, and Amsden Formation
carbonate
P&h
Hartville Formation
some carb
PM
Tensleep Sandstone and Amsden Formation
some carb
Pfs
Forelle Limestone and Satanka Shale
carbonate
Pmo
Minnekahta Limestone and Opeche Shale

carbonate

Pzr

Madison Limestone and Cambrian Rocks Cambrian Rocks
carbonate

Pzr

Minnekahta Limestone, Opeche Shale, Minnelusa Formation, Pahasapa and Englewood Limestones, Whitewood Dolomite
carbonate

Pzr

Madison Limestone, Darby Formation, Bighorn Dolomite, Gallatin Limestone, Gros Ventre Formation, and Flathead Sandstone
carbonate

Qb

Basalt Flows and Intrusive Igneous Rocks
lava tube

Sl

Laketown Dolomite--Uinta County
carbonate

Twg

Wasatch and Green River Formations, New Fork Tongue of Wasatch and Fontenelle Tongue or Member of Green River
some carb

Cr

Gallatin Limestone, Gros Verde Formation and Equivalents and Flathead Sandstone
some carb

Utah:

C2

sedimentary
carbonate

C3

sedimentary
some carb

D

sedimentary
carbonate

J1

sedimentary
carbonate

M1

sedimentary
carbonate

M2

sedimentary
carbonate

O

sedimentary
carbonate

P2

sedimentary
carbonate

PN

sedimentary
carbonate

PNP

sedimentary
carbonate

Qb

volcanic
lava tube

S

sedimentary
carbonate

T2

sedimentary/volcanic
some carb

TR1

sedimentary
carbonate

Nevada:

Cc

Limestone and Dolomite, Locally Thick Sequences of Shale and Siltstone
carbonate

Ct

Shale and Thin-Bedded or Laminated Limestone; Also Thinly Interbedded Limestone and Chert
some carb

DCc

Dolomite and Limestone
carbonate

Dc

Dolomite, Limestone, and Minor Amounts of Sandstone and Quartzite
carbonate

Dt

Argillaceous Limestone, Chert, and Shale
carbonate

Mc

Limestone and Minor Amounts of Dolomite and Shale

carbonate
Ml
Massive Limestone
carbonate
OCc
Dolomite and Limestone
carbonate
Oc
Limestone, Dolomite, Shale, and Quartzite
carbonate
PMc
Limestone, Dolomite, and Shale
carbonate
PPa
Antler Sequence of Silberling and Roberts
some carb
PPc
Limestone and Sparse Dolomite, Siltstone, and Sandstone
carbonate
PPcd
Sandy and Silty Limestone, Conglomerate, and Siltstone
carbonate
Pc
Limestone
carbonate
Pc+
Cherty Limestone and Sparse Dolomite, Shale, and Sandstone
carbonate
Pcd
Limestone, Cherty Limestone, Sandy Limestone, and Chert-Pebble Conglomerate
carbonate
Psc
Siltstone, Sandstone, Limestone and Dolomite (Commonly Silty or Sandy) and Gypsum
some carb
SOc
Dolomite
carbonate
Sc
Dolomite
carbonate
St
Platy Limestone and Limy Siltstone, Chert at Base
carbonate
TRPs

Silty Limestone, Minor Amounts of Shale, and Some Greenstone
carbonate

TRc

Limestone, Minor Amounts of Dolomite, Shale, and Sandstone; Locally Thick Conglomerate Units
carbonate

TRmt

Moenkopi Formation, Thaynes Formation, and Related Rocks
some carb

California:

C

Marine sedimentary and metasedimentary rocks
some carb

D

Marine sedimentary and metasedimentary rocks
carbonate

Kjfm

Marine sedimentary and metasedimentary rocks
some carb

Qv

volcanic rocks
lava tube

Qv?

volcanic rocks
lava tube

TR

Marine sedimentary and metasedimentary rocks
some carb

ls

Marine sedimentary and metasedimentary rocks
carbonate

Oregon:

Psv

Sedimentary and Volcanic Rocks, Partly Metamorphosed (Permian and Permian?)
some carb

QTb

Basalt (Pleistocene and Pliocene)
lava tube

QTba

Basalt and Basaltic Andesite (Pleistocene and Pliocene)

	lava tube
Tvm	
	Mafic Vent Deposits (Pleistocene, Pliocene, and Miocene?)
	lava tube
Qb	
	Basalt and Basaltic Andesite (Holocene and Pleistocene)
	lava tube
Qlb	
	Late Basalt (Holocene or Upper Pleistocene)
	lava tube

Obtaining Digital Data

The digital files which were used to make the bat habitat map are available as GIS coverages and associated data files. All data files and map images are maintained in the projection used for all ICBEMP products:

Projection:	Albers Equal Area
1st Standard Parallel:	43° N
2nd Standard Parallel:	48° N
Central Meridian:	117° W
Origin of Projection:	41° N
Y-offset (false easting):	700,000 m

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:

URL = http://wrgis.wr.usgs.gov/docs/geologic/northwest_region/ofr95-683.html

or anonymous FTP from **wrgis.wr.usgs.gov**, in the directory:

pub/geologic/northwest_region/misc/ofr95-683

These internet sites contain the bat habitat 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 a scale of 1:2,000,000. 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, **The Interior Columbia Basin Ecosystem Management Project**, above.

Obtaining Paper Maps

Paper copies of the bat habitat map are not available from the USGS at this time. However, with access to the Internet and access to a large-format color plotter, a 1:2,000,000-scale paper copy of the map can be made, as follows:

1. Download the digital version of the complete map from the USGS public access World Wide Web site on the Internet.

URL = http://wrgis.wr.usgs.gov/docs/geologic/northwest_region/ofr95-683.html

or anonymous FTP from **wrgis.wr.usgs.gov**, in the directory:

pub/geologic/northwest_region/misc/ofr95-683

These internet sites contain a file, **bat2m.hp**, which is in HPGL2 graphics language.

2. This file can be plotted by any large-format graphics plotter which can interpret the HPGL2 language. The finished plot is 29 by 39 inches.

Paper copies of the map can also be created by obtaining one of the versions of the digital files as described above, and then creating a plot file in a GIS.

Concluding Remarks

Derivative maps produced from state map scale geology are an appropriate first step to providing a regional context for land management decisions. The applications these maps are intended to address are very general. The 1:500,000 scale of the data is appropriate to regional applications concerning the entire Columbia River Basin. Although some of the state geologic maps are old, much of the evolution of geologic knowledge since the 1970's has been concerned with the temporal correlation of rock units, with details of the compositions of the individual units, and with when and how the existing spatial arrangement of rock units came to exist. These types of information have little bearing on the derivative maps presented here. Thus, the dominant lithologic character of the rock units is generally well represented in the state geologic maps and the maps are appropriate to regional applications in most areas.

Fundamental geologic information is a critical portion of any ecosystem study and should be part of the basis for land management decisions. Future ecosystem monitoring and adaptive management planning within the Columbia River Basin should include studies to improve the quality of the geologic data base.

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.

Bond, J. G. and Wood, C. H., 1978, Geologic map of Idaho: Idaho Department of Lands, Bureau of Mines and Geology, 1 figure, Scale 1:500,000.

Bookstrom, A. A., Raines, G. L., and Johnson, B. R., 1995, 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, 28 pp.

Bookstrom, A. A., Zientek, M. L., Box, S. E., Derkey, P. D., Elliott, J. E., Frishman, David, Ashley, R. P., Evarts, R. C., Stoesser, D.B., Moyer, L. A., Cox, D. P., and Ludington, Steve, 1996, Status and metal content of significant metallic mineral deposits in the Pacific Northwest: a contribution to the Interior Columbia Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-688, 96 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, 425 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 pp.

Hintze, L. F., 1980, Geologic map of Utah: Utah Geological and Mineral Survey, 2 figures, 1:500,000 scale.

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.

Hunting, M. T., Bennett, W. A., Livingston, V. E., Jr., and Moen, W. S., 1961, Geologic map of Washington: Washington Dept. of Conservation, Division of Mines and Geology, 1 figure, scale 1:500,000.

Jennings. C. W., 1977, Geologic map of California: California Divisions of Mines and Geology, Map No. 2, 1 figure, Scale 1:750,000.

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 figures.

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

King, P. B., and Beikman, H. M., 1974, Geologic Map of United States: U.S. Geological Survey, 2 figures, scale 1:2,500,000.

Love, J. D., and Christiansen, Ann Coe, 1985, Geologic map of Wyoming: U.S. Geological Survey, 3 Figures, Scale 1:500,000.

Raines, G. L. and Johnson, B. R., 1996a, Digital representation of the Montana state geologic map: map: a contribution to the Interior Columbia Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-691, 36 pp.

_____, 1996b, Digital representation of the Washington state geologic map: a contribution to the Interior Columbia Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-684, 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 maps for the Pacific Northwest: a contribution to the Interior Columbia Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-685, 29 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, 1 figure, Scale 1:500,000.

Stewart, J. H. and Carlson, J. E., 1978, Geologic map of Nevada: U.S. Geological Survey, 1 figure, scale 1:500,000.

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.

Walker, G. W. and MacLeod, N. S., 1991, Geologic map of Oregon: U.S. Geological Survey, 2 figures, scale 1:500,000.

Zientek, M. L., Bookstrom, A. A., Box, S. E., and Johnson, B. R., 1995, Future minerals related activity, Interior Columbia Basin Ecosystem Management Project area: an overview: U.S. Geological Survey Open-File Report 95-687, 30 pp.

Zientek, M. L., Bookstrom, A. A., Johnson, B. R., and Frost, T. P., in prep., Digital maps of acid mine-drainage potential in the Pacific Northwest: a contribution to the Interior Columbia Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-692.

Potential bat habitat map explanation

Carbonate rocks — areas with high potential for limestone caverns

Some carbonate rocks — areas with some potential for limestone caverns

Quaternary basalts — areas with high potential for lava tubes

Underground mines. From USBM MILS data

In figure 3, the mine locations shown are representative of the entire data set. The complete data is available in the larger-scale GIS and plotting files available for downloading from: http://wrgis.wr.usgs.gov/docs/geologic/northwest_region/ofr-95-683.html

Figure 2

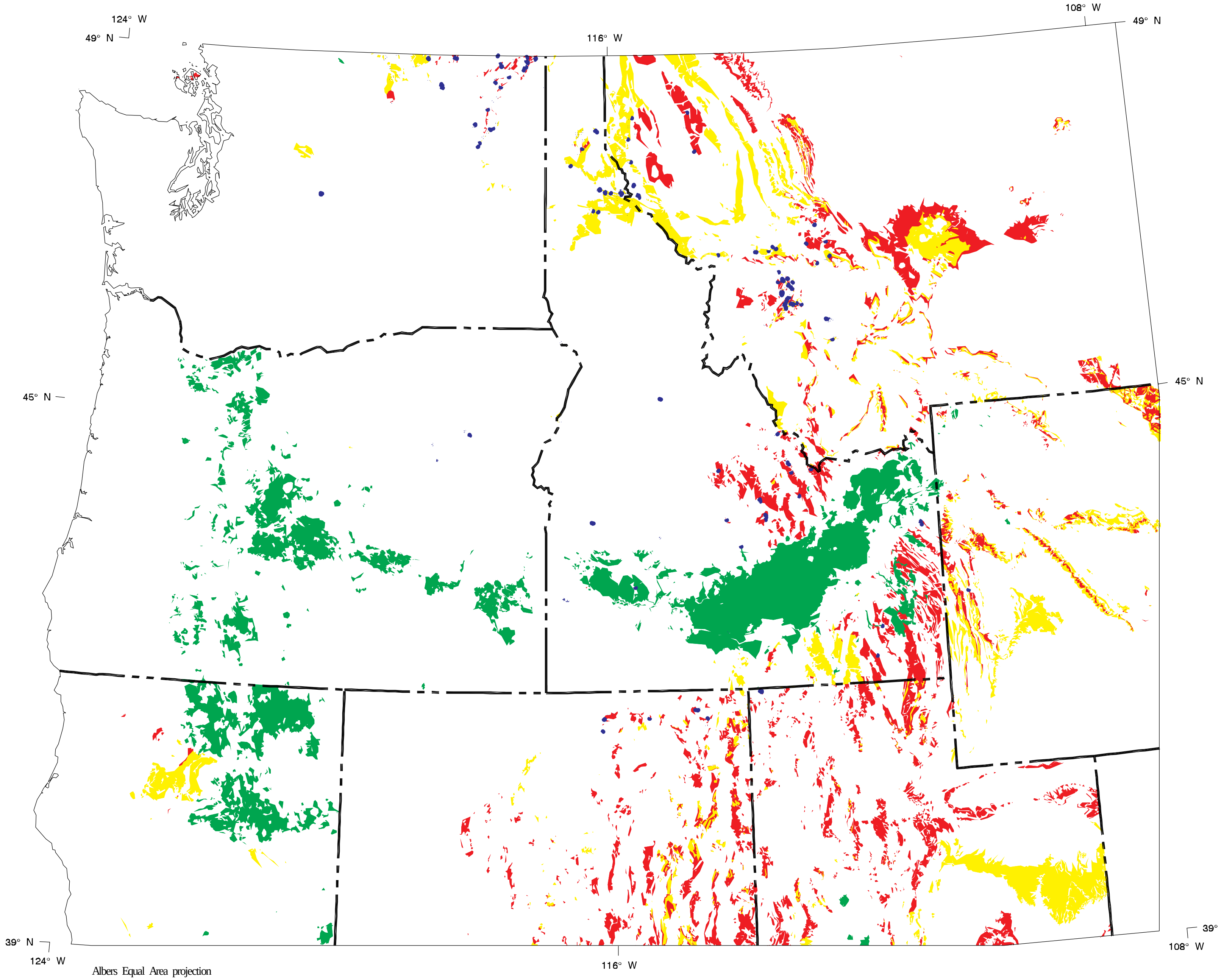

Figure 3. Areas with potential bat habitat, derived from lithologic characteristics and mine location data.