Prepared in cooperation with the Idaho Geological Survey and the Montana Bureau of Mines and Geology

Spatial databases for the geology of the Northern Rocky Mountains - Idaho, Montana, and Washington

By Michael L. Zientek, Pamela Dunlap Derkey, Robert J. Miller, J. Douglas Causey, Arthur A. Bookstrom, Mary H. Carlson, Gregory N. Green, Thomas P. Frost, David E. Boleneus, Karl V. Evans, Bradley S. Van Gosen, Anna B. Wilson, Jeremy C. Larsen, Helen Z. Kayser, William N. Kelley, and Kenneth C. Assmus

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Conventions

ArcInfo® coverage names and table names are shown in small caps.

Item (or field) names in tables are shown in italics.

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Abstract

A regionally-consistent and integrated geologic spatial database for the Northern Rocky Mountains of Montana, Idaho, and eastern Washington, brings together forty-three 1:100,000- to 1:250,000-scale digital geologic maps into a common database format. The regional geologic database is an ArcInfo® coverage (NR_GEO) that contains spatial data for both lines (contacts, faults, fold axes, dikes, sills, veins, garnet isograd, boundaries) and polygons (geologic units). The database represents the original content of the published maps and provides easily-used and consistent attribute content. We have also added information based on our interpretations of published reports. In particular, we have added attribute information that 1) classifies igneous rocks by age, composition, and name, and 2) allows the creation of derivative maps based on lithology.

Three schemes are used to classify polygons and lines in this spatial database. The first scheme is based on the original map units defined in the source maps used to compile this database. The second approach uses the age, composition, and mode of occurrence to define igneous map units. The last approach uses the names of igneous intrusions and volcanic units to define map units.

This database can be queried to address an assortment of geological questions and to produce a variety of derivative geological maps. Digital themes derived from these digital spatial geologic databases will be used by the U.S. Department of Agriculture Forest Service (USFS) for planning and research purposes and by the U.S. Geological Survey (USGS) to facilitate research and conduct mineral-resource assessments.

Introduction

Geologic maps have long been used to understand the Earth's history, its mineral, energy, and water resources, and geologic hazards. When used in conjunction with a variety of other types of spatial data, geologic information can be used to help make decisions on economic and social policy. This report describes a regionally-consistent geologic spatial database for the Northern Rocky Mountains that was developed at the request of the United States Department of Agriculture Forest Service (USFS). This compilation includes National Forest lands in Idaho north of the Snake River Plain, in western Montana, and in part of northeastern Washington (fig. 1) and was created from digital versions of 43 geologic maps (figs. 2 and 3).

The USFS emphasizes the use of science in their planning process (see sidebar on 36 CFR 219.22). Diverse information from a wide range of scientific disciplines is required to revise forest plans, conduct issue-driven assessments (in response to a listing of a threatened or endangered species), respond effectively and safely to major incidents (such as forest fires), or conduct research on ecosystem function and process. Increasingly, geographic information systems (GIS) are being used as a tool to integrate and deliver science information.

> ***36 CFR Parts 217 and 219 National Forest System Land Resource Management Planning; Final Rule***
> ***The Contribution of Science § 219.22 The overall role of science in planning.*** *(a) The responsible official must ensure that the best available science is considered in planning. The responsible official, when appropriate, should acknowledge incomplete or unavailable information, scientific uncertainty, and the variability inherent in complex systems.*

USFS staff from the Geology and Minerals Management Program in Regions 1 and 4 requested digital themes derived from geologic maps in order to address topics such as land use, resource management, and ecosystem function. For example, the USFS uses geologic maps to delineate disturbance regimes — domains that have similar response characteristics to disturbances such as fires, road-building, and timber harvesting. Geologic maps have also been used by the USFS to understand ecosystem function. Recent findings, involving tree growth responses to fertilization and natural tree-mortality dynamics on different soil parent materials, have demonstrated a significant influence of rock type on forest development (Moore, written comm. 1999; Jain and others, 2002; Froese and Robinson, 2002). USFS staff requested that the geologic spatial database be: 1) readily available and consistent to everyone throughout both USFS regions, 2) at a scale appropriate for regional planning, and 3) in a format compatible with the GIS used by the USFS.

Datasets and documentation presented in this report were developed primarily for use with ESRI® software, in particular ArcGIS® version 8 or higher. This format was selected because the USFS, agencies in the Department of the Interior, and the state geological surveys for Montana, Idaho, and Washington are using software developed by ESRI® in their GIS. GIS terminology specific to ESRI® software is used throughout this report; definitions of GIS-related terms and concepts can be found in Kennedy (2001) or online at http://support.esri.com/index.cfm?fa=knowledgebase.gisDictionary.gateway [accessed April 11, 2005].

Acknowledgements

We would like to thank Reed S. Lewis and Loudon R. Stanford with the Idaho Geological Survey and Karen Porter, Dick Berg, and Patrick Kennelly with the Montana Bureau of Mines and Geology for their cooperation in our effort to make this compilation. They worked with us to produce several new digital geologic maps and provided digital files of geologic maps and map-unit descriptions. They also answered numerous geologic questions that came up during the compilation process. Eastern Washington University students Rebecca Pitts, David Cleveland, Mike Koenig, and Richard D. West helped compile data. Ellen Burch, Information Systems Support, Inc., scanned map-unit descriptions and converted them to text format. Karen Lund and Mike O'Neill with the U.S. Geological Survey provided unpublished data for the database. Dave Bedford and Jordan Hastings, U.S. Geological Survey, and Ryan Stevens, Information Systems Support, Inc., provided Visual Basic programming for the Microsoft® Access database used to compile map attribute data. Lorre A. Moyer assisted in developing lithologic symbolization. Technical reviews by Bruce R. Johnson, Steven E. Box, Nora B. Shew, Peter N. Schweitzer, Lorre A. Moyer, Loudon R. Stanford, Reed S. Lewis, Karen Porter, and Ryan Portner greatly improved this report.

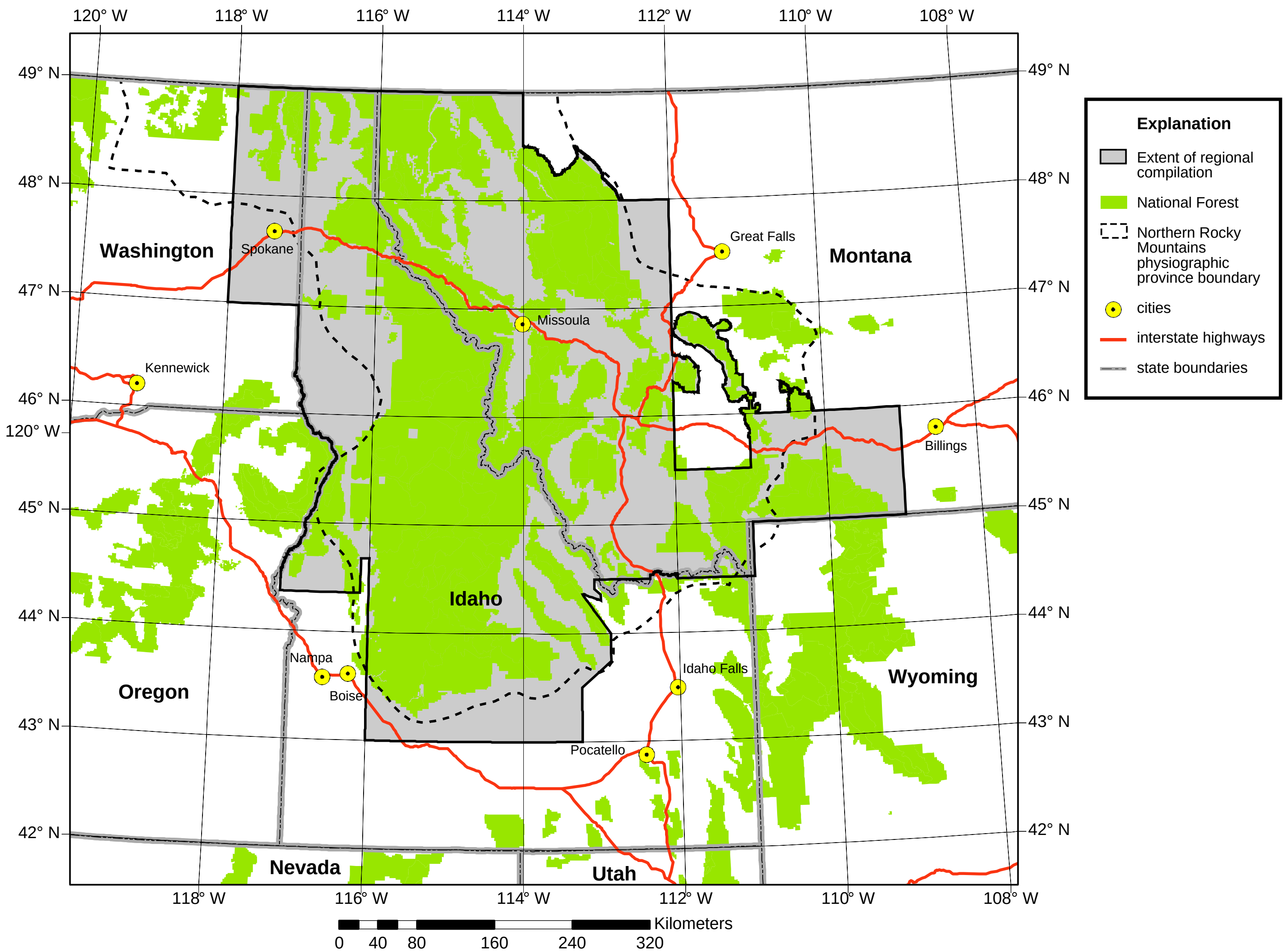

Figure 1. Map showing the extent of the regional geologic spatial database (solid lines and gray-filled polygons), lands managed by the U.S. Forest Service (green polygons), state outlines, interstate highways (red lines), and cities.

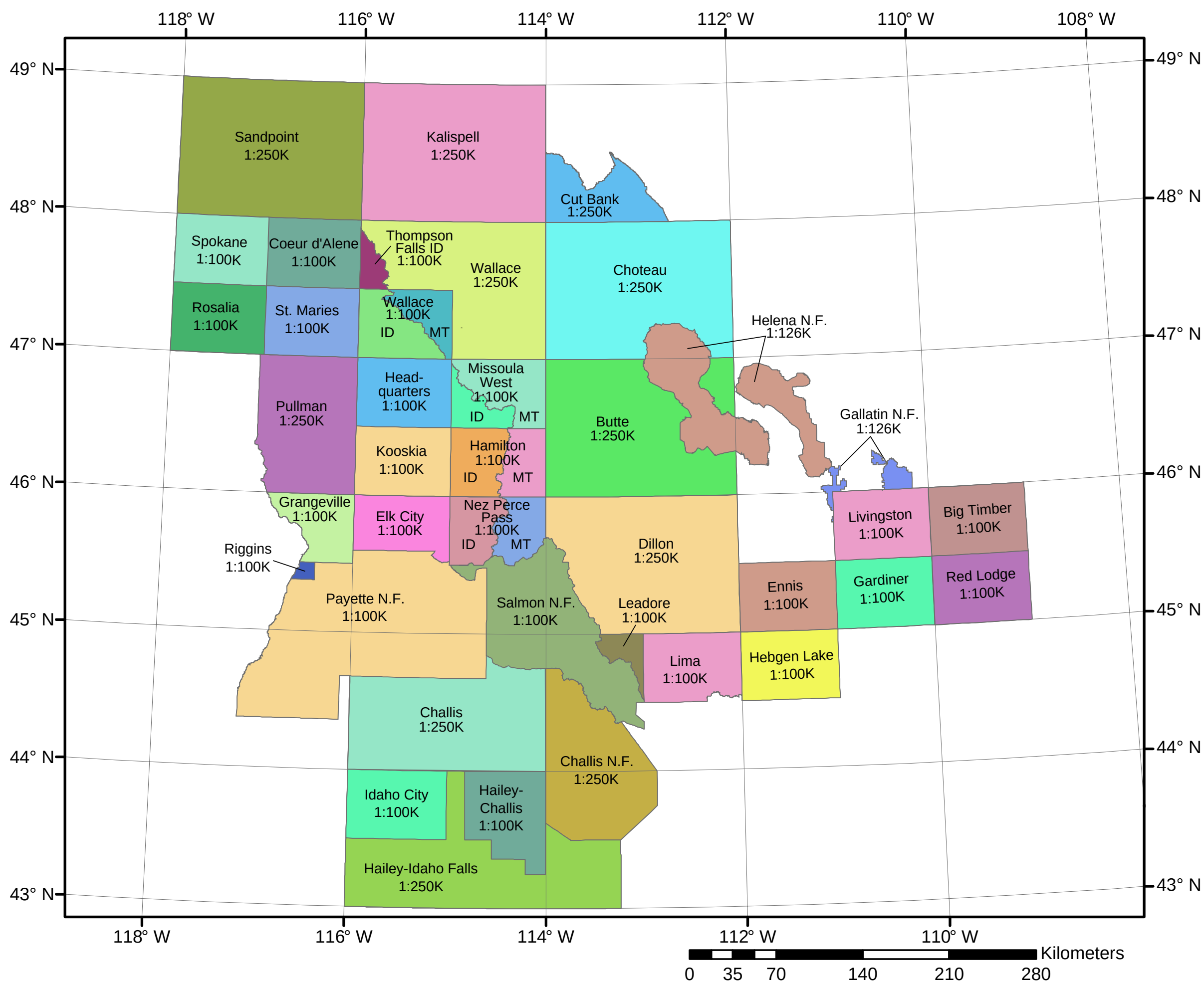

Figure 2. Index of the 43 geologic maps used as the principal source of information for the regional geologic spatial database.

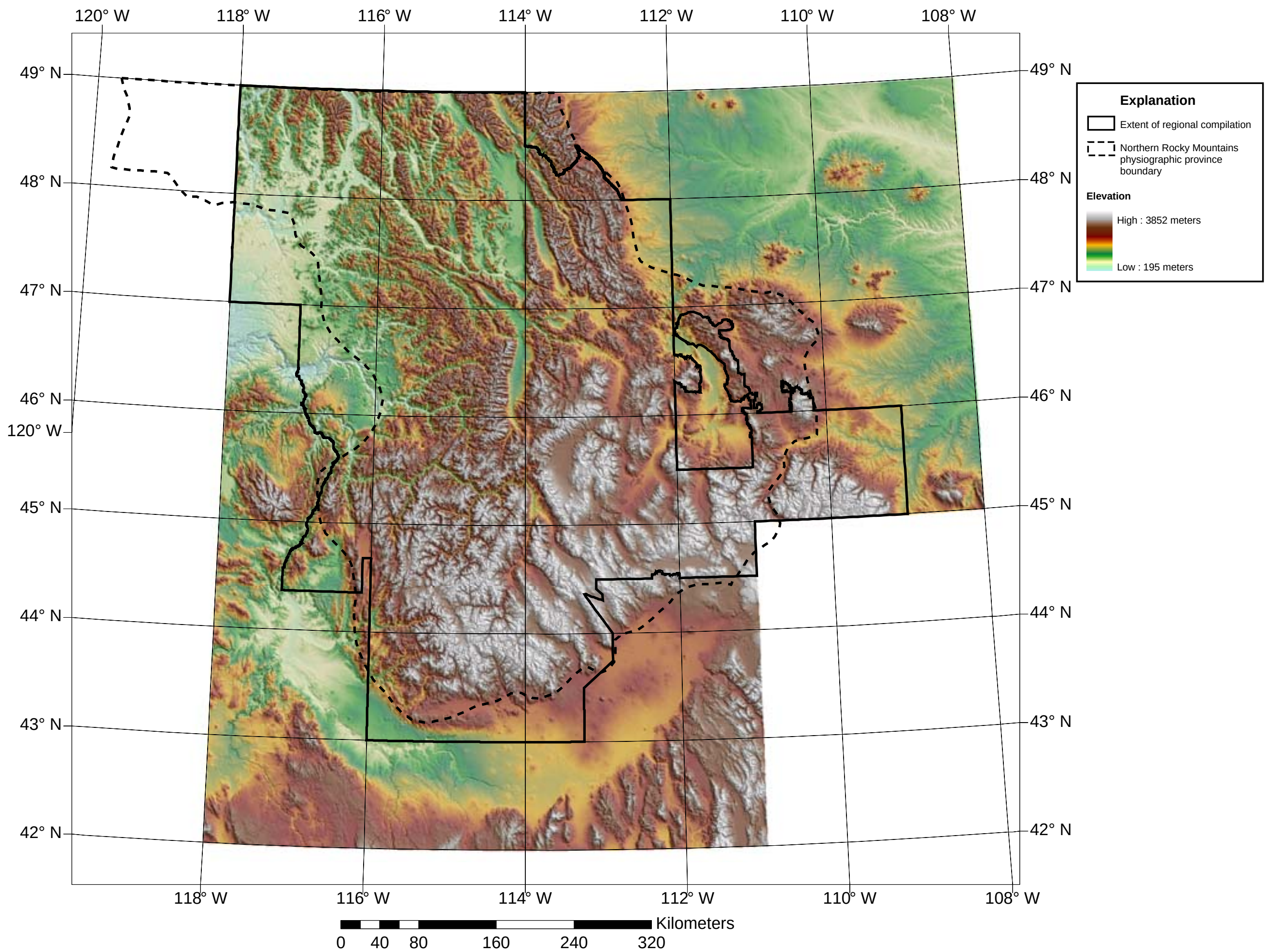

Figure 3. Map showing the extent of the regional geologic spatial database (solid line) and the Northern Rocky Mountains physiographic province (dashed line) on a hillshaded image of a digital elevation model symbolized by elevation.

Overview of Spatial Databases and Data Files

The information in this report includes spatial databases ready to use in a GIS along with files that provide a pre-established cartographic view of them. Vector and raster data models are both used to represent the geographic information developed for this report. The vector spatial databases are provided in an export format to ensure compatibility of the data with a wide range of GIS systems. Metadata files describe the geospatial data. A compilation of map unit descriptions, lists of terms found in the map unit descriptions, and definitions of lithologic terminology are also included. The spatial databases and files are listed and briefly described in tables 1 and 2 and are summarized in the following discussion.

Spatial databases and related files

Map features represented as vector data are stored in an ESRI® georelational data format called an ArcInfo® coverage (table 1). In a coverage, geographic objects (features) are stored as shapes – points, lines, or polygons. Descriptive (attribute) data corresponding to each geographic feature are stored in a set of tables. The arc attribute table (aat) and polygon attribute table (pat) store information about arcs and polygons, respectively. The spatial and descriptive data are linked so that both sets of information are always available (Kennedy, 2001).

The ArcInfo® coverages are made up of many files stored in two directories that can be accessed directly using ESRI® GIS software. Spatial data sets for each coverage are stored in a subdirectory containing ArcInfo® coverage data files (*.adf). The directory name is the same as the coverage name. Attribute data are stored in an INFO database in a subdirectory named *info*. File types in the info subdirectory include INFO attribute (*.dat) and INFO table definitions (*.nit) files. Many of the files that make up a coverage are stored in binary format and are only accessible using ESRI® GIS software. In general, files in the dataset directories should be managed using GIS software, such as ArcCatalog™.

Table 1. Description of the spatial databases prepared for the Northern Rocky Mountains compilation.

[Small caps are used to denote geospatial databases]

Spatial database (Format)	**Description**	**Metadata file name**	**ESRI® interchange file name**
NR_GEO (ArcInfo® coverage)	Regional geology compilation	nr_geo_metadata.htm	nr_geo.e00
NR_MAPS (ArcInfo® coverage)	Map sources primarily used to create the regional geology compilation	nr_map_metadata.htm	nr_maps.e00
NR_EXTENT (ArcInfo® coverage)	Study area boundary	nr_extent_metadata.htm	nr_extent.e00
NR_BASEMAP (ERDAS IMAGINE® image file)	Topographic base map for the compilation	nr_basemap_metadata.htm	

The ArcInfo® coverages were exported as ESRI® interchange files (table 1). The export process assembles all the spatial and attribute information for a coverage into a single ASCII file. Interchange files can be moved or copied with any copy utility without affecting the integrity of the spatial data. These interchange files can be used in a wide range of GIS systems; however, they must be processed in advance.

The single raster spatial database, NR_BASEMAP, is in an ERDAS IMAGINE® image file format (table 1). The raster database consists of a collection of files – the *.ige file stores the raster image, the *.img file is a header file that contains geospatial data, and the *.rrd (pyramid) file contains coarser copies of the original image to increase drawing speed at different magnification levels. The *.xml file contains metadata for the spatial database. These files are provided in a single ‘zip’ compressed archive file.

Compressed ‘zip’ files were created using the Windows program WINZIP® v9.0. For those users who do not have software capable of uncompressing the archived zip files, they may obtain a free version of the software from Winzip Computing, Inc. or Pkware, Inc.

FGDC-compliant[1] metadata provides information about the spatial databases, including data sources, data quality, projection, and how to obtain the data on the Internet, in addition to providing a data dictionary for the information in the database tables. ArcInfo® coverages and the ERDAS IMAGINE® image file contain metadata integrated into the spatial database that can be read in ESRI®’s ArcCatalog™ module. Metadata is also provided as hypertext markup language-format files (table1).

ArcGIS® layer files (*.lyr) provide a pre-defined cartographic view of the spatial databases. These files display symbols and classifications for a dataset when viewed in ArcGIS®. The layer files reference a data source, such as an ArcInfo® coverage, indicate which features are included (such as items in joined tables), and identify how the data should be displayed on a map. Cartographic views have been developed for the minimum age of units, maximum age of units, the age of units generalized to Period or Era in the geologic time scale, the age and composition of igneous rocks, and lithology. Layers files have also been developed to illustrate line types (such as faults and fold axes). A description of these files and how to use them is given in appendix A.

Map unit description, standardized rock terms and definitions, and related files

Map unit descriptions, along with selected information from look-up tables for the ArcInfo® coverage NR_GEO, are provided as an Adobe® Portable Document Format (pdf) document and a text file (table 2). The data in the pdf document are organized as a form that is easy to read and search. The text document can be imported into relational database management software. Lists of geology-related terms were developed from the map unit descriptions to facilitate database searches; these lists are provided as text files.

A standardized list of rock and sediment terms and their definitions are described in Appendix B and provided as a Microsoft® Excel 2003 workbook and a tab-delimited text format (table 2). These terms were used in populating some attribute tables in the ArcInfo® coverage NR_GEO.

Table 2. List and description of digital files developed for this report.

[Small caps are used to denote ArcInfo® coverage names]

File Name	File Description
Spatial databases in export format ESRI® interchange format files (*.e00)	
nr_geo.e00	Regional geologic spatial database compiled from 43 geologic maps
nr_maps.e00	Database showing extent of the 43 maps used for this compilation
nr_extent.e00	Study area boundary
Compressed archive file containing an ERDAS IMAGINE® image file and ESRI® layer file	
nr_basemap.zip	Base map for the study area derived from digital raster graphic files of 1:250,000 and 1:100,000 topographic maps. The archive contains the ERDAS IMAGINE® image files nr_basemap.ige, nr_basemap.img, nr_basemap.img.xml, and nr_basemap.rrd. The ESRI layer file nr_basemap.img.lyr stores symbolization information that can be used in ArcMap™.

1 Federal Geographic Data Committee (www.fgdc.gov)

Table 2. Continued.

Metadata files providing information about the spatial datasets hypertext markup language format files (*.htm)	
nr_geo_metadata.htm	Metadata for the spatial database, NR_GEO.
nr_maps_metadata.htm	Metadata for the spatial database, NR_MAPS
nr_extent_metadata.htm	Metadata for the spatial database, NR_EXTENT.
nr_basemap_metadata.htm	Metadata for the spatial database, NR_BASEMAP.
Symbolization files for polygons in the spatial database NR_GEO ESRI® layer files (*.lyr)	
age_mu.lyr	Symbolization based on the age of the 1,330 unique regional map units in this compilation. The age term is generalized to a Period or higher level for Phanerozoic age map units and Era or higher for Precambrian age units.
age_or_mu.lyr	Symbolization based on the age of the 2,135 original map units in this compilation. The age term is generalized to a Period or higher level for Phanerozoic age map units and Era or higher for Precambrian age units.
maxage_or_mu.lyr	Symbolization based on the maximum (oldest) age of the 2,135 original map units in this compilation.
minage_or_mu.lyr	Symbolization based on the minimum (youngest) age of the 2,135 original map units in this compilation.
ig_label_poly_igmu.lyr	Symbolization of igneous map units defined by age, composition, and mode of occurrence.
lname2_lith.lyr	Polygon symbolization file for displaying a generalized lithologic map.
Symbolization files for arcs in the spatial database NR_GEO ESRI® layer files (*.lyr)	
ig_label_arc_igmu.lyr	Arc symbolization file for displaying a map based on the age and composition of igneous rocks.
linetype1_lcd.lyr	Symbolization file for faults, fractures, dikes and sills, fold axes, veins, and volcano-tectonic structures.
Map-unit descriptions Adobe® Portable Document Format file (*.pdf) and text format file (*.txt)	
nr_geo_mapunits.pdf	Map-unit descriptions derived from the original sources. This file contains: an introduction; forms with unique number for each map-unit description, information on unit name and unit label, the map unit description, and an information source; and a list of references cited in the map unit descriptions.
nr_geo_mud.txt	Map unit descriptions derived from the original sources. This file also contains a unique number for each map-unit description.
nr_geo_mudrefs.txt.	References cited in the map unit descriptions.
Lists of terms found in the map unit descritions text format files (*.txt)	
wordlist_age.txt	Geologic age terms.
wordlist_color.txt	Color terms.
wordlist_geology.txt	Geologic terms.
wordlist_rock.txt	Rock name terms.
wordlist_minerals.txt	Mineral names.
wordlist_paleo.txt	Paleontological terms.
author_terms.txt	Rock and sediment names, may include one or more adjectives.
Standardized rock and sediment terms and definitions Microsoft® Excel 2003 workbook (*.xls) and text format file (*.txt)	
nr_geo_term.xls	Hierarchical list of rock and sediment terms and their definitions.
nr_geo_term.txt	Hierarchical list of rock and sediment terms and their definitions.

Description of spatial databases, look-up tables, and layer files

The ArcInfo® coverage NR_GEO is the regional geology compilation. The coverages NR_MAPS and NR_EXTENT and the raster database NR-BASEMAP are included to provide context and a frame-of-reference for the regional compilation. In the following sections, relations between the spatial objects in the ArcInfo® coverages and look-up tables are defined and illustrated. Items in the look-up tables are defined in summary tables. Layer files used to present a pre-defined view of the spatial database are also described. Detailed information about the spatial databases is also given in appendices of this report.

nr_geo database

The regional geologic spatial database, the ArcInfo® coverage NR_GEO, contains vector information for linear features (arcs) and geologic units (polygons) described in two feature attribute tables. Most of the data in the feature attribute tables are codes that can be joined to look-up (INFO) tables in a GIS to provide additional information about the arcs and polygons. A schematic of the relationships between the database tables is given in figures 4 and 5.

The ArcInfo® coverage NR_GEO, is a compilation that integrates forty-three digital geologic spatial databases. Prior to this project, the USGS, state geological surveys, and the USFS had prepared digital versions of some of the geologic maps in the project area. In order to complete this database, an additional 20 geologic maps were converted to a digital format. All 43 geologic spatial databases were then transformed to a common format in which arcs and polygons are managed in a single ArcInfo® coverage. Spatial databases bounded by lines of longitude and latitude were fitted to mathematically-generated quadrilaterals to eliminate small gaps or overlaps. For overlapping spatial databases, one database was selected to use in the compilation based on the quality and scale of the geologic information; spatial and attribute information was removed from the other databases for the area of overlap. Discrepancies at boundaries between the maps used to make this compilation are common; examples include contacts that fail to meet exactly, the juxtaposition of different map units, or the abrupt termination of a unit. These kinds of problems reflect how the maps were compiled and cannot be properly resolved without additional field mapping and interpretation. We did not modify the spatial databases to fix these discontinuities.

Systematically extracting and recording information from a map designed to visually convey geologic concepts into a database that can be queried and displayed is scientifically challenging. The problem is compounded when trying to work with many maps that were produced using different standards and conventions. For example, the quality of the information in the map unit descriptions used for this compilation was inconsistent, reflecting the interests of the author, the intended use of the map, or the quality of the technical and editorial reviews. Standards are an essential part of developing a consistent database. Even though all map-unit descriptions use rock and geologic time terms, published reports rarely indicate rock classification schemes or the selection of a geologic time chart.

The regional geologic spatial database compilation has been designed to represent the original content of the published maps, to provide information (attribute content) that has been normalized for consistency, and to provide additional information and interpretation not in the original published reports. Three different schemes are used to classify the polygons and arcs that make up the spatial database. In the first, polygons and arcs are classified according to the map units in the original publications. In the second, polygons and arcs corresponding to igneous features are classified into units based on the age and composition of the rocks; information from a variety of sources was used to assign the existing spatial objects to units. In the third, names for igneous intrusions and volcanic units were used to classify polygons and arcs. Again, a variety of sources of information was used to assign attributes to spatial objects. Each of these schemes is represented by a different key field in the polygon and arc attribute tables: original map unit classification by the item *mu_id*, igneous age and composition by the item *igmu_id*, and named intrusions and volcanic units by the item *ig_code*.

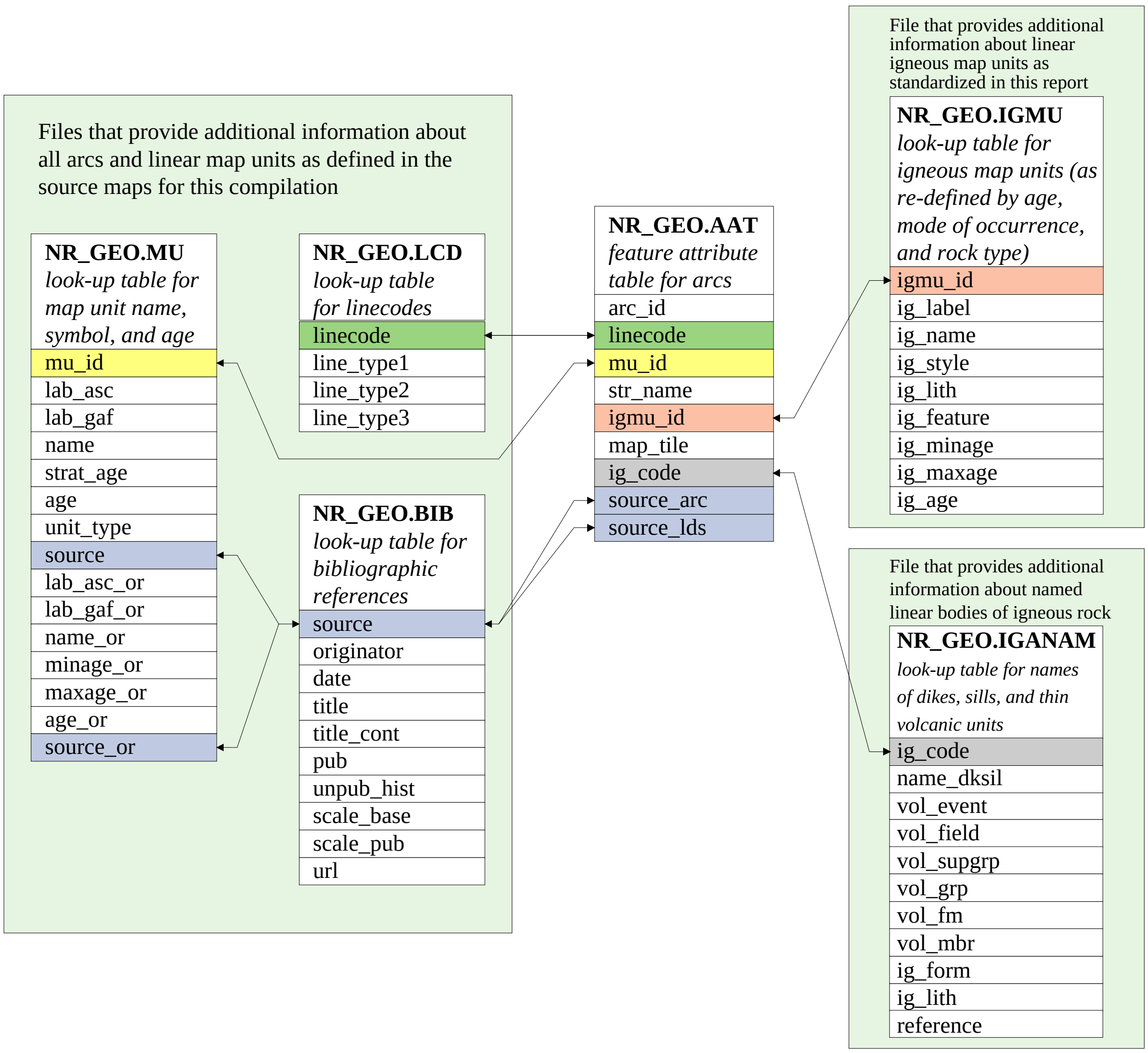

Figure 4. Relationships between the arc attribute table (NR_GEO arc) and associated look-up tables (NR_GEO.BIB, NR_GEO.IGANAM, NR_GEO.IGMU, NR_GEO.LCD, and NR_GEO.MU) in the NR_GEO geologic map database.

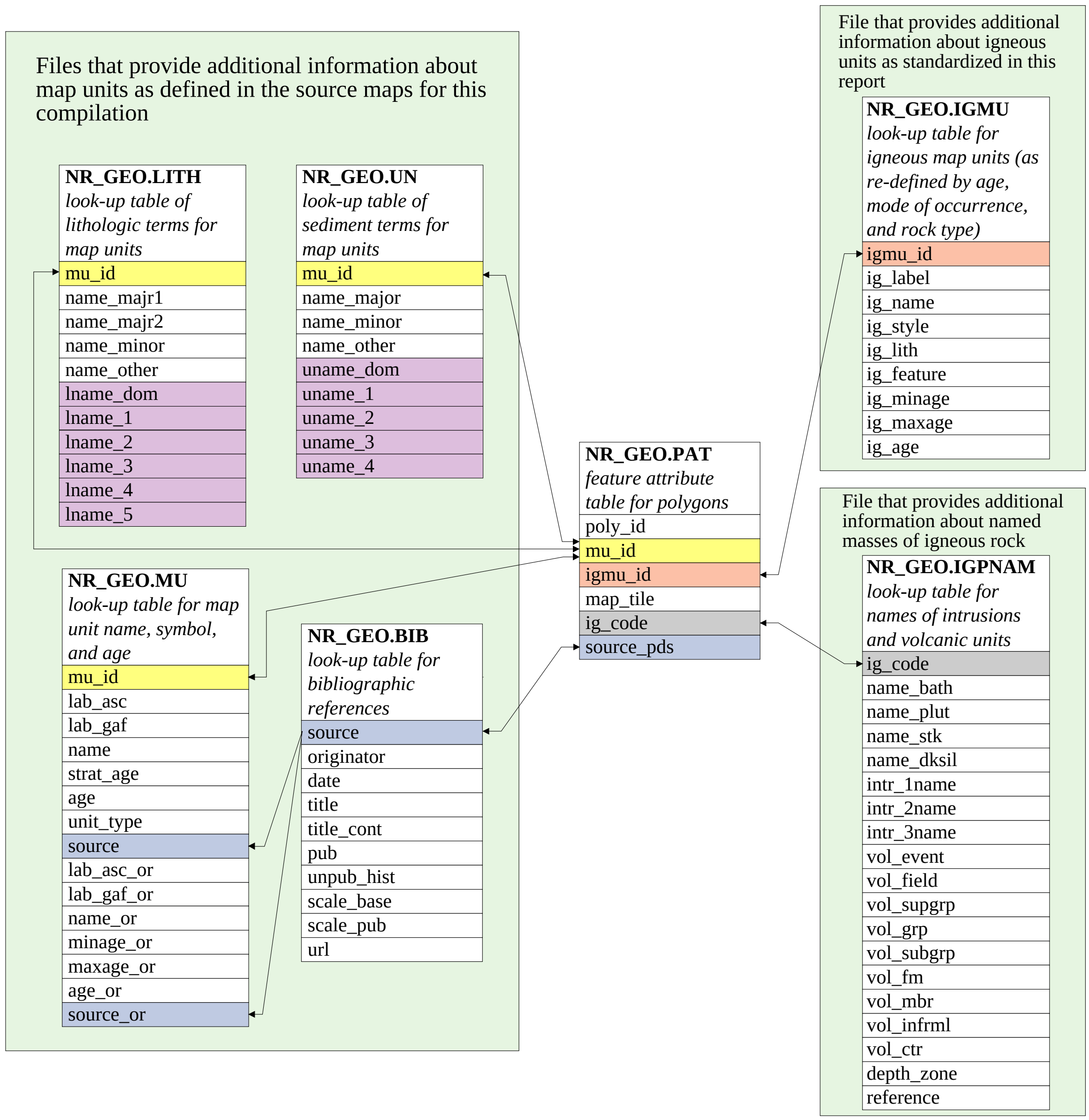

Figure 5. Relationships between the polygon attribute table (NR_GEO polygon) and associated look-up tables (NR_GEO.BIB, NR_GEO.IGPNAM, NR_GEO.IGMU, NR_GEO.LITH, NR_GEO.MU, and NR_GEO.UN) in the NR_GEO geologic map database.

ESRI® Feature Attribute Tables

The ArcInfo® coverage NR_GEO consists of polygons and arcs described by two feature attribute tables, NR_GEO.PAT and NR_GEO.AAT (tables 3 and 4). The polygons and arcs are topologically related to each other (that is, line segments generally form polygon boundaries and have directionality, and polygons are designated as occurring on either the left or right side of a line segment). Polygons represent geologic units or water bodies; arcs represent geologic contacts and structures, isograds, geologic units too thin to be represented by a polygon, map boundaries, shorelines, and scratch contacts. Most of the information in the feature attribute tables are codes that relate to descriptive information in look-up tables.

Arcs (line segments) that represent faults with known movement can be symbolized with lines having asymmetric patterns of decoration (for example, teeth attached to one side of a line indicate the upper plate of a thrust sheet). The placement of ornamentation is determined by orientation of the line as defined by the starting and endpoints of the arc. Following the right-hand rule convention, decoration is placed on the right side of the line directed from first point to the last point of the arc. If the arcs in NR_GEO are symbolized with right-reading linesets, the asymmetric line decorations should be correct. Right-reading linesets provide decorations on the bottom side of a horizontal line (if the starting point is at the left end and the ending point is at the right end of the line).

However, line directionality is the weakest part of the spatial database. Due to time and cost constraints, we focused on making sure that the polygons were correctly attributed rather than proofing all of the arcs for line directionality. Please realize that some arcs may still not be properly oriented.

Line symbolization can be verified by comparing the ArcInfo® coverage NR_GEO with the original maps used to create the compilation. Source maps published by the USGS are available as rectified images that can be integrated into a GIS (Larsen and others, 2004); maps published by the Idaho Geological Survey and the Montana Bureau of Mines and Geology may be available on their web sites.

Table 3. Summary of the ArcInfo® feature attribute table NR_GEO.PAT.

Table name	NR_GEO.PAT
Format	ESRI ArcInfo® feature attribute table
Description	The table provides information about polygons in the ArcInfo® coverage NR_GEO
User-defined items	**Description**
poly_id	A user-defined integer that uniquely identifies each polygon feature.
mu_id	This integer relates polygon features to rock unit descriptions in the table NR_GEO.MU. Full descriptions of the map units are provided in the file nr_geo_mapunits.pdf.
igmu_id	This integer relates polygon features to igneous rock unit descriptions in the NR_GEO.IGMU table.
map_tile	Name for one of the 43 maps that were the principal sources of information used in preparing the regional geology compilation. The name was coined by combining an abbreviation of a topographic map or National Forest name and the published map scale.
ig_code	A value that links to a name for stocks, plutons, batholiths, and volcanic units in the NR_GEO.IGPNAM table.
source_pds	This integer identifies the source of the description of the polygon feature. See the table NR_GEO.BIB for complete references for the sources.

Table 4. Summary of the ArcInfo® feature attribute table NR_GEO.AAT.

Table name	NR_GEO.AAT
Format	ESRI ArcInfo® feature attribute table
Description	The table provides information about arcs in the ArcInfo® coverage NR_GEO
User-defined items	**Description**
arc_id	A user-defined integer that uniquely identifies each arc feature.
linecode	This integer relates an arc feature to a cartographic description of a line in the table NR_GEO.LCD.
mu_id	This integer relates an arc to rock unit descriptions in the table NR_GEO.MU where the map unit is so thin that it is represented by an arc. Full descriptions of map units are provided in the file nr_geo_mapunits.pdf.
str_name	Name of fault or fold (as attributed in original information source).
igmu_id	This integer relates arc features to igneous rock unit descriptions in the NR_GEO.IGMU table.
map_tile	Name for one of the 43 maps that were the principal sources of information used in preparing the regional geology compilation. The name was coined by combining an abbreviation of a topographic map or National Forest name and the published map scale.
ig_code	A value that links dikes, sills, or dike swarms shown as linear features (arcs) to a name in the table NR_GEO.IGANAM.
source_arc	This integer identifies the source of the spatial location of the arc feature. See the table NR_GEO.BIB for complete references for the sources.
source_lds	This integer identifies the source of the description of the arc feature. See the table NR_GEO.BIB for complete references for the sources.

ESRI® INFO Tables for classifying original and regional map units

Tables that rely on the original map unit classification of spatial objects (*mu_id*) include the NR_GEO.MU look-up table of descriptive information about the geologic map units and the NR_GEO.LITH and NR_GEO.UN look-up tables for information on lithology and unconsolidated deposits, respectively. These tables can be related (and digitally joined) to geologic objects represented by the arc attribute table, NR_GEO.AAT, and the polygon attribute table, NR_GEO.PAT.

The linecode look-up table, NR_GEO.LCD, provides descriptions of the arcs as they appear in the original maps and relates to the arc attribute table, NR_GEO.AAT. The NR_GEO.BIB look-up table of bibliographic references for sources of map unit data relates to the arc attribute table, NR_GEO.AAT, the polygon attribute table, NR_GEO.PAT, and the look-up table NR_GEO.MU.

NR_GEO.MU TABLE

This ArcInfo® look-up table provides information on map unit name, symbol, and age (table 5). The arcs and polygons are classified according to the map units defined on the original published maps. Attributes for item names ending with *_or* reflect usage in the original maps. All other attributes are interpretations made for this compilation. For example, information in *name_or*, *lab_asc_or,* and *lab_gaf_or* reflects the map unit name and symbols for map units given in the original publication. Information in *name*, *lab_asc* ,and *lab_gaf* was generated by the authors of this compilation. Items names incorporating *_asc* refer to map symbols used to label geologic units that only use ASCII characters. Those that incorporate *_gaf* refer to map symbols used to label geologic units that require a special font to represent the special characters geologists use for some geologic ages.

Table 5. Summary of the ArcInfo® look-up table NR_GEO.MU.

Table name	NR_GEO.MU
Format	ESRI ArcInfo® look-up table
Description	The table summarizes information on original and regional unit names, symbols, and geologic age. The units are fully described in the files nr_geo_mapunits.pdf and nr_geo_mud.txt (provided in this data release).
Spatial object classification	Polygons are grouped into map units as they appear on the original published maps
Keyfield	*mu_id*
Relations	One-to-many relation to *mu_id* in the NR_GEO.PAT and NR_GEO.AAT tables
User-defined items	**Description**
mu_id	This integer relates rock unit descriptions to features in the tables NR_GEO.PAT and NR_GEO.AAT. Full descriptions of the units are provided in the file nr_geo_mapunits.pdf.
lab_asc	Map symbol, represented with ASCII characters, used to label regional geologic units in the geology compilation.
lab_gaf	Map symbol, represented with GeoAgeFullAlpha font, used to label regional geologic units in the geology compilation.
name	Name of unique regional geologic map unit used in the geology compilation.
strat_age	Stratigraphic age or age range of the unique regional geologic map unit in the geology compilation.
age	A generalization of geologic time terms used in *strat_age* to Period or Era in Phanerozoic time or to Era or Eon in Precambrian time.
unit_type	Code used to identify the stratigraphic status of the geologic map unit designated in the item *name*.
source	An integer used to identify this report as the source for the compiled information in the table NR_GEO.MU. See the table NR_GEO.BIB for complete references for the sources.
lab_asc_or	Map symbol, represented with ASCII characters, used on the original source map to label the geologic unit.
lab_gaf_or	Map symbol, represented with GeoAgeFullAlpha font, used on the original source map to label geologic unit.
name_or	Name of geologic map unit given on the source maps used for this compilation.
minage_or	Youngest geologic time term given for a unit in the source maps used for this compilation
maxage_or	Oldest geologic time term given for a unit in the source maps used for this compilation.
age_or	Geologic time term generalized to Period for the Phanerozoic and Era in the Precambrian for the map unit in the source maps used for this compilation
source_or	Integer used to identify the original map unit description. See the table NR_GEO.BIB for complete references for the sources.
Symbolization files	
age_mu.lyr	Symbolization based on the age of the 1,330 unique regional map units in this compilation. The age term is generalized to a Period or higher level for Phanerozoic age map units and Era or higher for Precambrian age units.
age_or_mu.lyr	Symbolization based on the age of the 2,135 original map units in this compilation. The age term is generalized to a Period or higher level for Phanerozoic age map units and Era or higher for Precambrian age units.
maxage_or_mu.lyr	Symbolization based on the maximum (oldest) age of the 2,135 original map units in this compilation.
minage_or_mu.lyr	Symbolization based on the minimum (youngest) age of the 2,135 original map units in this compilation.

When combined, the forty-three maps that make up this compilation have 2,135 geologic map units. Some geologic units appear on multiple maps, however, for the same geologic unit, the map unit name and symbols were often different between the map sources. We also found that the same informal geologic map unit name (such as “granite”) was applied to different geologic units. Of the 2,135 original units, only 1,330 geologic units were considered unique in the regional compilation. We determined the stratigraphic status of these unique regional geologic units (*unit_type*) and created consistent map unit names (*name*) and symbols (*lab_asc*, *lab_gaf*). The age of the unique regional geologic unit is given in *age* and *strat_age*. The process for developing new unit names is summarized in Appendix C.

The original maps included in this compilation used both geochronologic (Early Cambrian) and chronostratigraphic (lower Cambrian) age terms. In this database, we only coded geochronologic terms in the fields *age*, *strat_age*, *minage_or*, *maxage_or*, and *age_or* (table 2). Appendix D describes the geologic time scale we selected to use for this study and how we translated chronostratigraphic to geochronologic terms.

The fields *lab_gaf* and *lab_gaf_or* utilizes a special font, GeoAgeFullAlpha, to properly display special geologic map symbols for Precambrian, Proterozoic, Mesozoic, Paleozoic, Triassic, Pennsylvanian, and Cambrian map units. For these symbols to appear properly the GeoAgeFullAlpha font must be installed in the system font directory. Installation of the GeoAgeFullAlpha font is not critical, but without it these symbols will appear instead as an = (equal) for Precambrian, < (less than) for Proterozoic, } (right curly bracket) for Mesozoic, | (vertical line or pipe) for Paleozoic, ^ (caret) for Triassic, * (asterisk) for Pennsylvanian, and _ (underscore) for Cambrian (for example, _f for the Flathead Sandstone). The GeoAgeFullAlpha font is included in this publication, along with installation instructions.

The maps in figure 6 illustrate the distribution of the Wallace Formation symbolized on the items *name* and *name_or*. The Wallace Formation is made up of several informally-named subdivisions. Selecting the original names in the database (using the item *name_or*), 54 units appear on the map and are shown by different colors in figure 6a. Notice how the many units do not correlate across boundaries between different source maps in the compilation. If the regional names are selected in the database (using the item *name*), the map has only 25 units that show greater continuity.

NR_GEO.LITH TABLE

This ArcInfo® look-up table (table 6) provides lithologic information for the map units defined in the table NR_GEO.MU. The grammatical context of rock names in the published map-unit descriptions was used to estimate the relative abundance of various lithologies for the 1,877 original map units in this compilation that are rocks. The most abundant rock types are listed in the database fields *name_majr1* and *name_majr2*. Less abundant rock types are listed in *name_minor*. Rock types incidentally mentioned in the unit description are listed in *name_other*. Detailed descriptions of the procedures used to populate these fields are given in Appendix E.

The information in the fields *name_majr1* and *name_majr2* and other published sources was used to select a dominant rock type (*lname_dom*) from a standardized, hierachically-organized list of rock terms. In creating the list for this report, practical field-based rock classification schemes and terms were selected that are consistent with the usage in unit descriptions on the published maps used to create the compilation and that emphasize rock composition. This list of terms and their definitions are provided in Appendix B. If the geologic unit appeared on more than one of the 43 maps that make up the compilation, the values of *lname_dom* were compared and adjusted if necessary. The relations between terms in the list of lithologies were used to create a hierarchical list of rock types for each geologic unit. These values are given in *lname_1* (the most general terms) to *lname_5* (the most specific terms). Additional information on the development and use of these hierarchical lists is given in Appendix F.

Values in *lname_dom*, *lname_1* to *lname_5, uname_dom,* and *uname_1* to *uname_4* can be used to create lithology maps from the Northern Rocky Mountains geologic spatial database compilation at various levels of generalization. Figure 7 shows the digital compilation symbolized on the second level (*lname_2 and uname_2*) lithology terms.

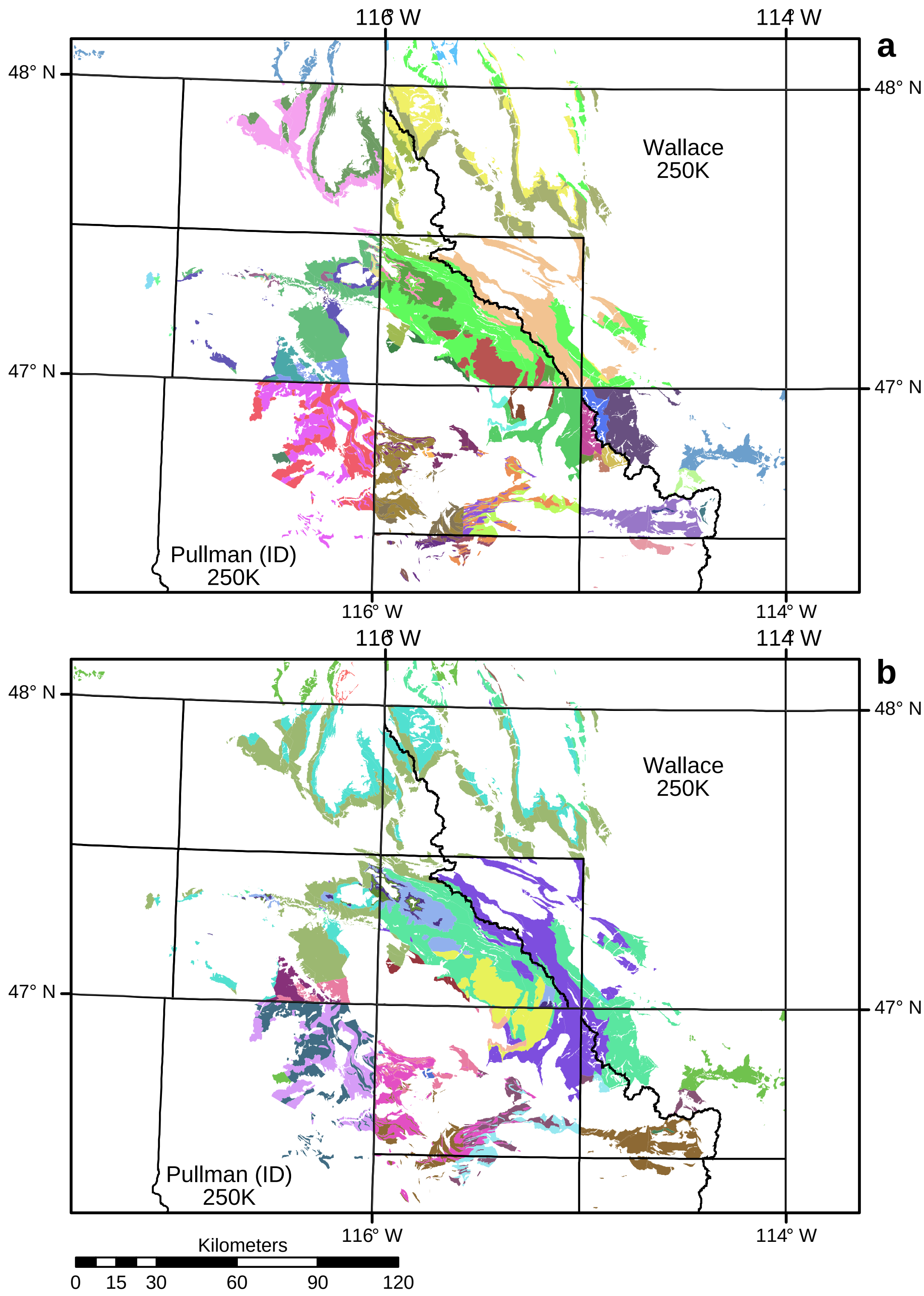

Figure 6. Maps symbolized to show the classification of the Wallace Formation using different items in look-up tables for the ArcInfo® coverage NR_GEO.

Table 6. Summary of the ArcInfo® look-up table NR_GEO.LITH.

Table name	NR_GEO.LITH
Format	ESRI ArcInfo® look-up table
Description	The table provides lithologic information for the map units defined in the table NR_GEO.MU. Lists of rock terms from the map-unit descriptions are organized into fields based on their relative abundance. An expanded hierarchy of dominant lithology terms is given.
Spatial object classification	Polygons and arcs are grouped into map units as they appear on the original published maps
Keyfield	*mu_id*
Relations	One-to-many relation to *mu_id* in the tables NR_GEO.PAT and NR_GEO.AAT.
User-defined items	**Description**
mu_id	This integer relates lithologic descriptions to features in the tables NR_GEO.PAT and NR_GEO.AAT. The map units are briefly described in the look-up table NR_GEO.MU; full descriptions are provided in the file nr_geo_mapunits.pdf.
name_majr1	List of rock terms used in the original map unit description. The grammatical structure of the map unit description indicates these terms represent the most important rock types in the unit.
name_majr2	Continuation of *name_majr1* entry where the list of rock terms used in the original map unit description exceeded 254 characters.
name_minor	List of rock terms used in the map unit description. The grammatical structure of the map unit description indicates these terms represent minor rock types in the unit.
name_other	List of rock terms used in the map unit description. The grammatical structure of the map unit description indicates these terms represent uncommon rock types in the unit.
lname_dom	A rock term selected from a standardized list that best describes the dominant lithology for the map unit. The term coded in *lname_dom* should be representative of the lithology (or lithologies) that make up 50 percent or more of the map unit.
lname_1	Dominant lithology term for the first (most general) level in a hierarchically-organized list of rock names.
lname_2	Dominant lithology term for the second level in a hierarchically-organized list of rock names (where the first level is the most general and the fifth level is the most specific term).
lname_3	Dominant lithology term for the third level in a hierarchically-organized list of rock names (where the first level is the most general and the fifth level is the most specific term).
lname_4	Dominant lithology term for the fourth level in a hierarchically-organized list of rock names (where the first level is the most general and the fifth level is the most specific term).
lname_5	Dominant lithology term for the fifth (most specific) level in a hierarchically-organized list of rock names.
Symbolization files	
lname2_lith.lyr	Polygon symbolization file for displaying a lithologic map with the NR_GEO spatial database, using the item *lname_2* in the ArcInfo® look-up table NR_GEO.LITH.

NR_GEO.UN TABLE

This ArcInfo® look-up table (table 7) provides information for unconsolidated deposits listed as map units in the table NR_GEO.MU. The grammatical context of names in the published map-unit descriptions was used to estimate the relative abundance of various sediments and deposit types for the 258 original map units in this compilation that consist of unconsolidated material. The most abundant sediments and deposit types are listed in the database field *name_major*. Less abundant sediments and deposit types are listed in *name_minor*. Sediments and deposit types incidentally mentioned in the unit description are listed in *name_other*. Detailed descriptions of the procedures used to populate these fields are given in Appendix E.

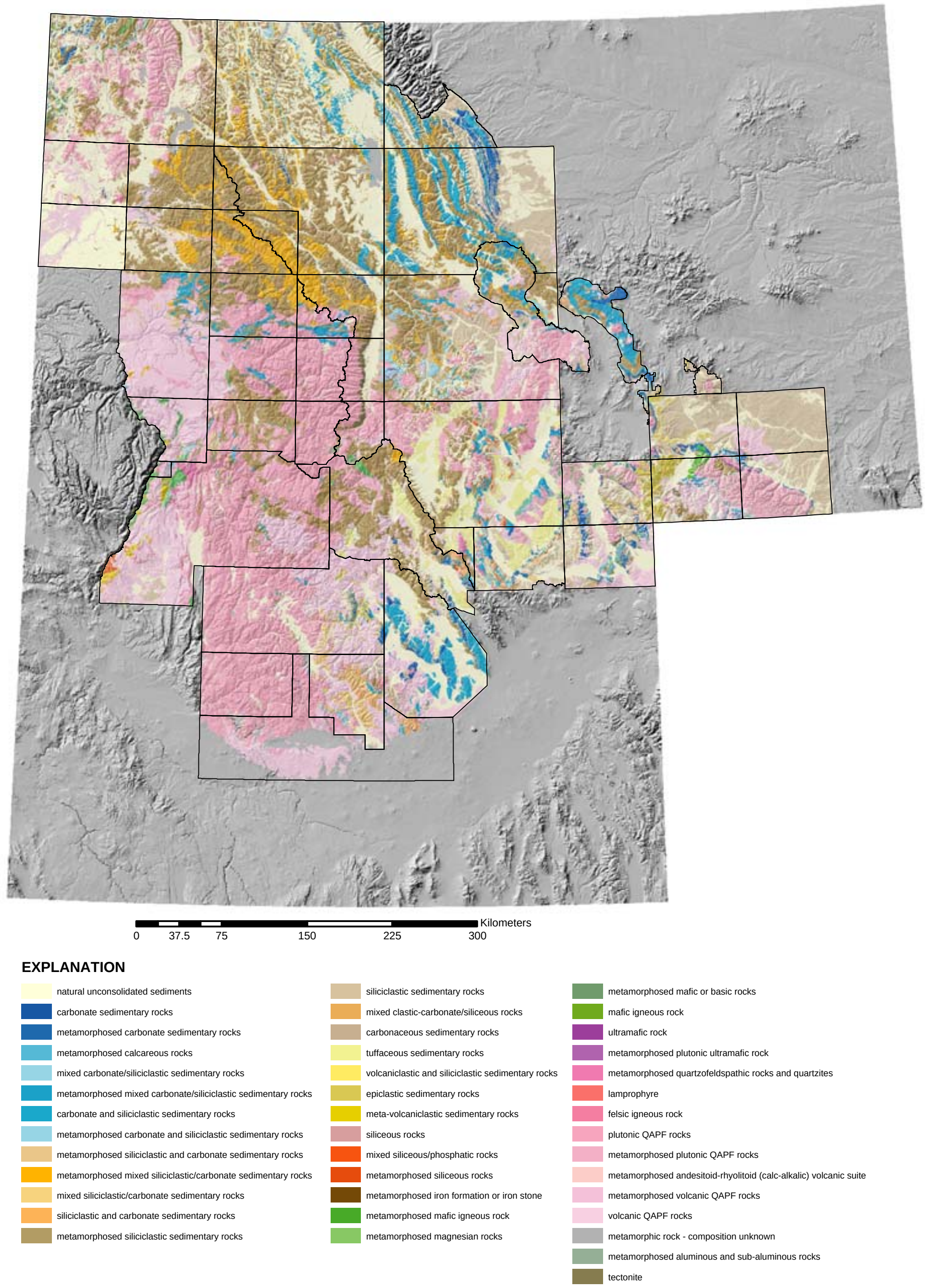

Figure 7. Lithologic map derived by symbolizing attributes in the field *lname_2* in the table NR_GEO.LITH for the regional spatial database.

The information in the field *name_major* and other published sources was used to select a sediment type (*uname_dom*) from a standardized, hierarchically-organized list of sediments and unconsolidated deposits. If the geologic unit appeared on more than one of the 43 maps that make up the compilation, the values of *uname_dom* were compared and adjusted if necessary. The relations between terms in the list of sediments and unconsolidated deposits were used to create a hierarchical list of sediment types for each geologic unit. These values are given in *uname_1* (the most general terms) to *uname_4* (the most specific terms). Additional information on the development and use of these hierarchical lists is given in Appendix F.

Table 7. Summary of the ArcInfo® look-up table NR_GEO.UN.

Table name	NR_GEO.UN
Format	ESRI ArcInfo® look-up table
Description	The table provides information for unconsolidated deposits in the map units defined in the table NR_GEO.MU. Lists of sediment terms from the map-unit descriptions are organized into fields based on their relative abundance. An expanded hierarchy of dominant sediment type is given.
Spatial object classification	Polygons and arcs are grouped into map units as they appear on the original published maps
Keyfield	*mu_id*
Relations	One-to-many relation to *mu_id* in the tables NR_GEO.PAT and NR_GEO.AAT.
User-defined items	**Description**
mu_id	This integer relates descriptions of unconsolidated material to features in the table NR_GEO.PAT. The map units are briefly described in the look-up table NR_GEO.MU; full descriptions are provided in the file nr_geo_mapunits.pdf.
name_major	List of terms for major types of unconsolidated material used in the original map unit description. The grammatical structure of the map unit description indicates these terms represent the most important types of unconsolidated material in the unit.
name_minor	List of terms for minor types of unconsolidated material used in the original map unit description. The grammatical structure of the map unit description indicates these terms represent minor types of unconsolidated material in the unit.
name_other	List of terms for uncommon types of unconsolidated material used in the original map unit description. The grammatical structure of the map unit description indicates these terms represent uncommon types of unconsolidated material in the unit.
uname_dom	A term selected from a standardized list that best describes the dominant type of unconsolidated material for the map unit. The term coded in *uname_dom* should be representative of 50 percent or more of the map unit.
uname_1	Term for the first (most general) level in a hierarchically-organized list of unconsolidated material terms.
uname_2	Term for the second level in a hierarchically-organized list of unconsolidated material terms (where the first level is the most general and the fifth level is the most specific term).
uname_3	Term for the third level in a hierarchically-organized list of unconsolidated material terms (where the first level is the most general and the fifth level is the most specific term).
uname_4	Term for the fourth level in a hierarchically-organized list of unconsolidated material terms (where the first level is the most general and the fifth level is the most specific term).

NR_GEO.BIB TABLE

This ArcInfo® look-up table provides references for sources of information. In addition, two attributes, *scale_base* and *scale_pub*, provide information on the spatial accuracy of the spatial objects in the database (table 8). *Scale_pub* describes the scale at which the original map was published. However, *scale_base* is the scale of the base materials on which the geologic information was compiled. In some cases, maps published at a scale of 1:126,720 were compiled on a base map with a scale of 1:250,000. The scale of the base materials affects the spatial accuracy of the spatial objects in the database. The variation in the base-map scale between different source maps in this compilation (fig. 2) should be considered when performing spatial analysis or combining this database with other information.

Table 8. Summary of the ArcInfo® look-up table NR_GEO.BIB.

Table name	NR_GEO.BIB
Format	ESRI ArcInfo® look-up table
Description	The table provides references for sources of information.
Spatial object classification	Not applicable
Keyfield	*source*
Relations	One-to-many relation to *source* and *source_or* in the table NR_GEO.MU; *source_arc* and *source_lds* in the table NR_GEO.AAT; and *source_pds* in the table NR_GEO.PAT.
User-defined items	**Description**
source	Identifier for data source
originator	Name(s) of author(s) or compiler(s) of data source
date	Date of data source publication (or date that data were made available for our use)
title	The first 250 characters of the title of the data source.
title_cont	The second set of 250 characters of the title of the data source.
pub	Publisher, publication series and number (or other designation), and remainder of reference in USGS style for published data.
unpub_hist	Contains information about unpublished data. It may include file name(s) and the name of the person who provided or acquired the data.
scale_base	Source scale (given as the denominator of the proportional fraction) of the original base map on which the geology was mapped or compiled.
scale_pub	Source scale (given as the denominator of the proportional fraction) of the published geologic map.
url	Uniform Resource Locator; an address that specifies the location of a file on the Internet

NR_GEO.LCD TABLE

This ESRI ArcInfo® look-up table provides cartographic descriptions for line types used in the compilation (table 9). The terms in *line_type1*, *line_type2*, and *line_type3* are hierarchically organized, with the simplest and most inclusive terms in *line_type1* and the most detailed terms in *line_type3*. For example, if line_type3 is “normal fault, approximate (dashed)”, then line_type2 is given as “normal fault”, and line_type1 is simply coded as “fault”.

Table 9. Summary of the ArcInfo® look-up table NR_GEO.LCD.

Table name	NR_GEO.LCD
Format	ESRI ArcInfo® look-up table
Description	The table defines line-types used in the compilation
Spatial object classification	Not applicable
Keyfield	*linecode*
Relations	One-to-many relation to *linecode* in the table NR_GEO.AAT.
User-defined items	**Description**
linecode	This integer relates cartographic description of a line in this table to an arc feature in the feature attribute table NR_GEO.AAT.
line_type1	General classification of linear feature
line_type2	Qualified classification of linear feature
line_type3	Complete description of linear feature (may also include description of line pattern used on source map).
Symbolization files	
linetype1_lcd.lyr	Symbolization file for faults, fractures, dikes and sills, fold axes, veins, and volcano-tectonic structures in the NR_GEO spatial database, using the item *line_type1* in the ArcInfo® look-up table NR_GEO.LCD.

ESRI® INFO Tables for describing igneous map units

Polygons and arcs were grouped into units based on the age, composition, and mode of occurrence of igneous rocks. In the feature attribute tables, the units are identified by integer values in the item *igmu_id*. When joined to the item *igmu_id* in the arc attribute table, NR_GEO.AAT, and the polygon attribute table, NR_GEO.PAT, the NR_GEO.IGMU look-up table provides descriptions of these igneous units.

NR_GEO.IGMU TABLE

This ArcInfo® look-up table provides information for map units defined by the age, mode of occurrence (extrusive versus intrusive), and lithology of igneous rocks in the compilation (table 10). The approach used to define igneous map units varied widely between the authors of the 43 maps that make up this compilation. The polygons associated with igneous rocks were re-grouped to make a consistent compilation for the region. Using information on the original maps and other literature, 154 map units were defined. Polygons and arcs are classified into these new map units that do not necessarily correspond to those used for the original map publications. The map unit name, symbol, and age information are given in *ig_name*, *ig_label*, *ig_minage*, *ig_maxage*, and *ig_age*. *Ig_lith* lists the rock types found in each unit in decreasing order of abundance; *ig_feature* provides information on the form or shape of the igneous unit. An in-depth discussion of this approach to classifying igneous map units is provided as Appendix G. Age-related items, *ig_minage*, *ig_maxage*, and *ig_age*, are also discussed in Appendix D.

Table 10. Summary of the ArcInfo® look-up table NR_GEO.IGMU.

Table name	NR_GEO.IGMU
Format	ESRI ArcInfo® look-up table
Description	The table summarizes information on unit name, unit symbol, lithology, emplacement style, and geologic age for igneous rock units.
Spatial object classification	Polygons and arcs for igneous features are grouped into map units based on age, mode of occurrence, and composition. The classification of spatial features does not necessarily correspond to those used by the authors of the original published maps.
Keyfield	*igmu_id*
Relations	One-to-many relation to *igmu_id* in NR_GEO polygon and arc attribute tables
User-defined items	**Description**
igmu_id	This integer relates igneous rock unit descriptions to features in the tables NR_GEO.PAT and NR_GEO.AAT.
ig_label	Map symbol used to label igneous rock units.
ig_name	Name of igneous rock unit.
ig_style	Terms for the mode of occurrence and form of igneous rocks.
ig_lith	Characteristic rock types of the unit, listed in decreasing order of abundance.
ig_feature	Geologic features that characterize the igneous rock map unit.
ig_minage	Youngest geologic time term used for a map unit.
ig_maxage	Oldest geologic time term used for a map unit.
ig_age	Geologic time terms generalized to Period in Phanerozoic time or to Era or Eon in Precambrian time for a map unit.
Symbolization files for polygons and arcs in the spatial database nr_geo	
ig_label_poly_igmu.lyr	Symbolization of igneous map units defined by age, composition, and mode of occurrence.
ig_label_arc_igmu.lyr	Arc symbolization file for displaying a map based on the age and composition of igneous rocks in the NR_GEO spatial database, using the item *ig_label* in the ArcInfo® look-up table NR_GEO.IGMU.

ESRI® INFO Tables for describing named igneous intrusions or volcanic units

Tables that rely upon the name of igneous intrusions or volcanic units to classify spatial objects are NR_GEO.IGPNAM and NR_GEO.IGANAM. These look-up tables relate (using the item *ig_code*) to the polygon attribute table, NR_GEO.PAT, and the arc attribute table, NR_GEO.AAT. In geoscience papers, igneous bodies are commonly referred to by informal names (such as the Marysville stock or the Idaho batholith). On 1:100,000- to 1:250,000-scale map compilations, these named igneous bodies may be grouped into a single map unit; the names may appear as annotations but commonly they do not. Index maps and annotated map compilations were related to the regional geology spatial database compilation and the names were associated with appropriate polygons and arcs.

NR_GEO.IGPNAM TABLE

This ArcInfo® look-up table provides information for the names given to igneous intrusions and volcanic units represented by polygons (table 11). Map units delineated in the tables NR_GEO.MU and NR_GEO.IGMU may consist of one or more named igneous intrusions. Names of batholiths; plutons; stocks; and dike swarms or sills in *name_bath*, *name_plut*, *name_stock*, and *name_dksil* correspond to names used in the literature. These names were then used to generate a three-level hierarchical name list in *intr_1name*, *intr_2name*, and *intr_3name*. The informal terms in the hierarchical list were invented for this compilation. The estimated depth of emplacement for igneous intrusions is recorded in the item *depth_zone*.

Table 11. Summary of the ArcInfo® look-up table NR_GEO.IGPNAM.

Table name	NR_GEO.IGPNAM
Format	ESRI ArcInfo® look-up table
Description	Names of igneous intrusions and volcanic units are associated with polygons. The table also summarizes information on depth of emplacement.
Spatial object classification	The classification of polygons defines stocks, plutons, batholith and named volcanic units. This classification rarely correspond to map units used by the authors of the original published maps (NR_GEO.MU) or to those based on the age and composition of igneous rocks (NR_GEO.IGMU).
Keyfield	*ig_code*
Relations	One-to-many relation to *ig_code* in the TABLE NR_GEO.PAT.
User-defined items	**Description**
ig_code	An identifier for names of stocks, plutons, batholiths, and volcanic units.
name_bath	Name for batholithic assemblages, large complexes of intrusive igneous rock that make up part of a regional-scale magmatic arc. Batholithic assemblages include batholiths (areal extent > 100 square km) together with smaller, spatially-related plutons and stocks that formed as part of the same magmatic event. The names are derived from terms used for batholiths in geologic literature.
name_plut	Name for batholiths (areal extent generally > 100 square km), intrusive complexes, clusters of intrusions, or suites of spatially and genetically related intrusive igneous rocks. The names are restricted to terms in geologic literature.
name_stk	Name for small pluton, stock, or named part or zone of intrusive complexes (areal extent generally < 100 square km). The names are restricted to terms in geologic literature.
name_dksil	Name for dike swarms or sills complexes. The names are restricted to terms in geologic literature.
intr_1name	Name for batholithic-sized association of genetically and spatially-related intrusions.
intr_2name	Name for plutonic-sized association of genetically and spatially-related intrusions.
intr_3name	Name for small stock, pluton, or sill-sized intrusions.
vol_event	Name of magmatic event or magmatic arc.
vol_field	Name of volcanic field, volcanic province, volcanic arc terrane, or volcanic flow unit.
vol_supgrp	Formal name of volcanic unit with stratigraphic rank of supergroup.
vol_grp	Formal name of volcanic unit with stratigraphic rank of group.
vol_subgrp	Formal name of volcanic unit with stratigraphic rank of subgroup.
vol_fm	Formal name of volcanic unit with stratigraphic rank of formation.
vol_mbr	Formal name of volcanic unit with stratigraphic rank of member.
vol_infrml	Informal name of volcanic unit.
vol_ctrr	Name of igneous caldera, graben, or embayment.
depth_zone	Estimated emplacement depth of igneous intrusions.
reference	Citation (author and date) for information used to describe the igneous rock unit.

Map unit names and the USGS Geologic Names Lexicon (MacLachlan, 1996 and GEOLEX (U.S. Geological Survey, 2004)) were used to populate a hierarchical list of stratigraphic terms for volcanic map units. The items *vol_supgrp***,** *vol_grp***,** *vol_subgrp*, *vol_fm***,** and *vol_mbr* contain names for formally-defined stratigraphic units at the rank of supergroup, group, subgroup, formation, and member, respectively. The names in the item, *vol_infrml*, correspond to informally named units. The named volcanic units were grouped into volcanic fields, provinces, or arc terranes in the item, *vol_field*. The units were then grouped in the item *vol_event* according to the processes responsible for causing the igneous activity– subduction related magmatic arcs or plume-related large magmatic events. The names of calderas and grabens that form as a result of magmatic activity are listed in *vol_ctr*.

Information consulted to attribute items in this table is cited in the item *reference*. Complete references for the citations in the item *reference* are given in Appendix G.

This report presents 3 different schemes for representing map units for igneous rocks. Most map units for intrusive igneous rocks are informally-defined; as a result, there is little consistency between the source maps used for this compilation. Figure 8 illustrates the different appearance of maps for igneous intrusions symbolized on the items *name*, *ig_name*, and *name_plut*. The map in figure 8a shows polygons for igneous intrusions symbolized using the regional names in the database (using the item *name* in the ArcInfo® look-up table NR_GEO.MU. Map units defined using this item can be related to the published map unit descriptions. Figure 8b shows igneous map units defined by age, composition, and mode of occurrence based on the item ig_name in the look-up table NR_GEO.IGMU. This approach uses a consistent approach to creating map units that is ultimately related to regional magmatic events that affected the map area. A different representation of the igneous rocks is show in figure 8c, where named plutons are symbolized using the item *name_plut* in the look-up table NR_GEO.IGPNAM. This approach emphasizes the identity of individual stocks, plutons, and batholiths. Each intrusion has a unique history of emplacement, crystallization, and cooling, which affects its physical characteristics and associated resources.

NR_GEO.IGANAM TABLE

This ArcInfo® look-up table provides information for the names given to igneous dikes and sills and to volcanic units represented as lines in the spatial files (table 12). Map units delineated in the tables NR_GEO.MU and NR_GEO.IGMU may consist of one or more named igneous features. Names of dikes or sills in *name_dksil* correspond to names used in the literature as well as terms invented for this study. Map unit names and GEOLEX (U.S. Geological Survey, 2004) were used to populate a hierarchical list of stratigraphic terms for volcanic units. The items *vol_supgrp*, *vol_grp*, *vol_fm*, and *vol_mbr* contain names for supergroup, group, formation, and member, respectively**.** The named volcanic units were grouped into flow units in the item, *vol_field*. The units were then grouped in the item *vol_event* according to the processes responsible for causing the igneous activity– in this case, a plume-related large magmatic event. The forms of the igneous bodies are recorded in the item *ig_form*. Rock types characteristic of the units are given in the item *ig_lith*. Information consulted to attribute items in this table is cited in the item *reference*. Complete references for the citations in the item *reference* are given in Appendix G.

nr_maps and nr_extent databases

The ArcInfo® coverage NR_MAPS shows the extent of the 43 maps that were the principal sources of information used in preparing the NR_GEO compilation (table 13). The polygon attribute table gives a short name for the map (*map_tile*) as well as a complete reference (*originator*, *date*, *title*, *title_cont*, *pub*, *unpub_hist*, and *url*). In addition, the scale of map publication (*scale_map*) and the scale of the base map (*scale_base*) on which the source map was originally compiled are also provided. The ArcInfo® coverage NR_EXTENT contains a single polygon that identifies the areal extent of the NR_GEO geologic spatial database (table 14).

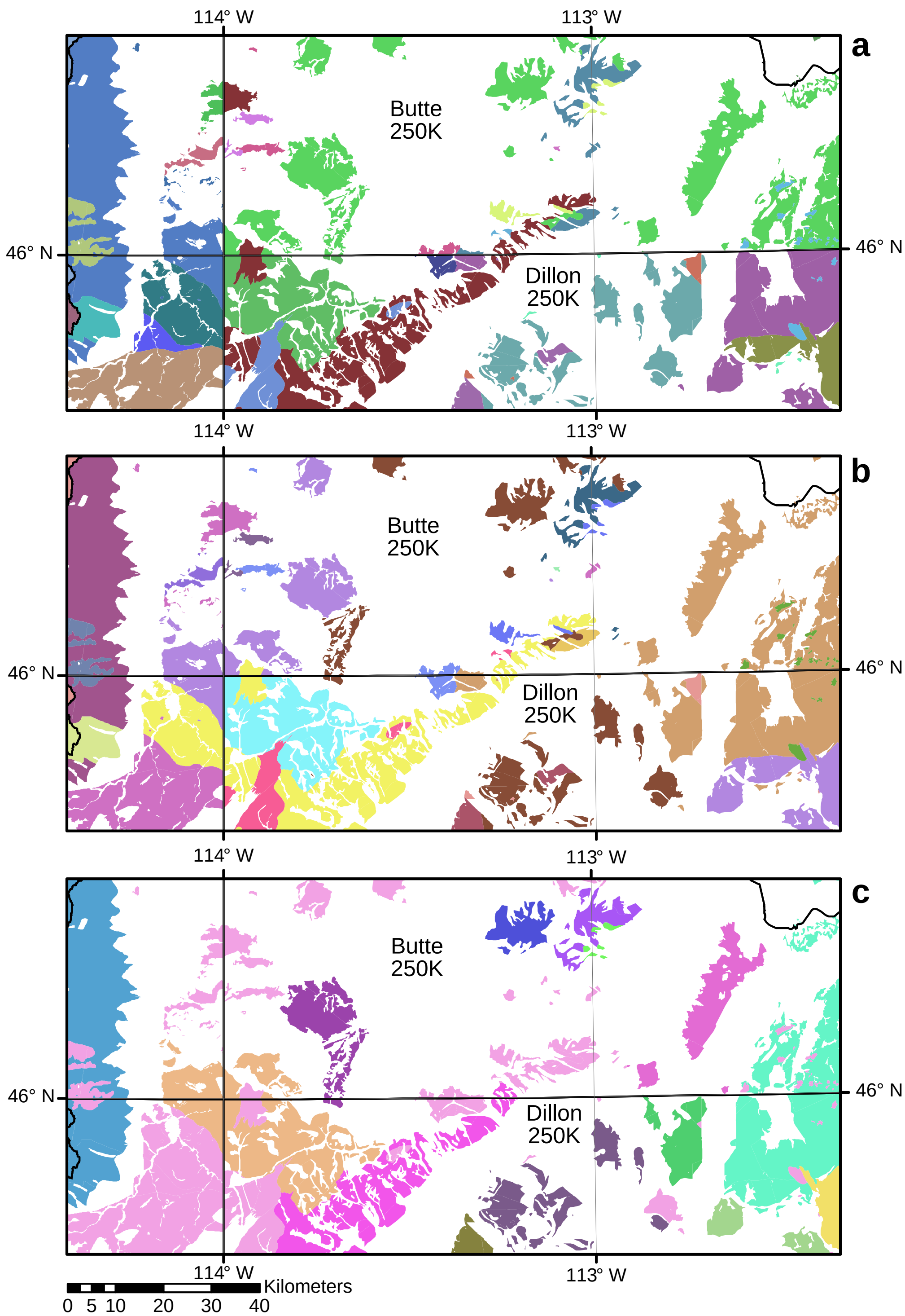

Figure 8. Maps symbolized to show the classification of igneous intrusive rocks using different items in look-up tables for the ArcInfo® coverage NR_GEO.

Table 12. Summary of the ArcInfo® look-up table NR_GEO.IGANAM.

Table name	NR_GEO.IGANAM
Format	ESRI ArcInfo® look-up table
Description	Names of igneous intrusions and volcanic units associated with arcs. The table also summarizes information on the form of the igneous unit and associated rock types
Spatial object classification	The classification of arcs defines dike swarms and sill complexes. It rarely corresponds to units used by the authors of the original published maps (NR_GEO.MU) or to those based on the age and composition of igneous rocks (nr_GEO.IGMU).
Keyfield	*ig_code*
Relations	One-to-many relation to *ig_code* in NR_GEO.AAT attribute tables
User-defined items	**Description**
ig_code	An identifier for names of dikes, sills, and dike swarms shown as linear features (arcs).
name_dksil	Name of dike swarms or sill complexes.
vol_event	Name of magmatic event or magmatic arc.
vol_field	Name of volcanic field, volcanic province, volcanic arc terrane, or volcanic flow unit.
vol_supgrp	Formal name of volcanic unit with stratigraphic rank of supergroup.
vol_grp	Formal name of volcanic unit with stratigraphic rank of group.
vol_fm	Formal name of volcanic unit with stratigraphic rank of formation.
vol_mbr	Formal name of volcanic unit with stratigraphic rank of member
ig_form	Form of igneous bodies that occur in the unit.
ig_lith	Rock types in the unit.
reference	Brief citation (author and date) for information source used to describe the igneous rock unit.

Table 13. Summary of the user defined items in the ArcInfo® feature attribute table NR_MAPS.PAT.

Table names	NR_MAPS.PAT
Format	ESRI ArcInfo® feature attribute table
Description	The table provides information about polygons in the ArcInfo® coverage NR_MAPS
User-defined items	**Description**
map_tile	Name for one of the 43 maps that were the principal sources of information used in preparing the regional geology compilation. The name was coined by combining an abbreviation of a topographic map or National Forest name and the published map scale.
originator	Name(s) of author(s) or compiler(s) of data source
date	Date of data source publication (or date that data were made available for our use)
title	The first 250 characters of the title of the data source.
title_cont	The second set of 250 characters of the title of the data source.
pub	Publisher, publication series and number (or other designation), and remainder of reference in USGS style for published data.
unpub_hist	Contains information about unpublished data. It may include file name(s) and the name of the person who provided or acquired the data.
scale_base	Source scale (given as the denominator of the proportional fraction) of the original base map on which the geology was mapped or compiled.
scale_pub	Source scale (given as the denominator of the proportional fraction) of the published geologic map.
url	Uniform Resource Locator; an address that specifies the location of a file on the Internet.

Table 14. Summary of the user defined item in the ArcInfo® feature attribute table NR_EXTENT.PAT.

Table name	NR_EXTENT.PAT
Format	ESRI ArcInfo® feature attribute table
Description	The table provides information about polygons in the ArcInfo® coverage NR_EXTENT
User-defined item	**Description**
area_desc	Extent of the NR_GEO spatial database

nr_basemap image

A mosaic of digital raster graphic (DRG) images was created from both 1:250,000-scale and 1:100,000-scale imagery to provide a topographic base map for the NR_GEO geologic spatial database. The mosaic, NR_BASEMAP, is an ERDAS IMAGINE® image format file. The scale of the constituent parts of the mosaic generally represents the scale on which the geology (provided in NR_GEO) was compiled. Information about how this mosaic was created and how it can be used in ESRI ArcGIS® software is summarized in Appendix H.

Non-Spatial Data Files included with the Compilation

Non-spatial data files include map-unit descriptions and lithologic definitions. Much of the descriptive information about the map units and lithologic definitions was too large to store in a single field or item in the NR_GEO spatial database. Consequently, the information was stored in a relational database (for internal USGS use) and exported as text and Adobe® Portable Document Format files for publication.

Map-unit descriptions

A digital compilation of the map-unit descriptions was created from the original map sources used to make this compilation. Unfortunately, the map unit descriptions are too long and complexly formatted to include as fields in an ArcInfo® look-up table. The key field *mu_id* and the map-unit description (*mu_desc*) are available in the ASCII text file, nr_geo_mud.txt. This file can be imported into relational database software. The nr_geo_mud.txt file contains a header row, consisting of the field names. The data are in delimited format; a pipe symbol (the "|" character (shift+\)) separates the *mu_id* number from *mu_desc* text. The geologic description is in single quotes, which are necessary for software to identify beginning and end of a string since some of the descriptions have more than one paragraph. Appendix I describes how the map-unit descriptions were compiled and gives instruction on how to export and import this information from Microsoft® Access. The map-unit descriptions contain hundreds of citations to literature and are included in the file nr_geo_mudrefs.txt.

Database tables optimized for storage and analysis can be difficult to read. Map-unit descriptions and cited references, along with selected attributes from the tables NR_GEO.PAT, NR_GEO.MU, and NR_GEO.BIB, were compiled into a form and saved as an Adobe® Portable Document Format file (nr_geo_mapunits.pdf). This file is also described in Appendix I.

Only terms for rock and sediment type were parsed from the map-unit descriptions into fields in the spatial database. Obviously, the map-unit descriptions contain additional data. Users can gain access to this information by using the file nr_geo_mapunits.pdf and the search function in Acrobat Reader. Data in the map-unit descriptions can also be queried if the file nr_geo_mud.txt is imported into database software. Word lists were developed to facilitate searching the map-unit description. The map-unit descriptions were indexed; out of this master list of words used in the descriptions, specific word lists for age, color, geology, minerals, and paleontology were developed. These word lists are presented in text files (wordlist_age.txt, wordlist_color.txt, wordlist_geology.txt, wordlist_minerals.txt, and wordlist_paleo.txt). The file, author_terms.txt, is a list of unique rock and sediment names derived from the items *name_major*, *name_majr1*, *name_majr2*, *name_minor*, and *name_other* in the ArcInfo® look-up tables NR_GEO.LITH and NR_GEO.UN.

Database and File Quality

Several tests were conducted to determine if the information in the database NR_GEO was correctly attributed. Some of the quality-assurance tests applied to spatial databases and related data files are summarized in table 15. These involve both visual inspections and various types of database queries that can test the data for errors. Any data that did not satisfy the quality assurance test were corrected if possible; problems not corrected are discussed later in this section.

Table 15. Summary of quality assurance tests applied to the databases.

Quality Assurance Test	**Description**
Spatial objects with no attributes	Some spatial objects in the forty-three original spatial databases were not attributed. If possible, attributes were provided by checking against sources of geologic mapping.
Topology of geologic features - contacts	Polygons adjacent to a line coded as a contact should have different unit labels. If the polygons had the same unit label value, original map sources were checked to verify line and polygon coding.
Topology of features – water bodies	Arcs surrounding polygons coded as water bodies should be coded as shoreline. If not, original map sources were checked to verify line and polygon coding.
Topology of features – map boundaries	Arcs that define the boundaries between the forty-three digital different spatial databases that make up this compilation should be coded as map boundaries. If not, line coding was checked and corrected as necessary
Consistency of table attributes - stratigraphic age	Confirms that minimum stratigraphic age is less than or equal to maximum stratigraphic age.
Consistency of table attributes – unconsolidated deposits	The items with *unit_type* = 'U' in the table NR_GEO.MU were compared to items with *uname_1* = 'unconsolidated sediments' in the table NR_GEO.LITH. Discrepancies between the tables were addressed.
Consistency of table attributes – intrusion style and depth of emplacement	The information in *ig_style* in the table NR_GEO.IGMU was compared to information in *depth_zone* in the table NR_GEO.IGPNAM. Discrepancies between the tables were addressed.
Geologic names – original usage	The geologic unit names in *name_or* in the table NR_GEO.MU were derived from the previously published databases. These names were compared to the original reports and revised as necessary to reflect their use in the published map explanations.
Geologic names – stratigraphic usage	All the geologic unit names in *name_or* in the table NR_GEO.MU were checked against the USGS Geologic Names Lexicon (MacLachlan, 1996 and GEOLEX (U.S. Geological Survey, 2004)). For the items in *name* in the table NR_GEO.MU, spelling was corrected and capitalization was revised to reflect formal versus informal usage of the geologic name.
Discontinuities at map boundaries	Polygons were selected for each attribute in *unit_type* in the table NR_GEO.MU and then symbolized by *name_or* from the same table. Each boundary between source maps was visually inspected. In some cases, the differences across the boundaries were due to coding errors. These were corrected.
Color map inspection	Visual inspection of map units to verify that the map makes geologic sense.
Map-unit description - spelling	All the map-unit descriptions were checked for spelling; misspelled words were corrected (including those that were spelled incorrectly in the original publication).
Map-unit description - references	The references cited in the map-unit descriptions were checked against reference lists in the publications. Missing publications were identified and added to the reference list for this report.

Constraints that affect the use of the database

There are several aspects of this dataset that will affect how it should be used. Some of these limitations are unavoidable because of the differences in the style of map compilation and conversion of the original source maps. Others reflect the time and resources available to complete this study. Others are nuances of how the database is constructed that may cause some confusion. Issues are summarized in table 16, below.

Table 16. Summary of issues that affect use of the ArcInfo® coverage NR_GEO.

Topic	Comments
Water bodies	NR_GEO should not be exclusively used for the location of water bodies. Many of the forty-three sources of data did not integrate water bodies into the geologic spatial database; water bodies shown on maps in the original publication were derived from other digital data sources.
Edge matching	Discontinuities at boundaries between the forty-three geology databases are common; examples include contacts that fail to meet exactly, the juxtaposition of different map units, or the abrupt termination of a unit. We did not modify the spatial databases to fix these discrepancies.
Positional accuracy of spatial objects	The positional accuracy of the spatial objects varies in direct relation to the scale of the base materials that were used to compile the geologic data. Maps used for this database were compiled on 1:100,000- and 1:250,000-scale base maps. Data compiled on 1:250,000-scale base materials will have higher positional uncertainty and will tend to be generalized relative to information compiled on 1:100,000-scale maps.
Point data	Point data were published with some of the forty-three spatial databases used for this compilation. Because so few of the maps included point data, we did not compile this information. We fitted the polygon and arcs in order to create the compiled spatial database. As a result, if point data from the original publications are combined with this compilation, the point data may not be in the "correct" location relative to polygons and arcs in the original published reports.
Decorated lines	Line decoration can be used to identify different types of structural features and indicate their geometry. For example, "sawteeth" on a fault identify it as a thrust fault and also indicate which side of the line is the upper plate of the fault. For many of the spatial databases that make up this report, arcs (line segments) were oriented according to the right-hand rule in order to accept an asymmetric pattern of line decorations. The orientation direction for arcs was not completely verified. If asymmetric line patterns are applied, the results should be checked against the source maps used to create this compilation to ensure that line orientation directions are correct. Source maps published by the USGS are available as rectified images (Larsen and others, 2004).
Names of geologic structures	The field *str_name* in the table NR_GEO.AAT only contains structure names in the original published spatial databases. This information was not consistently attributed in the original source datasets. We have not compiled new data to make this information regionally consistent.
File size	The file nr_geo_mapunits.pdf was developed to use online; be aware that it contains over 2,000 pages if you plan to print this document.

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Appendix A: Map Symbolization (layer files)

By Mary H. Carlson, Kenneth C. Assmus, and Michael L. Zientek

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Tables

Introduction

ArcGIS® layer files (*.lyr) provide a pre-defined cartographic view of spatial databases. These files display symbols and classifications for a dataset when viewed in ArcGIS®. A layer file references a data source, such as an ArcInfo® coverage, indicate which features are included (such as items in joined tables), and identifies how the data should be displayed on a map. A layer file stores symbology, symbology classifications, labeling properties, scale dependency, and definition. Cartographic views have been developed for the minimum age of units, maximum age of units, the age of units generalized to Period or Era in the geologic time scale, the age and composition of igneous rocks, and lithology. Layers files have also been developed to illustrate line types (such as faults and fold axes).

Overview of layer files

Eight layer files were created to symbolize polygon and arc features in the ArcInfo® coverage NR_GEO (table A-1). The lyr files for NR_GEO symbolize attributes in look-up tables. The appropriate look-up table was joined to NR_GEO to create each layer file. Each layer file name represents the item in the ArcInfo® coverage that is symbolized followed by the name of the look-up table that was joined to the coverage. Poly or arc in the name is added to the layer file name for layer files in which the value field and look-up table are the same. For example, ig_label_poly_igmu.lyr symbolizes igneous rocks represented by polygons and ig_label_arc_igmu.lyr symbolizes igneous rocks represented by arcs. Each name part is separated by an underscore (_).

Table A-1. Summary of the coverage and look-up tables associated with each .lyr file.

Layer file	Symbolizes	COVERAGE (feature class)	Look-up table (value field)	Join item
age_mu.lyr	The age of units generalized to Period or Era in the geologic time scale for a map unit.	NR_GEO (polygon)	NR_GEO.MU (*age*)	*mu_id*
age_or_mu.lyr	The age of units generalized to Period or Era in the geologic time scale for a map unit described in the original source maps used for this compilation.	NR_GEO (polygon)	NR_GEO.MU (*age_or*)	*mu_id*
minage_or_mu.lyr	Minimum age of map units.	NR_GEO (polygon)	NR_GEO.MU (*minage_or*)	*mu_id*
maxage_or_mu.lyr	Maximum age of map units.	NR_GEO (polygon)	NR_GEO.MU (*maxage_or*)	*mu_id*
ig_label_poly_igmu.lyr	Map units defined by the age, mode of occurrence, and lithology of igneous rocks.	NR_GEO (polygon)	NR_GEO.IGMU (*ig_label*)	*igmu_id*
ig_label_arc_igmu.lyr	Map units defined by the age, mode of occurrence, and lithology of igneous rocks.	NR _GEO (arc)	NR_GEO.IGMU (*ig_label*)	*igmu_id*
linetype1_lcd.lyr	Line types (such as faults, fold axes, and dikes) for selected arcs in the compilation.	NR _GEO (arc)	NR _GEO.LCD (*line_type1*)	*linecode*
lname2_lith.lyr	Dominant lithology terms for map units. These terms represent the second highest (more general) level in a hierarchical classification of lithology terms.	NR_GEO (polygon)	NR _GEO.LITH (*lname_2*)	*mu_id*

Using a layer file

The eight layer files can be added to an ArcMap™ 9.0 session by clicking the add data button and browsing to the location where the layer files are stored, or by dragging the layer file from Windows Explorer or ArcCatalog™ into an open ArcMap™ session. The symbolized map can be printed and colors modified but symbology classification cannot be changed. Remember a layer file stores how a map is classified and points to the data but is not the spatial dataset.

To change the symbology of an existing layer file, it must be updated in ArcMap™ and saved out as a new layer file. The following example will illustrate how to update age_mu.lyr if a new age term were added to the NR_GEO database.

- Add NR_GEO polygon coverage to an ArcMap™ session by right-clicking on **Layers** in the Table of Contents, click on **Add Data…,** Browse to the location where NR_GEO is stored and add the **polygon** feature class.
- Add NR_GEO.MU look-up table to an ArcMap™ session by right-clicking on **Layers** in the Table of Contents, click on **Add Data…,** Browse to the location where NR_GEO.MU is stored and add it to the session. (The table is stored with the NR _GEO coverage).
- Join NR _GEO.MU to the NR _GEO polygon coverage on *mu_id* by right-clicking on **NR_GEO polygon** in the Table of Contents, go to **Joins and Relates,** click on **Join**. Select ***mu_id*** in "1. Choose the field in this layer that the join will be based on:", Browse to and select **NR _GEO.MU** in "2. Choose the table to join to this layer, or load the table from disk:", Select ***mu_id*** in "3. Choose the field in the table to base the join on:". Click **OK**.
- Right click on **NR_GEO polygon** in the Table of Contents, click on **Properties**, make sure the Symbology section is visible, click on **Import…**, Click the **Browse** button

and locate the **age_mu.lyr** file (It should be stored with the NR _GEO coverage) press **OK**, make sure **nr_geo.mu:Age** is selected under Value Field, press **OK**

- To see how many polygons are coded under each heading click **Count**
- If new age terms need to be added to the layer file and symbolized click on **Add Values…**, values can be selected from the list or added by typing in the Add to List area. Step 4 must be performed in order for items to show up in the list.
- After all changes have been made to the layer file click **OK**, right click on **NR_GEO** in the Table of Contents, click on **Save As Layer File**, give it a new name or replace the old layer file

Troubleshooting

The layer files will work properly if stored in the same location as the coverage from which they were created and if the data path has not been broken. The "import geometry type does not match destination geometry type" is a common error that occurs when importing symbology into a coverage. The ESRI® website lists the following "cause" and "solution" for an error of this type. To view the on-line article visit, http://support.esri.com/index.cfm?fa=knowledgebase.techarticles.articleShow&d=22484

Cause

This message means that the .lyr file selected has a different geometry type than the current layer. You can only import symbology from a .lyr file of the same geometry type. For example, for a polygon layer you can only import symbology from a polygon.lyr file.

This message may also appear if you try to import symbology from a .lyr file with a broken data path. If the name of the file to which the layer file points to has changed a broken data path will result. You cannot import symbology from .lyr files with broken data paths.

Solution or workaround for a broken data path

- Open ArcCatalog™ and browse to the location of the .lyr file (maxage_or_mu.lyr).
- Double-click on the .lyr file (maxage_or_mu.lyr). to open the Layer Properties dialog box.
- Select the Source tab.
- Click Set Data Source and browse to the correct data source (nr_geo polygon), click Add.
- Click OK to close the Layer Properties dialog box.
- Open ArcMap™.
- Symbology from the .lyr file (maxage_or_mu.lyr) should now be available to import.

Appendix B. Standardized hierarchical list of rock and sediment terms

By Michael L. Zientek and J. Douglas Causey

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Figures

Hierarchical lists of rock and sediment terms

For this report, practical field-based rock classification schemes and terms were used to create a standardized, hierarchical list of rock and sediment terms that were used to code fields in ArcInfo® look-up tables. Two criteria were used to select terms and classification schemes. First, terms were selected to be consistent with usage in the map-unit descriptions for the maps used to create the compilation. Second, terms were chosen to emphasize rock composition and depositional environment. Compton (1962), Pettijohn (1975), Folk (1974), Hallsworth and Knox (1999), McMillan and Powell (1999), Winkler (1974), Le Maitre and others (2002), and Bates and Jackson (1987) were the primary sources consulted for sediment and rock classification and terminology. The lithology list has over 600 terms; 194 of these terms were used in coding the map units. The terms and their definitions are listed below and given in the Microsoft® Excel spreadsheet, nr_geo_term.xls, and the ASCII tab delimited text file, nr_geo_term.txt. The spreadsheet and text files also indicate how many times they were used in the compilation. The definitions refer to diagrams that illustrate rock classification from Le Maitre and others (2002), Compton (1962), Pettijohn (1975), and Folk (1974) and are provided in this Appendix as figures B-1 through B-14.

The information available in the map-unit descriptions was a major factor that determined the selection of specific terminology for rocks and sediments used in the report and their hierarchical classification. Early in the project, the terms used in the published map-unit descriptions for rocks and sediments were assessed. Most of the lithology words in these publications were field terms that emphasized color, mineralogy, and overall composition of the rock. Terms that require quantitative petrographic examination or chemical analysis were seldom used. For example, the terms, quartzite, silty quartzite, siltite, and argillite are used to describe the metamorphosed sedimentary rocks of the Belt Supergroup that underlie a large part of the study area. The general field practice for distinguishing these clastic rocks depends on a scratch test using a steel nail: quartzite will not scratch, while more argillaceous rocks will. Accordingly, our lithology list is largely based on field classifications of rocks. Descriptions of unconsolidated materials use terms for deposits that form in a particular depositional setting (alluvial deposits, talus, terrace, till); in some cases, the particle size of the deposit is also described. However, the rock types of the particles that make up the sediment are rarely described. Our lithology list provides classifications based both on depositional environment and grain size of the deposits.

Intended end-use was the other factor that influenced the selection of rock terms. Lists of terms can be selected and organized to emphasize the processes that form rocks, or the physical properties or compositional characteristics of rocks. For this study, terms were selected to emphasize the compositional characteristics of rocks.

Relationships between the rock and sediment terms can be used in generalizing data. For this report, the lists are organized as hierarchies. For example, in the lowest, most detailed level of the rock hierarchy, rocks are distinguished by subtle differences in mineralogy and composition. At intermediate levels in the hierarchy, terms associate rocks with broadly-shared mineralogical and compositional characteristics. At the most general (highest) level, the hierarchy used in this compilation groups terms following the conventional process-based classification of earth materials used by geologists; rock names reflect the process by which they formed – for example, igneous, sedimentary, or metamorphic. Similar relations are defined by hierarchies in the terms for unconsolidated material. Terms at the lowest level in the hierarchy refer to particular depositional environments or a grain size term. Related depositional settings are identified by terms in intermediate levels in the hierarchy. At the highest level, the general term "unconsolidated sediments" is used to refer to all deposits formed by the movement of surficial material by wind, water, ice, or man.

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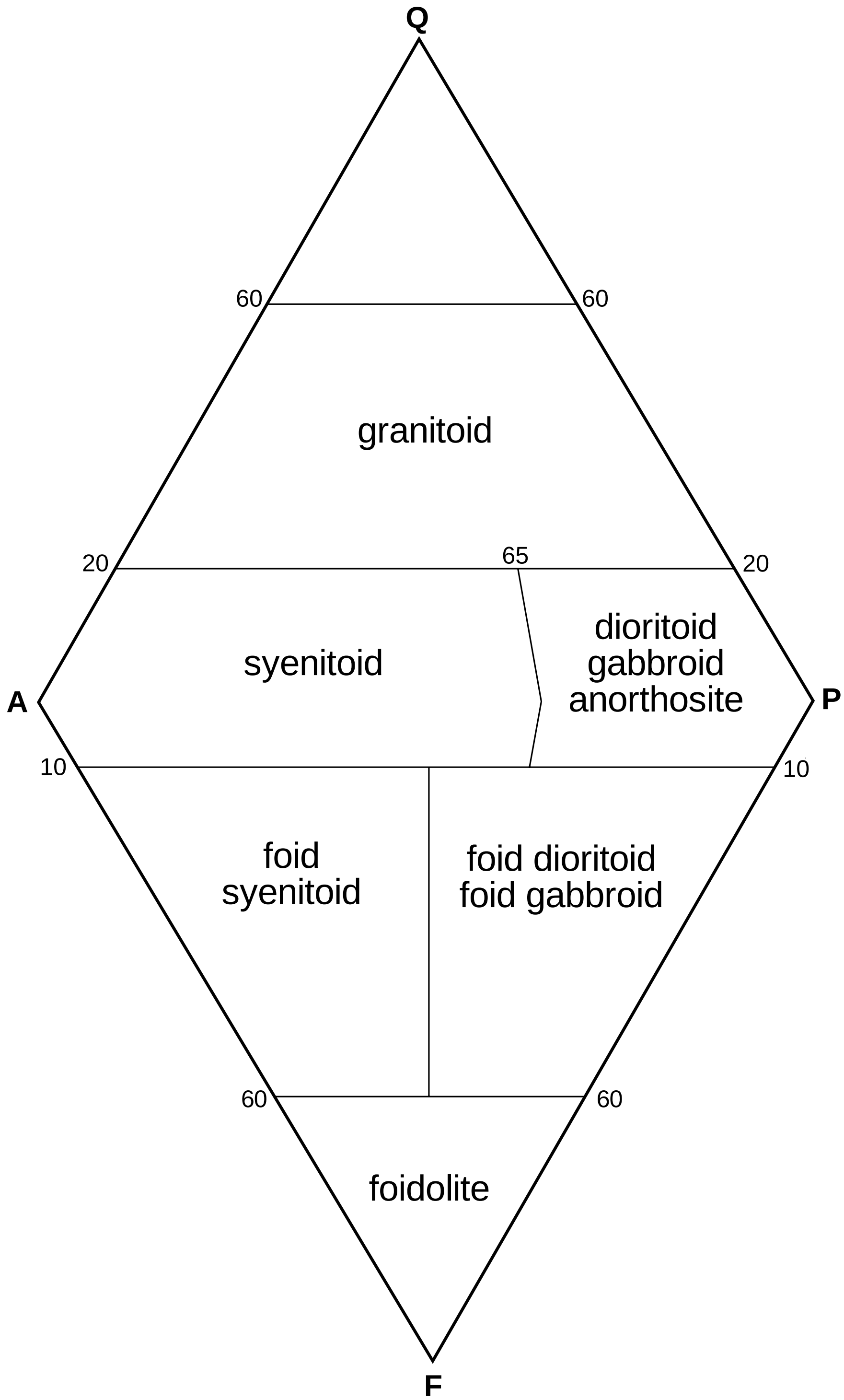

Figure B-1. Preliminary QAPF classification of plutonic rocks for field use. The corners of double triangle are Q = quartz, A = alkali feldspar, P = plagioclase and F = feldspathoid. This diagram must not be used for rocks in which the mafic mineral content, M, is greater than 90 percent. Modified from Le Maitre and others (2002, fig. 2.10).

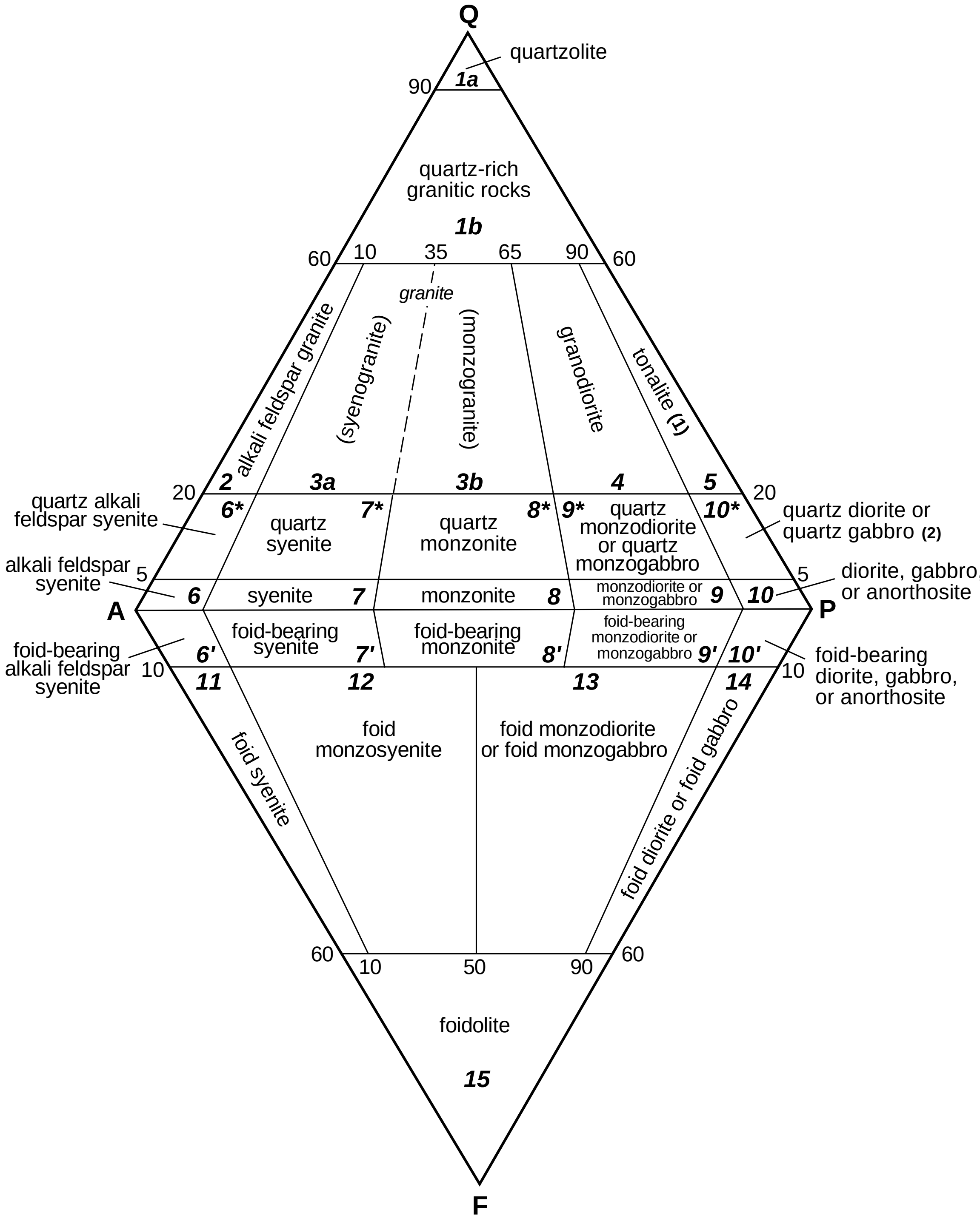

Figure B-2. QAPF modal classification of plutonic rocks. The corners of double triangle are Q = quartz, A = alkali feldspar, P = plagioclase and F = feldspathoid. This diagram must not be used for rocks in which the mafic mineral content, M, is greater than 90 percent. QAPF field numbers shown in bold-italic type. Modified from Le Maitre and others (2002, fig. 2.4).

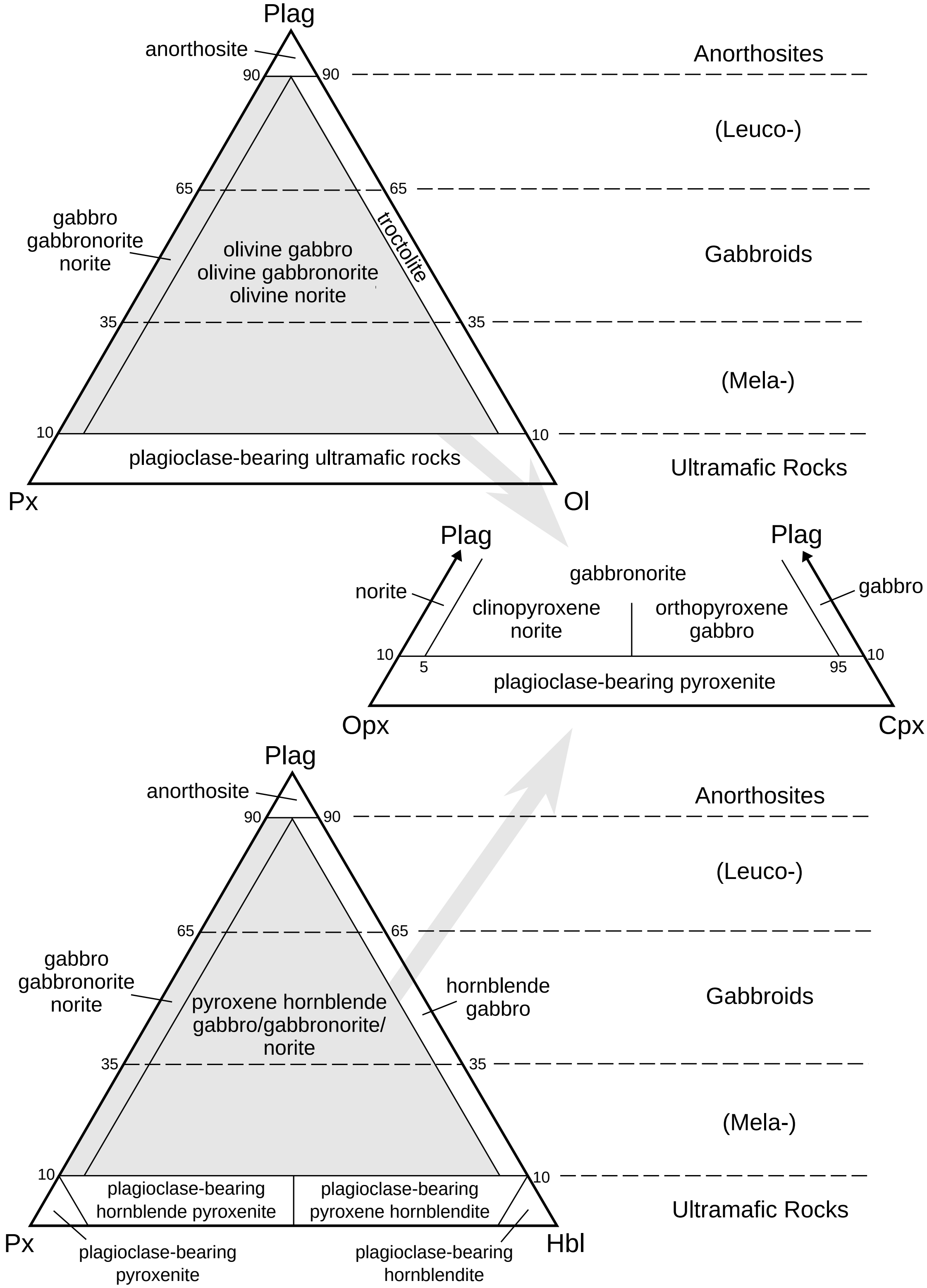

Figure B-3. Modal classification of gabbroic rocks based on the proportions of plagioclase (Plag), pyroxene (Px), olivine (Ol), orthopyroxene (Opx), clinopyroxene (Cpx), and hornblende (Hbl). Rocks falling in the shaded areas of either triangular diagram may be further subdivided according to the diagram pointed to by the arrows. Modified from Le Maitre and others (2002, fig. 2.6).

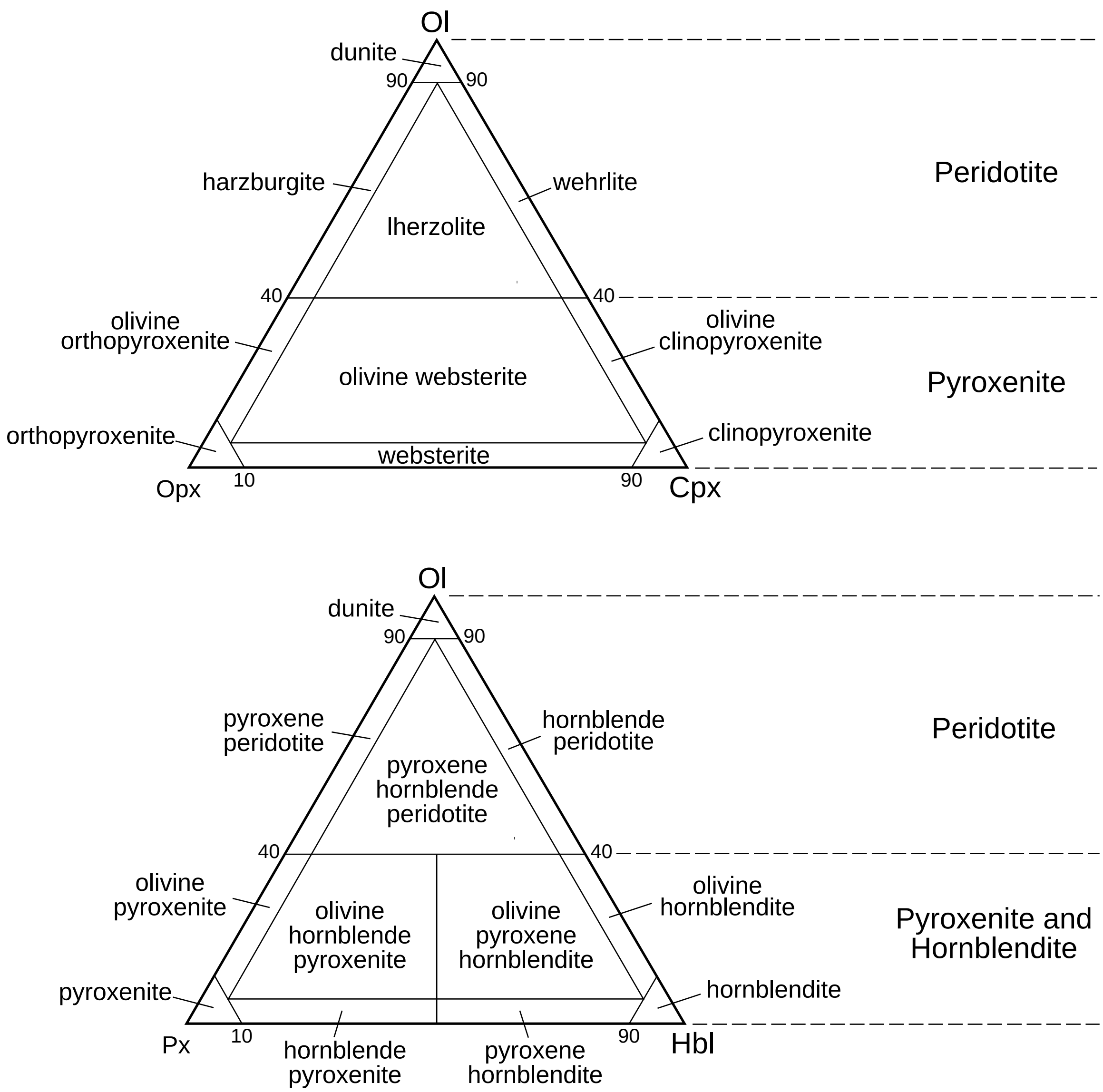

Figure B-4. Modal classification of ultramafic rocks based on the proportions of olivine (Ol), orthopyroxene (Opx), clinopyroxene (Cpx), pyroxene (Px) and hornblende (Hbl). Modified from Le Maitre and others (2002, fig. 2.9).

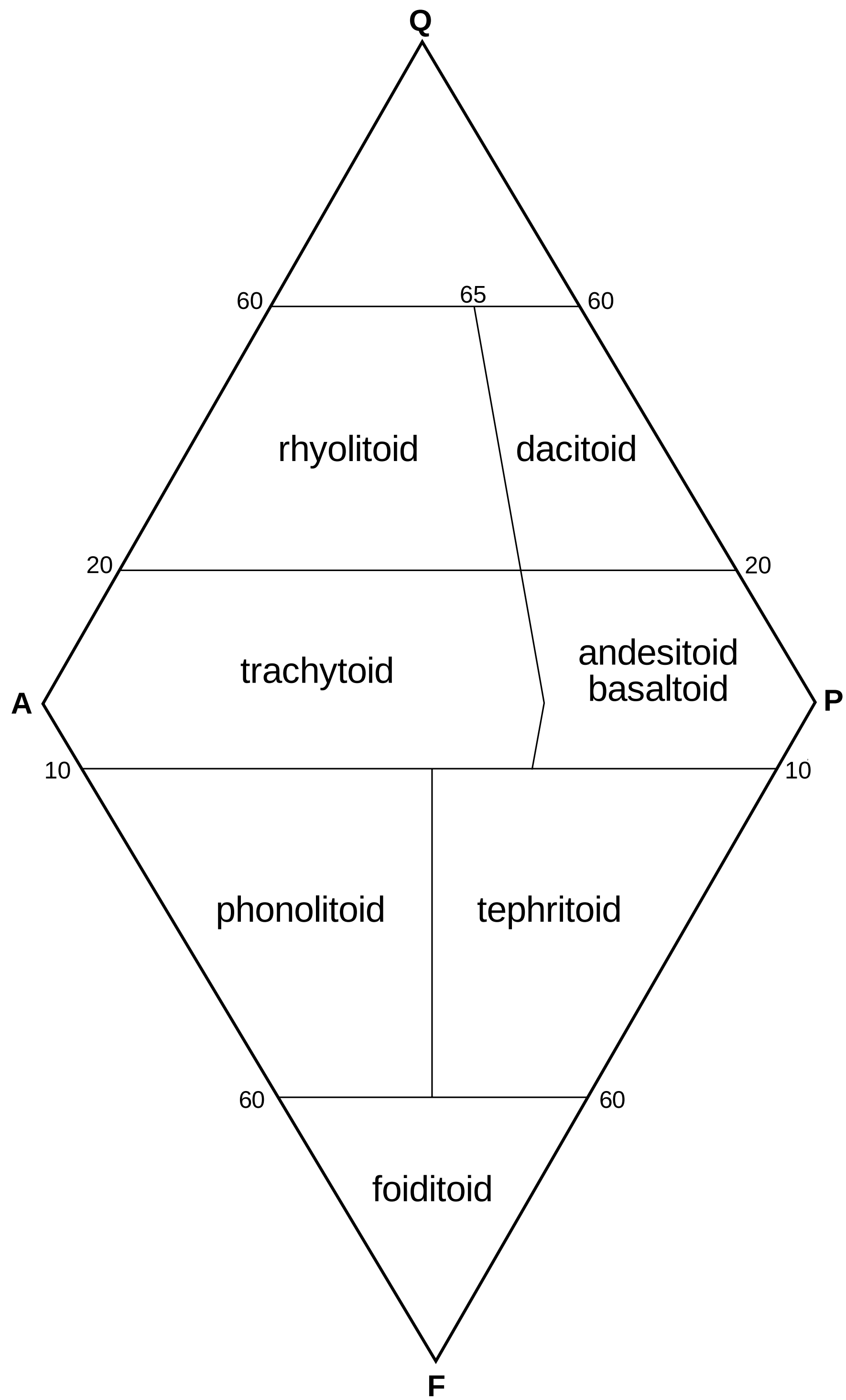

Figure B-5. Preliminary QAPF classification of volcanic rocks for field use. The corners of double triangle are Q = quartz, A = alkali feldspar, P = plagioclase and F = feldspathoid. This diagram must not be used for rocks in which the mafic mineral content, M, is greater than 90 percent. Modified from Le Maitre and others (2002, fig. 2.19).

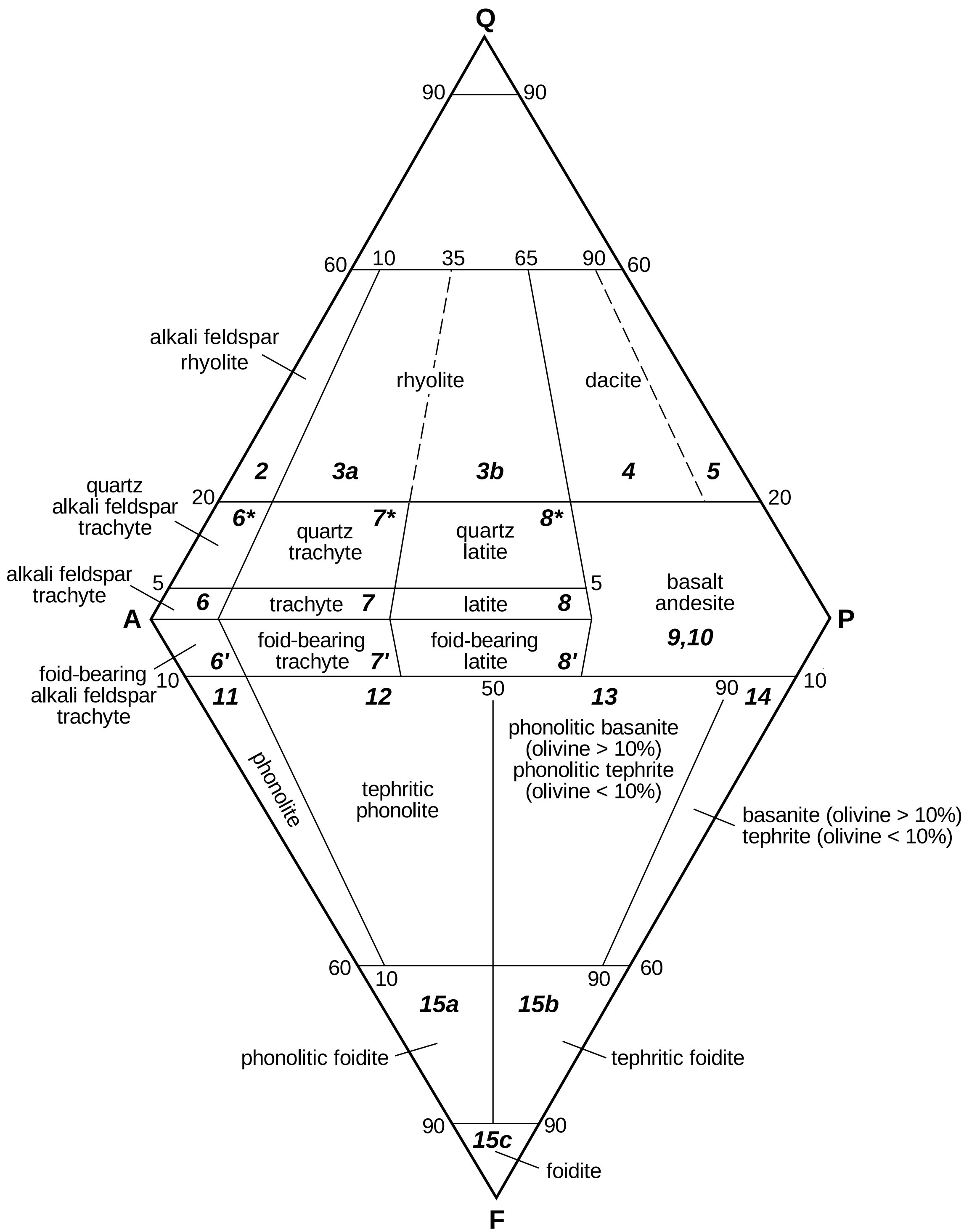

Figure B-6. QAPF modal classification of volcanic rocks. The corners of the double triangle are Q = quartz, A = alkali feldspar, P = plagioclase and F = feldspathoid. This diagram must not be used for rocks in which the mafic mineral content, M, is greater than 90 percent. QAPF field numbers shown in bold-italic type. Modified from Le Maitre and others (2002, fig. 2.11).

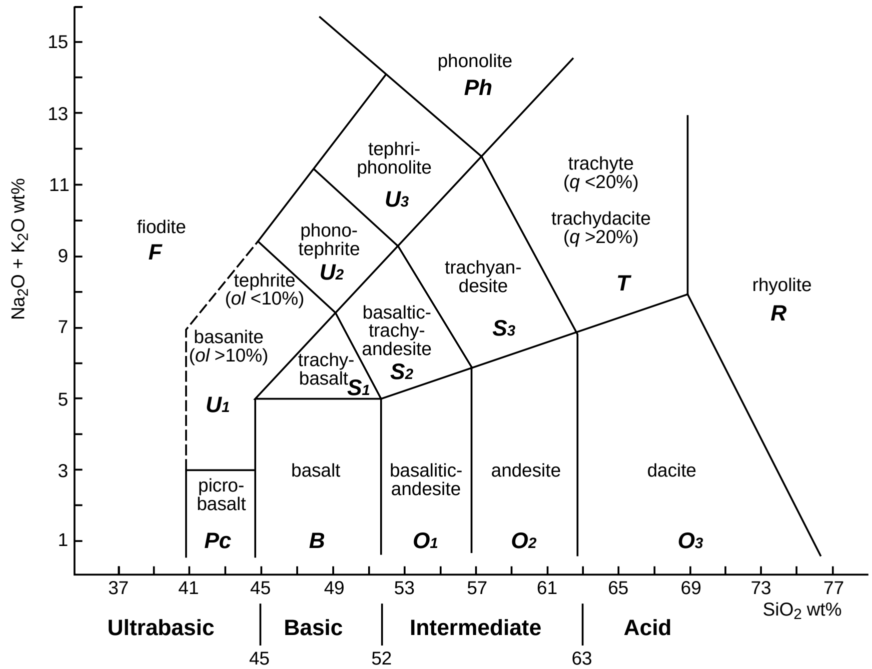

Figure B-7. Chemical classification of volcanic rocks using TAS (total alkali-silica diagram). The line between the foidite field and the basanite-tephrite field is dashed to indicate that further criteria must be used to separate these types. Abbreviations: ol = normative olivine, q = normative 100* Q / (Q + or + ab + an). Field symbols shown in bold type. Modified from Le Maitre and others (2002, fig. 2.1.4).

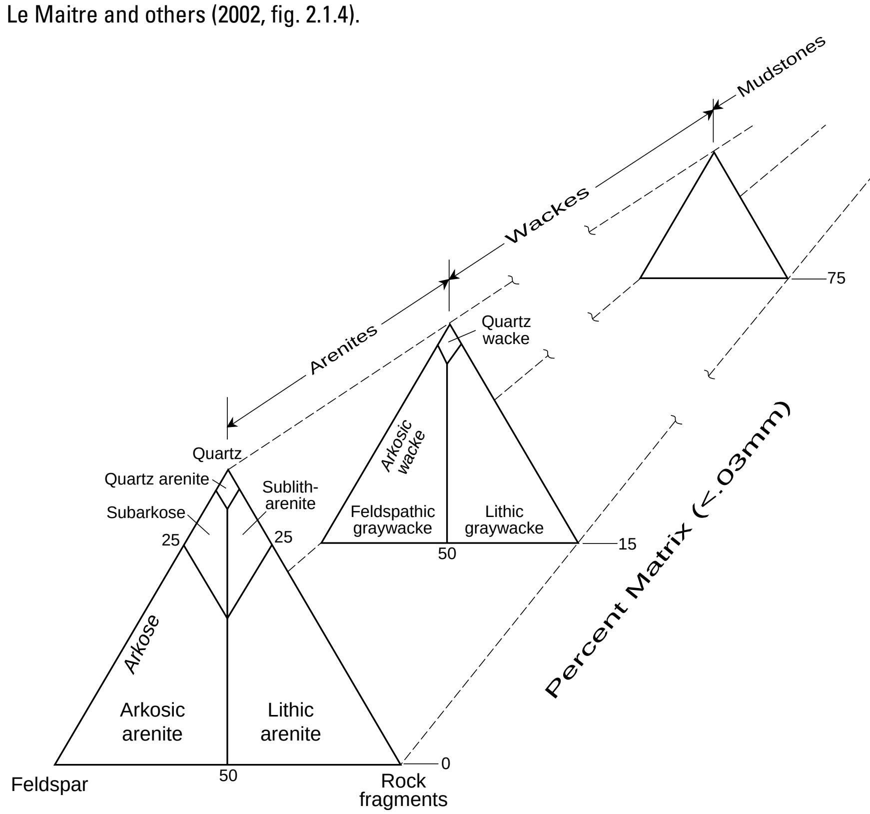

Figure B-8. A classification of terrigeneous sandstones using the relative proportion of quartz and feldspar grains and rock fragments. Modified from Pettijohn (1975, fig. 7-6).

Grain size of mud fraction	Unconsolidated	Indurated, non-fissile	Indurated, fissile
over 2/3 silt	silt	siltstone	silt-shale
subequal silt and clay	mud	mudstone	mud-shale
over 2/3 clay	clay	claystone	clay-shale

Figure B-9. Classification of sediment and rocks consisting of silt and clay. Mudrock is a general term used to cover terrigenous rocks that contain more than 50 percent silt and/or clay. Modified from Folk (1974, p.147).

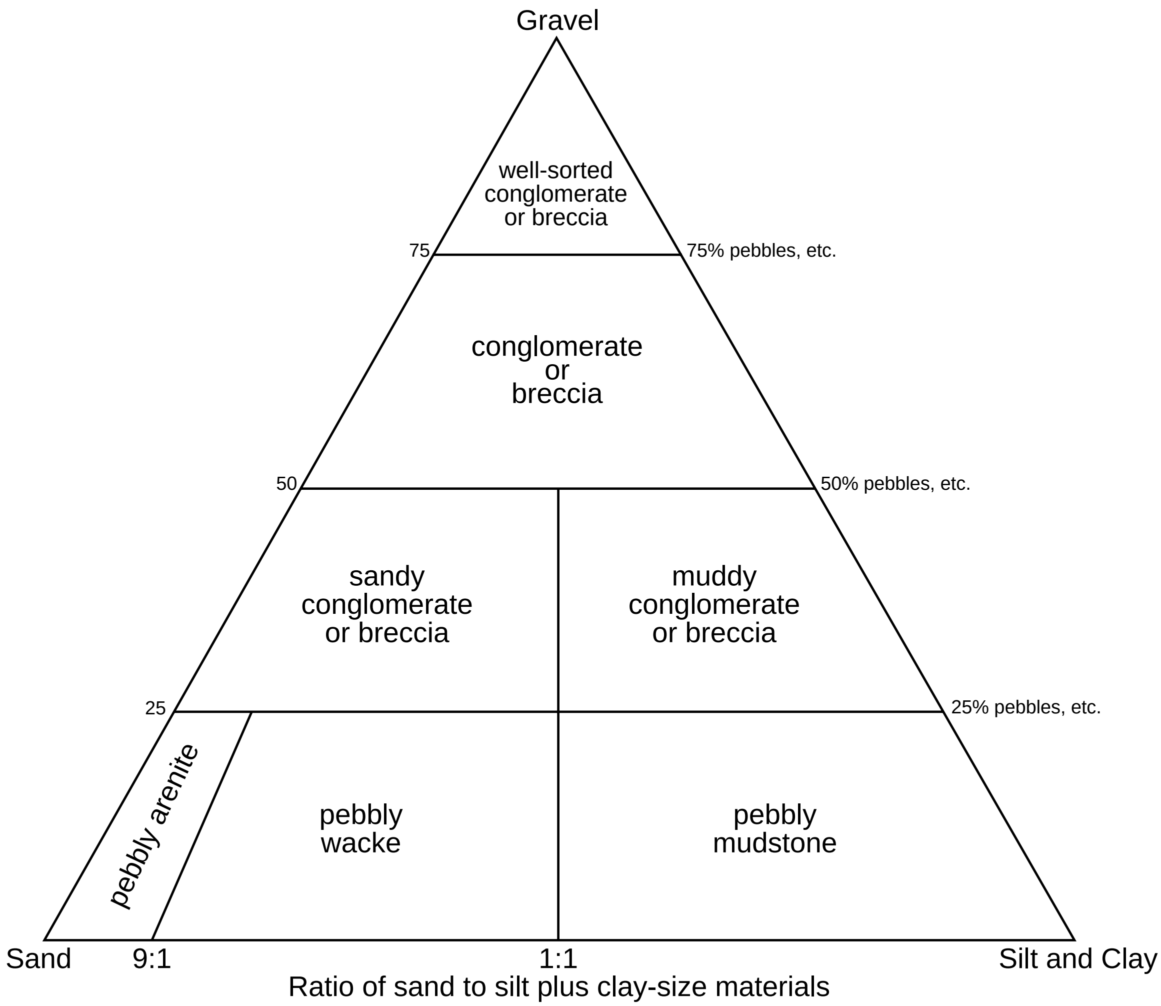

Figure B-10. Names for sedimentary rocks containing gravel-size fragments based on the proportion of gravel, sand, and silt and clay-sized grains. Modified from Compton (1962, fig. 12-5).

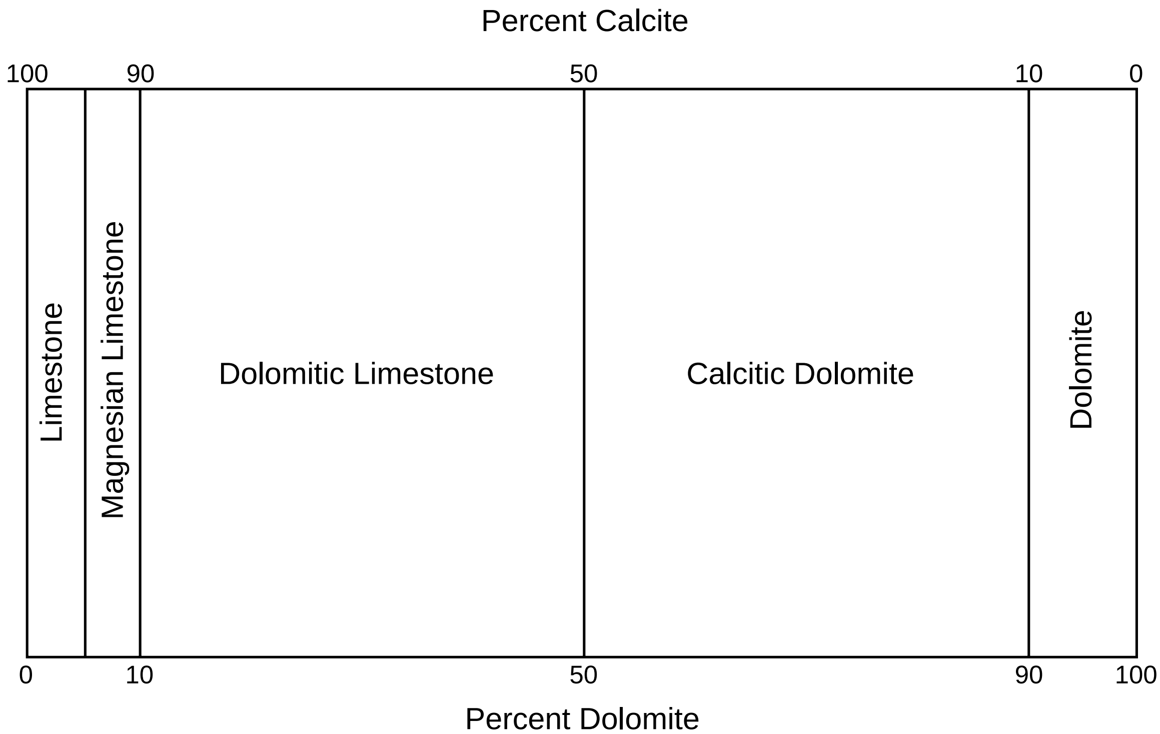

Figure B-11. Classification of calcite-dolomite mixtures. Modified from Pettijohn (1975, fig.10-43).

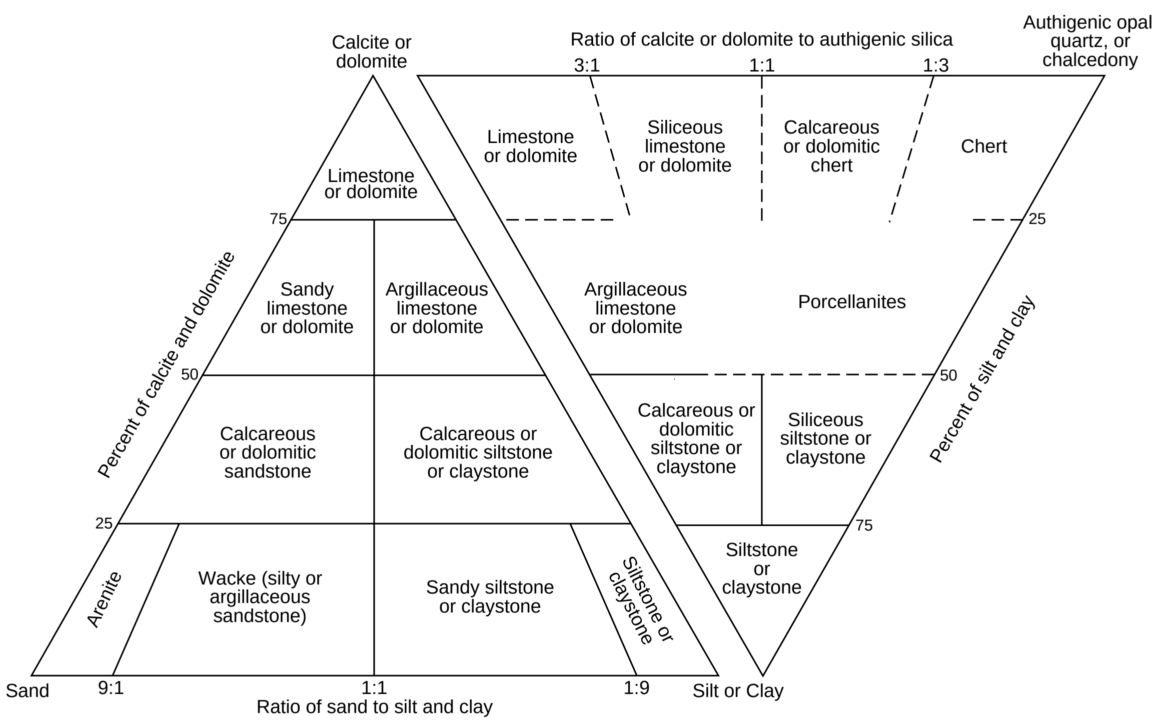

Figure B-12. Rock names for mixtures of various sedimentary materials. The sand, silt, and clay do not include detrital grains of calcite or dolomite. Modified from Compton (1962, fig. 12-3).

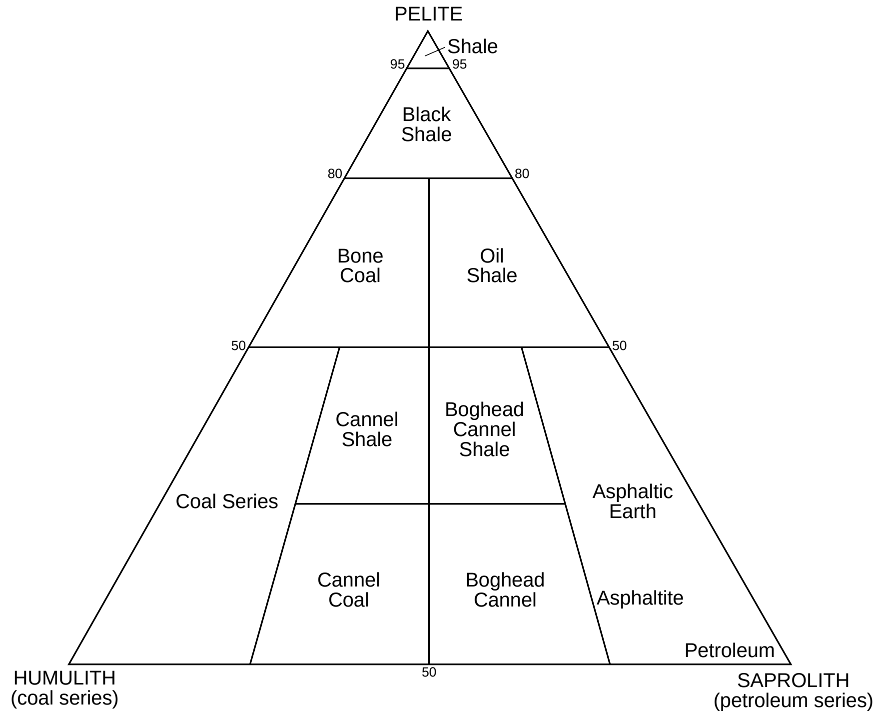

Figure B-13. Classification and nomenclature of the carbonaceous sediments. Modified from Pettijohn (1976, fig. 11-37).

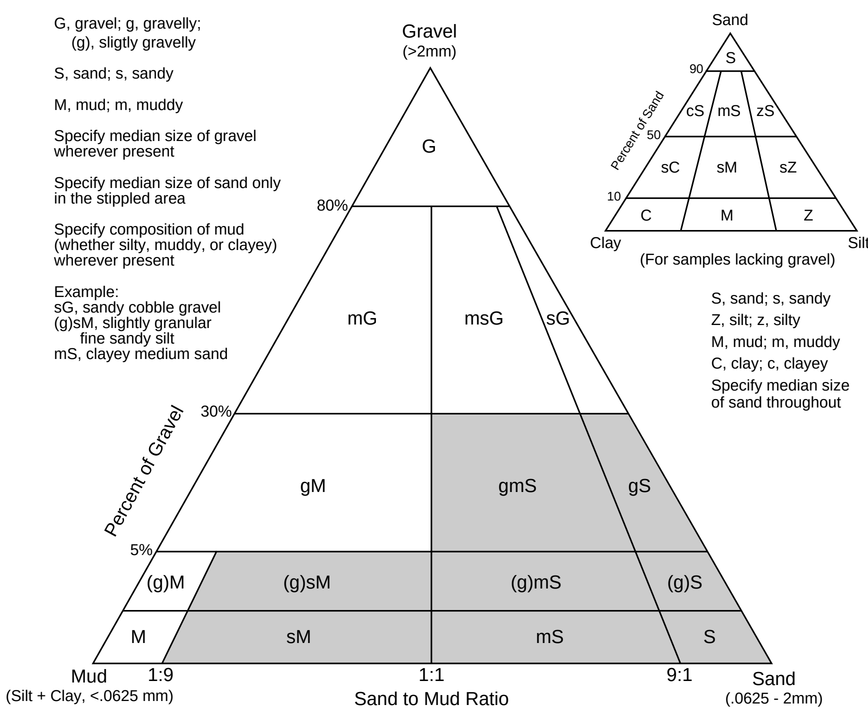

Figure B-14. Classification of sediments containing gravel, sand, clay, and silt. Modified from Folk (1974, p. 28).

Definitions of sediment and lithology terms.

1. **Water body** Rivers, lakes and other bodies of water.
2. I**gneous-plutonic** Rocks that formed from magma that solidified beneath the Earth's surface. For classification purposes, igneous rocks that are phaneritic, generally having grain size greater than 1 mm.
   2.1. **Plutonic QAPF rocks** Plutonic rocks that have color index (M) less than 90 percent. They can be classified according to the modal proportion of quartz (Q), alkali feldspar (A), plagioclase (P), and feldspathoids (F) (Le Maitre and others, 2002).
      2.1.1. **Dioritoid-granitoid (calc-alkaline) plutonic suite** A collective term for a suite of plutonic rocks that vary between the QAPF "field" classification for dioritoid and granitoid. Chemically, this suite of rocks contains CaO equal to K_2O+Na_2O at 61 percent SiO_2. Contain P>A.
      2.1.2. **Monzonitoid-granitoid (alkali-calcic) plutonic suite** A collective term for a suite of plutonic rocks that vary between QAPF field 9 (monzonite) and the QAPF "field" classification for granitoid. Chemically, this suite of rocks contains CaO equal to K_2O+Na_2O at 51 to 56 percent SiO_2. Contain P subequal A.
      2.1.3. **Monzonitoid-syenitoid (alkaline) plutonic suite** A collective term for a suite of plutonic rocks that vary between QAPF field 9 (monzonite) and the QAPF "field" classification for syenitoid. Chemically, this suite of rocks contain more sodium and/or potassium than is required to form feldspar with the available silica.
      2.1.4. **Quartz-rich-coarse-grained crystalline rock** A collective term for plutonic rocks having a quartz content greater than 60 percent; includes quartzolite and quartz-rich granite (fig. B-1; Le Maitre and others, 2002).
         2.1.4.1. **Quartzolite (silexite)** A collective term for plutonic rocks in which the quartz content is more than 90 percent of the felsic minerals. Defined modally in QAPF field 1a (fig. B-2; Le Maitre and others, 2002). These rocks have Q greater than or equal to 90.
         2.1.4.2. **Quartz-rich granitoid** A collective term for granitic rocks having a quartz content greater than 60 percent of the felsic minerals. Defined modally in QAPF field 1b (fig. B-2; Le Maitre and others, 2002).
      2.1.5. **Granitoid** A term proposed for preliminary use in the QAPF "field" classification (fig. B-1; Le Maitre and others, 2002) for plutonic rocks tentatively identified as granite, granodiorite or tonalite.
         2.1.5.1. **Alkali-feldspar granite** A special term for a variety of granite in which plagioclase is less than 10 percent of the total feldspar. Defined modally in QAPF field 2 (fig. B-2; Le Maitre and others, 2002). These rocks have Q between 20 and 60, and P/(A+P) less than 10.
         2.1.5.2. **Granite** A plutonic rock consisting essentially of quartz, alkali feldspar and sodic plagioclase in variable amounts usually with biotite and/or hornblende. Defined modally in QAPF field 3 (fig. B-2; Le Maitre and others, 2002). These rocks have Q between 20 and 60 percent and P/(A+P) between 10 and 65 percent.
            2.1.5.2.1 **Syenogranite** An optional term for a variety of granite in QAPF field 3a (fig. B-2; Le Maitre and others, 2002) consisting of alkali feldspar with subordinate plagioclase.
            2.1.5.2.2 **Monzogranite** An optional term for a variety of granite in QAPF field 3b (fig. B-2; Le Maitre and others, 2002) having roughly equal amounts of alkali feldspar and plagioclase.
         2.1.5.3. **Granodiorite** A plutonic rock consisting essentially of quartz, sodic plagioclase and lesser amounts of hornblende and biotite. Name first used by Becker on maps of the Gold Belt of the Sierra Nevada. Defined modally in QAPF field 4 (fig. B-2; Le

Maitre and others, 2002).These rocks have Q between 20 and 60 percent and P/(A+P) between 65 and 90 percent.

2.1.5.4. **Tonalite** A plutonic rock consisting essentially of quartz and intermediate plagioclase, usually with biotite and amphibole. Defined modally in QAPF field 5 (fig. B-2; Le Maitre and others, 2002). These rocks have Q between 20 and 60 percent and P/(A+P) greater than 90 percent.

2.1.6. **Syenitoid** A term proposed for preliminary use in the QAPF "field" classification (fig. B-1; Le Maitre and others, 2002) for plutonic rocks tentatively identified as syenite or monzonite. These rocks have Q less than 20 percent or F less than 10 percent, and P/(A+P) less than 65 percent.

2.1.6.1. **Quartz-alkali-feldspar syenite** A felsic plutonic rock composed mainly of alkali feldspar, quartz and mafic minerals. Defined modally in QAPF field 6* (fig. B-2; Le Maitre and others, 2002).

2.1.6.2. **Alkali-feldspar syenite** A special term for a variety of syenite in which plagioclase is less than 10 percent of the total feldspar. Defined modally in QAPF field 6 (fig. B-2; Le Maitre and others, 2002). These rocks have Q between 0 and 5 percent, and P/(A+P) less than 10 percent.

2.1.6.3. **Foid-bearing-alkali-feldspar syenite** A collective term for alkali feldspar syenites containing small amounts of feldspathoids (less than 10 percent of the felsic minerals). Defined modally in QAPF field 6' (fig. B-2; Le Maitre and others, 2002).

2.1.6.4. **Quartz syenite** A plutonic rock consisting essentially of alkali feldspar, quartz and mafic minerals. Defined modally in QAPF field 7* (fig. B-2; Le Maitre and others, 2002). These rocks have Q between 5 and 20 percent and P/(A+P) between 10 and 35 percent.

2.1.6.5. **Syenite** A plutonic rock consisting mainly of alkali feldspar with subordinate sodic plagioclase, biotite, pyroxene, amphibole and occasional fayalite. Minor quartz or nepheline may also be present. Defined modally in QAPF field 7 (fig. B-2; Le Maitre and others, 2002). These rocks have Q less than 5 percent or F/(F+A+P) less than 10 percent, and P/(A+P) between 10 and 35 percent.

2.1.6.6. **Foid-bearing syenite** A collective term for syenites containing small amounts of feldspathoids (less than 10 percent of the felsic minerals). Defined modally in QAPF field 7' (fig. B-2; Le Maitre and others, 2002).

2.1.6.7. **Quartz monzonite** A plutonic rock consisting of approximately equal amounts of alkali feldspar and plagioclase and with essential quartz but not enough to make the rock a granite. Defined modally in QAPF field 8* (fig. B-2; Le Maitre and others, 2002). These rocks have Q between 5 and 20 percent and P/(A+P) between 35 and 65 percent.

2.1.6.8. **Monzonite** A term commonly used for a plutonic rock containing almost equal amounts of plagioclase and alkali feldspar with minor amphibole and/or pyroxene. Defined modally in QAPF field 8 (fig. B-2; Le Maitre and others, 2002). These rocks have Q less than 5 percent or F/(F+A+P) less than 10 percent, and P/(A+P) between 35 and 65 percent.

2.1.6.9. **Foid-bearing monzonite** A collective term for monzonites containing small amounts of feldspathoids (less than 10 percent of the felsic minerals). Defined modally in QAPF field 8' (fig. B-2; Le Maitre and others, 2002).

2.1.7. **Dioritoid/gabbroid/anorthosite** A term proposed for preliminary use in the QAPF "field" classification (Streckeisen, 1973; figure 5a) for plutonic rocks tentatively identified as diorite, gabbro, or anorthosite. These rocks have Q less than 20 percent or F less than 10 percent, and P/(A+P) greater than 65 percent (fig. B-1; Le Maitre and others, 2002).

2.1.7.1. **Quartz monzodiorite** A plutonic rock consisting of essentially of sodic plagioclase, alkali feldspar, quartz and mafic minerals. Defined modally in QAPF field 9* (fig. B-2; Le Maitre and others, 2002). These rocks have Q between 5 and 20 percent and P/(A+P) between 65 and 90 percent, and plagioclase more sodic than An_{50}.

2.1.7.2. **Quartz monzogabbro** A plutonic rock consisting of essentially of calcic plagioclase, alkali feldspar, mafic minerals and quartz. Defined modally in QAPF field 9* (fig. B-2; Le Maitre and others, 2002).

2.1.7.3. **Monzodiorite** A plutonic rock intermediate between monzonite and diorite. Defined modally in QAPF field 9 (fig. B-2; Le Maitre and others, 2002). These rocks have Q less than 5 percent or F/(F+A+P) less than 10 percent, and P/(A+P) between 65 and 90 percent, and plagioclase more sodic than An_{50}.

2.1.7.4. **Monzogabbro** A plutonic rock of gabbroic aspect that contains minor but essential orthoclase as well as calcic plagioclase. Defined modally in QAPF field 9 (fig. B-2; Le Maitre and others, 2002).

2.1.7.5. **Foid-bearing monzodiorite** A collective term for monzodiorites containing small amounts of feldspathoids (less than 10 percent of the felsic minerals). Defined modally in QAPF field 9' (fig. B-2; Le Maitre and others, 2002).

2.1.7.6. **Foid-bearing monzogabbro** A collective term for monzogabbros containing small amounts of feldspathoids (less than 10 percent of the felsic minerals). Defined modally in QAPF field 9' (fig. B-2; Le Maitre and others, 2002).

2.1.7.7. **Foid-bearing diorite** A collective term for diorites containing small amounts of feldspathoids (less than 10 percent of the felsic minerals). Defined modally in QAPF field 10' (fig. B-2; Le Maitre and others, 2002).

2.1.7.8. **Foid-bearing gabbro** A collective term for gabbros containing small amounts of feldspathoids (less than 10 percent of the felsic minerals). Defined modally in QAPF field 10' (fig. B-2; Le Maitre and others, 2002).

2.1.7.9. **Foid-bearing anorthosite** A collective term for anorthosites containing small amounts of feldspathoids (less than 10 percent of the felsic minerals). Defined modally in QAPF field10' (fig. B-2; Le Maitre and others, 2002).

2.1.7.10. **Quartz diorite** Plutonic rocks consisting essentially of plagioclase, quartz and mafic minerals. Defined modally in QAPF field 10* (fig. B-2; Le Maitre and others, 2002). These rocks have Q between 5 and 20 percent, P/(A+P) greater than 90 percent, and plagioclase more sodic than An_{50}.

2.1.7.11. **Quartz gabbro** A plutonic rock composed mainly of calcic plagioclase, clinopyroxene and quartz. Defined modally in QAPF field 10* (fig. B-2; Le Maitre and others, 2002).

2.1.7.12. **Quartz anorthosite** A leucocratic plutonic rock consisting essentially of calcic plagioclase, quartz and small amounts of pyroxene. Defined modally in QAPF field 10* (fig. B-2; Le Maitre and others, 2002).

2.1.7.13. **Diorite** A plutonic rock consisting of intermediate plagioclase, commonly with hornblende and often with biotite or augite. Defined modally in QAPF field 10 (fig. B-2; Le Maitre and others, 2002). These rocks have Q between 0 and 5 percent or F/(F+A+P) less than 10 percent, P/(A+P) greater than 90 percent and plagioclase more sodic than An_{50}.

2.1.7.14. **Gabbro** A plutonic rock composed essentially of calcic plagioclase, pyroxene and iron oxides. Defined modally in QAPF field 10 (fig. B-2; Le Maitre and others, 2002). These rocks have Q between 0 and 5 percent or F/(F+A+P) less than 10 percent, P/(A+P) greater than 90 percent and plagioclase more calcic than An_{50}.

2.1.7.14.1 **Gabbro (s.s.)** A special name for rock defined modally in QAPF field 10 (fig. B-2; Le Maitre and others, 2002) that consists of plagioclase and clinopyroxene.

2.1.7.14.2 **Gabbronorite** A collective name for a plutonic rock consisting of calcic plagioclase and roughly equal amounts of clinopyroxene and orthopyroxene. Defined modally in the gabbroic rock classification (fig. B-3; Le Maitre and others, 2002). In these rocks, pl/(pl+px+ol) and pl/(pl+px+hbl) are between 10 and 90 percent, and ol/(pl+px+ol) and hbl/(pl+px+hbl) are less than 5 percent.

2.1.7.14.3 **Norite** A plutonic rock composed essentially of bytownite, labradorite or andesine and orthopyroxene. Defined modally in the gabbroic rock classification (fig. B-3; Le Maitre and others, 2002). In these rocks, pl/(pl+px+ol) is between 10 and 90 percent and opx/(opx+cpx) is greater than 95 percent.

2.1.7.14.4 **Olivine gabbro** A commonly used name for a gabbro containing essential olivine. Defined modally in the gabbroic rock classification (fig. B-3; Le Maitre and others, 2002) as a variety of gabbro in which olivine is between 5 percent and 85 percent.

2.1.7.14.5 **Olivine gabbronorite** A collective term for plutonic rocks consisting of 10 to 90 percent calcic plagioclase and accompanied by olivine, orthopyroxene and clinopyroxene in various amounts. Defined modally in the gabbroic rock classification (fig. B-3; Le Maitre and others, 2002) as a variety of gabbronorite in which olivine is between 5 percent and 85 percent.

2.1.7.14.6 **Olivine norite** A plutonic rock defined modally in the gabbroic rock classification (fig. B-3; Le Maitre and others, 2002) as a variety of norite in which olivine is between 5 percent and 85 percent.

2.1.7.14.7 **Troctolite** A variety of gabbro composed essentially of highly calcic plagioclase and olivine with little or now pyroxene. Defined modally in the gabbroic rock classification (fig. B-3; Le Maitre and others, 2002). In these rocks, pl/(pl+px+ol) is between 10 and 90 percent and px/(pl+px+ol) is less than 5 percent.

2.1.7.14.8 **Pyroxene-hornblende gabbro** Defined modally in the gabbroic rock classification (fig. B-3; Le Maitre and others, 2002) as a variety of gabbro in which hornblende is between 5 percent and 85 percent.

2.1.7.14.9 **Pyroxene-hornblende gabbronorite** Defined modally in the gabbroic rock classification (fig. B-3; Le Maitre and others, 2002) as a variety of gabbronorite in which hornblende is between 5 percent and 85 percent.

2.1.7.14.10 **Pyroxene-hornblende norite** Defined modally in the gabbroic rock classification (fig. B-3; Le Maitre and others, 2002) as a variety of norite in which hornblende is between 5 percent and 85 percent.

2.1.7.14.11 **Hornblende gabbro** A variety of gabbro in which primarily hornblende occurs. Defined modally in the gabbroic rock classification (fig. B-3; Le Maitre and others, 2002). In these rocks, pl/(pl+hbl+px) is between 10 and 90 percent, and px/(pl+hbl+px) is less than 5 percent.

2.1.7.15. **Anorthosite** A leucocratic plutonic rock consisting essentially of plagioclase often with small amounts of pyroxene. Defined modally in QAPF field 10 (fig. B-2; Le Maitre and others, 2002).

2.1.8. **Foid syenitoid** A term proposed for preliminary use in the QAPF "field" classification (Le Maitre and others, 2002, fig. 2.10, p. 29) for plutonic rocks thought to contain essential foids and in which alkali feldspar is thought to be more abundant than plagioclase (fig. B-1; Le Maitre and others, 2002).

2.1.8.1. **Foid syenite** A collective term for leucocratic alkaline plutonic rocks consisting of feldspathoids, alkali feldspar and mafic minerals. Defined modally in QAPF field 11 (fig. B-2; Le Maitre and others, 2002). These rocks have F between 10 and 60 percent, and P/(A+P) less than 10 percent.

2.1.8.2. **Foid monzosyenite** A collective term for rare alkaline plutonic rocks consisting of feldspathoids, alkali feldspar, plagioclase and mafic minerals. Defined modally in QAPF field 12 (fig. B-2; Le Maitre and others, 2002). These rocks have F between 10 and 60 percent, and P/(A+P) between 10 and 50 percent.

2.1.9. **Foid dioritoid and foid gabbroid** A term proposed for preliminary use in the QAPF "field" classification (fig. B-1; Le Maitre and others, 2002) for plutonic rocks thought to contain essential foids and in which plagioclase is thought to be more abundant than alkali feldspar.

2.1.9.1. **Foid monzodiorite** A collective term for alkaline plutonic rocks consisting of feldspathoids, intermediate plagioclase with subordinate alkali feldspar and large amounts of mafic minerals. Defined modally in QAPF field 13 (fig. B-2; Le Maitre and others, 2002). These rocks have F between 10 and 60 percent, P/(A+P) between 50 and 90 percent, and plagioclase more sodic than An_{50}.

2.1.9.2. **Foid monzogabbro** A collective term for basic alkaline plutonic rocks consisting of feldspathoids (10 to 60 percent of the felsic minerals), calcic plagioclase with subordinate alkali feldspar and large amounts of mafic minerals. Defined modally in QAPF field 13 (fig. B-2; Le Maitre and others, 2002).

2.1.9.3. **Foid diorite** A collective term for alkaline plutonic rocks consisting of feldspathoids, intermediate plagioclase and large amounts of mafic minerals. Defined modally in QAPF field 14 (fig. B-2; Le Maitre and others, 2002). These rocks have F between 10 and 60 percent, P/(A+P) greater than 90 percent, and plagioclase more sodic than An_{50}.

2.1.9.4. **Foid gabbro** A collective term for basic alkaline plutonic rocks consisting of feldspathoids (10 to 60 percent of the felsic minerals), calcic plagioclase and large amounts of mafic minerals. Defined modally in QAPF field 14 (fig. B-2; Le Maitre and others, 2002).

2.1.10. **Foidolite** A general term for plutonic rocks defined in QAPF field 15 (fig. B-2; Le Maitre and others, 2002), i.e. rocks containing more than 60 percent foids in total light colored constituents. If possible the most abundant foid should be used in the name, e.g. nephelinolite, leucitolite etc.

2.2. **Ultramafic rock** An igneous rock consisting essentially of mafic minerals. Defined as a rock with M greater than 90 percent (fig. B-4; Le Maitre and others, 2002).

2.2.1. **Peridotite** A collective term for ultramafic rocks consisting essentially of olivine with pyroxene and/or amphibole. Defined modally in the ultramafic rock classification (fig. B-4; Le Maitre and others, 2002). These rocks have M equal to or greater than 90 percent and ol/(ol+opx+cpx) greater than 40 percent.

2.2.1.1. **Dunite** An ultramafic plutonic rock consisting essentially of olivine. Defined modally in the ultramafic rock classification (fig. B-4; Le Maitre and others, 2002). These rocks have M equal to or greater than 90 percent and ol/(ol+opx+cpx) greater than 90 percent.

2.2.1.2. **Pyroxene peridotite** A term for ultramafic plutonic rocks composed mainly of olivine with up to 50 percent pyroxene. Defined modally in the ultramafic rock classification (fig. B-4; Le Maitre and others, 2002). These rocks have M equal to or greater than 90 percent, ol/(ol+hbl+px) between 40 and 90 percent, and hbl/(ol+hbl+px) less than 5 percent.

2.2.1.3. **Harzburgite** An ultramafic plutonic rock composed essentially of olivine and orthopyroxene. Defined modally in the ultramafic rock classification (fig. B-4; Le Maitre and others, 2002). These rocks have M equal to or greater than 90 percent, ol/(ol+opx+cpx) between 40 and 90 percent, and cpx/ol+opx+cpx) less than 5 percent.

2.2.1.4. **Lherzolite** An ultramafic plutonic rock composed essentially of olivine, clinopyroxene, and orthopyroxene. These rocks have M equal to or greater than 90 percent, ol/(ol+opx+cpx) between 40 and 90 percent (fig. B-4; Le Maitre and others, 2002).

2.2.1.5. **Wehrlite** An ultramafic plutonic rock composed of olivine and clinopyroxene often with minor brown hornblende. Defined modally in the ultramafic rock classification (fig. B-4; Le Maitre and others, 2002).

2.2.1.6. **Pyroxene-hornblende peridotite** An ultramafic plutonic rock consisting of 40 to 90 percent olivine and various amounts of pyroxene and amphibole. Defined modally in the ultramafic rock classification (fig. B-4; Le Maitre and others, 2002).

2.2.1.7. **Hornblende peridotite** An ultramafic plutonic rock consisting essentially of olivine with up to 50 percent amphibole. Defined modally in the ultramafic rock classification (fig. B-4; Le Maitre and others, 2002). These rocks have M equal to or greater than 90 percent, ol/(ol+hbl+px) between 40 and 90 percent, and px/(ol+hbl+px) less than 5 percent.

2.2.2. **Pyroxenite** A collective term for ultramafic plutonic rocks composed almost entirely of one or more pyroxenes and occasionally biotite, hornblende and olivine. Defined modally in the ultramafic rock classification (fig. B-4; Le Maitre and others, 2002). These rocks have M equal to or greater than 90 percent and ol/(ol+opx+cpx) less than 40 percent.

2.2.2.1. **Olivine pyroxenite** An ultramafic plutonic rock consisting essentially of pyroxene and up to 50 percent olivine. Defined modally in the ultramafic rock classification (fig. B-4; Le Maitre and others, 2002). These rocks have M equal to or greater than 90 percent, ol/(ol+hbl+px) between 5 and 40 percent, hbl/(ol+hbl+px) less than 5 percent, and px/(ol+hbl+px) less than 90 percent.

2.2.2.2. **Olivine orthopyroxenite** An ultramafic plutonic rock consisting essentially of orthopyroxene and up to 50 percent olivine. Defined modally in the ultramafic rock classification (fig. B-4; Le Maitre and others, 2002). These rocks have M equal to or greater than 90 percent, ol/(ol+opx+cpx) between 5 and 40, cpx/(ol+opx+cpx) less than 5 percent and opx/(ol+opx+cpx) less than 90 percent.

2.2.2.3. **Olivine websterite** An ultramafic plutonic rock consisting of 10 to 40 percent olivine with various amounts of clinopyroxene and orthopyroxene. Defined modally in the ultramafic rock classification (fig. B-4; Le Maitre and others, 2002). These rocks have M equal to or greater than 90 percent, ol/(ol+opx+cpx) between 5 and 40 percent, opx/(ol+opx+cpx) greater than 5 percent, and cpx/(ol+opx+cpx) greater than 5 percent.

2.2.2.4. **Olivine clinopyroxenite** An ultramafic plutonic rock consisting essentially of clinopyroxene and up to 50 percent olivine. Defined modally in the ultramafic rock classification (fig. B-4; Le Maitre and others, 2002). These rocks have M equal to or greater than 90 percent, ol/(ol+opx+cpx) between 5 and 40 percent, opx/(ol+opx+cpx) less than 5 percent, and cpx/(ol+opx+cpx) less than 90 percent.

2.2.2.5. **Pyroxenite (s.s.)** A special name for and ultramafic plutonic rock (M equal to or greater than 90 percent) in which pyroxene makes up more than 90 percent of the rock (fig. B-4; Le Maitre and others, 2002).

2.2.2.6. **Orthopyroxenite** An ultramafic plutonic rock consisting almost entirely of orthopyroxene. Defined modally in the ultramafic rock classification (fig. B-4; Le Maitre and others, 2002). These rocks have M equal to or greater than 90 percent, and opx/(ol+opx+cpx) greater than 90 percent.

2.2.2.7. **Websterite** A variety of pyroxenite consisting of equal amounts of orthopyroxene and clinopyroxene. Defined modally in the ultramafic rock classification (fig. B-4; Le Maitre and others, 2002).

2.2.2.8. **Clinopyroxenite** An ultramafic plutonic rock consisting almost entirely of clinopyroxene. Defined modally in the ultramafic rock classification (fig. B-4; Le Maitre and others, 2002). These rocks have M equal to or greater than 90 percent, and cpx/(ol+opx+cpx) greater than 90 percent.

2.2.2.9. **Olivine-hornblende pyroxenite** An ultramafic plutonic rock consisting of more than 30 percent pyroxene accompanied by amphibole and olivine in various amounts. Defined modally in the ultramafic rock classification (fig. B-4; Le Maitre and others, 2002).

2.2.2.10. **Hornblende pyroxenite** A collective term for pyroxenites containing up to 50 percent of amphibole. Defined modally in the ultramafic rock classification (fig. B-4; Le Maitre and others, 2002). These rocks have M equal to or greater than 90 percent, ol/(ol+hbl+px) less than 5 percent, and px/(px+hbl) between 50 and 90 percent.

2.2.3. **Hornblendite** A collective term for ultramafic plutonic rock with a large proportion of hornblende. Defined modally in the ultramafic rock classification (fig. B-4; Le Maitre and others, 2002). These rocks have M equal to or greater than 90; ol/(hbl+px+ol) less than 40 percent; and hbl:px greater than 1.

2.2.3.1. **Olivine hornblendite** An ultramafic plutonic rock consisting essentially of amphibole and up to 50 percent olivine. Defined modally in the ultramafic rock classification (fig. B-4; Le Maitre and others, 2002). These rocks have M equal to or greater than 90 percent, ol/(ol+hbl+px) between 5 and 40, px/(ol+hbl+px) less than 5 percent, and hbl/(ol+hbl+px) less than 90 percent.

2.2.3.2. **Olivine-pyroxene hornblendite** An ultramafic plutonic rock consisting of more than 30 percent amphibole accompanied by pyroxene and olivine in various amounts. Defined modally in the ultramafic rock classification (fig. B-4; Le Maitre and others, 2002). These rocks have M equal to or greater than 90 percent, ol/(ol+hbl+px) between 5 and 40 percent, and amphibole more abundant than pyroxene.

2.2.3.3. **Pyroxene hornblendite** A term for ultramafic plutonic rocks composed mainly of amphibole with up to 50 percent pyroxene. Defined modally in the ultramafic rock classification (fig. B-4; Le Maitre and others, 2002). These rocks have M equal to or greater than 90 percent, ol/(ol+hbl+px) less than 5 percent, and hbl/(px+hbl) between 50 and 90 percent.

2.2.3.4. **Hornblendite (s.s.)** An ultramafic plutonic rock composed almost entirely of hornblende. Defined modally in the ultramafic rock classification (fig. B-4; Le Maitre and others, 2002). These rocks have M equal to or greater than 90 percent and hbl/(hbl+px+ol) greater than 90 percent.

3. **Igneous-volcanic** Rocks that formed from magma that solidified on or near the Earth's surface. For classification purposes, igneous rocks that are aphanitic, generally having grain size less than 1 mm.

3.1. **Volcanic QAPF rocks** Volcanic rocks that have color index (M) less than 90 percent. In some instances, they can be classified according to the modal proportion of quartz (Q), alkali feldspar (A), plagioclase (P), and feldspathoids (F). These rocks can also be classified on the basis of their chemical composition (Le Maitre and others, 2002).

3.1.1. **Andesitoid-rhyolitoid (calc-alkalic) volcanic suite** A collective term for a suite of volcanic rocks that vary between the QAPF "field" classification for basaltoid/andesitoid and rhyolitoid. Chemically, this suite of rocks contains CaO equal to K_2O+Na_2O at 61 percent SiO_2. Contain P>A.

3.1.2. **Latitic-rhyolitic (alkali-calcic) volcanic suite** A collective term for a suite of volcanic rocks that vary between QAPF field 8 (latite) and the QAPF "field" classification for rhyolitoid. Chemically, this suite of rocks contain CaO equal to K_2O+Na_2O at 51 to 56 percent SiO_2. Contain P subequal A.

3.1.3. **Latitic-trachytic (alkaline) volcanic suite** A collective term for a suite of volcanic rocks that vary between QAPF field 8 (latite) and the QAPF "field" classification for trachytoid. Chemically, this suite of rocks contain more sodium and/or potassium than is required to form feldspar with the available silica. Contain A>P.

3.1.4. **Rhyolitoid** A term proposed for preliminary use in the QAPF "field" classification (fig. B-5; Le Maitre and others, 2002) for volcanic rocks tentatively identified as rhyolite.

3.1.4.1. **Alkali feldspar rhyolite** A special term for a variety of rhyolite in which plagioclase is less than 10 percent of the total feldspar. Defined modally in QAPF field 2 (fig. B-6; Le Maitre and others, 2002).

3.1.4.2. **Rhyolite** A collective term for silicic volcanic rocks consisting of phenocrysts of quartz and alkali feldspar, often with minor plagioclase and biotite, in a microcrystalline or glassy groundmass and having the chemical composition of granite. Defined modally in QAPF field 3 (fig. B-6; Le Maitre and others, 2002). These rocks have Q/(Q+A+P) between 20 and 60 percent and P/(P+A) between 10 and 35 percent. If modes are not available, chemically in TAS field R (fig. B-7; Le Maitre and others, 2002).

3.1.5. **Dacitoid** A term proposed for preliminary use in the QAPF "field" classification (fig. B-5; Le Maitre and others, 2002) for volcanic rocks tentatively identified as dacite.

3.1.5.1. **Dacite** A volcanic rock composed of quartz and sodic plagioclase with minor amounts of biotite and/or hornblende and/or pyroxene. The volcanic equivalent of granodiorite and tonalite. Defined modally in QAPF fields 4 and 5 (fig. B-6; Le Maitre and others, 2002). These rocks have Q/(Q+A+P) between 20 and 60 percent and P/(P+A) greater than 65 percent. If modes are not available, chemically in TAS field 03 (fig. B-7; Le Maitre and others, 2002).

3.1.6. **Rhyodacite** A term used for volcanic rocks intermediate between rhyolite and dacite, usually consisting of phenocrysts of quartz, plagioclase and a few ferromagnesian minerals in a microcrystalline groundmass (Le Maitre and others, 2002).

3.1.7. **Trachytoid** A term proposed for preliminary use in the QAPF "field" classification (fig. B-5; Le Maitre and others, 2002) for volcanic rocks tentatively identified as trachyte.

3.1.7.1. **Quartz-alkali feldspar trachyte** A felsic volcanic rock composed mainly of alkali feldspar, quartz and mafic minerals. Defined modally in QAPF field 6* (fig. B-6; Le Maitre and others, 2002).

3.1.7.2. **Alkali feldspar trachyte** A special term for a variety of trachyte in which plagioclase is less than 10 percent of the total feldspar. Defined modally in QAPF field 6 (fig. B-6; Le Maitre and others, 2002).

3.1.7.3. **Foid-bearing alkali-feldspar trachyte** A collective term for alkali feldspar trachytes containing small amounts of feldspathoids (less than 10 percent of the felsic minerals). Defined modally in QAPF field 6' (fig. B-6; Le Maitre and others, 2002).

3.1.7.4. **Quartz trachyte** A volcanic rock consisting of phenocrysts of alkali feldspar and quartz in a cryptocrystalline or glassy matrix. It is the volcanic equivalent of quartz syenite. Defined modally in QAPF field 7* (fig. B-6; Le Maitre and others, 2002). These rocks have normative quartz between 5 and 20 percent.

3.1.7.5. **Trachyte** A volcanic rock consisting essentially of alkali feldspar. Defined modally in QAPF field 7 (fig. B-6; Le Maitre and others, 2002) and, if modes are not available, chemically in TAS field T (fig. B-7; Le Maitre and others, 2002). These rocks have Q/(Q+A+P) less than 20 percent or F/(F+A+P) less than 10 percent, and P/(P+A) between 10 and 35 percent.

3.1.7.6. **Foid-bearing trachyte** A collective term for trachytes containing small amounts of feldspathoids (less than 10 percent of the felsic minerals). Defined modally in QAPF field 7' (fig. B-6; Le Maitre and others, 2002).

3.1.7.7. **Quartz latite** Volcanic rocks composed of alkali feldspar and plagioclase in roughly equal amounts, quartz and mafic minerals. Defined modally in QAPF field 8* (fig. B-6; Le Maitre and others, 2002). These rocks have Q/(Q+A+P) between 5 and 20 percent and P/(P+A) between 35 and 65 percent.

3.1.7.8. **Latite** A volcanic rock composed of approximately equal amounts of alkali feldspar and sodic plagioclase, i.e. the volcanic equivalent of monzonite. Defined modally in QAPF field 8 (fig. B-6; Le Maitre and others, 2002, fig. 2.11, p. 31). These rocks have Q/(Q+A+P) less than 5 percent or F/(F+A+P) less than 10 percent, and P/(P+A) between 35 and 65 percent. If modes are not available, these rocks are defined chemically as the potassic variety of trachyandesite in TAS field S3 (fig. B-7; Le Maitre and others, 2002).

3.1.7.9. **Foid-bearing latite** A collective term for latites containing small amounts of feldspathoids (less than 10 percent of the felsic minerals). Defined modally in QAPF field 8' (fig. B-6; Le Maitre and others, 2002).

3.1.7.10. **Trachydacite (TAS)** A term originally used for a variety of rhyolite containing bronzite (=enstatite) and an alkali feldspar to oligoclase ratio of 2:1. Defined chemically as rocks with more than 20 percent normative quartz in TAS field T (fig. B-7; Le Maitre and others, 2002).

3.1.7.11. **Trachyandesite (TAS)** A term originally used for volcanic rocks intermediate in composition between trachyte and andesite and containing approximately equal amounts of alkali feldspar and plagioclase. Later used for volcanic rocks containing foids as well as alkali feldspar and plagioclase. Defined chemically in TAS field S3 (fig. B-7; Le Maitre and others, 2002).

3.1.7.11.1 **Benmoreite (TAS)** A volcanic rocks consisting essentially of anorthoclase or sodic sanidine, Fe-olivine and ferroaugite (= augite). Defined chemically as the sodic variety of trachyandesite in TAS field S3 (fig. B-7; Le Maitre and others, 2002).

3.1.7.12. **Basaltic trachyandesite (TAS)** A group term introduced for rocks intermediate between trachyandesite and trachybasalt, i.e. an analogous name to basaltic andesite in the oversaturated rocks. Defined chemically in TAS field S2 (fig. B-7; Le Maitre and others, 2002).

3.1.7.12.1 **Mugearite (TAS)** A volcanic rock, often exhibiting flow texture, containing small phenocrysts of olivine, augite, and magnetite in a matrix of oligoclase, augite and magnetite with interstitial alkali feldspar. Defined chemically as the sodic variety of basaltic trachyandesite in TAS field S2 (fig. B-7; Le Maitre and others, 2002.

3.1.7.12.2 **Shoshonite (TAS)** A collective term for a trachyandesitic rock generally described as an orthoclase-bearing basalt. Defined chemically as the potassic variety of basaltic trachyandesite in TAS field S2 (fig. B-7; Le Maitre and others, 2002).

3.1.7.13. **Trachybasalt (TAS)** A term used for basaltic volcanic rocks containing labradorite and alkali feldspar. Defined chemically in TAS field S 1 (fig. B-7; Le Maitre and others, 2002).

3.1.7.13.1 **Hawaiite (TAS)** A term originally defined as a variety of olivine-bearing basalt in which the normative plagioclase is oligoclase or andesine. Defined chemically as the sodic variety of trachybasalt in TAS field S1 (fig. B-7; Le Maitre and others, 2002).

3.1.7.13.2 **Potassic trachybasalt (TAS)** A term introduced for the potassic analogue of hawaiite in TAS field S1 (fig. B-7; Le Maitre and others, 2002) to distinguish it from trachybasalt which is the collective name of the field.

3.1.8. **Andesitoid/basaltoid** A term proposed preliminary use in the QAPF "field" classification (fig. B-5; Le Maitre and others, 2002) for volcanic rocks tentatively identified as basalt or andesite.

3.1.8.1. **Andesite** An intermediate volcanic rock, usually porphyritic, consisting of plagioclase (frequently zoned from labradorite to oligoclase), pyroxene, hornblende and/or biotite. Defined modally in QAPF fields 9 and 10 (fig. B-6; Le Maitre and others, 2002). These rocks have Q/(Q+A+P) less than 20 percent or F/(F+A+P) less than 10 percent, P/(A+P) greater than 90 percent, and M less than 35.

3.1.8.2. **Basalt** A volcanic rock consisting essentially of calcic plagioclase and pyroxene. Olivine and minor foids or minor interstitial quartz may also be present. Defined modally in QAPF fields 9 and 10 (fig. B-6; Le Maitre, 2002). These rocks have Q/(Q+A+P) less than 20 percent or F/(F+A+P) less than 10 percent, P/(A+P) greater than 90 percent, and M greater than 35 percent. If modes are not available, chemically in TAS field B (fig. B-7; Le Maitre and others, 2002).

3.1.8.3. **Basaltic andesite (TAS)** A term for a volcanic rock which has plagioclase of variable composition with the ferromagnesian minerals more commonly found in basalts, e.g. olivine. Defined chemically in TAS field O1 (fig. B-7; Le Maitre and others, 2002).

3.1.9. **Phonolitoid** A term proposed for preliminary use in the QAPF "field" classification (fig. B-5; Le Maitre and others, 2002) for volcanic rocks thought to contain essential foids and in which alkali feldspar is thought to be more abundant than plagioclase.

3.1.9.1. **Phonolite** Defined in QAPF field 11 (fig. B-6; Le Maitre and others, 2002) as a volcanic rock consisting essentially of alkali feldspar and any foids. These rocks have F/(F+A+P) between 10 an 60 percent, and P/(P+A) less than 10 percent. If nepheline is the only foid then the term phonolite may be used by itself but if, leucite is the most abundant foid then the term leucite phonolite should be used, etc. If modes are not available phonolite is defined chemically in TAS field Ph (fig. B-7; Le Maitre and others, 2002).

3.1.9.2. **Tephritic phonolite** A collective term for alkaline volcanic rocks consisting of alkali feldspar, sodic plagioclase, feldspathoid and various mafic minerals. Defined modally in QAPF field 12 (fig. B-6; Le Maitre and others, 2002).

3.1.9.3. **Tephri-phonolite (TAS)** A synonym for tephritic phonolite of QAPF field 12 (fig. B-6; Le Maitre, 2002) and also defined chemically in TAS field U3 (fig. B-7; Le Maitre and others, 2002).

3.1.10. **Tephritoid** A term proposed for preliminary use in the QAPF "field" classification (fig. B-5; Le Maitre and others, 2002) for volcanic rocks thought to contain essential foids and in which plagioclase is thought to be more abundant than alkali feldspar.

3.1.10.1. **Phonolitic basanite** A collective term for alkaline basaltic rocks that are the volcanic equivalent to foid monzodiorites or monzogabbros and consist of plagioclase, feldspathoid, olivine, augite and often minor sanidine. If the amount of olivine is less than 10 percent it is a phonolitic tephrite. Defined modally in QAPF field 13 (fig. B-6; Le Maitre and others, 2002).

3.1.10.2. **Phonolitic tephrite** A collective term for alkaline volcanic rocks consisting of plagioclase, feldspathoid, augite and often minor olivine and sanidine. If the amount of olivine is greater than 10 percent it is a phonolitic basanite. Defined modally in QAPF field 13 (fig. B-6; Le Maitre, and others 2002).

3.1.10.3. **Basanite** A term used as a group name for rocks composed of clinopyroxene, plagioclase, essential foids and olivine. Defined modally in QAPF field 14 (fig. B-6; Le Maitre and others, 2002) and, if modes are not available, chemically in TAS field U1 (fig. B-7; Le Maitre and others, 2002).

3.1.10.4. **Tephrite** An alkaline volcanic rock composed essentially of calcic plagioclase, clinopyroxene and feldspathoid. Now defined modally in QAPF field 14 (fig. B-6; Le Maitre and others, 2002) and, if modes are not available, chemically in TAS field U1 (fig. B-7; Le Maitre and others, 2002).

3.1.10.5. **phono-tephrite (TAS)** A synonym for phonolitic tephrite of QAPF field 13 (fig. B-6; Le Maitre and others, 2002) and also defined chemically in TAS field U2 (fig. B-7; Le Maitre and others, 2002).

3.1.11. **Foiditoid** A term proposed for preliminary use in the QAPF "field" classification (fig. B-5; Le Maitre and others, 2002) for volcanic rocks tentatively identified as foidite.

3.1.11.1. **Phonolitic foidite** A collective term for alkaline volcanic rocks consisting of foids with some alkali feldspar as defined modally in QAPF field 15a (fig. B-6; Le Maitre and others, 2002). If possible the most abundant foid should be used in the name, e.g. phonolitic nephelinite, phonolitic leucitite.

3.1.11.2. **Basanitic foidite** A collective term for alkaline volcanic rocks consisting of foids with some plagioclase as defined modally in QAPF field 15b (fig. B-6; Le Maitre and others, 2002). It is distinguished from tephritic foidite by having more than 10 percent modal olivine. If possible the most abundant foid should be used in the name, e.g. basanitic nephelinite, basanitic leucitite etc.

3.1.11.3. **Tephritic foidite** A collective term for alkaline volcanic rocks consisting of foids with some plagioclase as defined modally in QAPF field 15b (fig. B-6; Le Maitre and others, 2002). It is distinguished from basanitic foidite by having less than 10 percent modal olivine. If possible the most abundant foid should be used in the name, e.g. tephritic nephelinite, tephritic leucitite etc.

3.1.11.4. **Foidite** A general term for volcanic rocks defined in QAPF field 15 (fig. B-6; Le Maitre and others, 2002), i.e. rocks containing more than 60 percent foids in total light-colored constituents. If modes are not available, chemically defined in TAS field F (fig. B-7; Le Maitre and others, 2002). If possible the most abundant foid should be used in the name, e.g. nephelinite, leucitite etc.

3.1.12. **Picrobasalt (TAS)** A chemical term for volcanic rocks, which will include certain picritic and accumulative rocks, which was introduced for TAS field Pc (fig. B-7; Le Maitre and others, 2002).

3.2. **High-Mg volcanic rocks** A collective term for ultrabasic, basic, and intermediate volcanic rocks enriched in magnesium, such boninite, komatiite, meimechite, and picrite (Le Maitre and others, 2002).

3.2.1. **Boninite** A high magnesia, low alkali, andesitic rock consisting of phenocrysts of protoenstatite (which inverts to clinoenstatite), orthopyroxene, clinopyroxene and olivine in a glassy base full of crystallites. The rock exhibits textures characteristic of rapid growth and was originally described as a hyaloandesite. Defined chemically in the TAS classification (Le Maitre and others, 2002, fig. 2.13, p. 34).

3.2.2. **Picrite** A term used for a variety of basalt extremely rich in olivine and pyroxene. Defined chemically in the TAS classification (Le Maitre and others, 2002, fig. 2.13, p. 34).

3.2.3. **Komatiite** A variety of ultramafic lavas that crystallize from high temperature magmas with 18 percent to 32 percent MgO. They often form pillows and have chilled flow-tops and usually display well-developed spinifex textures with intergrown skeletal and bladed olivine and pyroxene crystals set in abundant glass. The more highly magnesian varieties are often termed peridotitic komatiite. Defined chemically in the TAS classification (Le Maitre and others, 2002, fig. 2.13, p. 34).

3.2.4. **Meimechite** An ultramafic volcanic rock composed of olivine phenocrysts in a groundmass of olivine, clinopyroxene, magnetite and glass. Defined chemically in the TAS classification (Le Maitre and others, 2002, fig. 2.13, p. 34).

4. **Igneous-other** A term for igneous rocks that do not use the classification schemes for ultramafic rocks or QAPF rocks.

4.1. **Carbonatite** A collective term for an igneous rocks in which the modal amount of primary carbonate minerals greater than 50 percent (Le Maitre and others, 2002, section 2.3, p. 10).

4.1.1. **Calcite-carbonatite** A variety of carbonatite in which the main carbonate is calcite (Le Maitre and others, 2002, section 2.3, p. 10).

4.1.2. **Dolomite-carbonatite** A variety of carbonatite in which the main carbonate is dolomite (Le Maitre and others, 2002, section 2.3, p. 10).

4.1.3. **Ferrocarbonatite** A term now used in two senses: (1) modally as a variety of carbonatite in which the main carbonate is iron-rich (p.10) and (2) chemically as a variety of carbonatite in which weight percent CaO / (CaO+MgO+FeO+Fe_2O_3+MnO) less than 0.8 and MgO less than (FeO+Fe_2O_3+MnO) (Le Maitre and others, 2002, fig. 2.2, p. 10).

4.1.4. **Natrocarbonatite** A rare variety of carbonatite lava, currently only known from one locality, consisting essentially of the Na-Ca-K carbonate minerals, nyerereite and gregoryite. It has also been called lengaite (Le Maitre and others, 2002).

4.2. **Melilite-bearing rock** A collective term for an igneous rock that contains greater than 10 percent modal melilite and, if feldspathoids are present, melilite greater than feldspathoid (Le Maitre and others, 2002).

4.3. **Kalsilite-bearing rock** A collective term for an igneous rock containing modal kalsilite. The principal minerals of these igneous rocks include clinopyroxene, kalsilite, leucite, melilite, olivine, and phlogopite (Le Maitre and others, 2002).

4.4. **Lamproite** A comprehensive term originally used for lamprophyric extrusive rocks rich in potassium and magnesium, corresponding to the lamproitic magma-type of Niggli. Lamproite is no longer regarded as a lamprophyre. Now part of the IUGS classification and although it cannot be defined it is characterized by the mineralogical and chemical criteria given in Le Maitre and others (2002, section 2.7, p. 16).

4.5. **Kimberlite** An ultramafic rock consisting of major amounts of serpentinized olivine with variable amounts of phlogopite, orthopyroxene, clinopyroxene, carbonate and chromite. Characteristic accessory minerals include pyrope garnet, monticellite, rutile and perovskite. It cannot be defined but is characterized by the mineralogical criteria given in Le Maitre and others (2002, section 2.6, p. 13).

4.6. **Leucite-bearing rock** A collective term for igneous rock containing modal leucite (Le Maitre and others, 2002).

4.7. **Lamprophyre** A name for a distinctive group of rocks which are strongly porphyritic in mafic minerals, typically biotite, amphiboles and pyroxenes, with any feldspars being confined to the groundmass. They commonly occur as dikes or small intrusions and often show signs of hydrothermal alteration. Further details of the subdivision of these rocks are given in Le Maitre and others (2002, section 2.9 and Table 2.9, p. 19).

4.8. **Mafic igneous rock** An igneous rock composed chiefly of one or more ferromagnesian, dark-colored minerals in its mode (Bates and Jackson, 1987).

4.9. **Felsic igneous rock** An igneous rock having abundant light-colored minerals (quartz, feldspars, feldspathoids, muscovite) in its mode (Bates and Jackson, 1987).

4.9.1. **Porphyry** An igneous rock that contains conspicuous phenocrysts in a fine-grained groundmass (Bates and Jackson, 1987).

5. **Sedimentary rock** A rock resulting from the consolidation of loose sediment that has accumulated in layers (Bates and Jackson, 1987).

5.1. **Siliciclastic sedimentary rocks** Clastic sedimentary rocks primarily made up of silicate minerals (such as quartz, feldspars, and clay minerals) and silicate rock fragments (Bates and Jackson, 1987).

5.1.1. **Mudrock (shale)** A fine-grained siliciclastic sedimentary rocks composed of particles of sand, silt, and clay; the proportion of silt and clay make up more than 50 percent of the rock (fig. B-9; Folk, 1974).

5.1.1.1. **Claystone or clay-shale** A fine-grained siliciclastic sedimentary rocks composed of particles of sand, silt, and clay; the proportion of silt and clay make up more than 50 percent of the rock. This term applies to rocks in which the grain size of the mud fraction is over 2/3 clay (fig. B-9; Folk, 1974).

5.1.1.2. **Mudstone or mud-shale** A fine-grained siliciclastic sedimentary rocks composed of particles of sand, silt, and clay; the proportion of silt and clay make up more than 50 percent of the rock. This term applies to rocks in which the grain size of the mud fraction has subequal amounts of clay and silt (fig. B-9; Folk, 1974).

5.1.1.3. **Siltstone or silt-shale** A fine-grained siliciclastic sedimentary rocks composed of particles of sand, silt, and clay; the proportion of silt and clay make up more than 50 percent of the rock. This term applies to rocks in which the grain size of the mud fraction is over 2/3 silt (fig. B-9; Folk, 1974).

5.1.2. **Wacke** A medium-grained siliciclastic sedimentary rock composed of abundant rounded or angular fragments of sand size set in 15 to 50 percent fine-grained matrix (silt or clay) (fig. B-8; Pettijohn, 1975; Folk, 1974; Bates and Jackson, 1987).

5.1.2.1. **Quartz-wacke** A medium-grained siliciclastic sedimentary rock composed of abundant rounded or angular fragments of sand size set in 15 to 50 percent fine-grained matrix (silt or clay). This term applies to rocks that contain less than 5 percent sand-sized particles of feldspar and less than 5 percent sand-sized particles of rock fragments (fig. B-8; Pettijohn, 1975).

5.1.2.2. **Feldspathic wacke** A medium-grained siliciclastic sedimentary rock composed of abundant rounded or angular fragments of sand size set in 15 to 50 percent fine-grained matrix (silt or clay). This term applies to rocks that contain more than 5 percent sand-sized particles of feldspar and in which the proportion of sand-sized particles of feldspar to rock fragments is greater than 1:1 (fig. B-8; Pettijohn, 1975).

5.1.2.3. **Lithic-wacke** A medium-grained siliciclastic sedimentary rock composed of abundant rounded or angular fragments of sand size set in 15 to 50 percent fine-grained matrix (silt or clay). This term applies to rocks that contain more than 5 percent sand-sized particles of rock fragments and in which the proportion of sand-sized particles of rock fragments to feldspar is greater than 1:1 (fig. B-8; Pettijohn, 1975).

5.1.3. **Sandstone or arenite** A medium-grained siliciclastic sedimentary rock composed almost exclusively of sand-sized particles. Argillaceous material (silt or clay) is less than 15 percent of the rock (fig. B-8; Pettijohn, 1975; Bates and Jackson, 1987).

5.1.3.1. **Quartz-arenite** A medium-grained siliciclastic sedimentary rock containing less than 5 percent sand-sized particles of feldspar and less than 5 percent sand-sized particles of rock fragments. Argillaceous material (silt or clay) is less than 15 percent of the rock (fig. B-8; Pettijohn, 1975).

5.1.3.2. **Subarkose (subfeldspathic arenite)** A medium-grained siliciclastic sedimentary rock containing 5 to 25 percent sand-sized particles of feldspar and in which the proportion of sand-sized particles of feldspar to rock fragments is greater than 1:1. Argillaceous material (silt or clay) is less than 15 percent of the rock (fig. B-8; Pettijohn, 1975).

5.1.3.3. **Sublitharenite (sublithic arenite)** A medium-grained siliciclastic sedimentary rock containing 5 to 25 percent sand-sized particles of rock fragments and in which the proportion of sand-sized particles of rock fragments to feldspar is greater than 1:1. Argillaceous material (silt or clay) is less than 15 percent of the rock (fig. B-8; Pettijohn, 1975).

5.1.3.4. **Arkosic arenite (feldspathic arenite)** A medium-grained siliciclastic sedimentary rock containing more than 25 percent sand-sized particles of feldspar and in which the proportion of sand-sized particles of feldspar to rock fragments is greater than 1:1. Argillaceous material (silt or clay) is less than 15 percent of the rock (fig. B-8; Pettijohn, 1975).

5.1.3.5. **Lithic arenite** A medium-grained siliciclastic sedimentary rock containing more than 25 percent sand-sized particles of rock fragments and in which the proportion of sand-sized particles of rock fragments to feldspar is greater than 1:1. Argillaceous material (silt or clay) is less than 15 percent of the rock (fig. B-8; Pettijohn, 1975).

5.1.4. **Siliciclastic rocks with gravel-sized particles** A coarse-grained siliciclastic sedimentary rock, composed of rounded to subangular fragments larger than 2mm in diameter set in a fine grained matrix of sand or silt, and commonly cemented by calcium carbonate, iron oxide, silica, or hardened clay (Bates and Jackson, 1987).

5.1.4.1. **Well sorted conglomerate** A coarse-grained siliciclastic sedimentary rock containing more than 75 percent pebbles with a matrix of sand, silt, and clay (fig. B-10; Compton, 1962).

5.1.4.2. **Conglomerate** A coarse-grained siliciclastic sedimentary rock containing 25 to 50 percent pebbles with a matrix of sand, silt, and clay. The ratio of sand to silt/clay is greater than 1:1 (fig. B-10; Compton, 1962).

5.1.4.3. **Sandy conglomerate** A coarse-grained siliciclastic sedimentary rock containing 25 to 50 percent pebbles with a matrix of sand, silt, and clay. The ratio of sand to silt/clay is greater than 1:1 (fig. B-10; Compton, 1962).

5.1.4.4. **Muddy conglomerate** A coarse-grained siliciclastic sedimentary rock containing 25 to 50 percent pebbles with a matrix of sand, silt, and clay. The ratio of sand to silt/clay is less than 1:1 (fig. B-10; Compton, 1962).

5.1.4.5. **Pebbly arenite** A coarse-grained siliciclastic sedimentary rock containing less than 25 percent pebbles in a matrix of sand, silt, and clay. The ratio of sand to silt/clay varies is greater than 9:1 (fig. B-10; Compton, 1962).

5.1.4.6. **Pebbly wacke** A coarse-grained siliciclastic sedimentary rock containing less than 25 percent pebbles in a matrix of sand, silt, and clay. The ratio of sand to silt/clay varies between 9:1 and 1:1 (fig. B-10; Compton, 1962).

5.1.4.7. **Pebbly mudstone** A coarse-grained siliciclastic sedimentary rock containing less than 25 percent pebbles in a matrix of sand, silt, and clay. The ratio of sand to silt/clay is less than 1:1 (fig. B-10; Compton, 1962).

5.2. **Carbonate sedimentary rocks** A sedimentary rock consisting primarily of carbonate minerals.

5.2.1. **Limestone** A sedimentary rock containing greater than 75 percent carbonate minerals; the remainder of the rock consists of up to 25 percent siliciclastic material (sand, silt, or clay). Calcite makes up more than 95 percent of the carbonate minerals (figs. B-11 and B-12; Compton, 1962 and Pettijohn, 1975).

5.2.1.1. **Travertine** A dense, finely crystalline massive or concretionary limestone, of white, tan, or cream color, often having a fibrous or concentric structure and splintery fracture, formed by rapid chemical precipitation of calcium carbonate from solution in surface and ground waters, as by agitation of stream water or by evaporation around the mouth or in the conduit of a spring, esp. a hot spring (Bates and Jackson, 1987).

5.2.2. **Magnesian limestone** A sedimentary rock consisting primarily of carbonate minerals in which calcite makes up 90 to 95 percent of the carbonate minerals (fig. B-11; Pettijohn, 1975).

5.2.3. **Dolomitic limestone** A sedimentary rock consisting primarily of carbonate minerals in which calcite:dolomite varies between 9:1 and 1:1 (90 to 50 percent calcite) (fig. B-11; Pettijohn, 1975).

5.2.4. **Calcitic dolomite** A sedimentary rock consisting primarily of carbonate minerals in which calcite:dolomite varies between 1:1 and 1:9 (50 to 10 percent calcite) (fig. B-11; Pettijohn, 1975).

5.2.5. **Dolomite** A sedimentary rock consisting primarily of carbonate minerals in which calcite:dolomite is greater less 1:9 (less than 10 percent calcite) (fig. B-11; Pettijohn, 1975).

5.2.6. **Na carbonate sedimentary rocks** A non-clastic sedimentary rock consisting primarily of sodium carbonate minerals formed by evaporation of saline water.

5.2.6.1. **Thermonatrite** A non-clastic sedimentary rock consisting primarily of the sodium carbonate mineral thermonatrite.

5.2.6.2. **Natron** A non-clastic sedimentary rock consisting primarily of the sodium carbonate mineral natron.

5.2.6.3. **Trona** A non-clastic sedimentary rock consisting primarily of the sodium carbonate mineral trona.

5.2.6.4. **Gaylussite** A non-clastic sedimentary rock consisting primarily of the sodium carbonate mineral gaylussite.

5.2.7. **Carbonate rocks with gravel-sized particles** A coarse-grained carbonate sedimentary rock, composed of rounded to subangular fragments larger than 2mm in diameter set in a finer-grained matrix.

5.2.7.1. **Limestone conglomerate** A coarse-grained sedimentary rock, composed of rounded to subangular fragments of limestone larger than 2mm in diameter set in a finer-grained matrix.

5.3. **Phosphorite** A sedimentary rock containing more than 50 percent phosphate minerals (Hallsworth and Knox, 1999).

5.4. **Siliceous rocks** A non-clastic sedimentary rock containing more than 50 percent silica of biogenic or chemical origin (opal, quartz, or chalcedony) (Hallsworth and Knox, 1999).

5.4.1. **Chert** A hard, extremely dense or compact, dull to semi-vitreous, microcrystalline or cryptocrystalline non-clastic sedimentary rock, composed primarily of interlocking crystals of quartz less than 30 µm in diameter. Chert typically has porosity less than 10 percent (Bates and Jackson, 1987; Hallsworth and Knox, 1999).

5.4.1.1. **Opaline chert** A non-clastic siliceous sedimentary rock largely made up of amorphous silica. Chert typically has porosity less than 10 percent (Hallsworth and Knox, 1999).

5.4.1.2. **Quartzose chert** A vitreous, sparkly, shiny chert, which under high magnification shows a heterogeneous mixture of pyramids, prisms, and faces of quartz, but also including chert in which the secondary quartz is largely anhedral. Chert typically has porosity less than 10 percent (Bates and Jackson, 1987; Hallsworth and Knox, 1999).

5.4.1.3. **Jasper** A variety of chert associated with iron ores and containing iron-oxide impurities that give it various colors, characteristically red, although yellow, green, grayish-blue, brown, and black cherts have also been called jasper (Bates and Jackson, 1987).

5.4.1.4. **Flint** A homogeneous, dark-gray or black variety of chert (Bates and Jackson, 1987).

5.4.1.5. **Agate** A translucent cryptocrystalline variety of quartz, being a variegated chalcedony frequently mixed or alternating with opal, and characterized by colors arranged in alternating stripes or bands, in irregular clouds, or in moss-like forms (Bates and Jackson, 1987).

5.4.2. **Diatomite** A light-colored soft friable siliceous sedimentary rock, consisting chiefly of opaline frustules of the diatom, a unicellular aquatic plant related to the algae. Porosities range from 50 to 90 percent (Bates and Jackson, 1987; Hallsworth and Knox, 1999).

5.4.3. **Radiolarite** A comparatively hard fine-grained chertlike sedimentary rock composed primarily of the remains of Radiolaria. Porosities range from 50 to 90 percent (Bates and Jackson, 1987; Hallsworth and Knox, 1999).

5.4.4. **Spiculite** A sedimentary rock composed principally of the siliceous spicules of invertebrates. Porosities range from 50 to 90 percent (Bates and Jackson, 1987; Hallsworth and Knox, 1999).

5.4.5. **Sinter** A chemical sedimentary rock deposited as a hard incrustation on rocks or on the ground by precipitation from hot or cold mineral waters of springs, lakes, or streams. Porosities range from 50 to 90 percent (Bates and Jackson, 1987; Hallsworth and Knox, 1999).

5.5. **Iron formation or iron stone** A chemical sedimentary rock, typically thin-bedded and/or finely laminated, containing at least 15 percent iron of sedimentary origin, and commonly but not necessarily containing layers of chert (Bates and Jackson, 1987).

5.6. **Evaporite** A non-clastic sedimentary rock composed primarily of minerals produced as a result of extensive or total evaporation of saline water (Bates and Jackson, 1987).

5.6.1. **Gypsum-stone** A non-clastic sedimentary rock composed primarily of the evaporite mineral gypsum.

5.6.2. **Anhydrite-stone** A non-clastic sedimentary rock composed primarily of the evaporite mineral anhydrite.

5.6.3. **Barite-stone** A non-clastic sedimentary rock composed primarily of the evaporite mineral barite.

5.6.4. **Polyhalite-stone** A non-clastic sedimentary rock composed primarily of the evaporite mineral polyhalite.

5.6.5. **Kieserite-stone** A non-clastic sedimentary rock composed primarily of the evaporite mineral kieserite.

5.6.6. **Kainite-stone** A non-clastic sedimentary rock composed primarily of the evaporite mineral kainite.

5.6.7. **Halite-stone** A non-clastic sedimentary rock composed primarily of the evaporite mineral halite.

5.6.8. **Sylvite-stone** A non-clastic sedimentary rock composed primarily of the evaporite mineral sylvite.

5.6.9. **Carnallite-stone** A non-clastic sedimentary rock composed primarily of the evaporite mineral carnallite.

5.6.10. **Borax-stone** A non-clastic sedimentary rock composed primarily of the evaporite mineral borax.

5.6.11. **Kemite-stone** A non-clastic sedimentary rock composed primarily of the evaporite mineral kernite.

5.6.12. **Ulexite-stone** A non-clastic sedimentary rock composed primarily of the evaporite mineral ulexite.

5.6.13. **Colemanite-stone** A non-clastic sedimentary rock composed primarily of the evaporite mineral colemanite.

5.7. **Carbonate and siliciclastic sedimentary rocks** A collective term for a layered sequence of carbonate and siliciclastic sedimentary rocks. Carbonate sedimentary rocks make up more than half of the succession.

5.8. **Mixed carbonate/siliciclastic sedimentary rocks** A sedimentary rock consisting primarily of carbonate minerals with some clastic silicate material.

5.8.1. **Sandy carbonate** A sedimentary rock containing 50 to 75 percent carbonate minerals; the rest of the rock consists of siliciclastic material (sand, silt, and clay). The ratio of sand to silt or clay is greater than 1:1 (fig. B-12; Compton, 1962).

5.8.1.1. **Sandy limestone** A sedimentary rock containing 50 to 75 percent calcite; the rest of the rock consists of siliciclastic material (sand, silt, and clay). The ratio of sand to silt or clay is greater than 1:1 (fig. B-12; Compton, 1962).

5.8.1.2. **Sandy dolomite** A sedimentary rock containing 50 to 75 percent dolomite; the rest of the rock consists of siliciclastic material (sand, silt, and clay). The ratio of sand to silt or clay is greater than 1:1 (fig. B-12; Compton, 1962).

5.8.2. **Argillaceous carbonate** A sedimentary rock containing 50 to 75 percent carbonate minerals; the rest of the rock consists of siliciclastic material (sand, silt, and clay). The ratio of sand to silt or clay is less than 1:1 and the ratio of carbonate minerals to authigenic silica is greater than 3:1 (fig. B-12; Compton, 1962).

5.8.2.1. **Argillaceous limestone** A sedimentary rock containing 50 to 75 percent calcite; the rest of the rock consists of siliciclastic material (sand, silt, and clay). The ratio of sand to silt or clay is less than 1:1 and the ratio of calcite to authigenic silica is greater than 3:1 (fig. B-12; Compton, 1962).

5.8.2.2. **Argillaceous dolomite** A sedimentary rock containing 50 to 75 percent dolomite; the rest of the rock consists of siliciclastic material (sand, silt, and clay). The ratio of sand to silt or clay is less than 1:1 and the ratio of dolomite to authigenic silica is greater than 3:1 (fig. B-12; Compton, 1962).

5.9. **Siliciclastic and carbonate sedimentary rocks** A collective term for a layered sequence of siliciclastic and carbonate sedimentary rocks. Siliciclastic sedimentary rocks make up more than half of the succession.

5.10. **Mixed siliciclastic/carbonate sedimentary rocks** A sedimentary rock consisting primarily of clastic silicate material with some carbonate minerals.

5.10.1. **Carbonate-bearing sandstone** A siliciclastic sedimentary rock containing 25 to 50 percent carbonate minerals. The ratio of sand to silt or clay is greater than 1:1 (fig. B-12; Compton, 1962).

5.10.1.1. **Calcareous sandstone** A siliciclastic sedimentary rock containing 25 to 50 percent calcite. The ratio of sand to silt or clay is greater than 1:1 (fig. B-12; Compton, 1962).

5.10.1.2. **Dolomitic sandstone** A siliciclastic sedimentary rock containing 25 to 50 percent dolomite The ratio of sand to silt or clay is greater than 1:1 (fig. B-12; Compton, 1962).

5.10.2. **Carbonate-bearing siltstone or claystone** A siliciclastic sedimentary rock containing 25 to 50 percent carbonate minerals. The ratio of sand to silt or clay is less than 1:1 and the ratio of carbonate minerals to authigenic silica is greater than 3:1.

5.10.2.1. **Calcareous siltstone or claystone** A siliciclastic sedimentary rock containing 25 to 50 percent calcite. The ratio of sand to silt or clay is less than 1:1 and the ratio of calcite to authigenic silica is greater than 3:1 (fig. B-12; Compton, 1962).

5.10.2.2. **Dolomitic siltstone or claystone** A siliciclastic sedimentary rock containing 25 to 50 percent dolomite The ratio of sand to silt or clay is less than 1:1 and the ratio of dolomite to authigenic silica is greater than 3:1 (fig. B-12; Compton, 1962).

5.11. **Siliceous and phosphatic rocks** A collective term for a layered sequence of non-clastic siliceous sedimentary rocks and phosphorites. Non-clastic siliceous sedimentary rocks make up more than half of the succession.

5.12. **Mixed siliceous/phosphatic rocks** A sedimentary rock consisting primarily of non-clastic siliceous material with some phosphate minerals.

5.12.1. **Phosphatic chert** A sedimentary rock, chert, containing phosphate minerals.

5.13. **Siliceous and clastic-carbonate rocks** A collective term for a layered sequence of non-clastic siliceous, siliciclastic, and carbonate sedimentary rocks. Non-clastic siliceous sedimentary rocks make up more than half of the succession.

5.14. **Mixed siliceous/clastic-carbonate rocks** A sedimentary rock consisting primarily of non-clastic siliceous material with some clastic silicate material and carbonate minerals.

5.14.1. **Carbonate-bearing chert** A sedimentary rock composed primarily of authigenic siliceous material (opal, quartz, or chalcedony) with subordinate carbonate minerals. The ratio of carbonate minerals to authigenic silica is between 1:1 and 1:3. Up to 25 percent silt and clay may be present (fig. B-12; Compton, 1962).

5.14.1.1. **Dolomitic chert** A sedimentary rock composed primarily of authigenic siliceous material (opal, quartz, or chalcedony) with subordinate dolomite. The ratio of dolomite to authigenic silica is between 1:1 and 1:3. Up to 25 percent silt and clay may be present (fig. B-12; Compton, 1962).

5.14.1.2. **Calcareous chert** A sedimentary rock composed primarily of authigenic siliceous material (opal, quartz, or chalcedony) with subordinate calcite. The ratio of calcite to authigenic silica is between 1:1 and 1:3. Up to 25 percent silt and clay may be present (fig. B-12; Compton, 1962).

5.14.2. **Porcellanite** A siliceous rock that is less hard, dense, and vitreous than chert. The term has been used for an impure chert, in part argillaceous and calcareous. These rocks have the texture, dull luster, hardness, conchoidal fracture, and general appearance of unglazed porcelain. These rocks have porosities ranging from 15 to 30 percent (fig. B-12; Bates and Jackson, 1987; Compton, 1962; Hallsworth and Knox, 1999).

5.14.2.1. **Opaline porcellanite** A porcellanite in which the siliceous material is amorphous silica (Hallsworth and Knox, 1999).

5.14.2.2. **Quartzose porcellanite** A porcellanite in which the siliceous material is quartz (Hallsworth and Knox, 1999).

5.15. **Clastic-carbonate and siliceous rocks** A collective term for a layered sequence of siliciclastic, carbonate, and non-clastic siliceous sedimentary rocks. Siliciclastic and carbonate sedimentary rocks make up more than half of the succession.

5.16. **Mixed clastic-carbonate/siliceous rocks** A sedimentary rock consisting primarily of clastic silicate material and carbonate minerals with some non-clastic siliceous material.

5.16.1. **Siliceous carbonate** A sedimentary rock composed primarily of carbonate minerals with subordinate authigenic siliceous material (opal, quartz, or chalcedony). The ratio of carbonate minerals to authigenic silica is between 3:1 and 1:1. Up to 25 percent silt and clay may be present (fig. B-12; Compton, 1962).

5.16.1.1. **Siliceous limestone** A sedimentary rock composed primarily of calcite with subordinate authigenic siliceous material (opal, quartz, or chalcedony). The ratio of calcite to authigenic silica is between 3:1 and 1:1. Up to 25 percent silt and clay may be present (fig. B-12; Compton, 1962).

5.16.1.1.1 **Cherty limestone** A sedimentary rock composed primarily of calcite with subordinate chert.

5.16.1.2. **Siliceous dolomite** A sedimentary rock composed primarily of dolomite with subordinate authigenic siliceous material (opal, quartz, or chalcedony). The ratio of calcite to authigenic silica is between 3:1 and 1:1. Up to 25 percent silt and clay may be present (fig. B-12; Compton, 1962).

5.16.1.2.1 **Cherty dolomite** A sedimentary rock composed primarily of dolomite with subordinate chert.

5.16.2. **Siliceous siltstone or claystone** A sedimentary rock containing 50 to 75 percent silt and clay and with the ratio of calcite or dolomite to authigenic silica that is less than 1:1 (fig. B-12; Compton, 1962).

5.17. **Phosphorite and siliciclastic rocks** A collective term for a layered sequence of phosphorite and siliciclastic sedimentary rocks. Phosphorite makes up more than half of the succession.

5.18. **Mixed phosphorite/siliciclastic rocks** A sedimentary rock consisting primarily of phosphate minerals with some clastic silicate material.

5.18.1. **Shaly phosphorite** A sedimentary rock composed primarily of phosphate minerals with lesser amounts of silicate silt and clay minerals.

5.19. **Siliciclastic rocks and phosphorite** A collective term for a layered sequence of siliciclastic sedimentary rocks and phosphorite. Siliciclastic sedimentary rocks make up more than half of the succession.

5.20. **Mixed siliciclastic rocks/phosphorite** A sedimentary rock consisting primarily of clastic silicate material with some phosphate minerals.

5.20.1. **Phosphatic sandstone** A siliciclastic sedimentary rock, sandstone, containing phosphate minerals.

5.20.2. **Phosphatic mudstone** A siliciclastic sedimentary rock, mudstone, containing phosphate minerals.

5.20.3. **Phosphatic claystone** A siliciclastic sedimentary rock, claystone, containing phosphate minerals.

5.21. **Carbonaceous sedimentary rocks** A sedimentary rock that consists of, or contains an appreciable amount of, original or subsequently introduced organic material, including plant and animal residues and organic derivatives greatly altered (carbonized or bituminized) from the original remains (Bates and Jackson, 1987).

5.21.1. **Coal series** A readily combustible rock containing more than 50 percent by weight and more than 70 percent by volume of carbonaceous material including inherent moisture, formed from compaction and induration of variously altered plant remains similar to those in peat. The ratio of humic residues to sapropelic residues is greater than 3:1. Differences in kinds of plant materials (type), in degree of metamorphism (rank), and in the range of impurity (grade) are characteristic of coal and are used in classification (fig. B-13; Bates and Jackson, 1987; Pettijohn, 1975).

5.21.1.1. **Lignite** A brownish-black coal that is intermediate in coalification between peat and subbituminous coal; consolidated coal with a calorific value less than 8300 BTU/lb, on a moist, mineral-matter-free basis (Bates and Jackson, 1987).

5.21.1.2. **Subbituminous** A black coal, intermediate in rank between lignite and bituminous coals; or, in some classifications, the equivalent of black lignite. It is distinguished from lignite by higher carbon and lower moisture content (Bates and Jackson, 1987).

5.21.1.3. **Bituminous** Coal that ranks between subbituminous coal and anthracite and that contains more than 14 percent volatile matter (on a dry, ash-free basis) and has a calorific value of more than 11,500 BTU/lb (moist, mineral-matter-free) or more than 10,500 BTU/lb if agglomerating (Bates and Jackson, 1987).

5.21.2. **Bone coal** Coal that has a high ash content. It is hard and compact. It contains 20 to 50 percent carbonaceous material and the ratio of humic residues to sapropelic residues is greater than 1 (fig. B-13; Bates and Jackson, 1987; Pettijohn, 1975).

5.21.3. **Cannel shale** A sedimentary rock that contains 50 to 75 percent carbonaceous material with the remainder being silt and clay. The proportion of humic residues to sapropelic residues varies from 3:1 to 1:1 (fig. B-13; Pettijohn 1975).

5.21.4. **Cannel coal** A sedimentary rock that contains more than 75 percent carbonaceous material with the remainder being silt and clay. The proportion of humic residues to sapropelic residues varies from 3:1 to 1:1 (fig. B-13; Pettijohn 1975).

5.21.5. **Boghead cannel shale** A sedimentary rock that contains 50 to 75 percent carbonaceous material with the remainder being silt and clay. The proportion of humic residues to sapropelic residues varies from 1:1 to 1:3 (fig. B-13; Pettijohn 1975).

5.21.6. **Asphaltic earth** A rock containing more than 50 percent by weight carbonaceous material and has a ratio of humic residues to sapropelic residues that is less than 1:3 (fig. B-13; Pettijohn 1975).

5.21.7. **Asphaltite** Any one of the naturally occurring black solid bitumens that are soluble in carbon disulfide and fuse above 230F (fig. B-13; Pettijohn 1975).

5.21.8. **Oil shale** A kerogen-bearing, finely laminated brown or black sedimentary rock that will yield liquid or gaseous hydrocarbon on distillation. It contains 20 to 50 percent carbonaceous material and the ratio of humic residues to sapropelic residues is less than 1 (fig. B-13; Bates and Jackson, 1987; Pettijohn, 1975).

5.21.9. **Black shale** A dark, thinly laminated carbonaceous shale, exceptionally rich in organic matter (5 percent to 20 percent) and sulfide (esp. iron sulfide, usually pyrite), and often containing unusual concentrations of certain trace elements (U, V, Cu, Ni) (fig. B-13; Bates and Jackson, 1987; Pettijohn, 1975).

5.21.10. **Carbonaceous limestone** A dark-gray or black limestone with a significant content of carbon.

5.21.11. **Carbonaceous calcareous sandstone** A sandstone with a significant content of carbon and carbonate minerals.

5.22. **Epiclastic sedimentary rocks** A sedimentary rock containing less than 25 percent pyroclastic material (Le Maitre and others, 2002).

5.22.1. **Epiclastic conglomerate** A conglomerate containing less than 25 percent pyroclastic material (Le Maitre and others, 2002).

5.22.2. **Epiclastic sandstone** A sandstone containing less than 25 percent pyroclastic material (Le Maitre and others, 2002).

5.22.3. **Epiclastic mudrock** A mudrock containing less than 25 percent pyroclastic material (Le Maitre and others, 2002).

5.23. **Tuffaceous sedimentary rocks** A sedimentary rock containing 25 to 75 percent pyroclastic material (Le Maitre and others, 2002).

5.23.1. **Tuffaceous conglomerate** A conglomerate containing 25 to 75 percent pyroclastic material (Le Maitre and others, 2002).

5.23.2. **Tuffaceous sandstone** A sandstone containing 25 to 75 percent pyroclastic material (Le Maitre and others, 2002).

5.23.3. **Tuffaceous mudstone** A mudstone containing 25 to 75 percent pyroclastic material (Le Maitre and others, 2002).

5.24. **Siliciclastic and volcaniclastic sedimentary rocks** A collective term for a layered sequence of siliciclastic and volcaniclastic sedimentary rocks. Siliciclastic sedimentary rocks make up more than half of the succession.

5.25. **Volcaniclastic and siliciclastic sedimentary rocks** A collective term for a layered sequence of volcaniclastic and siliciclastic and volcaniclastic sedimentary rocks. Volcaniclastic sedimentary rocks make up more than half of the succession.

6. **Metamorphosed plutonic rock** Metamorphosed plutonic rock; despite metamorphism, the original igneous rock protolith can be recognized. See definition of plutonic rock.

6.1. **Metamorphosed plutonic QAPF rocks** Metamorphosed plutonic QAPF rocks; despite metamorphism, the original igneous rock protolith can be recognized. See definition of plutonic QAPF rocks.

6.1.1. **Meta-quartz-rich-coarse-grained crystalline rock** Metamorphosed quartz-rich-coarse-grained crystalline rock; despite metamorphism, the original igneous rock protolith can be recognized. See definition of quartz-rich-coarse-grained crystalline rock.

6.1.1.1. **Meta-quartzolite (silexite)** Metamorphosed quartzolite (silexite); despite metamorphism, the original igneous rock protolith can be recognized. See definition of quartzolite (silexite).

6.1.1.2. **Meta-quartz-rich granitoid** Metamorphosed quartz-rich granitoid; despite metamorphism, the original igneous rock protolith can be recognized. See definition of quartz-rich granitoid.

6.1.2. **Meta-granitoid** Metamorphosed granitoid; despite metamorphism, the original igneous rock protolith can be recognized. See definition of granitoid.

6.1.2.1. **Meta-alkali-feldspar granite** Metamorphosed alkali-feldspar granite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of alkali-feldspar granite.

6.1.2.2. **Meta-granite** Metamorphosed granite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of granite.

6.1.2.2.1 **Meta-syenogranite** Metamorphosed syenogranite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of syenogranite.

6.1.2.2.2 **Meta-monzogranite** Metamorphosed monzogranite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of monzogranite.

6.1.2.3. **Meta-granodiorite** Metamorphosed granodiorite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of granodiorite.

6.1.2.3. **Meta-tonalite** Metamorphosed tonalite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of tonalite.

6.1.3. **Meta-syenitoid** Metamorphosed syenitoid; despite metamorphism, the original igneous rock protolith can be recognized. See definition of syenitoid.

6.1.3.1. **Meta-quartz-alkali-feldspar syenite** Metamorphosed quartz-alkali-feldspar syenite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of quartz-alkali-feldspar syenite.

6.1.3.2. **Meta-alkali-feldspar syenite** Metamorphosed alkali-feldspar syenite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of alkali-feldspar syenite.

6.1.3.3. **Meta-foid-bearing-alkali-feldspar syenite** Metamorphosed foid-bearing-alkali-feldspar syenite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of foid-bearing-alkali-feldspar syenite.

6.1.3.4. **Meta-quartz syenite** Metamorphosed quartz syenite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of quartz syenite.

6.1.3.5. **Meta-syenite** Metamorphosed syenite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of syenite.

6.1.3.6. **Meta-foid-bearing syenite** Metamorphosed foid-bearing syenite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of foid-bearing syenite.

6.1.3.7. **Meta-quartz monzonite** Metamorphosed quartz monzonite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of quartz monzonite.

6.1.3.8. **Meta-monzonite** Metamorphosed monzonite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of monzonite.

6.1.3.9. **Meta-foid-bearing monzonite** Metamorphosed foid-bearing monzonite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of foid-bearing monzonite.

6.1.4. **Meta-dioritoid/gabbroid/anorthosite** Metamorphosed dioritoid/gabbroid/anorthosite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of dioritoid/gabbroid/anorthosite.

6.1.4.1. **Meta-quartz monzodiorite** Metamorphosed quartz monzodiorite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of quartz monzodiorite.

6.1.4.2. **Meta-quartz monzogabbro** Metamorphosed quartz monzogabbro; despite metamorphism, the original igneous rock protolith can be recognized. See definition of quartz monzogabbro.

6.1.4.3. **Meta-monzodiorite** Metamorphosed monzodiorite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of monzodiorite.

6.1.4.4. **Meta-monzogabbro** Metamorphosed monzogabbro; despite metamorphism, the original igneous rock protolith can be recognized. See definition of monzogabbro.

6.1.4.5. **Meta-foid-bearing monzodiorite** Metamorphosed foid-bearing monzodiorite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of foid-bearing monzodiorite.

6.1.4.6. **Meta-foid-bearing monzogabbro** Metamorphosed foid-bearing monzogabbro; despite metamorphism, the original igneous rock protolith can be recognized. See definition of foid-bearing monzogabbro.

6.1.4.7. **Meta-quartz diorite** Metamorphosed quartz diorite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of quartz diorite.

6.1.4.8. **Meta-quartz gabbro** Metamorphosed quartz gabbro; despite metamorphism, the original igneous rock protolith can be recognized. See definition of quartz gabbro.

6.1.4.9. **Meta-quartz anorthosite** Metamorphosed quartz anorthosite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of quartz anorthosite.

6.1.4.10. **Meta-diorite** Metamorphosed diorite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of diorite.

6.1.4.11. **Meta-anorthosite** Metamorphosed anorthosite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of anorthosite.

6.1.4.12. **Meta-gabbro** Metamorphosed gabbro; despite metamorphism, the original igneous rock protolith can be recognized. See definition of gabbro.

6.1.4.13. **Meta-foid-bearing diorite** Metamorphosed foid-bearing diorite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of foid-bearing diorite.

6.1.4.14. **Meta-foid-bearing gabbro** Metamorphosed foid-bearing gabbro; despite metamorphism, the original igneous rock protolith can be recognized. See definition of foid-bearing gabbro.

6.1.4.15. **Meta-foid-bearing anorthosite** Metamorphosed foid-bearing anorthosite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of foid-bearing anorthosite.

6.1.5. **Meta-foid-syenitoid** Metamorphosed foid-syenitoid; despite metamorphism, the original igneous rock protolith can be recognized. See definition of foid-syenitoid.

6.1.5.1. **Meta-foid syenite** Metamorphosed foid syenite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of foid syenite.

6.1.5.2. **Meta-foid monzosyenite** Metamorphosed foid monzosyenite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of foid monzosyenite.

6.1.6. **Meta-foid dioritoid and foid gabbroid** Metamorphosed foid dioritoid and foid gabbroid; despite metamorphism, the original igneous rock protolith can be recognized. See definition of foid dioritoid and foid gabbroid.

6.1.6.1. **Meta-foid monzodiorite** Metamorphosed foid monzodiorite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of foid monzodiorite.

6.1.6.2. **Meta-foid monzogabbro** Metamorphosed foid monzogabbro; despite metamorphism, the original igneous rock protolith can be recognized. See definition of foid monzogabbro.

6.1.6.3. **Meta-foid diorite** Metamorphosed foid diorite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of foid diorite.

6.1.6.4. **Meta-foid gabbro** Metamorphosed foid gabbro; despite metamorphism, the original igneous rock protolith can be recognized. See definition of foid gabbro.

6.1.7. **Meta-foidolite** Metamorphosed foidolite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of foidolite.

6.2. **Metamorphosed plutonic ultramafic rock** Metamorphosed plutonic ultramafic rock; despite metamorphism, the original igneous rock protolith can be recognized. See definition of plutonic ultramafic rock.

6.2.1. **Meta-peridotite** Metamorphosed peridotite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of peridotite.

6.2.2. **Meta-pyroxenite** Metamorphosed pyroxenite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of pyroxenite.

6.2.3. **Meta-hornblendite** Metamorphosed hornblendite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of hornblendite.

7. **Metamorphosed volcanic rock** Metamorphosed volcanic rock; despite metamorphism, the original igneous rock protolith can be recognized. See definition of volcanic rock.

7.1. **Metamorphosed volcanic QAPF rocks** Metamorphosed volcanic QAPF rocks; despite metamorphism, the original igneous rock protolith can be recognized. See definition of volcanic QAPF rocks.

7.1.1. **Meta-rhyolitoid** Metamorphosed rhyolitoid; despite metamorphism, the original igneous rock protolith can be recognized. See definition of rhyolitoid.

7.1.1.1. **Meta-alkali feldspar rhyolite** Metamorphosed alkali feldspar rhyolite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of alkali feldspar rhyolite.

7.1.1.2. **Meta-rhyolite** Metamorphosed rhyolite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of rhyolite.

7.1.2. **Meta-dacitoid** Metamorphosed dacitoid; despite metamorphism, the original igneous rock protolith can be recognized. See definition of dacitoid.

7.1.2.1. **Meta-dacite** Metamorphosed dacite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of dacite.

7.1.3. **Meta-trachytoid** Metamorphosed trachytoid; despite metamorphism, the original igneous rock protolith can be recognized. See definition of trachytoid.

7.1.3.1. **Meta-quartz-alkali feldspar trachyte** Metamorphosed quartz-alkali feldspar trachyte; despite metamorphism, the original igneous rock protolith can be recognized. See definition of quartz-alkali feldspar trachyte.

7.1.3.2. **Meta-alkali feldspar trachyte** Metamorphosed alkali feldspar trachyte; despite metamorphism, the original igneous rock protolith can be recognized. See definition of alkali feldspar trachyte.

7.1.3.3. **Meta-foid-bearing alkali-feldspar trachyte** Metamorphosed foid-bearing alkali-feldspar trachyte; despite metamorphism, the original igneous rock protolith can be recognized. See definition of foid-bearing alkali-feldspar trachyte.

7.1.3.4. **Meta-quartz trachyte** Metamorphosed quartz trachyte; despite metamorphism, the original igneous rock protolith can be recognized. See definition of quartz trachyte.

7.1.3.5. **Meta-trachyte** Metamorphosed trachyte; despite metamorphism, the original igneous rock protolith can be recognized. See definition of trachyte.

7.1.3.6. **Meta-foid-bearing trachyte** Metamorphosed foid-bearing trachyte; despite metamorphism, the original igneous rock protolith can be recognized. See definition of foid-bearing trachyte.

7.1.3.7. **Meta-quartz latite** Metamorphosed quartz latite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of quartz latite.

7.1.3.8. **Meta-latite** Metamorphosed latite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of latite.

7.1.3.9. **Meta-foid-bearing latite** Metamorphosed foid-bearing latite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of foid-bearing latite.

7.1.3.10. **Meta-trachydacite (TAS)** Metamorphosed trachydacite (TAS); despite metamorphism, the original igneous rock protolith can be recognized. See definition of trachydacite (TAS).

7.1.3.11. **Meta-trachyandesite (TAS)** Metamorphosed trachyandesite (TAS); despite metamorphism, the original igneous rock protolith can be recognized. See definition of trachyandesite (TAS).

7.1.3.11.1 **Meta-benmoreite (TAS)** Metamorphosed benmoreite (TAS); despite metamorphism, the original igneous rock protolith can be recognized. See definition of benmoreite (TAS).

7.1.3.12. **Meta-basaltic trachyandesite (TAS)** Metamorphosed basaltic trachyandesite (TAS); despite metamorphism, the original igneous rock protolith can be recognized. See definition of basaltic trachyandesite (TAS).

7.1.3.12.1 **Meta-mugearite (TAS)** Metamorphosed mugearite (TAS); despite metamorphism, the original igneous rock protolith can be recognized. See definition of mugearite (TAS).

7.1.3.12.2 **Meta-shoshonite (TAS)** Metamorphosed shoshonite (TAS); despite metamorphism, the original igneous rock protolith can be recognized. See definition of shoshonite (TAS).

7.1.3.13. **Meta-trachybasalt (TAS)** Metamorphosed trachybasalt (TAS); despite metamorphism, the original igneous rock protolith can be recognized. See definition of trachybasalt (TAS).

7.1.3.13.1 **Meta-hawaiite (TAS)** Metamorphosed hawaiite (TAS); despite metamorphism, the original igneous rock protolith can be recognized. See definition of hawaiite (TAS).

7.1.3.13.2 **Meta-potassic trachybasalt (TAS)** Metamorphosed potassic trachybasalt (TAS); despite metamorphism, the original igneous rock protolith can be recognized. See definition of potassic trachybasalt (TAS).

7.1.4. **Meta-andesitoid/basaltoid** Metamorphosed andesitoid/basaltoid; despite metamorphism, the original igneous rock protolith can be recognized. See definition of andesitoid/basaltoid.

7.1.4.1. **Meta-andesite** Metamorphosed andesite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of andesite.

7.1.4.2. **Meta-basalt** Metamorphosed basalt; despite metamorphism, the original igneous rock protolith can be recognized. See definition of basalt.

7.1.4.3. **Meta-basaltic andesite (TAS)** Metamorphosed basaltic andesite (TAS); despite metamorphism, the original igneous rock protolith can be recognized. See definition of basaltic andesite (TAS).

7.1.5. **Meta-phonolitoid** Metamorphosed phonolitoid; despite metamorphism, the original igneous rock protolith can be recognized. See definition of phonolitoid.

7.1.5.1. **Meta-phonolite** Metamorphosed phonolite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of phonolite.

7.1.5.2. **Meta-tephritic phonolite** Metamorphosed tephritic phonolite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of tephritic phonolite.

7.1.5.3. **Meta-tephri-phonolite (TAS)** Metamorphosed tephri-phonolite (TAS); despite metamorphism, the original igneous rock protolith can be recognized. See definition of tephri-phonolite (TAS).

7.1.6. **Meta-tephritoid** Metamorphosed tephritoid; despite metamorphism, the original igneous rock protolith can be recognized. See definition of tephritoid.

7.1.6.1. **Meta-phonolitic basanite** Metamorphosed phonolitic basanite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of phonolitic basanite.

7.1.6.2. **Meta-phonolitic tephrite** Metamorphosed phonolitic tephrite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of phonolitic tephrite.

7.1.6.3. **Meta-basanite** Metamorphosed basanite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of basanite.

7.1.6.4. **Meta-tephrite** Metamorphosed tephrite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of tephrite.

7.1.6.5. **Meta-phono-tephrite (TAS)** Metamorphosed phono-tephrite (TAS); despite metamorphism, the original igneous rock protolith can be recognized. See definition of phono-tephrite (TAS).

7.1.7. **Meta-foiditoid** Metamorphosed foiditoid; despite metamorphism, the original igneous rock protolith can be recognized. See definition of foiditoid.

7.1.7.1. **Meta-phonolitic foidite** Metamorphosed phonolitic foidite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of phonolitic foidite.

7.1.7.2. **Meta-basanitic foidite** Metamorphosed basanitic foidite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of basanitic foidite.

7.1.7.3. **Meta-tephritic foidite** Metamorphosed tephritic foidite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of tephritic foidite.

7.1.7.4. **Meta-foidite** Metamorphosed foidite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of foidite.

7.2. **Metamorphosed high-Mg volcanic rocks** Metamorphosed high-Mg volcanic rocks; despite metamorphism, the original igneous rock protolith can be recognized. See definition of high-Mg volcanic rocks.

8. **Other metamorphosed igneous rocks** Other metamorphosed igneous rocks; despite metamorphism, the original igneous rock protolith can be recognized. See definition of other igneous rocks.

8.1. **Metamorphosed carbonatite** Metamorphosed carbonatite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of carbonatite.

8.2. **Metamorphosed melilite-bearing rock** Metamorphosed melilite-bearing rock; despite metamorphism, the original igneous rock protolith can be recognized. See definition of melilite-bearing rock.

8.3. **Metamorphosed kalsilite-bearing rock** Metamorphosed kalsilite-bearing rock; despite metamorphism, the original igneous rock protolith can be recognized. See definition of kalsilite-bearing rock.

8.4. **Metamorphosed lamproite** Metamorphosed lamproite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of lamproite.

8.5. **Metamorphosed kimberlite** Metamorphosed kimberlite; despite metamorphism, the original igneous rock protolith can be recognized. See definition of kimberlite.

8.6. **Metamorphosed leucite-bearing rock** Metamorphosed leucite-bearing rock; despite metamorphism, the original igneous rock protolith can be recognized. See definition of leucite-bearing rock.

8.7. **Metamorphosed lamprophyres** Metamorphosed lamprophyres; despite metamorphism, the original igneous rock protolith can be recognized. See definition of lamprophyres.

8.8. **Metamorphosed dioritoid-granitoid (calc-alkaline) plutonic suite** A collective term for a metamorphosed suite of plutonic igneous rocks that vary between the QAPF "field" classification for dioritoid and granitoid; despite metamorphism, the original igneous rock protolith can be recognized.

8.9. **Metamorphosed andesitoid-rhyolitoid (calc-alkalic) volcanic suite** A collective term for a metamorphosed suite of volcanic igneous rocks that vary between the QAPF "field" classification for basaltoid/andesitoid and rhyolitoid; despite metamorphism, the original igneous rock protolith can be recognized.

8.10. **Metamorphosed monzonitoid-granitoid (alkali-calcic) plutonic suite** A collective term for a metamorphosed suite of plutonic igneous rocks ranging between QAPF field 9 (monzonite) and the QAPF "field" classification for granitoid; despite metamorphism, the original igneous rock protolith can be recognized.

8.11. **Metamorphosed latitic-rhyolitic (alkali-calcic) volcanic suite** A collective term for a metamorphosed suite of volcanic igneous rocks that vary between QAPF field 8 (latite) and the QAPF "field" classification for rhyolitoid; despite metamorphism, the original igneous rock protolith can be recognized.

8.12. **Metamorphosed monzonitoid-syenitoid plutonic (alkaline) suite** A collective term for a metamorphosed suite of plutonic igneous rocks that vary between QAPF field 9 (monzonite) and the QAPF "field" classification for syenitoid; despite metamorphism, the original igneous rock protolith can be recognized.

8.13. **Metamorphosed latitic-trachytic (alkaline) volcanic suite** A collective term for a metamorphosed suite of volcanic igneous rocks that vary between QAPF field 8 (latite) and the QAPF "field" classification for trachytoid; despite metamorphism, the original igneous rock protolith can be recognized.

8.14. **Metamorphosed mafic igneous rock** Metamorphosed mafic igneous rock; despite metamorphism, the original igneous rock protolith can be recognized. See definition of mafic igneous rock.

8.15. **Metamorphosed felsic igneous rock** Metamorphosed felsic igneous rock; despite metamorphism, the original igneous rock protolith can be recognized. See definition of felsic igneous rock.

8.15.1. **Metamorphosed porphyry** Metamorphosed porphyry; despite metamorphism, the original igneous rock protolith can be recognized. See definition of porphyry.

9. **Metamorphosed sedimentary rock** Metamorphosed sedimentary rock; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of sedimentary rock.

9.1. **Metamorphosed siliciclastic sedimentary rocks** Metamorphosed siliciclastic sedimentary rocks; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of siliciclastic sedimentary rocks.

9.1.1. **Meta-mudrock (shale)** Metamorphosed mudrock (shale); despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of mudrock (shale).

9.1.1.1. **Meta-claystone** Metamorphosed claystone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of claystone.

9.1.1.2. **Meta-mudstone** Metamorphosed mudstone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of mudstone.

9.1.1.3. **Meta-siltstone** Metamorphosed siltstone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of siltstone.

9.1.2. **Meta-wacke** Metamorphosed wacke; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of wacke.

9.1.2.1. **Meta-quartz-wacke** Metamorphosed quartz-wacke; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of quartz-wacke.

9.1.2.2. **Meta-feldspathic wacke** Metamorphosed feldspathic wacke; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of feldspathic wacke.

9.1.2.3. **Meta-lithic-wacke** Metamorphosed lithic-wacke; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of lithic-wacke.

9.1.3. **Meta-sandstone or arenite** Metamorphosed sandstone or arenite; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of sandstone or arenite.

9.1.3.1. **Meta-quartz-arenite** Metamorphosed quartz-arenite; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of quartz-arenite.

9.1.3.2. **Meta-subfeldspathic arenite** Metamorphosed subfeldspathic arenite; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of subfeldspathic arenite.

9.1.3.3. **Meta-sublithic arenite** Metamorphosed sublithic arenite; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of sublithic arenite.

9.1.3.4. **Meta-feldspathic arenite** Metamorphosed feldspathic arenite; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of feldspathic arenite.

9.1.3.5. **Meta-lithic arenite** Metamorphosed lithic arenite; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of lithic arenite.

9.1.4. **Meta-siliciclastic rocks with gravel-sized particles** Metamorphosed siliciclastic rocks with gravel-sized particles; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of siliciclastic rocks with gravel-sized particles.

9.1.4.1. **Meta-well sorted conglomerate** Metamorphosed well sorted conglomerate; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of well sorted conglomerate.

9.1.4.2. **Meta-conglomerate** Metamorphosed conglomerate; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of conglomerate.

9.1.4.3. **Meta-sandy conglomerate** Metamorphosed sandy conglomerate; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of sandy conglomerate.

9.1.4.4. **Meta-muddy conglomerate** Metamorphosed muddy conglomerate; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of muddy conglomerate.

9.1.4.5. **Meta-pebbly arenite** Metamorphosed pebbly arenite; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of pebbly arenite.

9.1.4.6. **Meta-pebbly wacke** Metamorphosed pebbly wacke; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of pebbly wacke.

9.1.4.7. **Meta-pebbly mudstone** Metamorphosed pebbly mudstone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of pebbly mudstone.

9.2. **Metamorphosed carbonate sedimentary rocks** Metamorphosed carbonate sedimentary rocks; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of carbonate sedimentary rocks.

9.2.1. **Meta-limestone** Metamorphosed limestone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of limestone.

9.2.2. **Meta-magnesian limestone** Metamorphosed magnesian limestone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of magnesian limestone.

9.2.3. **Meta-dolomitic limestone** Metamorphosed dolomitic limestone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of dolomitic limestone.

9.2.4. **Meta-calcitic dolomite** Metamorphosed calcitic dolomite; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of calcitic dolomite.

9.2.5. **Meta-dolostone (dolomite)** Metamorphosed dolostone (dolomite); despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of dolostone (dolomite).

9.2.6. **Meta-Na carbonate sedimentary rocks** Metamorphosed Na carbonate sedimentary rocks; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of Na carbonate sedimentary rocks.

9.2.7. **Meta-carbonate rocks with gravel-sized particles** Metamorphosed carbonate rocks with gravel-sized particles; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of carbonate rocks with gravel-sized particles.

9.3. **Metamorphosed phosphorite** Metamorphosed phosphorite; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of phosphorite.

9.4. **Metamorphosed siliceous rocks** Metamorphosed siliceous rocks; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of siliceous rocks.

9.5. **Metamorphosed iron formation or iron stone** Metamorphosed iron formation or iron stone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of iron formation or iron stone.

9.6. **Metamorphosed evaporite** Metamorphosed evaporite; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of evaporite.

9.6.1. **Meta-gypsum-stone** Metamorphosed gypsum-stone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of gypsum-stone.

9.6.2. **Meta-anhydrite-stone** Metamorphosed anhydrite-stone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of anhydrite-stone.

9.6.3. **Meta-barite-stone** Metamorphosed barite-stone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of barite-stone.

9.7. **Metamorphosed carbonate and siliciclastic sedimentary rocks** A collective term for a layered sequence of metamorphosed carbonate and siliciclastic sedimentary rocks. Metamorphosed carbonate sedimentary rocks make up more than half of the succession. Despite metamorphism, the original sedimentary rock protolith can be recognized.

9.8. **Metamorphosed mixed carbonate/siliciclastic sedimentary rocks** Metamorphosed mixed carbonate/siliciclastic sedimentary rocks; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of mixed carbonate/siliciclastic sedimentary rocks.

9.8.1. **Meta-sandy carbonate** Metamorphosed sandy carbonate; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of sandy carbonate.

9.8.1.1. **Meta-sandy limestone** Metamorphosed sandy limestone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of sandy limestone.

9.8.1.2. **Meta-sandy dolomite** Metamorphosed sandy dolomite; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of sandy dolomite.

9.8.2. **Meta-argillaceous carbonate** Metamorphosed argillaceous carbonate; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of argillaceous carbonate.

9.8.2.1. **Meta-argillaceous limestone** Metamorphosed argillaceous limestone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of argillaceous limestone.

9.8.2.2. **Meta-argillaceous dolomite** Metamorphosed argillaceous dolomite; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of argillaceous dolomite.

9.9. **Metamorphosed siliciclastic and carbonate sedimentary rocks** A collective term for a layered sequence of metamorphosed siliciclastic and carbonate sedimentary rocks. Metamorphosed siliciclastic sedimentary rocks make up more than half of the succession. Despite metamorphism, the original sedimentary rock protolith can be recognized.

9.10. **Metamorphosed mixed siliciclastic/carbonate sedimentary rocks** Metamorphosed mixed siliciclastic/carbonate sedimentary rocks; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of mixed siliciclastic/carbonate sedimentary rocks.

9.10.1. **Meta-carbonate-bearing sandstone** Metamorphosed carbonate-bearing sandstone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of carbonate-bearing sandstone.

9.10.1.1. **Meta-calcareous sandstone** Metamorphosed calcareous sandstone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of calcareous sandstone.

9.10.1.2. **Meta-dolomitic sandstone** Metamorphosed dolomitic sandstone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of dolomitic sandstone.

9.10.2. **Meta-carbonate-bearing siltstone or claystone** Metamorphosed carbonate-bearing siltstone or claystone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of carbonate-bearing siltstone or claystone.

9.10.2.1. **Meta-calcareous siltstone or claystone** Metamorphosed calcareous siltstone or claystone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of calcareous siltstone or claystone.

9.10.2.2. **Meta-dolomitic siltstone or claystone** Metamorphosed dolomitic siltstone or claystone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of dolomitic siltstone or claystone.

9.11. **Metamorphosed siliceous and phosphatic rocks** A collective term for a layered sequence of metamorphosed non-clastic siliceous sedimentary rocks and phosphorites. Metamorphosed non-clastic siliceous sedimentary rocks make up more than half of the succession. Despite metamorphism, the original sedimentary rock protolith can be recognized.

9.12. **Metamorphosed mixed siliceous/phosphatic rocks** Metamorphosed mixed siliceous/phosphatic rocks; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of mixed siliceous/phosphatic rocks.

9.12.1. **Meta-phosphatic chert** Metamorphosed phosphatic chert; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of phosphatic chert.

9.13. **Metamorphosed siliceous and clastic-carbonate rocks** A collective term for a layered sequence of metamorphosed non-clastic siliceous, siliciclastic, and carbonate sedimentary rocks. Metamorphosed non-clastic siliceous sedimentary rocks make up more than half of the succession. Despite metamorphism, the original sedimentary rock protolith can be recognized.

9.14. **Metamorphosed mixed siliceous/clastic-carbonate rocks** Metamorphosed mixed siliceous/clastic-carbonate rocks; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of mixed siliceous/clastic-carbonate rocks.

9.14.1. **Meta-carbonate-bearing chert** Metamorphosed carbonate-bearing chert; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of carbonate-bearing chert.

9.14.2. **Meta-dolomitic chert** Metamorphosed dolomitic chert; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of dolomitic chert.

9.14.3. **Meta-calcareous chert** Metamorphosed calcareous chert; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of calcareous chert.

9.14.4. **Meta-porcellanite** Metamorphosed porcellanite; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of porcellanite.

9.15. **Metamorphosed clastic-carbonate and siliceous rocks** A collective term for a layered sequence of metamorphosed siliciclastic, carbonate, and non-clastic siliceous sedimentary rocks. Metamorphosed siliciclastic and carbonate sedimentary rocks make up more than half of the succession. Despite metamorphism, the original sedimentary rock protolith can be recognized.

9.16. **Metamorphosed mixed clastic-carbonate/siliceous rocks** Metamorphosed mixed clastic-carbonate/siliceous rocks; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of mixed clastic-carbonate/siliceous rocks.

9.16.1. **Meta-siliceous carbonate** Metamorphosed siliceous carbonate; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of siliceous carbonate.

9.16.2. **Meta-siliceous limestone** Metamorphosed siliceous limestone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of siliceous limestone.

9.16.3. **Meta-siliceous dolomite** Metamorphosed siliceous dolomite; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of siliceous dolomite.

9.16.4. **Meta-siliceous siltstone or claystone** Metamorphosed siliceous siltstone or claystone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of siliceous siltstone or claystone.

9.17. **Metamorphosed phosphorite and siliciclastic rocks** A collective term for a layered sequence of metamorphosed phosphorite and siliciclastic sedimentary rocks. Metamorphosed phosphorite makes up more than half of the succession. Despite metamorphism, the original sedimentary rock protolith can be recognized.

9.18. **Metamorphosed mixed phosphorite/siliciclastic rocks** Metamorphosed mixed phosphorite/siliciclastic rocks; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of mixed phosphorite/siliciclastic rocks.

9.18.1. **Meta-shaly phosphorite** Metamorphosed shaly phosphorite; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of shaly phosphorite.

9.19. **Metamorphosed siliciclastic rocks and phosphorite** A collective term for a layered sequence of metamorphosed siliciclastic sedimentary rocks and phosphorite. Metamorphosed siliciclastic sedimentary rocks make up more than half of the succession. Despite metamorphism, the original sedimentary rock protolith can be recognized.

9.20. **Metamorphosed mixed siliciclastic rocks/phosphorite** Metamorphosed mixed siliciclastic rocks/phosphorite; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of mixed siliciclastic rocks/phosphorite.

9.20.1. **Meta-phosphatic sandstone** Metamorphosed phosphatic sandstone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of phosphatic sandstone.

9.20.1. **Meta-phosphatic mudstone** Metamorphosed phosphatic mudstone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of phosphatic mudstone.

9.20.2. **Meta-phosphatic claystone** Metamorphosed phosphatic claystone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of phosphatic claystone.

9.21. **Metamorphosed carbonaceous sedimentary rocks** Metamorphosed carbonaceous sedimentary rocks; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of carbonaceous sedimentary rocks.

9.21.1. **Meta-coal series** Metamorphosed coal series; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of coal series.

9.21.1.1. **Semianthracite** Coal having a fixed-carbon content of 86 percent to 92 percent. It is between bituminous coal and anthracite in metamorphic rank, although its physical properties more closely resemble those of anthracite (Bates and Jackson, 1987).

9.21.1.2. **Anthracite** Coal of the highest metamorphic rank, in which fixed-carbon content is between 92 percent and 98 percent (on a dry, mineral-matter-free basis). It is hard and black, and has a semimetallic luster and semiconchoidal fracture (Bates and Jackson, 1987).

9.21.2. **Meta-black shale** Metamorphosed black shale; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of black shale.

9.22. **Meta-volcaniclastic sedimentary rocks** Metamorphosed volcaniclastic sedimentary rocks; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of volcaniclastic sedimentary rocks.

9.22.1. **Meta-volcanic conglomerate** Metamorphosed volcanic conglomerate; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of volcanic conglomerate.

9.22.2. **Meta-volcanic sandstone** Metamorphosed volcanic sandstone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of volcanic sandstone.

9.22.3. **Meta-volcanic mudrock** Metamorphosed volcanic mudrock; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of volcanic mudrock.

9.23. **Metamorphosed tuffaceous sedimentary rocks** Metamorphosed tuffaceous sedimentary rocks; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of tuffaceous sedimentary rocks.

9.23.1. **Metamorphosed tuffaceous conglomerate** Metamorphosed tuffaceous conglomerate; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of tuffaceous conglomerate.

9.23.2. **Metamorphosed tuffaceous sandstone** Metamorphosed tuffaceous sandstone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of tuffaceous sandstone.

9.23.3. **Metamorphosed tuffaceous mudstone** Metamorphosed tuffaceous mudstone; despite metamorphism, the original sedimentary rock protolith can be recognized. See definition of tuffaceous mudstone.

9.24. **Metamorphosed siliciclastic and volcaniclastic sedimentary rocks** A collective term for a layered sequence of metamorphosed siliciclastic and volcaniclastic sedimentary rocks. Metamorphosed siliciclastic sedimentary rocks make up more than half of the succession. Despite metamorphism, the original sedimentary rock protolith can be recognized.

9.25. **Metamorphosed volcaniclastic and siliciclastic sedimentary rocks** A collective term for a layered sequence of metamorphosed volcaniclastic and siliciclastic sedimentary rocks. Metamorphosed volcaniclastic sedimentary rocks make up more than half of the succession. Despite metamorphism, the original sedimentary rock protolith can be recognized.

10. **Higher-grade metamorphic rocks** Metamorphic rocks characterized by metamorphic minerals, texture, and approximate composition. Recognition of protolith may be ambiguous.

10.1. **Metamorphosed aluminous and sub-aluminous rocks** A metamorphic rock derived from sediments variably enriched in aluminum (clay minerals). In addition to quartz, the following metamorphic minerals are common constituents of these rocks: pyrophyllite, andalusite, kyanite, sillimanite, staurolite, chloritoid, cordierite, chlorite, almandine-rich garnet, K-bearing micas, Na-bearing micas, and stilpnomelane (Winkler, 1974).

10.1.1. **Pelitic rock** A metamorphic rock derived from argillaceous or a fine-grained aluminous sediment (such as sedimentary rocks with a high proportion of clay minerals) (Bates and Jackson, 1987).

10.1.2. **Semi-pelitic rock** A metamorphic rock derived from sediment relatively-enriched in aluminum (such as sedimentary rocks with enriched in clay minerals).

10.2.2. **Metamorphosed quartzofeldspathic rocks and quartzites** Metamorphic rocks composed primarily of quartz and/or feldspar.

10.2.1. **Quartzofeldspathic rock** A metamorphic rock composed primarily of feldspar and quartz and formed by recrystallization of siliceous sedimentary rocks (feldspathic sandstones) or granitic rocks.

10.2.2. **Quartzite (metaquartzite)** A granoblastic metamorphic rock consisting mainly of quartz and formed by recrystallization of sandstone or chert by either regional or thermal metamorphism (Bates and Jackson, 1987).

10.2.3. **Felsic gneiss** A gneissic rock dominated by light-colored minerals, commonly quartz and feldspar (Bates and Jackson, 1987).

10.3.3. **Metamorphosed calcareous rocks** Metamorphosed carbonate and quartz-bearing carbonate rocks; metamorphic minerals include: tremolite, forsterite, diopside, wollastonite, periclase (brucite), monticellite, akermanite, spurrite, mervinite, larnite, and grossularite-rich garnet (Winkler, 1974).

10.3.1. **Marble** A metamorphic rock composed primarily of fine- to coarse-grained recrystallized calcite and/or dolomite, usually with a granoblastic, saccharoidal texture (Bates and Jackson, 1987).

10.3.2. **Calcsilicate rock** A metamorphic rock consisting mainly of calcium-bearing silicates such as diopside and wollastonite, and formed by metamorphism of impure limestone or dolomite (Bates and Jackson, 1987).

10.3.3. **Calcic skarn** A metasomatic rock consisting of calcium-bearing silicates derived by the introduction of large amounts of Si, Al, Fe and Mg into calcareous sedimentary rocks (generally limestone). The rock can contain garnet, clinopyroxene, pyroxenoids, amphiboles, chlorite, epidote, clays, carbonates, and sulfide minerals.

10.4.3. **Metamorphosed mafic or basic rocks** Metamorphosed mafic rocks such as basalt, andesite, and their plutonic equivalents. Metamorphic minerals include: prehnite, pumpellyite, zoisite, albite, actinolite, chlorite, epidote, hornblende, and possibly almandine garnet (Winkler, 1974).

10.4.1. **Amphibolite** A crystalloblastic metamorphic rock consisting mainly of amphibole and plagioclase with little or no quartz (Bates and Jackson, 1987).

10.4.2. **Mafic metavolcanic rocks** Metamorphosed rocks of basaltic or andesitic composition.

10.4.2.1. **Greenstone (metavolcanic)** A field term applied to any compact dark-green altered or metamorphosed basic igneous rock (e.g. spilite, basalt, gabbro, diabase) that owes its color to the presence of chlorite, actinolite, or epidote (Bates and Jackson, 1987).

10.4.2.2. **Spilite (metavolcanic)** An altered basalt, characteristically amygdaloidal or vesicular, in which the feldspar has been albitized and is typically accompanied by chlorite, calcite, epidote, chalcedony, prehnite, or other low-temperature hydrous crystallization products characteristic of a greenstone (Bates and Jackson, 1987).

10.4.3. **Greenschist** A schistose metamorphic rock whose green color is due to the presence of chlorite, epidote, or actinolite; a common product of low-grade regional metamorphism of pelitic or basic igneous rocks (Bates and Jackson, 1987).

10.4.4. **Mafic gneiss** A gneissic metamorphic rock dominated by dark-colored minerals, commonly biotite and hornblende (Bates and Jackson, 1987).

10.5.4. **Metamorphosed magnesian rocks** Metamorphosed rocks rich in magnesium, such as ultramafic rocks. Metamorphic minerals include serpentine, talc, anthophyllite, enstatite, forsterite, brucite, periclase, magnesite. If aluminum and calcium are available, chlorite and diopside may also be present (Winkler, 1974).

10.5.1. **Serpentinite** A metamorphic rock consisting almost wholly of serpentine-group minerals derived from the hydration of ferromagnesian silicate minerals such as olivine and pyroxene (Bates and Jackson, 1987).

10.5.2. **Soapstone** A metamorphic rock of massive, schistose, or interlaced fibrous or flaky texture and soft, unctuous feel, composed essentially of talc with varying amounts of micas, chlorite, amphibole, pyroxenes, etc. and derived from the alteration of ferromagnesian silicate minerals (Bates and Jackson, 1987).

10.5.3. **Magnesian skarn** A metasomatic rock consisting of magnesium-bearing silicates derived by the introduction of large amounts of Si, Al, Fe and Mg into calcareous sedimentary rocks (generally dolomite). The rock can contain forsterite, humite, periclase, clinopyroxene, phlogopite, magnetite, serpentine, talc, brucite, tremolite, chlorite, and pyrite.

10.6.3. **Metamorphosed ferruginous rocks** Metamorphic rocks rich in iron, such as iron-rich cherts or ironstones. Metamorphic minerals include: greenalite, minnesotaite, ferroactinolite, ferrocummingtonite, hematite, magnetite, ferrosilite, fayalite, ferrohedenburgite, and almandine garnet (Nelson, 2003).

10.7.3. **Metamorphosed manganiferous rocks** Metamorphic rocks rich in manganese. Metamorphic minerals include stilpnomelene, piedmontite, and spessartine (Nelson, 2003).

10.8.3. **Metamorphic rock - composition unknown** Metamorphic rocks characterized only by their fabric and texture with little or no information on their mineralogy or composition.

10.8.1. **Hornfels - composition unknown** A fine-grained rock composed of a mosaic of equidimensional grains without preferred orientation and typically formed by contact metamorphism (Bates and Jackson, 1987).

10.8.2. **Granofels - composition unknown** A field name for a medium- to coarse-grained granoblastic metamorphic rock with little or no foliation or lineation (Bates and Jackson, 1987).

10.8.3. **Phyllite - composition unknown** A metamorphosed rock, intermediate in grade between slate and mica schist. Minute crystals of sericite and chlorite impart a silky sheen to the surfaces of cleavage (or schistosity) (Bates and Jackson, 1987).

10.8.4. **Schist - composition unknown** A strongly foliated crystalline rock, formed by dynamic metamorphism, that can be readily split into thin flakes or slabs due to the well developed parallelism of more than 50 percent of the minerals present, particularly those of lamellar or elongate prismatic habit, e.g. mica and hornblende (Bates and Jackson, 1987).

10.8.5. **Gneiss - composition unknown** A foliated rock formed by regional metamorphism, in which bands or lenticles of granular minerals alternate with bands or lenticles in which minerals having flaky or elongate prismatic habits predominate. Generally less than 50 percent of the minerals show preferred parallel orientation (Bates and Jackson, 1987).

11. **Unconsolidated sediments** Solid fragmental material that occurs as layers on the Earth's surface in a loose, unconsolidated form.

11.1. **Natural unconsolidated sediments** Solid fragmental material that originates from weathering of rocks and is transported by air, water, or ice, or that accumulates by other natural agents and accumulates in layers on the Earth's surface in a loose, unconsolidated form (Bates and Jackson, 1987).

11.1.1. **Modern fluvial sediments (alluvium)** Sediments deposited by running water of streams and rivers. It may occur on terraces well above present streams, on the present flood plains or deltas, or as a fan at the base of a slope (Soil Science Society of America, 1998).

11.1.1.1. **Braided streams - gravel dominated** Gravel that occurs in a stream with multiple channels that interweave as a result of repeated bifurcation and convergence of flow around interchannel bars, resembling (in plan view) the strands of a complex braid. Braiding is generally confined to broad, shallow streams of low sinuosity, high bedload, non-cohesive bank material, and a steep gradient (Soil Science Society of America, 1998).

11.1.1.2. **Braided streams - sand dominated** Sand that occurs in a stream with multiple channels that interweave as a result of repeated bifurcation and convergence of flow around interchannel bars, resembling (in plan view) the strands of a complex braid. Braiding is generally confined to broad, shallow streams of low sinuosity, high bedload, non-cohesive bank material, and a steep gradient.

11.1.1.3. **Sand-dominated, meandering streams** Sand that occurs in a river channel that winds sinuously across low gradient floodplains. The channels of meandering rivers shift across the floodplain by depositing sediment on the inside of bends while simultaneously eroding the outer banks of the meander bends.

11.1.1.4. **Alluvial fan and fan deltas** A generic term for constructional landforms that are built of stratified alluvium with or without debris-flow deposits and that occur on the pediment slope, downslope from their source of alluvium (Soil Science Society of America, 1998).

11.1.2. **Older alluvium** Sediments deposited by running water of streams and rivers that occur in abandoned stream channels.

11.1.2.1. **Braidplain and braidplain delta** Sheet-like deposits of fluvial sand and gravel that form from braided steams.

11.1.2.2. **Sheet gravels** Sheet-like deposits of gravel that form from braided steams.

11.1.2.3. **Sheet sands** Sheet-like deposits of sand that form from braided steams.

11.1.2.4. **Point bar deposits** A low ridge of sediment that forms along the inner bank of a meandering stream. Houghton Mifflin (undated).

11.1.2.5. **Ribbon sand bodies** Deposits of sand that formed in stream channels.

11.1.2.6. **Terrace deposits** One of a series of platforms in a stream valley, flanking and more or less parallel to the stream channel, originally formed near the level of the stream, and representing the dissected remnants of an abandoned flood plain, stream bed, or valley floor produced during a former state of erosion or deposition (Soil Science Society of America, 1998).

11.1.3. **Eolian deposits (eluvium)** Earth material transported and deposited by the wind including dune sands, sand sheets, loess, and parna. (Soil Science Society of America, 1998).

11.1.3.1. **Loess** a fine-grained unstratified accumulation of clay and silt deposited by the wind (Cognative Science Laboratory, undated).

11.1.3.2. **Sandy desert (ergs)** Vast area of drifting sand. Erg is an Arabic word for a sand sea. (http://diziet.scenario.co.uk/tictoc/Phase3/Resource/glossary.html).

11.1.4. **Lacustrine sediments** Clastic sediments and chemical precipitates deposited in lakes (Soil Science Society of America, 1998).

11.1.4.1. **Evaporite-dominated lake deposits** Deposits that accumulate in lakes that primarily consist of mineral salts formed by the evaporation of water.

11.1.4.2. **Carbonate-dominated lake deposits** Deposits that accumulate in lakes that primarily consist of carbonate minerals.

11.1.4.3. **Siliciclastic-dominated lake deposits- nearshore** Deposits of sands and gravels that accumulate in lakes that are distributed within a narrow, steeply sloping zone by oscillating waves and changing currents (McMillan and Powell, 1999).

11.1.4.4. **Siliciclastic-dominated lake deposits- offshore** Deposits of siliciclastic material (silt, sand, and gravel) that accumulate in lakes.

11.1.5. **Colluvium** Unconsolidated, unsorted earth material being transported or deposited on sideslopes and/or at the base of slopes by mass movement (e.g., direct gravitational action) and by local, unconcentrated runoff (Soil Science Society of America, 1998).

11.1.5.1. **Talus slopes, colluvial mantles, snow avalanche deposits, rockslide debris** Deposits of loose rock fragments that accumulate on sloping surfaces.

11.1.5.2. **Debris flow or mudflow** A general term for a mass movement landform and a process characterized by a flowing mass of predominantly fine-grained earth material (particles less than 2 mm comprising more than 50 percent of the solid material) possessing a high degree of fluidity during movement. If more than half of the solid fraction consists of material larger than sand size, debris flow is preferred (Soil Science Society of America, 1998).

11.1.5.3. **Slumps and landslides** A general term for a mass movement landform and a process characterized by moderately rapid to rapid (greater than 30 cm per year) downslope transport, by means of gravitational stresses, of a mass of rock and regolith that may or may not be water saturated (Soil Science Society of America, 1998).

11.1.6. **Glacial sediments** A general term applied to all mineral material transported by a glacier and deposited directly by or from the ice, or by running water emanating from a glacier. Drift includes unstratified material (till) that forms moraines, and stratified glaciofluvial deposits that form outwash plains, eskers, kames, varves, and glaciolacustrine sediments (Soil Science Society of America, 1998; Eyles and Eyles, 1992).

11.1.6.1. **Glaciofluvial** Material moved by glaciers and subsequently sorted and deposited by streams flowing from the melting ice. The deposits are stratified and may occur in the form of outwash plains, deltas, kames, eskers, and kame terraces (Soil Science Society of America, 1998; Eyles and Eyles, 1992).

11.1.6.2. **Glaciolacustrine** Material ranging from fine clay to sand derived from glaciers and deposited in glacial lakes by water originating mainly from the melting of glacial ice. Many are bedded or laminated with varves (Soil Science Society of America, 1998; Eyles and Eyles, 1992).

11.1.6.3. **Glaciated valley** Material deposited in high-relief glacioterrestrial depositional settings. Deposits are dominated by interbedded debris flow diamicts, braided river gravels, and glaciolacustrine deposits (Eyles and Eyles, 1992).

11.1.6.4. **Subglacial** Accumulations of till, sand, and gravel deposited beneath glaciers. Includes drumlins, eskers, and kames.

11.1.7. **Volcanic sediments** Clastic deposits containing volcanic material.

11.1.7.1. **Pyroclastic fall** Deposits formed from the shower-like falling of pyroclastic material from an volcanic eruption column. The deposits range from small volume, localized scoria and cinder cone accumulations to large volume sequences that mantle topography over large distances (Lajoie and Stix, 1992).

11.1.7.2. **Pyroclastic flow** Deposit formed by the lateral flowage of a turbulent mixture of hot gases and unsorted pyroclastic material (volcanic fragments, crystals, ash, pumice, and glass shards). Pyroclastic flows are dense and most are confined to valleys around a volcano. (U.S. Geological Survey, 2002).

11.1.7.3. **Pyroclastic surge** Deposits formed by low-density variants of pyroclastic flows. Pyroclastic surges are of two types: "hot" pyroclastic surges that consist of "dry" clouds of rock debris and gases that have temperatures appreciably above 100 degrees C, and "cold" pyroclastic surges that consist of rock debris and steam or water at or below a temperature of 100 degrees C. Pyroclastic surges typically hug the ground and depending on their density and speed, may or may not be controlled by the underlying topography (U.S. Geological Survey, 2002).

11.1.7.4. **Lahar** Mudflows and debris flows that originate from the slopes of a volcano (U.S. Geological Survey, 2002).

11.1.8. **Organic materials** Deposits primarily composed of the remains of organisms (Bates and Jackson, 1987).

11.1.8.1. **Peat** Organic soil material in which the original plant parts are recognizable (fibric material) (Soil Science Society of America, 1998).

11.1.9. **Residual material** Weathering product remaining in situ following alteration of the parent material by the action of chemical and/or physical weathering processes (McMillan and Powell, 1999).

11.2.9. **Anthropogenic unconsolidated sediments** Deposits of unconsolidated fragmental material formed by human activity.

11.2.1. **Made ground** Areas where the ground is known to have been deposited by man on the former, natural ground surface: road, rail, reservoir and screening embankments; flood defenses; spoil (waste) heaps; coastal reclamation fill; offshore dumping grounds; constructional fill (McMillan and Powell, 1999).

11.2.2. **Disturbed ground** Areas of surface and near-surface mineral workings where ill-defined excavations, areas of man-induced subsidence caused by the workings and spoil are complexly associated with each other, for example collapsed bell pits and shallow mine workings (McMillan and Powell, 1999).

11.3.2. **Deposits of unclassified origin** A term for unconsolidated materials described only by particle size; genetic classification of materials not provided.

11.3.1. **Gravel** Mixture of gravel, sand, and mud; the percent gravel is equal to or greater than 80 (fig. B-14; Folk, 1974).

11.3.2. **Muddy gravel** Mixture of gravel, sand, and mud; the percent gravel varies between 30 and 80 and the sand:mud ratio is less than 1:1 (fig. B-14; Folk, 1974).

11.3.3. **Muddy sandy gravel** Mixture of gravel, sand, and mud; the percent gravel varies between 30 and 80 and the sand:mud ratio is varies from 1:1 to 9:1 (fig. B-14; Folk, 1974).

11.3.4. **Sandy gravel** Mixture of gravel, sand, and mud; the percent gravel varies between 30 and 80 and the sand:mud ratio is greater than 9:1 (fig. B-14; Folk, 1974).

11.3.5. **Gravelly mud** Mixture of gravel, sand, and mud; the percent gravel varies between 5 and 30 and the sand:mud ratio is less than 1:1 (fig. B-14; Folk, 1974).

11.3.6. **Gravelly muddy sand** Mixture of gravel, sand, and mud; the percent gravel varies between 5 and 30 and the sand:mud ratio is varies from 1:1 to 9:1 (fig. B-14; Folk, 1974).

11.3.7. **Gravelly sand** Mixture of gravel, sand, and mud; the percent gravel varies between 5 and 30 and the sand:mud ratio is greater than 9:1 (fig. B-14; Folk, 1974).

11.3.8. **Slightly gravelly mud** Mixture of gravel, sand, and mud; the percent gravel varies between trace (0.01) and 30 and the sand:mud ratio is less than 1:9 (fig. B-14; Folk, 1974).

11.3.9. **Slightly gravelly sandy mud** Mixture of gravel, sand, and mud; the percent gravel varies between trace (0.01) and 30 and the sand:mud ratio varies from 1:9 to 1:1 (fig. B-14; Folk, 1974).

11.3.10. **Slightly gravelly muddy sand** Mixture of gravel, sand, and mud; the percent gravel varies between trace (0.01) and 30 and the sand:mud ratio varies from 1:1 to 9:1 (fig. B-14; Folk, 1974).

11.3.11. **Slightly gravelly sand** Mixture of gravel, sand, and mud; the percent gravel varies between trace (0.01) and 30 and the sand:mud ratio greater than 9:1 (fig. B-14; Folk, 1974).

11.3.12. **Mud (silt and clay)** Mixture of gravel, sand, and mud; the percent gravel is below a trace (0.01) and the sand:mud ratio is less than 1:9 (fig. B-14; Folk, 1974).

11.3.13. **Sandy mud** Mixture of gravel, sand, and mud; the percent gravel is below a trace (0.01) and the sand:mud ratio varies from 1:9 to 1:1 (Folk, 1974, p. 28).

11.3.14. **Muddy sand** Mixture of gravel, sand, and mud; the percent gravel is below a trace (0.01) and the sand:mud ratio varies from 1:1 to 9:1 (fig. B-14; Folk, 1974).

11.3.15. **Sand** Mixture of gravel, sand, and mud; the percent gravel is below a trace (0.01) and the sand:mud ratio greater than 9:1 (fig. B-14; Folk, 1974).

11.3.16. **Clayey sand** Mixture of sand, silt, and clay; the percent sand varies from 50 to 90 and the clay:silt ratio is greater than 2:1 (fig. B-14; Folk, 1974).

11.3.17. **Silty sand** Mixture of sand, silt, and clay; the percent sand varies from 50 to 90 and the clay:silt ratio is less than 1:2 (fig. B-14; Folk, 1974).

11.3.18. **Sandy clay** Mixture of sand, silt, and clay; the percent sand varies from 10 to 50 and the clay:silt ratio is greater than 2:1 (fig. B-14; Folk, 1974).

11.3.19. **Sandy silty** Mixture of sand, silt, and clay; the percent sand varies from 10 to 50 and the clay:silt ratio is less than 1:2 (fig. B-14; Folk, 1974).

11.3.20. **Clay** Mixture of sand, silt, and clay; the percent sand is less than 10 and the clay:silt ratio is greater than 2:1 (fig. B-14; Folk, 1974).

11.3.21. **Silt** Mixture of sand, silt, and clay; the percent sand is less than 10 and the clay:silt ratio is less than 1:2 (fig. B-14; Folk, 1974).

12. **Igneous plutonic and metamorphic rocks** A collective term for suite of igneous plutonic and metamorphic rocks. Igneous plutonic rocks make up more than half of the suite.

13. **Metamorphic and igneous plutonic rocks** A collective term for suite of metamorphic and igneous plutonic rocks. Metamorphic rocks make up more than half of the suite.

14. **Volcanic and sedimentary rocks** A collective term for a layered sequence of igneous volcanic and sedimentary rocks. Igneous volcanic rocks make up more than half of the succession.

15. **Metamorphosed volcanic and metamorphosed sedimentary rocks** A collective term for suite of metamorphosed volcanic and sedimentary rocks. Metamorphosed volcanic rocks make up more than half of the suite.

16. **Sedimentary and volcanic rocks** A collective term for a layered sequence of sedimentary and igneous volcanic rocks. Sedimentary rocks make up more than half of the succession.
17. **Metamorphosed sedimentary and metamorphosed volcanic rocks** A collective term for suite of metamorphosed sedimentary and volcanic rocks. Metamorphosed sedimentary rocks make up more than half of the suite.
18. **Plutonic and volcanic rocks** A collective term for a suite of igneous plutonic and volcanic rocks. Igneous plutonic rocks make up more than half of the suite.
19. **Volcanic and unconsolidated rocks** A collective term for a suite of igneous volcanic rocks and unconsolidated deposits. Igneous volcanic rocks make up more than half of the suite.
20. **Unconsolidated and volcanic rocks** A collective term for a suite of unconsolidated deposits and igneous volcanic rocks. Unconsolidated deposits make up more than half of the suite.
21. **Igneous plutonic and igneous other rocks** A collective term for a suite of igneous rocks that contains igneous plutonic rocks that can be classified using the QAPF or ultramafic modal classification schemes as well as igneous rocks that cannot be named using these approaches. See definitions for igneous-plutonic and igneous-other.
22. **Unconsolidated and sedimentary rocks** A collective term for a suite of unconsolidated deposits and sedimentary rocks. Unconsolidated deposits make up more than half of the suite.
23. **Volcanic and metamorphic rocks** A collective term for a suite of igneous volcanic and metamorphic rocks. Volcanic rocks make up more than half of the suite.
24. **Sedimentary and metamorphic rocks** A collective term for a suite of sedimentary and metamorphic rocks. Sedimentary rocks make up more than half of the suite.
25. **Structurally modified rocks** A collective term for rocks that can be described by fabrics developed during deformation. No compositional information is indicated.
    - 25.1. **Tectonite** Any rock whose fabric reflects the history of its deformation; a rock whose fabric clearly displays coordinated geometric features that indicate continuous solid flow during formation (Bates and Jackson, 1987).
        - 25.1.1. **Tectonic mélange** A body of rock produced by tectonic processes that is characterized by a lack of internal continuity of contacts or strata and by the inclusion of fragments and blocks of all sizes, both exotic and native, embedded in a fragmental matrix of finer-grained material (Bates and Jackson, 1987).
        - 25.1.2. **Cataclasite** A rock containing angular fragments that have been produced by the crushing and fracturing of preexisting rocks as a result of mechanical forces in the crust; a metamorphic rock produced by cataclasis. Its fabric is a structureless rock powder (Bates and Jackson, 1987).
        - 25.1.3. **Phyllonite** A rock that macroscopically resembles phyllite but that is formed by mechanical degradation (mylonization) of initially coarser rocks (e.g. graywacke, granite, or gneiss). Silky films of recrystallized mica or chlorite, smeared out along schistosity surfaces, and formation by dislocation metamorphism are characteristic (Bates and Jackson, 1987).
        - 25.1.4. **Mylonite** A compact, chertlike rock without cleavage, but with a streaky or banded structure, produced by the extreme granulation and shearing of rocks that have been pulverized and rolled during overthrusting or intense dynamic metamorphism (Bates and Jackson, 1987).
        - 25.1.5. **Ultramylonite** An ultra-crushed variety of mylonite, in which primary structures and porphyroclasts have been obliterated so that the rock becomes homogeneous and dense, with little if any parallel structure (Bates and Jackson, 1987).
        - 25.1.6. **Pseudotachylyte** A dense rock produced in the compression and shear associated with intense fault movements, involving extreme mylonitization and/or partial melting (Bates and Jackson, 1987).
        - 25.1.7. **Tectonic breccia** A breccia formed as a result of crustal movements, usually developed from brittle rocks (Bates and Jackson, 1987).

25.1.8. **Gouge** Soft, uncemented pulverized clayey or claylike material, commonly a mixture of minerals in finely divided form, found along some faults or between the walls of a fault, and filling or partly filling a fault zone (Bates and Jackson, 1987).

Appendix C. Procedure for naming unique regional geologic units for the compilation

By Michael L. Zientek and J. Douglas Causey

Tables

One objective of creating the compilation was to identify the regional geologic units that occur throughout the study area. In the process of assembling information for the spatial database, we found that a combined list of the map unit names given in each of the source maps does not represent the unique map units in the compilation. In some situations, the same geologic unit was given different names on the source maps. These differences commonly reflected variations in spelling or editorial style. However, the differences in names also resulted from changes in stratigraphic nomenclature. For example, a regionally-extensive arkosic quartzite in the Missoula Group of the Belt Supergroup occurs on 9 of the 43 maps used for this compilation. On some maps, it is called the Bonner Quartzite; on others, it is the Bonner Formation. We recognize it as the same unit and apply one name (Bonner Quartzite) to it for this study. In other cases, the same unit name was applied to different geologic formations. For example, the unit name “granodiorite” was applied to igneous rock units on different maps that were widely separated geographically and clearly were not co-magmatic. However, by standardizing the spelling and style for map unit names and inspecting symbolized spatial databases, 1,330 unique geologic entities in the regional compilation were identified from the 2,135 geologic map units in the original maps. We have retained the original version of the unit name in the field *name_or* in the ArcInfo® look-up table NR_GEO.MU. Map unit names for the unique, regional geologic units are stored in the field *name* in the same table.

In compiling the unique regional geologic units, our intent is to identify a unit that occurs on more than one map; however, we did not correlate rocks. For example, the Spokane Formation, correlates with the Grinnell Formation, and with the stratigraphic interval consisting of the Burke, Revett, and St. Regis Formations. We retained all of these units in the compilation rather than combining them into a single map unit. Relations between units that reflect correlation or membership in other units could be recorded in a separate database table. We did not develop such a correlation table for this study.

Selection of a name for the unique, regional map unit depends on the stratigraphic status of the map unit (Hansen, 1001). We used the USGS Geologic Names Lexicon (MacLachlan, 1996 and GEOLEX (U.S. Geological Survey, 2004)) to establish the stratigraphic status of each unit. We determined if the unit was formally named, an informal subdivision of a formally-named unit, or an informal map unit (table C-1). For informal units, we further differentiated those that were unconsolidated deposits. This information was coded in the field *unit_type* in the ArcInfo® look-up table NR_GEO.MU. 697 of the unique map units are formally-named, 392 are informal subdivisions of a formal unit, 260 are unconsolidated deposits, and the remainders, 787, are informally named units. Unconsolidated deposits that have formal names (for example Palouse Formation) are coded as formal. The rules we used to name units for this compilation follow:

- Names for formally-defined stratigraphic units follow usage in the USGS Geologic Names Lexicon Database (MacLachlan, 1996 and GEOLEX (U.S. Geological Survey, 2004)). The name in the database was applied to all map units; the unit name and/or the unit rank terms are capitalized (Flathead Sandstone, Maywood Formation). If more than one accepted usage of the name was in the database (for example, Jefferson Dolomite, Jefferson Formation, Jefferson Dolostone, Jefferson

Limestone), the most recent usage generally was selected to use in the compilation. Another consideration for selecting a name was geographic variations in use; formations with many accepted names may occur over large regions. We selected a name appropriate for our study area.

- If a map unit consists of more than one formal geologic unit, the names are given, as much a possible, in descending stratigraphic order (youngest to oldest) followed by the word “undivided” (for example, Park Shale, Meagher Limestone, Wolsey Shale, and Flathead Sandstone, undivided).
- Units that are informal subdivisions (such as a member) of formal units retained their informal names, but were prefixed by the name of the formal unit to which they belong. The informal part of the name is not capitalized; the formal part of the name is. Normally, the formal name would follow the informal name (lower member of the Wallace Formation). However, we inverted the order (Wallace Formation, lower member) to facilitate sorting and selecting information in a database.
- Names of unconsolidated rock units were standardized according to deposit type. For example, alluvium; alluvial deposits; alluvium, undivided; alluvial and fluvial channel deposits, alluvium of modern channels and flood plains, and alluvial deposit of the present flood plain are all called “Alluvial deposits.” The exceptions to this rule are unconsolidated units that were specifically subdivided and could be related to a specific geographic feature on the source map. In the database, we found names like “terrace level 1”, and “terrace level 2”. We determined that many of these mapped terraces could be related to a specific river and could be correlated between different source maps, in these cases, the map unit name consists of a unconsolidated deposit term followed by the name of the drainage (Alluvial gravel, terrace level 1, Yellowstone River; Alluvial gravel, terrace level 2, Yellowstone River).
- Names for informal units generally consist of a lithologic term followed by a geographic term (granodiorite of Wrenco). Our first choice for a geographic term was a prominent, named landform (such as a mountain or a lake). When no landform feature was available, the name of a nearby town was used. The geographic terms were selected from features on 1:250,000 and 1:100,000 scale topographic maps. Some informal map units are areally extensive and can be best described in relation to regional geologic or physiographic features. In this case, the name was constructed with a regional geologic feature term followed by the lithologic term (for example, Idaho batholith, granodiorite). The normal order was inverted to make it easier to sort and select information in a database. The major features recognized in this area include: Blue Mountains island arc, Boulder batholith, Pioneer batholith, Challis magmatic complex, Elk City metamorphic sequence, Idaho batholith, Meadow Creek metamorphic sequence, Priest River Complex, Priest River metamorphic complex, Purcell sills, Syringa metamorphic sequence, and Wyoming Province. One formally named unit (Stillwater Complex) is lumped within a major feature (Wyoming Province) and several formally named units are included in the Blue Mountains island arc.

The approach to informal units varied significantly between the different source maps. Different strategies were used to construct units and the convention of naming units with lithologic and geographic terms was inconsistently applied. Entities separated on one map were aggregated on others. For example, the Boulder batholith was grouped with other granitic rocks on the Butte geologic map (Lewis, 1998). For polygon classification by the keyfield *mu_id* in the tables NR_GEO.PAT and NR_GEO.AAT, we retained the units as defined by the authors even though geologic relations may be obscure and unit names are cumbersome. Appendix G describes how we reclassified polygons into consistent informal units.

Uncertainties expressed on the source maps by “?” or “(uncertain)” were preserved with the question mark (?) added to the name. The placement of the question mark indicates what is questioned. For example, “Wallace Formation (?), schist” means that the formation is questionable, while “Absaroka Volcanic Supergroup, dacite (?) flows near Cinnabar Mountain” indicates the rock type is questionable.

“Everts Formation (?) and Virgelle Sandstone, undivided” means that only the Everts Formation is questioned while “Saturday Mountain Formation, Kinnikinic Quartzite, and Ella Dolostone, undivided (?)” questions all the formations.

Table C1. Definitions of the codes in the field *unit_type* in the ArcInfo® look-up table NR_GEO.MU.

unit_type	Value	Definition
F	Formal name	Map unit name is in online USGS Geologic Names Lexicon (GEOLEX, U.S. Geological Survey, 2004) and categorized as formal, or formally accepted in literature (in other words, approved for publication by a USGS author in external publication). If a formal map unit contains more than one named stratigraphic entity (such as Formation and Group), all parts must also be formally named units.
I	Informal name	Map unit name is in GEOLEX and categorized as informal, or is not listed in GEOLEX and not formally established in the literature.
IF	Informal part of formal unit	Member, part, bed, or other subdivision of a formal geologic unit. The formal name precedes the informal name in the name field. This code is also used for a map unit containing both formal and informal parts.
U	Unconsolidated unit	A map unit consisting of unconsolidated rock material, which has not been formally named.

References cited

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Appendix D: Coding geologic time in the database

By J. Douglas Causey and Michael L. Zientek

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Introduction

This appendix explains how geologic time terms are used in the Northern Rocky Mountains spatial database. It describes the geologic time chart used for this study, how geologic time terms were standardized for use in the database, and the information provided in eight items in NR_GEO spatial database.

The first part of this appendix discusses the time chart selected for this report. The source maps used for this compilation were published over a 30-year period in which there were advances in the use of geochronology to establish the boundary ages for geologic time terms and the ages of igneous rocks. During the same time period, the geologic community suggested revisions to the geologic time terms. The geologic time chart selected for this report is consistent with the usage of time terms in the source maps and with recently published dates for unit boundaries.

The source maps for this compilation used both lithostratigraphic and geochronologic terms for geologic time. The second part of the appendix documents how lithostratigraphic terms were converted to geochronologic terms.

The final part of this appendix describes how geologic age terms were coded in database fields in look-up tables. Eight items found in the ArcInfo® look-up tables NR_GEO.MU (*minage_or, maxage_or, age_or, strat_age,* and *age*) and NR_GEO.IGMU (*ig_maxage*, *ig_minage*, *ig_age*) are described.

Age information associated with the 2,135 original map units is coded in the items *minage_or, maxage_or,* and *age_or* in the table NR_GEO.MU. The *minage_or* and *maxage_or* items contain the minimum and maximum age terms used for original geologic units on the source maps. The a*ge_or* item contains a single age term created from the data in the items *minage_or* and *maxage_or* and generalized to a Period or higher level for Phanerozoic age map units and Era or higher for Precambrian age units. The attributes in *age_or* are consistent with the map unit ages used on the original maps.

Two items, *strat_age* and *age* in table NR_GEO.MU, contain the age terms for the 1,330 regional geologic map units (*name*) in the Northern Rocky Mountains compilation. The s*trat_age* item contains terms that best describes the age of the compiled geologic units as defined in this report. The a*ge* item contains terms that generalize the *strat_age* term to a Period or higher level for Phanerozoic age map units and Era or higher for Precambrian age unit and is consistent with the map symbols for the unique, regional geologic units.

Ages of the revised igneous units are coded in the table NR_GEO.IGMU. Some of the igneous map unit polygons have been re-grouped and the ages corrected (see Appendix G). The terms in *ig_maxage*, *ig_minage*, and *ig_age* are the age terms that apply to the new igneous rock compilation in this spatial database.

Geologic time chart

The time chart constructed for the Northern Rocky Mountains geologic spatial database reflects the usage of geologic time terms in the publications used to create this compilation (fig. D-1). The usage of subdivisions of geologic time in the map-unit descriptions, particularly for the epochs in the Paleozoic, generally agrees with the subdivisions published by Hansen (1991). However, Hansen (1991) does not have absolute age estimates for all the boundaries between geologic time units. We examined a variety of published stratigraphic time scales (Palmer, 1983; Harland and others, 1990; Hansen, 1991; Gradstein and Ogg, 1996; Pan Terra, 1998; Haq and Van Eysinga, 1998; Grant, 1999; Palmer and Geissman, 1999; Topinka, 2001; Remane, 2002; International Commission on Stratigraphy, 2003) and created a composite chart from two sources that appear to be consistent with the subdivisions of geologic time and absolute ages used by the source maps for this compilation. The charts by Hansen (1991, fig. 15, p. 59) and Haq and Van Eysinga (1998) are the source of the absolute ages illustrated in figure D-1. Of the published sources that we considered, Haq and Van Eysinga (1998) was the only publication that had absolute minimum and maximum boundary ages for all the Phanerozoic time subdivisions used in this compilation. For this compilation, the “North America/California and General” age boundaries of Haq and Van Eysinga are adopted for the Cretaceous Period. The remainder of the Phanerozoic Eon age boundaries was taken from the general terms within the eon, era, period, and epoch geologic-time units on their Geologic Time Table. Eon and Era names and absolute boundaries for the Precambrian came from Hansen (1991, p. 59).

Precambrian time is the most difficult period to resolve because the understanding of that time has resulted in major revisions of its subdivisions and nomenclature. Bishop and others (1978) had Precambrian listed as an era or erathem, which was subdivided into four “informal time divisions” (Precambrian Z – 570-600 Ma, Precambrian Y – 600-1600 Ma, Precambrian X – 1600-2500 Ma, and Precambrian W – 2500 Ma and older). In the subsequent suggestions to U.S. Geological Survey authors publication (Hansen, 1991), Precambrian time was not shown on the divisions of geologic time (Figure 15, Hansen, 1001), but instead Proterozoic and Archean Eon/Eonothem, with their respective era or erathem subdivisions (Late, Middle, Early Proterozoic; and Late, Middle, Early Archean) was used. Precambrian was relegated to an informal name.

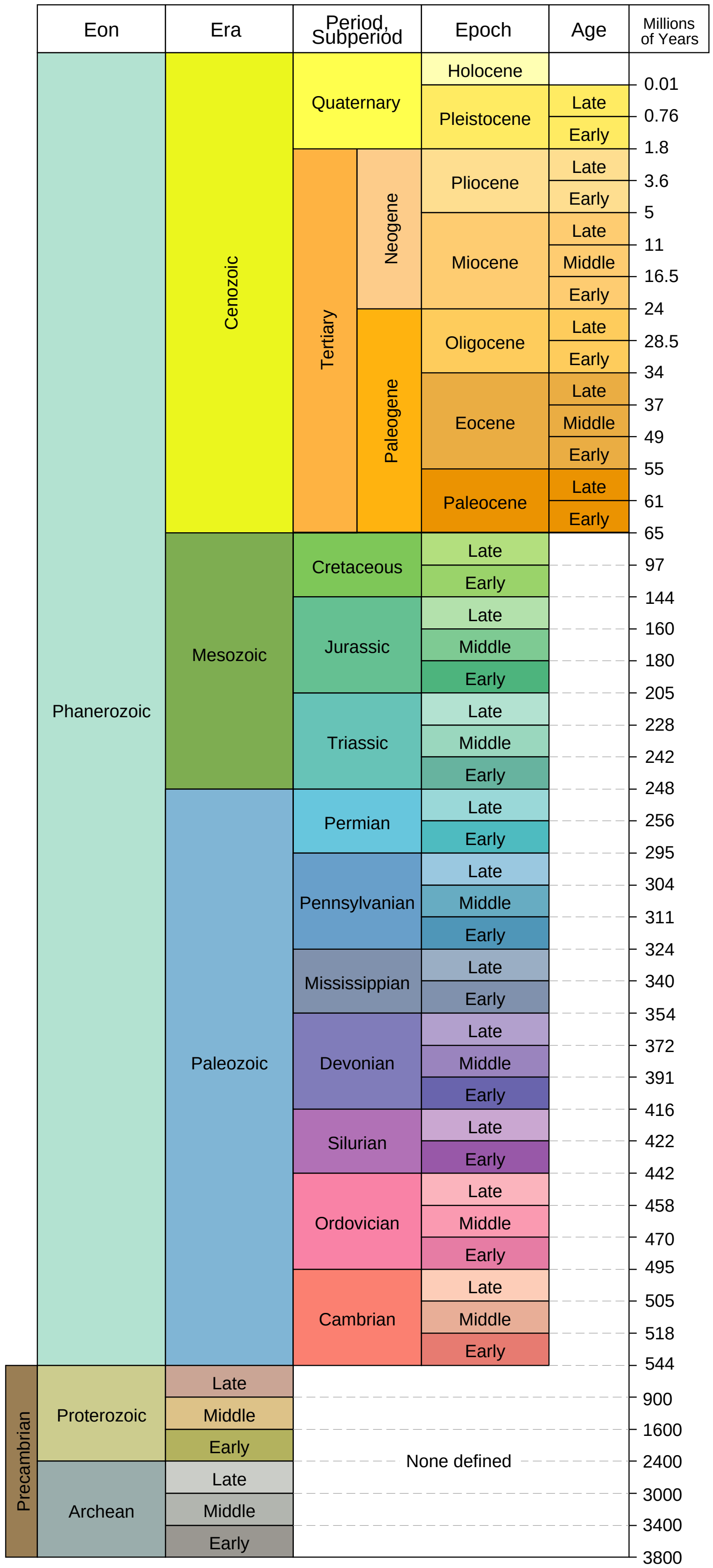

Figure D-1. Divisions of geologic time used to code the database items in this compilation.

Only 21 of the original map units do not have age dates adequate to properly put them into modern subdivisions and must still be called Precambrian. For our chart we compromised and used Hansen's (1991) subdivisions for ages older than Cambrian as it is the present U.S. Geological Survey standard for geologic mapping. We assumed that maps published by other agencies followed similar standards, unless there was evidence to the contrary. For example, O'Neill and Christiansen (2002) indicate Middle Archean as >3.1 Ga years old, while Hansen (1991) has the upper boundary at 3.0 Ga.

Current research has significantly revised the estimates of absolute ages associated with some boundaries between geologic time units in the Phanerozoic. For example, the Precambrian-Cambrian boundary has been redefined as closer to 540 Ma rather than the 570 Ma reported by Hansen (1991). Less dramatic, but significant revisions have also been reported for the boundary between the Jurassic and Cretaceous, Pennsylvanian and Permian, and Cambrian and Ordovician Periods.

To determine if these changes in absolute ages would have any affect on the information we were collecting from the geologic maps, geologic time terms were selected from the chart in figure C-1 using radiometric ages in map-unit descriptions. These terms were then compared to the stratigraphic age term in the published map unit description. Of 22 units with discrepancies, most were because the map's author determined that the radiometric date was too young due to such factors as excess argon or a reset age. In two cases, the radiometric age indicates that a different stratigraphic time term could be used because the stratigraphic boundaries used in this report are different than those probably used by the original author. For units with *mu_id* equal to 1905 and 4768, the radiometric dates would place the units in different stratigraphic time units (Cretaceous and Late Archean, respectively) than we have them. The unit, *mu_id* = 1905, has a single fission track date with a 17.4 my error that overlaps the geologic age boundary. We felt that this single date did not provide strong evidence to reclassify the whole unit to a younger age. The author of the report with the unit, *mu-id* = 4768, uses a newer interpretation of the Archean-Proterozoic boundary than this paper, so we did not modify the stratigraphic age term for that unit to fit our time chart. Based on this analysis, we decided to use the time terms in the original map unit description in our compilation.

Standardizing time terms

The source maps used in this compilation used both lithostratigraphic and geochronologic terms for geologic time (for example, Upper Permian and Late Permian). Lithostratigraphic terms refer to material units, based on actual bodies of rock, whereas geochronologic terms refer to nonmaterial units, based on the abstract concept of geologic time (Owen, 1987). Informal age terms not recognized in published geologic time charts (for example, 'middle Mesozoic') were also used. Whenever these undefined modifiers were used, the modifier was dropped (for example, 'early Tertiary' became Tertiary).

For this compilation, only geochronologic terms are used to convey information about geologic time. When necessary, lithostratigraphic and informal terms used on published maps have been converted to the equivalent geochronologic term (table D-1). The term Neogene is used only in the NR_GEO.IGMU table, not on any of the source maps.

Two non-time terms are used in the look-up table NR_GEO.MU. Map units with no age information are coded "Unknown." The attribute entry for polygons identified as water bodies is NA.

Table D-1. Table defining how equivalent geologic time terms in the source publications were recoded for use in the *maxage_or* and *minage_or* items.

Age terms used in this compilation	**Age terms used in the original publications**
Phanerozoic	Phanerozoic
Quaternary	Quaternary
Holocene	Holocene
Pleistocene	Pleistocene, Pleistocene?
Late Pleistocene	Upper Pleistocene, upper? Pleistocene
Tertiary	Tertiary, Early Tertiary, Tertiary?
Neogene	Term not used on source maps, but entered for igneous map units in the items *ig_minage* and *ig_maxage* in the look-up table NR_GEO.IGMU.
Paleogene	Term not used on source maps, but entered for igneous map units in the items *ig_minage* and *ig_maxage* in the look-up table NR_GEO.IGMU.
Pliocene	Pliocene, Pliocene?
Late Pliocene	Late Pliocene?
Miocene	Miocene, Miocene?, Miocene(?)
Late Miocene	Upper Miocene, upper Miocene?
Middle Miocene	Middle Miocene
Early Miocene	Lower Miocene
Oligocene	Oligocene, Oligocene?
Late Oligocene	Late Oligocene
Middle Oligocene	Middle Oligocene
Early Oligocene	Lower Oligocene
Eocene	Eocene, Eocene?
Late Eocene	Upper Eocene
Middle Eocene	mid-Eocene
Early Eocene	Early Eocene
Paleocene	Paleocene, Paleocene?
Mesozoic	Mesozoic, middle Mesozoic
Cretaceous	Cretaceous, Cretaceous?
Late Cretaceous	Late Cretaceous, Upper Cretaceous, Late (?) Cretaceous, latest Cretaceous
Early Cretaceous	Lower Cretaceous
Jurassic	Jurassic
Late Jurassic	Upper Jurassic
Middle Jurassic	Middle Jurassic
Early Jurassic	Early Jurassic
Triassic	Triassic
Late Triassic	Upper Triassic
Middle Triassic	Middle Triassic
Early Triassic	Lower Triassic, Early Triassic
Paleozoic	Paleozoic, Late Paleozoic, Paleozoic?, lower Paleozoic
Permian	Permian
Early Permian	Lower Permian, Early Permian
Pennsylvanian	Pennsylvanian, Pennsylvanian?
Late Pennsylvanian	Upper Pennsylvanian
Middle Pennsylvanian	Middle Pennsylvanian
Early Pennsylvanian	Lower Pennsylvanian
Mississippian	Mississippian, Mississippian?
Late Mississippian	Upper Mississippian
Early Mississippian	Lower Mississippian, Lower Mississippian?
Devonian	Devonian
Late Devonian	Upper Devonian

Table D-1. Continued.

Age terms used in this compilation	Age terms used in the original publications
Middle Devonian	Middle Devonian
Early Devonian	Lower Devonian
Silurian	Silurian
Early Silurian	Lower Silurian
Ordovician	Ordovician, Ordovician?
Late Ordovician	Upper Ordovician, Late Ordovician
Middle Ordovician	Middle Ordovician
Early Ordovician	Lower Ordovician
Cambrian	Cambrian, Cambrian?
Late Cambrian	Late Cambrian, Upper Cambrian
Middle Cambrian	Middle Cambrian, Middle? Cambrian
Early Cambrian	Early Cambrian, Lower Cambrian
Precambrian	Precambrian
Proterozoic	Proterozoic, Proterozoic?
Late Proterozoic	Late Proterozoic, Proterozoic Z, Upper? Proterozoic, Neoproterozoic, Neoproterozoic?
Middle Proterozoic	Middle Proterozoic, Proterozoic Y, Middle Proterozoic?, Mesoproterozoic, Mesoproterozoic?, Precambrian Y
Early Proterozoic	Early Proterozoic, Early Proterozoic?, Paleoproterozoic
Archean	Archean, Archean?
Late Archean	Late Archean
Middle Archean	Middle Archean

Source map age data

Age information for the 2,135 geologic map units on the source maps is stored in the items *minage_or*, *maxage_or*, and *age_or* in the table NR_GEO.MU. The *minage_or* and *maxage_or* items contain the minimum and maximum age, respectively, which the authors assigned to the individual map units. As described in the previous section, lithostratigraphic and informal age terms have been converted to geochronologic terms.

The estimates of geologic age for some units have been revised after the maps were originally published. In this case, the source maps for this study may show different ages for the same unit than more recent publications. In general, we did not modify the terms in *minage_or* or *maxage_or* in the table NR_GEO.MU to address these changes. The major exception involves rocks of the Belt Supergroup. Early studies list these rocks as Precambrian; subsequent work has shown they are Middle Proterozoic. In order to normalize the information for these rocks, we have coded all Belt Supergroup units as Middle Proterozoic.

The *age_or* item contains 53 time terms, which can be used for viewing and displaying a generalized version of the original time designations. The terms in a*ge_or* were determined from the *minage_or* and *maxage_or* data by generalizing geologic age terms to Period for the Phanerozoic and Era in the Precambrian. If the attributes in the items *minage_or* and *maxage_*or belong to the same Period in the Phanerozoic (for example, Early Cretaceous to Late Cretaceous), the Period term was used in the *age_or* item. If the attributes in the items *minage_or* and *maxage_*or include two or more Periods in the Phanerozoic (for example, Early Permian to Late Devonian), the geologic time term in *age_or* is a combination of the two Period terms, listed from youngest to oldest (Permian-Devonian). When the minimum and maximum ages spanned an Era in the Phanerozoic (for example, Permian to Cambrian), the Era name was used. A similar approach was used for Precambrian rocks except that terms were generalized to Era then Eon. Following the convention that Precambrian is an informal term, no units were generalized to Precambrian. If the term Precambrian was used on the original map, that term was retained when we did not have better information. The 53 unique stratigraphic age terms in *age_or* are listed in Table D-2.

Table D-2. List of all stratigraphic age terms used in the item *age_or,* table NR_GEO.MU.

Terms used in the item *age_or*	**Terms used in the item *age_or***
Quaternary	Mississippian-Cambrian
Quaternary-Tertiary	Devonian
Tertiary	Devonian-Ordovician
Tertiary-Cretaceous	Devonian-Cambrian
Tertiary-Proterozoic	Silurian
Tertiary-Precambrian	Silurian-Ordovician
Mesozoic	Ordovician
Cretaceous	Ordovician-Cambrian
Cretaceous-Jurassic	Ordovician-Late Proterozoic
Cretaceous-Permian	Cambrian
Cretaceous-Middle Proterozoic	Cambrian-Late Proterozoic
Cretaceous-Precambrian	Cambrian-Middle Proterozoic
Jurassic	Paleozoic-Late Proterozoic
Jurassic-Triassic	Paleozoic-Proterozoic
Jurassic-Permian	Late Proterozoic
Triassic	Late Proterozoic-Middle Proterozoic
Triassic-Permian	Middle Proterozoic
Mesozoic-Paleozoic	Middle Proterozoic-Early Proterozoic
Paleozoic	Early Proterozoic
Permian	Early Proterozoic-Late Archean
Permian-Pennsylvanian	Early Proterozoic-Archean
Permian-Mississippian	Proterozoic-Archean
Permian-Devonian	Archean
Pennsylvanian	Late Archean
Pennsylvanian-Mississippian	Middle Archean
Mississippian	Precambrian
Mississippian-Devonian	--

Northern Rocky Mountains geologic unit age data

Age information for the new compilation is contained in five items in two tables. One group of ages refers to all the geologic units in the NR_GEO spatial database. These are described in the following section. The other group of ages is specific to the re-classified igneous units in this spatial database. They are described in the igneous classification age section.

Geologic classification age

Two items (s*trat_age* and *age*) in the NR_GEO spatial database contain coding specific to ages of units defined in the Northern Rocky Mountains geologic compilation. The s*trat_age* item in the table NR_GEO.MU contains age information for the 1,330 unique geologic units in nr_geo. Terms in *strat_age* provide the most definitive description of the age of each unique unit in this compilation. The item *age* provides a generalized time term useful for regional display.

The *strat_age* item was determined by comparing the *minage_or* and *maxage_or* on all maps in which the newly named geologic unit occurs. The values for *minage_or* and *maxage_or* were compared for all units that have the same name (in *name* item) and the age range was computed. The values in *minage_or* on each source map were compared to determine the youngest age for a unit. Likewise, the values in *maxage_or* were compared to determine the oldest age. After determination of the age range of a unit, the minimum and maximum ages were compared. If the minimum and maximum ages were identical, a single age term is reported in *strat_age*. If the age terms were not the same but exactly correspond to a higher order age term, the higher order term was used. For example, if the ages associated with a unit ranged from

Late Cretaceous to Early Cretaceous, the Period term, Cretaceous, would be used. Similarly, if the ages for a unit ranged from Permian to Cambrian, then the corresponding Era term, Paleozoic, would be entered in the table. If the ages were different and did not correspond to a higher order age term, the unit was given a compound hyphenated name. In the compound name, the age terms are listed from youngest to oldest. For example, if the minimum and maximum age terms were Middle Devonian and Middle Cambrian, respectively, the compound name would be Middle Devonian-Middle Cambrian. However, if the range of ages could be equated to higher ranked age terms, the higher order term was substituted into the compound name. For example, Late Cretaceous to Middle Triassic would be coded as Cretaceous-Middle Triassic. Early Permian to Early Silurian would be coded Early Permian-Silurian. Late Devonian to Early Cambrian would be coded Devonian-Cambrian.

We checked the geologic age of formal geologic units in the online lexicon of stratigraphic nomenclature (GEOLEX, U.S. Geological Survey, 2004). In some cases, revised age information for a unit was available in more recent publications. For these units, the revised ages in GEOLEX were used to populate the item *strat_age*.

The *age* item provides a quick way to symbolize the Northern Rocky Mountains compilation based on generalized geologic ages. There are only 55 unique stratigraphic age terms in the *age* item (Table D-3) rather than the 128 terms in the *strat_age* item. Terms in *age* were created from data in *strat_age* using a procedure similar to that used to populate *age_or*.

Table D-3. List of all stratigraphic age terms used in the item *age*, table NR_GEO.MU.

Terms used in the item *age*	**Terms used in the item *age***
Quaternary	Mississippian-Devonian
Quaternary-Tertiary	Mississippian-Ordovician
Tertiary	Mississippian-Cambrian
Tertiary-Cretaceous	Devonian
Tertiary-Proterozoic	Devonian-Ordovician
Tertiary-Archean	Devonian-Cambrian
Mesozoic	Silurian
Cretaceous	Silurian-Ordovician
Cretaceous-Jurassic	Silurian-Cambrian
Cretaceous-Permian	Ordovician
Cretaceous-Cambrian	Ordovician-Cambrian
Cretaceous-Middle Proterozoic	Ordovician-Late Proterozoic
Cretaceous-Early Proterozoic	Cambrian
Jurassic	Cambrian-Late Proterozoic
Jurassic-Triassic	Cambrian-Middle Proterozoic
Jurassic-Permian	Proterozoic
Triassic	Late Proterozoic
Triassic-Permian	Late Proterozoic-Middle Proterozoic
Mesozoic-Paleozoic	Middle Proterozoic
Paleozoic	Middle Proterozoic-Early Proterozoic
Permian	Early Proterozoic
Permian-Pennsylvanian	Early Proterozoic-Late Archean
Permian-Mississippian	Early Proterozoic-Archean
Permian-Devonian	Proterozoic-Archean
Permian-Proterozoic	Archean
Pennsylvanian	Middle Archean
Pennsylvanian-Mississippian	Precambrian
Mississippian	--

Igneous classification age

There are three items with age terms in the table NR_GEO.IGMU, *ig_minage* (youngest age), *ig_maxage* (oldest age), and *ig_age* (generalized age). The ages coded in *ig_minage*, *ig_maxage*, and *ig_age* items in the table NR_GEO.IGMU result from the examination of the source geologic maps and other published information, including radiometric dating, specific to the igneous features in the table NR_GEO.IGPNAM. A list of the 25 unique age terms found in the *ig_age* item is shown in table D-4.

The items *ig_minage* and *ig_maxage* are the best terms to use with the re-defined igneous units in nr_geo. Any differences from the ages listed in the source publications occur because newer information was discovered during research into the igneous rocks. The references used for the revised dates are included in the *reference* item in the table NR_GEO.IGPNAM.

The *ig_age* item provides a quick way to symbolize the Northern Rocky Mountains compilation based on generalized ages of the igneous rocks. This item is created in a similar manner as *age* and *age_or* described above. One difference involves the age term Neogene. As used in *ig_minage* and *ig_maxage*, it only includes Pliocene and Miocene and is a subperiod. Therefore, in *ig_age* Neogene is converted to the Tertiary Period.

Age terms in the table NR_GEO.IGMU are to be used with the NR_GEO.PAT table's *igmu_id* item only. This is because polygons were re-grouped in some areas. For example, Boulder batholithic rocks were combined with several other plutonic units in construction of the Butte 1:250,000 scale geologic map (Lewis, 1998). The igneous tables and items can therefore be used to distinguish the Boulder batholith from other plutonic units in this area, both on name and on age.

Table D-4. List of all age terms used in item *ig_age*, table NR_GEO.IGMU.

Terms used in the item *ig_age*	**Terms used in the item *ig_age***
Quaternary	Triassic
Quaternary-Tertiary	Triassic-Permian
Tertiary	Permian
Tertiary-Cretaceous	Ordovician
Cretaceous	Late Proterozoic
Cretaceous-Jurassic	Late Proterozoic-Middle Proterozoic
Cretaceous-Triassic	Late Proterozoic-Early Proterozoic
Cretaceous-Permian	Late Proterozoic-Archean
Cretaceous-Middle Proterozoic	Middle Proterozoic
Cretaceous-Early Proterozoic	Early Proterozoic
Jurassic	Early Proterozoic-Archean
Jurassic-Triassic	Archean
Jurassic-Permian	--

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Appendix E. Procedures for coding rock terms into the fields *name_major*, *name_majr1*, *name_majr2*, *name_minor* and *name_other* in ArcInfo® look-up tables

By Michael L. Zientek, J. Douglas Causey, and Thomas P. Frost

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Tables

Introduction

For this compilation, descriptions of map units and cited references were extracted from published maps, associated pamphlets and publications (see nr_geo_mapunits.pdf and Appendix I). The individual map-unit descriptions can be searched for rock terms; however, having rock-type information organized into database fields facilitates analysis. We used two approaches to code rock-type information in the database tables. This appendix describes how we used the grammatical structure of the map-unit descriptions to infer the relative abundance of rock types. The second approach, using expert judgment to select a dominant rock type for the unit from a hierarchically-structured list of lithology terms, is described in Appendix F.

Ideally, volumetric percentages as well as the accuracy, or quality, of the percentage that each rock composition contributes to the map unit would be recorded in the database. We found we could not use this approach for this compilation because the map-unit descriptions for the maps used in this compilation did not provide quantitative proportions of lithologies. Most map-unit descriptions provide at best lists of the representative lithologies, such as, “sandstone, shale, conglomerate, and minor limestone”. Because it was impossible to quantitatively infer a percentage of contribution for each composition from the map-unit description, the grammatical context of rock terms is the only measure we have that indicates relative rank or abundance of rock types, and it is far from quantitative in most cases.

The paragraph and sentence structure of the map-unit description, along with modifying adjectives, are used to parse rock terms used into the fields *name_majr1*, *name_majr2*, *name_minor*, and *name_other* in the ArcInfo® look-up table NR_GEO.LITH and the fields *name_major*, *name_minor*, and *name_other* in the ArcInfo® look-up table NR_GEO.UN. In general, if the terms are mentioned prominently but with no evidence to indicate relative rank, all the terms go in the field *name_major*. If the term is mentioned prominently in the description but occurs with adjectives indicating a lesser relative rank or is present in a dependent clause, it goes in the field *name_minor*. If the rock types are only incidentally mentioned in the unit, it goes into the field *name_other*. In this appendix, the discussion for the fields *name_minor* and *name_other* applies equally to these items in the look-up tables NR_GEO.LITH and NR_GEO.UN. The discussion of the field *name_major* in this appendix applies to this item in the look-up table NR_GEO.UN as well as to *name_majr1* and *name_majr2* in the look-up table NR_GEO.LITH. In order to allow users to export data from a coverage to an ESRI® shapefile, no item in any of the ArcInfo® look-up tables developed for this report contains more than 254 characters, the limit for an attribute in a shapefile theme table. Parsed lithology terms often exceeded the 254 character limit. As a result, the parsed rock terms had to be extended into two fields for the table NR_GEO.LITH.

Rock terms (and compositional modifiers) are included in the database fields; however, grain-size, textural terms, and color usually are not. Compositional modifiers include lists of minerals that precede a rock name (hornblende-biotite granodiorite), the color term ‘black’ when used as a synonym for ‘organic-rich’, and adjectives like argillaceous, carbonaceous, calcareous, silty, sandy, dolomitic, and so on. Rock terms are in the order that they appear in the original description and are separated by commas. The author may have listed the terms in decreasing order of abundance but, from a simple list, it is impossible to determine if each contributes roughly equal amounts to a map unit, or if some contribute very minor or accessory amounts.

In some cases, other knowledge about the unit is available from sources other than the written map-unit description. The objective of this effort is to code just the information provided by the authors of the reports in their map-unit descriptions; expert knowledge is used in the coding of database fields described in Appendix F. For the database fields described here, the process of extracting information from published maps was consistently applied, regardless of the individual expertise of the person doing the attribution.

The general concepts for parsing the descriptions follow:

1). If one or more rock terms appear in the independent clause of the topic sentence of the paragraph AND if these terms do not have adjectives indicating lesser rank or importance, they are copied into the *name_major* field. Example:

“This unit contains sandstone and shale.” – Sandstone and shale are included in *name_major*.

2). If one or more rock terms appear in the independent clause of the topic sentence of the paragraph AND if these terms have adjectives indicating lesser rank or importance, they are copied into the *name_minor* field. Example:

“This unit contains sandstone and minor shale.” – The term, shale, would be included in the *name_minor* field.

3). If one or more rock terms appear in a modifying phrase or clause of the topic sentence of the paragraph AND the phrase or clause implies the rocks are less abundant, the rock terms in the modifying phrase or clause are copied into the *name_minor* field. Example:

“This unit contains sandstone and shale, with minor limestone.” – The term, limestone, would be included in the *name_minor* field.

4). Terms occurring later in the paragraph, particularly with adjective indicating lower rank, are included in the *name_other* field. Example:

“This unit contains sandstone and shale, with minor limestone. Locally, chert nodules can be found in some limestone beds.” – The term, chert, is entered into the *name_other* field.

In addition, the words listed in table E-1 provide clues to the relative abundance of rock types and were used to parse rock terms into database fields. This table is a general guideline; these and similar terms were used to estimate the relative rank of rock terms in the map-unit description. Note that the adjective “some” can be used to place a rock in either of two categories depending on the rest of the description.

Table E-1. Rock type modifier terms and appropriate database field to use for rock terms with these modifier words.

Database Field	**Adjectives**	**Nouns**
name_major	Dominantly, mostly, predominantly, much, principally	
name_minor	Widespread, minor, subordinate, many, some	
name_other	Some, locally, “locally some”, sparse, few, “in places”, dispersed,	Lenses, nodules, xenoliths, partings, thin partings and interbeds, partings and interbeds, scattered beds and zones, scattered lenses, few beds, several zones, some beds, thin lenses

The map-unit descriptions that accompany the maps that make up this compilation vary in style and content. Table E-2 describes five styles of map-unit descriptions we have identified for the maps included in this compilation. For each style, we created rules to apply this grammatical approach to parse text descriptions into the fields *name_major*, *name_majr1*, *name_majr2*, *name_minor*, and *name_other* in the ArcInfo® look-up tables NR_GEO.LITH and NR_GEO.UN (Table E-2). These guidelines were used to parse rock types into these database fields. In the following sections we describe these guidelines in more detail.

Table E-2. Rules used to parse rock names into *name_major*, *name_minor*, and *name_other* fields in database

Rule name	**Rule description**
General parsing rule	One object (geologic unit), one description
Multi-unit parsing rule	Many objects (multiple distinct geologic units lumped together), one description
Complex description parsing rule	Many objects (multiple distinct geologic units lumped together), one general and many specific descriptions
Formation list parsing rule	Formation names only, no description
No description parsing rule	No unit description or formation name

General parsing rule - one geologic object with a description

The map-unit description consists of one or more paragraphs that provide a general explanation of the map unit, including lithology terms. The grammatical approach to parsing the lithological terms summarized earlier can be applied with little ambiguity.

From the Choteau 1:250,000-scale quadrangle map (Mudge and others, 1982):

“SHEPARD FORMATION (PROTEROZOIC Y) Consists mostly of greenish-gray to grayish-yellow micaceous siltite and some silty limestone and argillite. Beds of maroon siltite and argillite widespread in the middle part and locally in the upper part. Thin glauconitic quartzite lentils widespread in the upper part of the formation in the eastern outcrop, but sparse elsewhere. Ripple marks, minute cross lamination, load casts, and mud cracks also common in the eastern outcrop. An edgewise conglomerate present near the base of the formation in the east, but elsewhere a stromatolitic limestone bed occurs at the same horizon. Other beds of stromatolitic limestone also present in the lower part of the formation in the Mission Range (Harrison and others, 1969). The formation thickens westward and southward, from 249 m in the eastern outcrop to about 900 m in the west in the Swan Range and about 715 m in the south”

Database Field	Author Terms
name_major	micaceous siltite
name_minor	silty limestone, argillite, siltite
name_other	glauconitic quartzite, conglomerate, limestone

Additional examples illustrate nuances in coding information.

"Black" as a synonym for "organic-rich"

As a general rule, we do not include color terms in the database fields. The exception is the color term "black" when it is used as a synonym for "carbonaceous", "organic-rich", or "petroliferous". In the following example, the word "black" provides information on rock composition (see figure 11-37 in Pettijohn, 1975). Additionally, we infer that "black,… carbonaceous" describes both of the first named lithologies, and so is repeated for each in the *name_major* field. The textural term "fissile" is not included, nor is the fossil information (see below).

From the Challis 1:250,000-scale quadrangle map (Fischer and others, 1992):

"Black, carbonaceous, graptolite-bearing shale and argillite (Ordovician)—Black, fissile, carbonaceous shale; bedding obscured by cleavage. Exposures totaling less than 1 km^2 along lower reaches of Big Lake Creek and Pine Creek (44°09' N., 114°23' W.), tributaries to East Fork of Salmon River. Generally deformed, especially in highest exposures beneath thrust contact with Salmon River assemblage (Pzsr). Tentatively correlated with Ordovician Phi Kappa Formation to south, as suggested by Dover and others (1980). Maximum of 35 m of unit exposed, total thickness unknown."

Database Field	Author Terms
name_major	Black carbonaceous shale, black carbonaceous argillite
name_minor	
name_other	

Mineral names

Lists of minerals preceding rock names are considered part of the lithology term and are coded in the database.

Texture and grain size

Textural terms and grain size terms are not included in the lithologic term.

From the Sandpoint 1:250,000-scale quadrangle map (Miller and others, 1999):

"*Granodiorite of Wrenco (Eocene)*—Medium- to coarse-grained, highly porphyritic hornblende-biotite granodiorite; hornblende distinctly subordinate to biotite. Sphene and xenoliths abundant. Typically has 1- to 8-cm-long orthoclase phenocrysts. Homogeneous composition in southern half of unit except for felsic phase near margin; heterogeneous mixture of magmatically mixed mafic and felsic rocks in northern part. Texture variable; much of pluton has variably developed foliation, and rocks along northwestern margin have fine-grained matrix. Color index averages about 16. Zircon gives uranium-lead age of 51 Ma (Whitehouse and others, 1992); biotite gives potassium-argon age of 46 Ma (Miller and Engels, 1975, recalculated using current IUGS constants, Steiger and Jaeger, 1977)"

Database Field	Author Terms
name_major	hornblende-biotite granodiorite
name_minor	
name_other	

Adjectives

Adjectives may apply to more than one noun in a string. See example below:

From the Sandpoint 1:250,000-scale quadrangle map (Miller and others, 1999):

"Silver Point Quartz Monzonite (Eocene)—Hornblende-biotite monzogranite, granodiorite, quartz monzonite, and quartz monzodiorite; porphyritic with groundmass having distinctive bi-modal grain size. Occurs as two non-contiguous plutons. Extremely homogeneous with respect to composition and texture, except for foliate, mafic zone along north side of largest pluton near Davis Lake. Zircon gives slightly discordant uranium-lead age of 52 Ma (Whitehouse and others, 1992); biotite and hornblende give potassium-argon ages of 49 and 48 Ma, respectively, on one sample, and 52 and 48 Ma, respectively, on another (Miller, 1974c, recalculated using current IUGS constants, Steiger and Jaeger, 1977)"

Does the adjective "hornblende-biotite" only apply to the first lithology name in the word list or to all of them? Commonly, an adjective will appear at the beginning of a string of rock terms; it is ambiquous whether the adjective applies only to the first term in the the list or to all the rock names. Project scientists were asked to look for this situation and decide which rock terms the adjective modifies. For these co-magmatic igneous rock that presumably were derived from similar source regions and have similar oxidation states, we infer that the adjective modifies all rock names. In this example, the modifying adjective is repeated for all rock terms in the database field.

Database Field	**Author Terms**
name_major	hornblende-biotite monzogranite, hornblende-biotite granodiorite, hornblende-biotite quartz monzonite, hornblende-biotite quartz monzodiorite
name_minor	
name_other	

Multi-unit parsing rule - many geologic objects described separately in one map unit

The map unit consists of separate descriptions of subdivisions of the mapped unit. For example, the extent of a formation is shown on the map but, in the map-unit description, is described as consisting of several members. The map-unit description does not have a summary description of the unit. Information from each separate description is included in the appropriate fields, in the order in which it is described in the map-unit description (usually youngest to oldest rocks), using the following format:

thickness-thicknessunits$_{subunit1}$(lithology$_1$, lithology$_2$, …,lithology$_n$)| thickness-thicknessunits$_{subunit2}$(lithology$_1$, lithology$_2$, …,lithology$_n$)| …|thickness-thicknessunits$_{subunitn}$(lithology$_1$, lithology$_2$,…,lithology$_n$)

From the Choteau 1:250,000-scale quadrangle map (Mudge and others, 1982).

"Castle Reef Dolomite and Allan Mountain Limestone - Mississippian rocks are the main cliff former in the eastern part of the mountains and are assigned to the Madison Group. The total thickness of the Mississippian rocks ranges from 275 m to 520 m. The Madison is divided into two formations, the Castle Reef Dolomite and the Allan Mountain Limestone, by Mudge, Sando, and Dutro (1962)

Castle Reef Dolomite (Upper and Lower Mississippian) Divided into two members. Sun River Member at the top, which consists of thin to thick beds of medium to finely crystalline light-gray dolomite and locally some interbedded calcitic dolomite. Many beds contain thick lenses of encrinite and scattered brachiopods and corals. The Sun River is from less than 1 m to 137 m thick. The lower member is thick-bedded, fine to coarsely crystalline, light- to medium-gray dolomite, calcitic dolomite, dolomitic limestone, and limestone. The coarsely crystalline beds are encrinite and are more numerous in the northern and western outcrop. The lower member contains brachiopods and corals, locally abundant in the lower part. The lower member is 114 m to 145 m thick. Both members thin eastward, mainly as a result of pre-Jurassic erosion

Allan Mountain Limestone (Lower Mississippian) Ranges in thickness from 163 m to 200 m, and contains three unnamed members. The upper member consists of gray, fine-grained, thin to thick beds of limestone, magnesian limestone, and dolomitic limestone. Nodules and lentils of gray- to gray-brown chert are common (Mudge, 1972). It has a large and varied fauna, mostly brachiopods and corals, and locally, lenses and beds of encrinite. Upper member 60 to 90 m thick. The middle member consists of dark-gray, fine-grained, thin to medium beds of limestone with some dolomitic limestone. Characteristically contains nodules and irregular-shaped to even-bedded lenses of dark-gray chert, of which some have a fibrous appearance (Mudge, 1972). Contains sparse brachiopods and corals (Mudge, Sando, and Dutro, 1962). The middle member about 45 m thick. The lower member mostly dark-gray, very thin bedded, argillaceous dolomitic limestone with many calcareous shale partings. Contains dense, gray, moderately thick limestone interbedded with dark-gray mudstone. The mudstone has abundant brachiopods and corals. Thickness of lower member 60 m to 89 m"

Database Field	**Author Terms**
name_major	1-137m(dolomite)| 114-145m(dolomite, calcitic dolomite, dolomitic limestone, limestone)| 60-90m(limestone, magnesian limestone, dolomitic limestone)|45m(limestone)| 60-89m(argillaceous dolomitic limestone)
name_minor	1-137m(calcitic dolomite)| 114-115m| 60-90m| 45m(dolomitic limestone, chert)| 60-89m(calcareous shale)
name_other	1-137m| 114-145m| 60-90m(encrinite)| 45m(chert)| 60-89m (mudstone)

From the Coeur d'Alene 1:100,000-scale quadrangle (Munts, 2000):

"Rennie Shale and Gold Creek Quartzite - Rennie Shale - a fissile olive colored fossiliferous shale, about 100 feet thick; exposed only infrequently and generally poorly so. This units lies conformably between the Gold Creek Quartzite and the overlying Lakeview Limestone and is here mapped with the Gold Creek Quartzite. Gold Creek Quartzite – White- to pinkish- vitreous, coarse-grained quartzite. Some pebble conglomerate is always present at base. The quartzites are usually thick-bedded and commonly crossbedded; the unit is about 500 feet thick."

Database Field	**Author Terms**
name_major	100ft(shale)| 500ft(quartzite)
name_minor	
name_other	100ft| 500ft(pebble conglomerate)

Complex description parsing rule - many geologic objects described generally and separately in one map unit

The map-unit description consists of a summary description of the mapped feature, followed by descriptions of subdivisions of the unit. In the examples we found, the summary description contained less information than the description of the subunits. We decided to retain as much of the detailed information as possible by including information from each separate description in the appropriate fields using the following format:

thickness-thicknessunits$_{subunit1}$(lithology$_1$, lithology$_2$, …,lithology$_n$)| thickness-thicknessunits$_{subunit2}$(lithology$_1$, lithology$_2$, …,lithology$_n$)| …|thickness-thicknessunits$_{subunitn}$(lithology$_1$, lithology$_2$,…,lithology$_n$)

In the examples below, the map-unit description is given as published. Then it is broken down into sections illustrating the summary and subunit descriptions. Following that, we have demonstrated differences in parsing the unit description by using the summary sentence versus the descriptions of the subunits.

From the Lima 1:100,000-scale quadrangle map (Lonn and others, 2000):

"Quadrant Formation - Sandstone, dolomite, and dolomitic limestone. Upper two-thirds of formation is predominantly yellowish-gray to pale olive-gray to pale yellowish-brown and grayish-orange, fine-grained to medium-grained, well sorted and well rounded, commonly cross-bedded, partly calcareous, quartzitic sandstone in beds 1 to 4 ft thick or massive. Locally includes thin interbeds of light gray to medium gray, sandy limestone or dolomite. Lower one-third of formation is interbedded light gray to medium-dark gray, fine-grained, locally cherty dolomite in beds 0.5 to 5 ft thick, and yellowish-gray to brownish-gray, fine-grained, well sorted and rounded, quartzitic, calcareous sandstone in 1- to 3-ft beds. Basal sandstone of formation, which may be as much as 50 ft thick, is light gray to pale yellowish-gray, fine- to medium-grained, well rounded and sorted, and thin-bedded (0.2 to 1 ft). Thickness of formation ranges from 600 to about 350 ft, thinning northward (Saperstone and Ethridge, 1984; Saperstone, 1986; Gealy, 1953)."

Summary statement: Sandstone, dolomite, and dolomitic limestone.

Subunit 1: Upper two-thirds of formation is predominantly yellowish-gray to pale olive-gray to pale yellowish-brown and grayish-orange, fine-grained to medium-grained, well sorted and well rounded, commonly cross-bedded, partly calcareous, quartzitic sandstone in beds 1 to 4 ft thick or massive. Locally includes thin interbeds of light gray to medium gray, sandy limestone or dolomite.

Subunit 2: Lower one-third of formation is interbedded light gray to medium-dark gray, fine-grained, locally cherty dolomite in beds 0.5 to 5 ft thick, and yellowish-gray to brownish-gray, fine-grained, well sorted and rounded, quartzitic, calcareous sandstone in 1- to 3-ft beds. Basal sandstone of formation, which may be as much as 50 ft thick, is light gray to pale yellowish-gray, fine- to medium-grained, well rounded and sorted, and thin-bedded (0.2 to 1 ft).

Coding results using the summary statement for the unit:

Database Field	**Author Terms**
name_major	sandstone, dolomite, dolomitic limestone
name_minor	
name_other	

Preferred coding option. From topic sentences describing parts of unit ("Upper two-thirds" interpreted to mean two-thirds of the upper and lower limits of the total thickness = 2/3x350 to 2/3x600 rounded to nearest 10 ft):

Database Field	**Author Terms**
name_major	230-400ft(quartzitic sandstone)| 120-200ft(dolomite, quartzitic calcareous sandstone, sandstone)
name_minor	230-400ft(sandy limestone, sandy dolomite)| 120-200
name_other	120-200ft(cherty dolomite)| 120-200

From Challis 1:250,000-scale quadrangle (Fisher and others, 1992):

"Middle Canyon Formation - Succession of medium-bedded cherty limestone and impure limestone exposed as smooth, float-covered slopes in southeast corner of quadrangle. Upper half is impure, medium-dark-gray to medium-gray, cherty, microgranular limestone. Black chert abundant in layers and nodules. Weathers to medium- or light-gray, small, irregularly shaped blocks that have slight yellow or pink mottling. Lower half is very fine-grained sandy limestone, silicified in part. Float in lower half is more brightly colored and more angular than that of upper part. Locally, limestone is replaced by jasperoid; see discussion under Scott Peak Formation (Msp), above. Thickness about 200 m"

Summary statement: Succession of medium-bedded cherty limestone and impure limestone exposed as smooth, float-covered slopes in southeast corner of quadrangle.

Subunit 1: Upper half is impure, medium-dark-gray to medium-gray, cherty, microgranular limestone. Black chert abundant in layers and nodules. Weathers to medium- or light-gray, small, irregularly shaped blocks that have slight yellow or pink mottling.

Subunit 2: Lower half is very fine-grained sandy limestone, silicified in part. Float in lower half is more brightly colored and more angular than that of upper part. Locally, limestone is replaced by jasperoid; see discussion under Scott Peak Formation (Msp), above.

Coding results using the summary statement.

Database Field	**Author Terms**
name_major	cherty limestone, impure limestone
name_minor	
name_other	

Preferred coding option. From topic sentences describing parts of unit ("lower half" interpreted to mean half of total thickness = 200 m/2 = 100m):

Database Field	**Author Terms**
name_major	100m(cherty limestone)| 100m(sandy limestone)
name_minor	100m(black chert)| 100m
name_other	100m| 100m(jasperoid)

From Livingston 1:100,000-scale quadrangle map (Berg and others, 2000):

"Meagher Limestone - Thin- to massive-bedded, light-gray to brownish-gray, finely crystalline limestone. Locally oolitic, especially in upper part. Upper 30 m is thin-bedded, gray limestone that contains conspicuous orange mottles; upper few meters contain fissile gray-green shale. Middle 50 m is medium- to massive-bedded limestone, locally mottled tan, and containing small silicic limestone stringers. Lower 30 m is thin- to medium-bedded, tan-mottled, gray limestone that contains a few intercalated micaceous shale beds in lower part. Forms cliffs. Conformably overlies Wolsey Shale. About 100-150 m thick in the Madison Range (Tysdal, 1990; Kellogg, 1992), 100-110 m thick in the Gravelly Range (Hadley, 1980), but only about 50 m thick in northern Gallatin Range (McMannis and Chadwick, 1964)"

Summary statement: Thin- to massive-bedded, light-gray to brownish-gray, finely crystalline limestone. Locally oolitic, especially in upper part.

Subunit 1: Upper 30 m is thin-bedded, gray limestone that contains conspicuous orange mottles; upper few meters contain fissile gray-green shale.

Subunit 2: Middle 50 m is medium- to massive-bedded limestone, locally mottled tan, and containing small silicic limestone stringers.

Subunit 3: Lower 30 m is thin- to medium-bedded, tan-mottled, gray limestone that contains a few intercalated micaceous shale beds in lower part.

Coding results using the summary statement.

Database Field	**Author Terms**
name_major	Limestone
name_minor	
name_other	

Preferred coding option. From topic sentences describing parts of unit:

Database Field	**Author Terms**
name_major	30m(limestone)| 50m(limestone)| 30m(limestone)
name_minor	
name_other	30m(shale)| 50m(silicic limestone)| 30m(micaceous shale)

Formation list parsing rule – just a list of formations.

In some instances, the description of the map unit is a list of formations with no descriptions of the rocks. For these map units, lithologic information in the Stratigraphic Nomenclature Databases for the United States, its possessions, and territories (MacLachlan, 1996) was used to populate the *name_major*, *name_minor*, and *name_other* fields. Lithologic information for units in the Stratigraphic Nomenclature Databases is stored in coded fields called Lith1, Lith2, and Lith3. Codes can be deciphered using information in the file geonames.doc in MacLachlan (1996). Values in Lith1 are used to populate *name_major*; values in Lith2 and Lith3 are used to populate name_minor.

From the Butte 1:250,000-scale quadrangle (Lewis, 1998):

"SEDIMENTARY ROCKS (PERMIAN THROUGH DEVONIAN)-Unit includes, in descending order: Permian Shedhorn Sandstone, Phosphoria Formation, and Park City Formation, Pennsylvanian Quadrant Quartzite, Snowcrest Range Group (Pennsylvanian and Mississippian), Madison Group and related rocks (Mississippian), Three Forks Formation (Mississippian and Devonian) and Jefferson and Maywood Formations (Devonian)."

Information for unit name, lithology, and thickness extracted from the stratigraphic nomenclature databases (MacLachlan, 1996) is summarized below.

Name	Lith1	Lith2	Lith3	Thickness
SHEDHORN,SS*	SS			29
PHOSPHORIA,FM*	MS	CH		No data for MT; 140 in ID
PARK CITY [A],FM*	LS			No data
QUADRANT,QTZ*	QTZ			No data
SNOWCREST RANGE,GP*	SED			148
MADISON [C],GP*	LS			No data
THREE FORKS,FM*	LS			69
JEFFERSON,FM*	DOL			190
MAYWOOD,FM*	LS			91

Where:

MS mudstone
QTZ quartzite
SED sedimentary_rock
LS limestone
DOL dolomite,_dolostone
CH chert
SS sandstone

This information was used to code the database fields in this compilation as follows.

Database Field	Author Terms
name_major	sedimentary rock, dolostone, limestone, mudstone, quartzite, sandstone
name_minor	chert
name_other	

No description parsing rule - No unit description or formation name

Some of the geologic map units were not given a formal or informal name; instead, a simple list of lithologies was provided to both name and describe the unit. No additional descriptive information was provided. In these situations, the rock terms that make up the unit name were copied into the field **name_major**.

From the Riggins map sheet (Idaho Geological Survey, written comm., 1996):

“Gray schist and phyllite” is given as the unit name. No map-unit description.

Database Field	Author Terms
name_major	schist, phyllite
name_minor	
name_other	

From the Lima 1:100,000-scale quadrangle map (Lonn and others, 2000):

“SEDIMENTARY ROCKS, UNDIVIDED (JURASSIC)” is given as the unit name. No map-unit description.

Database Field	Author Terms
name_major	sedimentary rocks
name_minor	
name_other	

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Appendix F. Selecting dominant lithology and sediment terms from a standardized, hierarchical list

By J. Douglas Causey, Michael L. Zientek, and Thomas P. Frost

Contents

Introduction

The Northern Rocky Mountains geologic spatial database compilation includes a dominant rock or sediment term that best represents the majority of the rock or sediment types for each map unit. The rock type and sediment terms were selected from a standardized list developed specifically for this project (Appendix B). A standardized list enforces consistency in terminology which facilitates analysis because variant names or spellings for similar rock types are eliminated. The compositional and process-based relationships between rock and sediment terms are recorded as hierarchies in the standardized list. Hierarchical relationships between terms can be used to derive lithologic maps which may have fewer units than a traditional geologic map. Derivative lithologic maps and data can be related to surface disturbance effects, ecological processes, or soil development.

Recent research in the Pacific Northwest supports creation of a dominant lithology dataset. A lithologic map derived from a spatial geologic database was first prepared in the Pacific Northwest for the Interior Columbia Basin Ecosystem Management Project (Johnson and Raines, 1995; Johnson and Raines, 2001). This spatial data, combined with research of tree growth responses to fertilization and natural tree-mortality dynamics on different soil parent materials, has demonstrated a significant correlation between substrate lithology and forest development (J.A. Moore, University of Idaho, written comm. 1999). Preliminary versions of the current spatial geologic database have been used to show the importance of geology as one of the biophysical characteristics affecting western white pine development in northern Idaho (Jain and others, 2002), forest growth modeling (Froese and Robinson, 2002), and susceptibility of forest species to insect infestations (Garrison-Johnston and others, 2003).

In this appendix, we describe the application of expert judgment in selecting a dominant rock or sediment term, and the derivation of the dominant lithology and sediment database item in the ArcInfo® lookup tables NR_GEO.LITH and NR_GEO.UN.

Dominant lithology

Dominant lithology is estimated for each of the 1877 map units that are composed of rocks in the Northern Rocky Mountains geologic spatial database compilation. The dominant lithology terms were selected from the standardized list (Appendix B) and stored in the item *lname_dom* in the ArcInfo® lookup table NR_GEO.LITH. Project scientists used expert judgement to select the term for dominant lithology, basing their decisions initially on the map-unit description and the information coded in the database fields *name_majr1* and *name_majr2* in the ArcInfo® look-up table NR_GEO.LITH (Appendix E). These initial interpretations were coded in a preliminary version of the spatial database; dominant lithology interpretations were then revised to address inconsistent patterns in the spatial distribution of rock types between adjoining map areas. In revising the dominant lithology selection, any source of information could be used. Apparent discrepancies between the term in the item *lname_dom* (table NR_GEO.LITH) and information in the map-unit description or the items *name_majr* and *name_majr2* largely reflect the use of other information in selection of a dominant lithology term.

Several situations made it difficult to select a dominant lithology term. In most cases, authors of reports did not indicate what classification scheme was used for naming rocks or defining terms. Depending on the classification scheme, a given term can have different definitions. Project scientists had to consider the date of publication and the use of other terms to infer which classification scheme was used. We also encountered problems when the original map authors used a classification schemes that differed from the one we used for the standardized list (Appendix B). Most of the igneous rock terms in the map-unit descriptions were compatible with the hierarchical classification implied by the IUGS classification (Le Maitre and others, 2002); this scheme formed the basis of the classification of igneous rocks in our standardized list of lithology terms. However, some authors used terms like felsic, intermediate, or mafic igneous rocks; this nomenclature represents terms at a relatively high level in a different igneous hierarchical classification scheme; one that commonly is used by field geologists without formal definition. We addressed these higher order terms by inserting short, parallel hierarchies in our rock classification that ultimately meet at a higher-order node in the IUGS hierarchy.

Another problem arose where the map unit is described as containing igneous rocks of a wide range of composition (for example, gabbro to granite) with no information on their relative abundance. Commonly, these rocks are associated by igneous differentiation or fractionation processes. Phrases were added to the lithology list to be able to code dominant lithology for these rocks. For these compositionally diverse igneous map units, the phrase consists of two rock terms followed by the word ‘suite’. For example, the phrase ‘dioritoid-granitoid (calc-alkaline) plutonic suite’ is used for a map unit consisting of plutonic rocks that vary in composition between the QAPF "field" classification for dioritoid and granitoid.

Finally, some map units described by the map authors are a combination of two or more, lithologically diverse geologic formations. Commonly, only a list of formation names was provided as the map-unit description. Each formation can have different dominant lithologies; however, no information was provided on the rock types or the relative thicknesses of the formations that make up the map unit. We felt uncomfortable selecting a single dominant lithology term for these varied sequences of rocks. For these situations, special terms were added to the lithology list to be able to code map units consisting of several poorly described formations. These phrases all contain the word ‘and’. For example, the phrase “siliciclastic and carbonate sedimentary rocks” refers to a map unit consisting of a layered sequence of siliciclastic and carbonate sedimentary rocks, in which, to the best of our knowledge, siliciclastic sedimentary rocks make up more than half of the succession, while the carbonate rocks are less than half, but still a significant percentage. If the percentages are reversed, then the term would be “carbonate and siliciclastic sedimentary rocks.” If the relative proportion of rock types is unknown, a more inclusive rock term is selected for dominant lithology. In the example given above, if the relative proportions of siliciclastic and carbonate rocks are unknown, “sedimentary rock”would be entered for the dominant lithology. These compound terms were used for less than 200 of the map units in the compilation.

Dominant unconsolidated materials

The list of rock and sediment terms was also used to code information about units that consist of unconsolidated material. As before, we considered all information and selected a term from the list for each of the 258 map units composed of unconsolidated material. Their selection is reported in the item *uname_dom* in the ArcInfo® table NR_GEO.UN. The selection of a term was not limited to the map-unit description or the information coded in the database field *name_major* in the ArcInfo® look-up table NR_GEO.UN (Appendix E) for a particular published map. We used any available source of information to make an expert selection.

Hierarchical relations and generalization

For a given dominant rock or sediment term, hierarchical relations identified in the list of terms can be represented in a relational database and used to calculate the names of all rock terms higher in the hierarchy. For example, manipulation of the word list and hierarchy in a relational database will identify that a “quartz arenite” is a specific type of “sandstone or arenite” that belongs to the broad category of “siliciclastic sedimentary” rock that, obviously, is a “sedimentary rock”. This process of manipulating the terms and relations is called “expanding the hierarchy” for rock or sediment terms.

In relational databases, hierarchies can be represented by adjacency lists, materialized paths, “ancestor” trees, or nested sets (Celko, 1996; Tropashko, undated; van Tulder, 2003; Hastings, 2003; Brodaric and others, 2002). For this compilation, we used the “ancestor tree” model to manipulate hierarchical data in a relational database. Data management was done in a relational database (Microsoft® Access 2000) and information was extracted as flat-file tables to include in the Northern Rocky Mountains spatial database (NR_GEO). The expanded hierarchies for the rock and sediment terms are coded in the items *lname_1* to *lname_5* and *uname_1* to *uname_4* in the ArcInfo® tables NR_GEO.LITH and NR_GEO.UN. For the example in the previous paragraph, where *lname_dom* = ‘quartz-arenite’, *lname_4* will have the value ‘quartz-arenite’ because this term is at the fourth level in the hierarchy. The values of *lname_1*, *lname_2*, and *lname_3* are calculated to be ‘sedimentary rock’, ‘siliciclastic sedimentary rock’, and ‘sandstone or arenite’, respectively. If *lname_dom* = ‘limestone’, *lname_3* will have the value ‘limestone’ because this term is at the third level in the hierarchy. In this case, only the values of *lname_1*, and *lname_2* are calculated (‘sedimentary rock’ and ‘carbonate sedimentary rock’, respectively).

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Appendix G. Igneous Map Units and Named Bodies of Igneous Rocks

By Arthur A. Bookstrom, Michael L. Zientek, Reed S. Lewis, J. Douglas Causey, David Cleveland, Mary H. Carlson, Jeremy C. Larsen, and Robert J. Miller

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Introduction

Appendix G describes how we classify igneous rocks and apply formal and informal stratigraphic names to igneous-rock bodies and assemblages in this compilation for the Northern Rocky Mountains. For this study, we have reviewed available information for each igneous map unit and developed a scheme that can be universally applied to all mapped igneous units.

The purpose of this study was to systematically tabulate available information on the age, mode of occurrence, lithologic composition, stratigraphic nomenclature, and depth of emplacement of igneous rocks in the Northern Rockies. Digital maps can then be made, to display any combination of these types of information with any other types of geo-spatial information available for the study area. Such maps may be useful for studies of geologic history, igneous processes, mineral resources, geologic hazards, and environmental responses related to igneous rocks of the study area.

Objectives

Our first objective was to develop and apply a consistent scheme for lithologic classification of igneous rocks throughout the study area. Most of the igneous rock units in the study area are informally named; as a result, igneous rock units of the same or similar age, texture, and composition commonly were named and symbolized differently on different source maps. Using information on the maps and from supplemental sources, we classified all igneous units based on age, mode of occurrence, and lithology. The 154 igneous units defined for this study are summarized in table G-1. In the spatial database, the results of this work are presented in the ArcInfo® look-up table NR_GEO.IGMU.

Our second objective was to associate names given to igneous intrusions and volcanic units to objects in the spatial database. In scientific literature, igneous rock bodies are commonly given a name - the Crossport C sill, the Big Timber stock, the Idaho batholith. Even though these names have been propagated through the literature, it is often difficult to determine the exact location of the feature. We have used index maps at a variety of scales to associate names of dike swarms, sills, stocks, plutons, and batholiths with objects in our spatial database. We have also associated the formal and informal stratigraphic names for volcanic formations with spatial objects in the database. This information is given in the ArcInfo® look-up tables NR_GEO.IGPNAM and NR_GEO.IGANAM and is summarized in tables G-2, G-3, G-4, and G-5.

Our third objective was to estimate the depth of emplacement for intrusive igneous bodies in the study area, because hydrothermal mineral deposits are more commonly associated with volcanic to upper crustal magmatism than with deeper plutonism. Information about the depth of emplacement is presented in the tables NR_GEO.IGMU and NR_GEO.IGPNAM.

Methods and Quality Control

The principal sources of information for igneous map units and named bodies of igneous rocks for the study area were the 43 geologic maps, most of which were compiled at scales of 1:100,000 to 1:250,000, and had been previously published and converted into digital format. These maps are the source of the spatial objects (polygons and arcs) used for this study; the size and shapes of the objects have not been modified. Other sources of information were consulted to assist with the definition of units based on age, mode of occurrence, and lithology and to associate names with masses of igneous rock. This compilation focuses primarily on igneous and meta-igneous rocks; however, igneous-derived sedimentary units with a large fraction of igneous rock fragments are also included.

Age, mode of occurrence, and lithologic composition are used to group spatial objects on source maps into igneous map units. In some cases, these units correspond to those defined in the original publications; in other cases, entirely new units are delineated. Each of these units is given a name and a map symbol and is briefly summarized. Map-unit age classifications were checked against isotopic age determinations reported in the National Geochronological Database (Zartman and others, 1995). Results of our classification of igneous rocks of the Northern Rockies are shown in table G-1.

ESRI® shapefiles derived from the 43 ArcInfo® coverages were used to capture attribute information for spatial objects associated with igneous rocks. Spatial objects associated with a unit based on age, mode of occurrence, and lithology were selected and tagged with a label; the label refers to a look-up table with attributes summarizing the igneous map unit name, mode of occurrence, lithology, and other information (table G-1). We prepared many preliminary representations of the spatial data (plot files illustrating a map of the new units) as compilation progressed, and checked repeatedly for inconsistencies between the map and the map-unit explanation, and between adjacent source-maps.

After completing a preliminary map of the study area, we searched for named igneous features and checked them against the GEOLEX online lexicon of stratigraphic nomenclature (U.S. Geological Survey, 2004). Many related igneous intrusive bodies had not previously been assigned to larger groups of named intrusions. We therefore devised and populated a 3-level hierarchy of intrusions, geologically grouped intrusions, and regionally grouped assemblages of intrusions (table G-5). We checked emplacement styles (and depth classifications) against emplacement depths estimated by Mark Barton (written communication, 2002) in a database prepared to support a paper on Mesozoic contact metamorphism in the western United States (Barton and others, 1988). Names associated with spatial objects, an estimate of the depth of emplacement, and reference citations were entered directly into fields in the shapefile theme table. Bibliographic citations for references listed in these tables are included at the end of this appendix.

Ultimately, all the attributes in the shapefiles were re-associated with the 43 coverages. The information was reviewed for consistency and re-organized so that the information for igneous units based on age, mode of occurrence and lithology are in the look-up table NR_GEO.IGMU and the information about names and depth of emplacement are in the ArcInfo® tables NR_GEO.IGPNAM and NR_GEO.IGANAM. The table NR_GEO.IGMU uses the field *igmu_id* to relate to the compiled coverage NR_GEO. The key field that relates the tables NR_GEO.IGPNAM and NR_GEO.IGANAM to the compiled coverage is *ig_code*. Additional information about processing steps can be found in the metadata for the ArcInfo® coverage NR_GEO.

Our work does not simply represent a reclassification of map units as defined in the original maps. In some cases, we found that several units that could be distinguished by age, mode of occurrence, and lithology had been grouped in the published map. In these situations, we used other published sources of information to reassign polygons of the original map unit into two or more units in our age-mode of occurrence-lithology classification. In the spatial database, subdivided units will have two or more values in the field *igmu_id* for a given value of the field *mu_id* in the ArcInfo® table NR_GEO.PAT or NR_GEO.AAT. In some cases, multiple original map units were grouped into a single age, mode of occurrence, and lithology unit. In this situation, a given value of *igmu_id* will have more than one *mu_id* value for a given map source. Name of stocks, plutons, and batholiths usually have little or no relation to the map units as originally defined in the publication. The named igneous bodies may not include all of the polygons assigned to a particular lithologic map unit, and they may include polygons of multiple lithologic map units.

Discussion – Units Based on Age, Mode of Occurrence, and Lithology

Developing a consistent scheme for classification of igneous rock units of the entire study area was a challenging exercise. Igneous rock units of the same or similar age, texture and composition commonly were named and symbolized differently on different source maps. Reasons for this include:

- Editorial style. In the simplest cases differences in names reflect variations in spelling or editorial style.

- Compilation scale and style. Differences in compilation scale and style reflect the sources of available information (scale and thoroughness of mapping, petrologic methods, and availability of geochemical and geochronological information), the intended use of the map, and the interest of the scientists who compiled it.
- Knowledge of geochronology of igneous rocks. The quality and quantity of age determinations on igneous rocks varies from map to map, depending on what methods were available and applied. In some areas, uncertainty and controversy about ages of igneous rocks remain to be resolved. Methods of isotopic dating of igneous rocks have improved, and our understanding of how to interpret these dates has become more sophisticated over time. Each published map reflects the technology and knowledge available when the map was compiled. Subsequent work in the same or adjacent map areas may have significantly revised our understanding of the ages and thermal histories of igneous rocks in an area. Other developments include refinements in radioactive decay constants used to calculate age determinations, and adjustments of geo-chronometric values associated with boundaries between geologic time units.
- Application and evolution of scientific language. Like all language, the terminology of igneous rocks has local variations, which change over time. Before 1973 several approaches to naming and describing igneous rocks were used in the project area. Unfortunately, the authors of source maps rarely indicate what approach they used to classify igneous rocks or define igneous rock terms. Although the International Union of Geological Sciences (IUGS) published a classification scheme for igneous rocks in 1973 (Streckeisen, 1973), it has not been universally accepted or applied by all authors. Nevertheless, that is the classification scheme we have adopted, insofar as possible.

We develop and apply a consistent classification scheme for igneous and meta-igneous map units in order to achieve consistency in naming of map units throughout the study area (table G-1). We also develop a consistent approach to naming and labeling these units. Names are created by listing terms for age, mode of occurrence, formal name (if available), and lithology (in that order). Labels are acronyms composed of characters to abbreviate key words of map-unit names in a consistent order, denoting age, mode of occurrence, lithologic texture and composition of rocks represented by each map unit. Each element of this approach to unit classification is discussed in the following sections.

Geologic age

Geologic age is an important organizing principle, because sequences of geologic ages define geologic history, and these sequences provide clues that are important to our understanding of geologic processes and their rates. The scale used to define units of geologic time for our classification of igneous rocks of the Northern Rocky Mountains study area is discussed in Appendix D.

Relative ages of geologic materials can be bracketed by stratigraphic position and cross-cutting relationships. In a normal stratigraphic succession, the ages of rocks decrease up-section. Bio-stratigraphic ages of fossil-bearing strata can be estimated on the basis of the fossils they contain. Relative ages of igneous intrusions can be bracketed by the ages of strata they intrude, and of strata that were deposited upon them. Relative ages determined at one site can be generalized to other sites by stratigraphic correlation, but the accuracy of such correlations depends on distance, stratigraphic and structural continuity, and exposure.

Isotopic dating methods can be used to determine the ages of igneous rocks, if those rocks contain radioactive elements, the relative amounts of parent elements and decay products can be accurately measured, the decay rates are accurately known, and products of decay have not been added or removed since crystallization. However, each isotopic age determination has an associated range of uncertainty; different methods, applied to the same or different minerals may yield different ages, especially if the rock to be dated has had a complicated thermal history.

Approach

Based on information from source maps and relevant geologic literature, we assigned igneous-map units to geochronologic units defined in Appendix D (fig. D-1). To test whether magmatic episodes of the study area are well represented by these standard units of geologic time, we made histograms of K-Ar age determinations for igneous rocks of the study area, as classified into geologic time units (figs. G-1 and 2). The K-Ar age determinations are from the National Geochronological Data Base of Zartman and others (1995) and Sloan and others (2003), and include determinations on whole-rock samples of igneous rock, or on biotite or hornblende separated from igneous rocks in the study area.

The frequency diagram of K-Ar ages for igneous rock samples (fig. G-1) shows significant episodes of magmatism in the study area during the Late Archean, Early Proterozoic, Middle Proterozoic, and Late Proterozoic Eras; and the Late Cretaceous, Eocene, Miocene, and Pleistocene Epochs. Figure G-2 shows in more detail the distribution of K-Ar age determinations for igneous rocks emplaced during the Cretaceous, Tertiary and Quaternary Periods. As represented by numbers of K-Ar age determinations, major pulses of magmatism occurred in the study area during the Late Cretaceous, Eocene, and Miocene to Holocene Epochs. Relatively minor magmatism also occurred during the Paleocene and Oligocene Epochs. These episodes of magmatism in the study area can be represented by grouping igneous rocks into map units represented by the Archean Eon; Early, Middle, and Late Proterozoic Eras; the Cretaceous Period, and the Paleogene and Neogene Subperiods of the Tertiary Period. The Paleogene magmatic event is called Tertiary to eliminate confusion in generating labels for the igneous map units.

Available Information

Ages of some Precambrian igneous rocks can only be bracketed between Early Proterozoic and Archean, or between Late and Middle Proterozoic. Ages of some metavolcanic rocks of the western accreted oceanic terranes can only be bracketed between Triassic and Permian, or Jurassic and Permian. Ages of some intrusions, probably emplaced during the Laramide orogeny, can only be bracketed between Late Cretaceous and Early Tertiary.

The small number of K-Ar determinations for Columbia River Basalt under-represent the very large volume of basalt that was erupted during the Miocene, because most of that basalt is west of the study area, and most basalt is not amenable to K-Ar dating. Nevertheless, K-Ar age determinations are relatively abundant for felsic volcanics of the Miocene Idavada Group, and for Pliocene to Quaternary volcanics of the Snake River and Yellowstone Groups.

Rules/Application

The first upper-case letter, or set of upper-case letters in the igneous map-unit symbol (*ig_label*) signifies the geologic age of the rocks represented by the unit. If a map unit includes rocks of more than one geologic-age unit, or if the uncertainty in the ages of rocks in a map unit spans more than one age unit, the symbol for the younger age unit precedes that of the older age unit. Rocks of Miocene to Pliocene age are designated as Neogene, but other rocks of Tertiary age are designated only as Tertiary. Most of these rocks are Paleogene in age, but some are of Tertiary age, undivided.

Mode of Occurrence

Mode of occurrence can be defined as style of emplacement, as in extrusive (volcanic or volcaniclastic) versus intrusive (hypabyssal or plutonic). Post-emplacement deformation or thermal metamorphism can modify the original mode of occurrence of a body of igneous rock.

Approach

Igneous rock units can be classified by mode of occurrence on the basis of geologic context, their geologic form, and lithologic composition and texture. For example, stratiform subaerial volcanic flows may show compositional and textural evidence of rapid solidification from flowing lava, which chilled to form glass at its base, and evolved gas, to form vesicles near its top. Lava emplaced under water may form nested pillow- or tube-shaped flows.

Pyroclastic rock is composed of fragmental material formed by volcanic explosion, whereas epiclastic rocks are sedimentary rocks formed by consolidation of fragments of pre-existing rocks. Both pyroclastic and volcanic-derived sedimentary rocks can be classified as volcaniclastic rocks, which are fragmental rocks containing volcanic material (Bates and Jackson, 1987). A pyroclastic ash-flow tuff, composed of fragments of volcanic glass, crystals and rocks, may be densely welded near its base, and partially welded to non-welded in its upper parts and distal margins. Pyroclastic and epiclastic debris are mixed in volcaniclastic sedimentary rocks, such as tuffaceous mudstone, siltstone, sandstone, or conglomerate.

Sills, dikes and stocks are examples of subvolcanic or hypabyssal intrusions. Sills are stratiform and structurally concordant with their host rocks; they may have chilled top and bottom margins. Dikes and stocks are generally structurally discordant to their host rocks, fine-grained along their margins, and coarser grained inward and downward. They commonly have porphyro-aphanitic texture, with visible crystals in a microcrystalline (aphanitic) matrix or groundmass. Plutonic intrusions, such as large stocks and batholiths, commonly are partly concordant and partly discordant, and are composed largely of phaneritic (visible) crystals of rock-forming and accessory minerals. They may be porphyritic, in that they may contain populations of distinctly larger and smaller crystals, but even the smaller crystals generally are visible. The lower surface of the intrusion in contact with surrounding country rocks may be indicated by gravity anomalies. They are commonly foliated, especially near their margins. Zones of injected dikes may also be common along their margins. Examples are the Bitterroot and Atlanta lobes of the Idaho batholith.

Effects of post-emplacement dynamic and thermal metamorphism include re-crystallization of minerals to produce metamorphic textures, and mineral transformations to produce metamorphic mineral assemblages. Such metamorphic textures and mineral assemblages are indicative of the post-emplacement metamorphic history of the igneous rock on which they are superimposed.

Available Information

Source-map-unit descriptions generally provide the information needed to classify the mode of occurrence of igneous rocks that comprise each map unit. Additional descriptive and interpretive information is available in the published geologic literature cited for each igneous map unit.

Rules / Application

For volcanic and subvolcanic units, the first lower-case letter, or set of lower-case letters in the igneous map-unit symbol (*ig_label*) indicates the mode of occurrence of the rocks represented by the map unit. For example, “v” indicates volcanic, “vc” indicates volcaniclastic, “s” indicates sediments and sedimentary, and “i” indicates an intrusive unit that is subvolcanic (or hypabyssal). Phaneritic plutonic rocks are intrusive by definition. For brevity, we therefore omit the word “intrusive” in plutonic-unit names, and omit the letter “i” from their symbols. For example, the plutonic unit, Cretaceous granodiorite, is represented by the symbol Kgd. Post-scripts to the symbol for an igneous map unit indicate post-emplacement modifications of that unit. Words and symbols used as modifiers follow the rock name. For example, the symbol for Cretaceous granodiorite with biotite and hornblende is Kgdbh, and for Cretaceous granodiorite, foliated and metamorphosed, is Kgdf~ (“f” to indicate foliated and “~” to indicate metamorphosed).

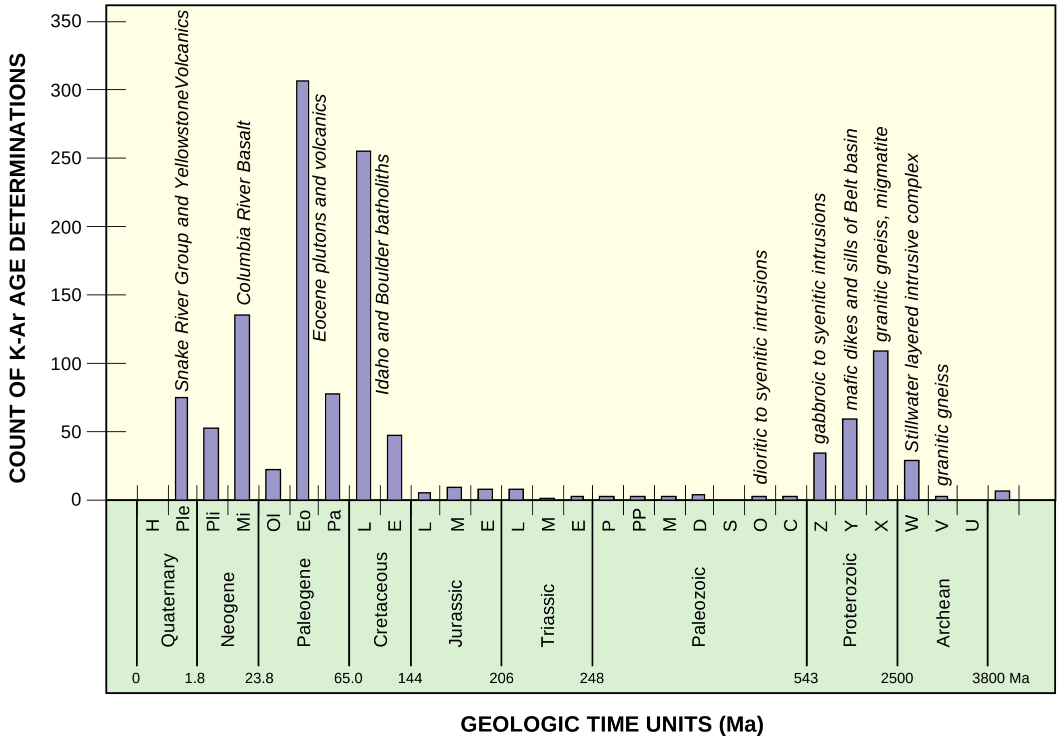

Figure G-1. Histogram of K-Ar age determinations on igneous rocks of the Northern Rockies study area, counted for units of geologic time from Archean to Quaternary (Sloan and others, 2003).

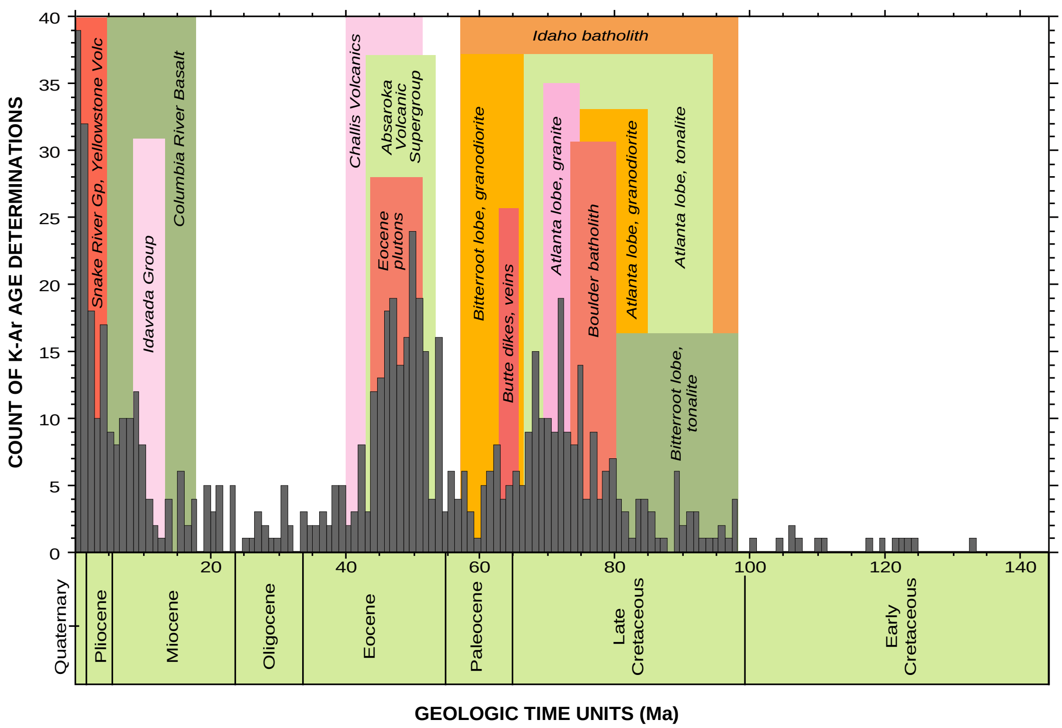

Figure G-2. Histogram of K-Ar age determinations on igneous rocks of the Northern Rockies study area, counted by 1-m.y. time intervals, from 140 to 0 Ma (Sloan and others, 2003).

Lithologic Classification

"Lithology is the description of rocks, especially in hand specimen and in outcrop, on the basis of such characteristics as color, mineralogic composition, and grain size" (Bates and Jackson, 1987). Our lithologic classification of igneous map units is based on lithologic characteristics of the rock types they include.

Approach

The first step in classifying igneous rocks according to lithology is to distinguish predominantly phaneritic from predominantly aphanitic rocks. According to Bates and Jackson (1987) "phaneritic is said of the texture of an igneous rock in which the individual components are distinguishable with the unaided eye" in contrast "aphanitic is any fine-grained igneous rock whose constituents are too small to be distinguished by the unaided eye. One set of terms applies to predominantly phaneritic rocks, and another parallel set of terms applies to predominantly aphanitic rocks. For example, the aphanitic equivalent of gabbro is basalt, of diorite is andesite, of granodiorite is dacite, and of granite is rhyolite (fig. G-3). Rhyolite porphyry is a porphyro-aphanitic rock of granitic composition with visible phenocrysts in an aphanitic groundmass.

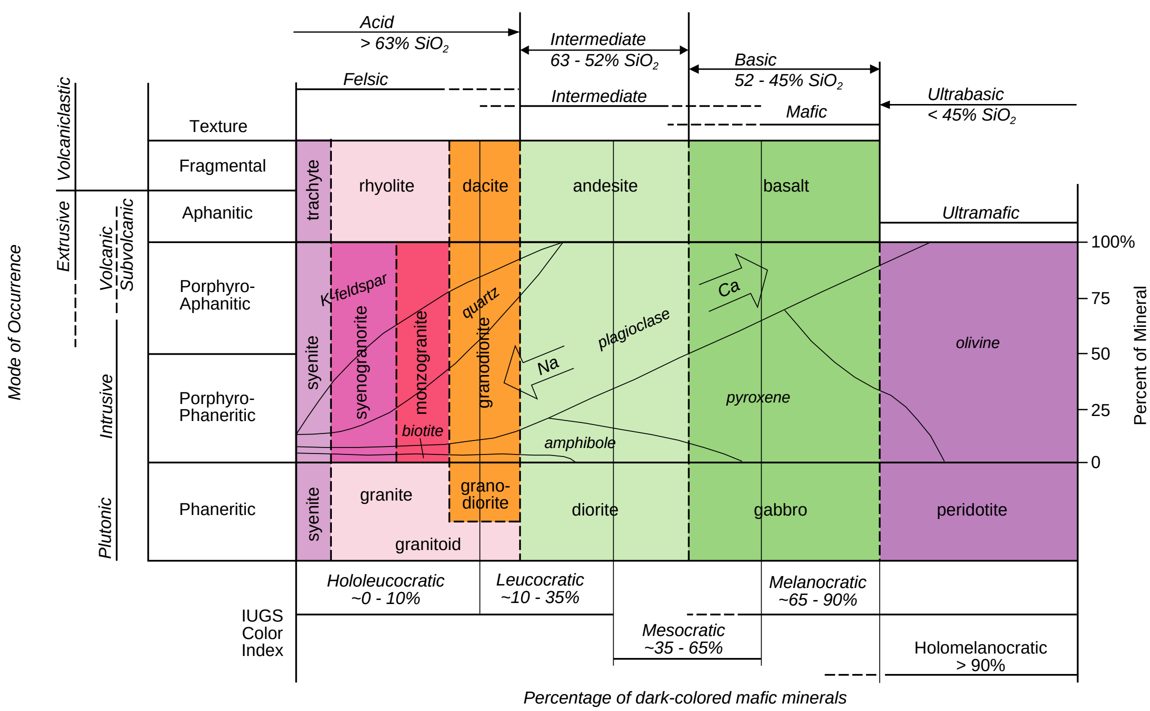

Figure G-3. An introductory scheme for classification of igneous rocks (modified from Hamblin, 1989).

The second step in classifying igneous rocks by lithology is to estimate their proportion of ferromagnesian, or mafic minerals, which are commonly relatively dark-colored minerals. The color index of a phaneritic igneous rock is its volume percentage of ferromagnesian minerals, such as olivine, pyroxene, amphibole and biotite. The terminology applied to ranges of color indices has varied over time, but has recently been standardized according to the IUGS color index (Le Maitre, 2002), as shown in figure G-3.

Terminology for aphanitic-rock compositions, as indicated by color, is simpler and more indefinite, because the percentage of dark minerals may be impossible to determine in the field. According to Bates and Jackson (1987) the term "felsic" applies to igneous rocks with abundant light-colored (feldspathic and silica-rich) minerals, "mafic" applies to igneous rocks with abundant dark-colored (ferromagnesian) minerals, and "intermediate" applies to igneous rocks that are intermediate between felsic and mafic (fig. G-3). Aphanitic igneous rocks can also be classified according to their concentrations of silica (Le Maitre, 2002). According to a silica classification scheme, *acid* rocks contain more than 63 percent of silica, *intermediate* rocks contain 52 to 63 percent of silica, *basic* rocks contain 45 to 52 percent of silica, and *ultrabasic* rocks contain less than 45 percent of silica (fig. G-3).

Insofar as possible, we classified igneous rocks of the study area according to the recommendations of the International Union of Geological Sciences (IUGS) Subcommission on the Systematics of Igneous Rocks, edited by Le Maitre (2002). This system has gained increasingly worldwide acceptance, since it was introduced by Streckeisen (1973), and adopted by Compton (1985). Figure G-4 shows compositional fields and names for common plutonic (phaneritic) igneous rock types. The compositions are displayed in terms of modal proportions of quartz (Q), plagioclase (P), and alkali feldspar (A), as determined by visual estimation or modal analysis. Figure G-5 shows a parallel set of modal compositional fields and names for aphanitic rock types. Figure G-6 shows chemical compositional fields for aphanitic rocks in terms of ratios of weight percent $Na_2O + K_2O$ versus SiO_2 (after LeBas and others, 1986). This provides a way to name volcanic glass, and other aphanitic rocks in which a significant proportion of the rock consists of materials that cannot be identified visually or microscopically. However, only unaltered samples should be used to classify igneous rocks (whether aphanitic or phaneritic) on the basis of chemical composition.

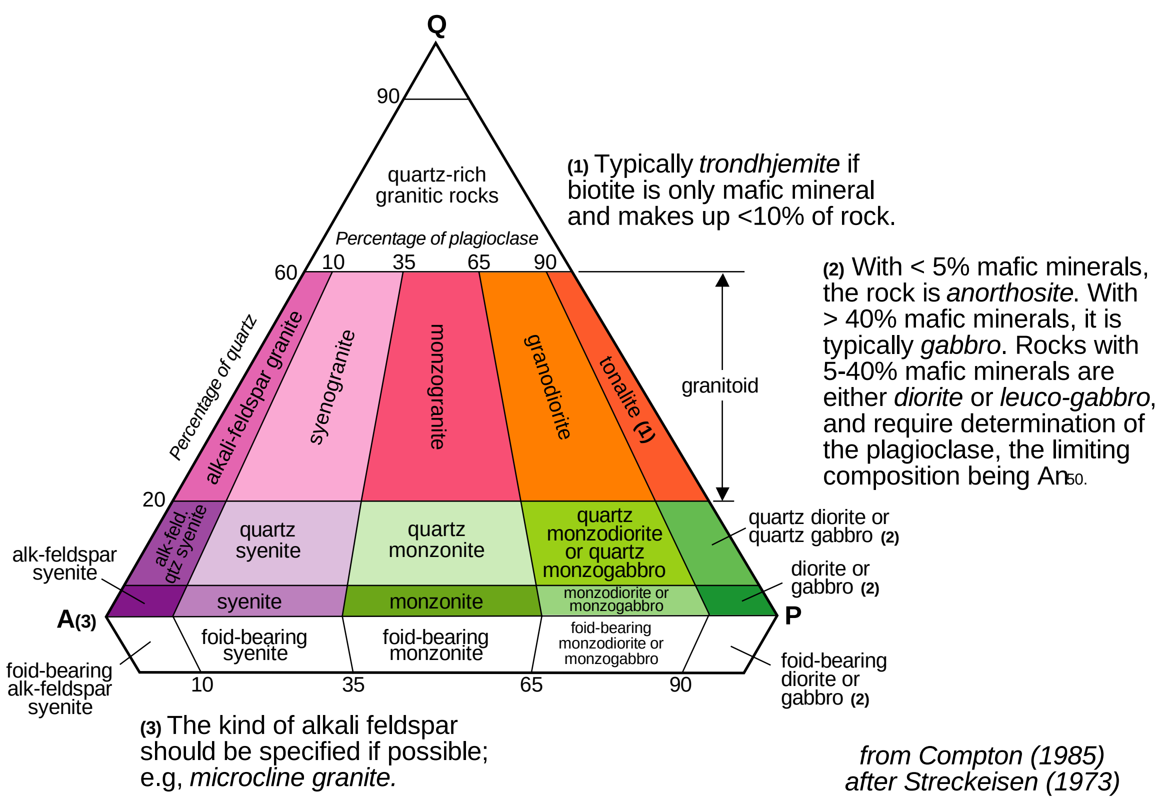

Figure G-4. Modal classification of plutonic rocks, using a QAPF (quartz-alkali feldspar-plagioclase-feldspathoid) diagram (from Compton, 1985, after Strekeisen, 1973).

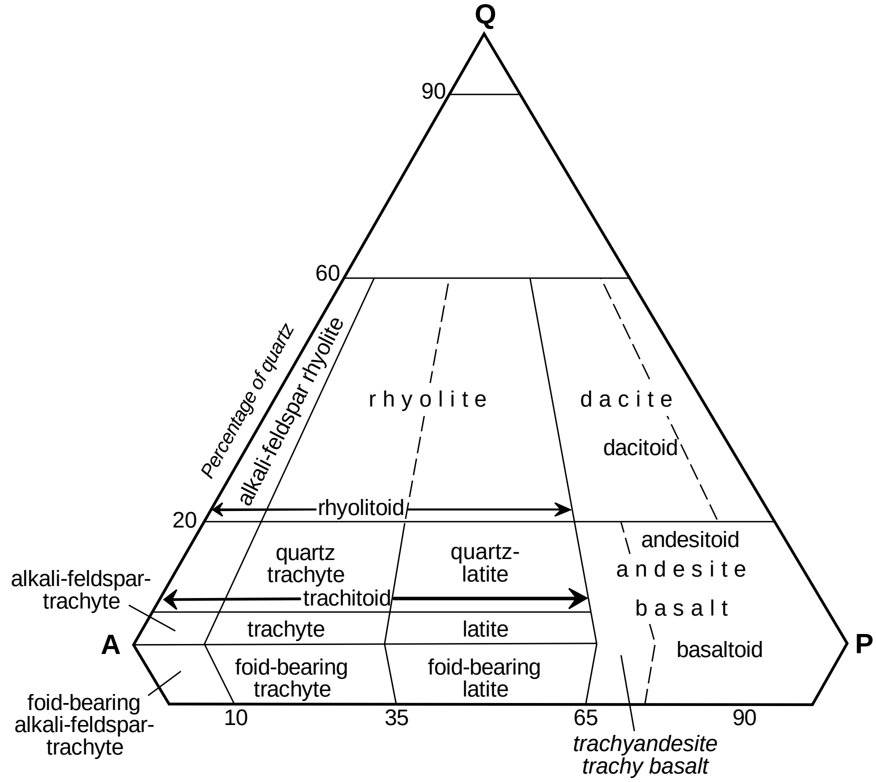

Figure G-5. Modal classification of volcanic rocks, using a QAPF (quartz-alkali feldspar-plagioclase-feldspathoid) diagram, (from Le Maitre 2002, after Streckeisen, 1979).

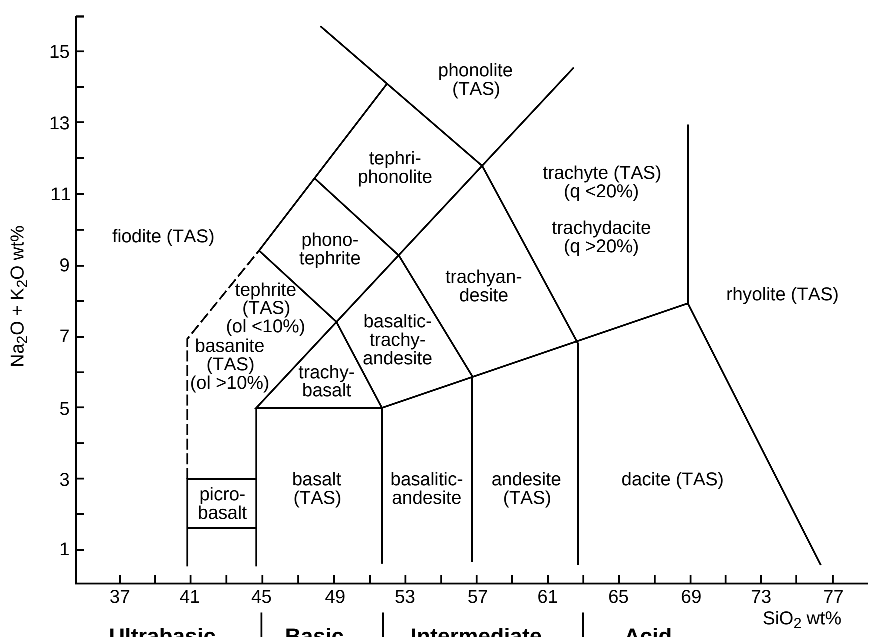

Figure G-6. Chemical classification of volcanic rocks, using a TAS (total alkali-silica) diagram (from Le Maitre, 2002, after Le Bas and others, 1986).

Some suites of geologically related igneous rocks include a range of compositions that spans multiple rock types, as defined in the IUGS classification system. For example, Lewis and Kiilsgaard (1991) divided Eocene plutonic rocks in south-central Idaho into a pink granite suite, and a quartz-monzodiorite suite. The pink granite suite is predominantly monzogranite, but varies to syenogranite. The quartz-monzogranite suite varies from diorite to monzogranite, and includes quartz diorite, quartz monzonite and granodiorite (fig. G-7). We separate granitoid rocks of the quartz-monzodiorite suite into a separate igneous-map unit, which we interpret to represent granitoid differentiates of the quartz monzodiorite suite.

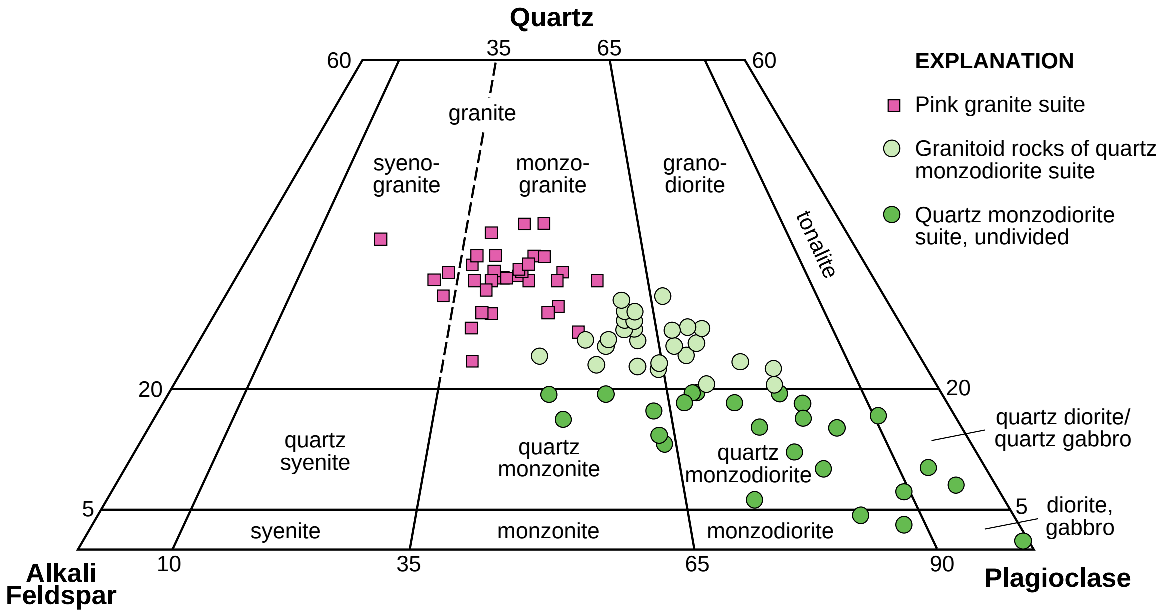

Figure G-7. Modal QAPF (quartz-alkali feldspar-plagioclase) diagram, showing compositional ranges of samples from the Eocene pink monzogranite and quartz monzodiorite suites of Lewis and Kiilsgaard (1991).

The U.S. Forest Service uses a classification scheme for igneous rocks by Travis (1955), which is shown in figure G-8. In general, the terms in that scheme are similar with those in the IUGS system. However, the IUGS makes additional distinctions. For example, the scheme by Travis (1955) equates quartz diorite with tonalite, but in the IUGS scheme, quartz diorite contains less than 20 percent of quartz, whereas tonalite contains more than 20 percent of quartz, so that tonalite is a granitoid rock, more similar to granodiorite than to diorite. In the Travis scheme, the boundary between monzonite and quartz monzonite is at 10 percent of quartz, and all rocks with potash feldspar / total feldspar between 1/3 and 2/3 are named quartz monzonite. In the IUGS system, however, monzonite contains less than 5 percent of quartz, quartz monzonite contains 5 to 20 percent of quartz, and monzogranite contains more than 20 percent of quartz. Thus, monzogranite is a granitoid rock, but quartz monzonite is not. Furthermore, the compositional field of granite is expanded, but is divided into three subtypes: monzogranite, syenogranite, and alkali-feldspar granite (fig. G-4). We prefer the IUGS system largely for this increased specificity in the classification of granitoid rocks, which are abundant in the Northern Rocky Mountain region.

<table>
<tr><th colspan="2" rowspan="4">Essential Minerals</th><th colspan="3">Potash Feldspar > 2/3 Total Feldspar</th><th colspan="3">Potash Feldspar 1/3-2/3 Total Feldspar</th><th colspan="6">Plagioclase Feldspar > 2/3 Total Feldspar</th><th colspan="2">Little or no Feldspar</th><th rowspan="4">Special Types</th></tr>
<tr><th rowspan="3">Quartz >10%</th><th rowspan="3">Quartz <10%
Feldspathoid <10%</th><th rowspan="3">Feldspathoid >10%</th><th rowspan="3">Quartz >10%</th><th rowspan="3">Quartz <10%
Feldspathoid <10%</th><th rowspan="3">Feldspathoid >10%</th><th rowspan="2">Potash Feldspar >10% Total Feldspar</th><th colspan="5">Potash Feldspar <10% Total Feldspar</th><th rowspan="3">Chiefly Pyroxene and/or Olivine</th><th rowspan="3">Chiefly Ferro-Magnesian Minerals and Feldspathoids</th></tr>
<tr><th colspan="2">Sodic Plagioclase</th><th colspan="3">Calcic Plagioclase</th></tr>
<tr><th>Quartz >10%</th><th>Quartz >10%</th><th>Quartz <10%
Feldspathoid <10%</th><th colspan="2">Quartz <10%
Feldspathoid <10%</th><th>Feldspathoid >10%
Pyroxene >10%</th></tr>
<tr><td colspan="2">Characterizing Accessory Minerals</td><td colspan="3">Chiefly : Hornblende, Biotite, Pyroxene, Muscovite
Also : Sodic Amphiboles, Aegirine, Cancrinite, Sodalite, Tourmaline</td><td colspan="3">Chiefly : Hornblende, Biotite, Pyroxene
Also : Sodic Amphiboles, Aegirine</td><td colspan="3">Chiefly : Hornblende, Biotite, Pyroxene (in Andesite)
Also : Pyroxene, Feldspathoid, Sodic Amphiboles</td><td colspan="3">Chiefly : Pyroxene, Uralite, Olivine
Also : Hornblende, Bioitite, Quartz, Analcite, Aegirine, Sodic Amphiboles</td><td>Chiefly : Serpentine, Iron Ore
Also : Hornblende, Biotite</td><td>Hornblende
Biotite
Iron Ore</td><td rowspan="10"></td></tr>
<tr><td colspan="2">Color Index</td><td>10</td><td>15</td><td>20</td><td>20</td><td>25</td><td>30</td><td>20</td><td>20</td><td>25</td><td colspan="2">50</td><td>60</td><td>95</td><td>55</td></tr>
<tr><td rowspan="8">Average Chemical Composition (Daly)</td><td>SiO_2</td><td>71.5</td><td>60.4</td><td>56.0</td><td>66.8</td><td>57.0</td><td>54.1</td><td>65.3</td><td>61.6</td><td>58.2</td><td colspan="2">48.6</td><td>47.4</td><td>41.1</td><td>42.0</td></tr>
<tr><td>Al_2O_3</td><td>14.0</td><td>17.0</td><td>19.2</td><td>15.8</td><td>17.1</td><td>21.0</td><td>16.1</td><td>16.2</td><td>17.0</td><td colspan="2">16.8</td><td>15.4</td><td>4.8</td><td>17.9</td></tr>
<tr><td>Fe_2O_3</td><td>1.5</td><td>2.7</td><td>2.9</td><td>2.3</td><td>3.4</td><td>1.8</td><td>2.1</td><td>2.5</td><td>3.2</td><td colspan="2">4.8</td><td>4.9</td><td>4.0</td><td>5.7</td></tr>
<tr><td>FeO</td><td>1.4</td><td>2.9</td><td>1.6</td><td>1.3</td><td>3.6</td><td>3.3</td><td>2.3</td><td>3.8</td><td>3.7</td><td colspan="2">6.0</td><td>5.4</td><td>7.1</td><td>5.7</td></tr>
<tr><td>MgO</td><td>0.6</td><td>1.8</td><td>0.6</td><td>1.0</td><td>2.3</td><td>1.1</td><td>1.7</td><td>2.8</td><td>3.5</td><td colspan="2">5.1</td><td>5.0</td><td>32.2</td><td>3.4</td></tr>
<tr><td>CaO</td><td>1.6</td><td>3.7</td><td>2.0</td><td>2.8</td><td>5.4</td><td>3.2</td><td>3.9</td><td>5.4</td><td>6.3</td><td colspan="2">8.9</td><td>9.7</td><td>4.4</td><td>10.3</td></tr>
<tr><td>Na_2O</td><td>3.4</td><td>4.2</td><td>8.5</td><td>3.7</td><td>4.7</td><td>6.2</td><td>3.8</td><td>3.4</td><td>3.5</td><td colspan="2">3.7</td><td>3.8</td><td>0.5</td><td>8.0</td></tr>
<tr><td>K_2O</td><td>4.3</td><td>5.1</td><td>5.3</td><td>4.2</td><td>3.7</td><td>5.9</td><td>2.7</td><td>2.1</td><td>2.1</td><td colspan="2">1.9</td><td>3.5</td><td>1.0</td><td>2.4</td></tr>
<tr><td>Phaneritic</td><td>Equigranular
Batholiths, lopoliths, stocks, thick dikes, large laccoliths, and sills.</td><td>Granite
Alaskite - few dark minerals
Graphic Granite - graphic texure
Alkali Granite - abundant albite and sodic amphibole or pyroxene
Charnockite - with orthopyroxene
Luxullianite - tourmalinized</td><td>Syenite
Quartz Syenite - a little quartz
Alkali Syenite - no plagioclase except albite
Pulaskite - a little nepheline
Nordmarkite - a little quartz
Larvikite - with "blue" feldspar
Shonkinite - abundant FeMg minerals</td><td>Nepheline Syenite
Leucite Syenite - pseudoleucite only feldspathoid
Sodalite Syenite - sodalite only feldspathoid
Foyaite - abundant feldspar
Malignite - abundant FeMg minerals
Ditroite - with nepheline and sodalite</td><td>Quartz Monzonite (Adamellite)</td><td>Monzonite</td><td>Nepheline Monzonite</td><td>Granodiorite</td><td>Quartz Diorite (Tonalite)</td><td>Diorite</td><td>Gabbro
Gabbro - with clinopyroxene
Norite - with orthopyroxene
Olivine Gabbro - with olivine
Troctolite - olivine and plagioclase only
Anorthosite - plagioclase only
Quartz Gabbro - with quartz</td><td rowspan="2">Diabase (dolerite of British)
Phaneritic diabasic texture, normally medium or fine-grained.</td><td>Theralite
(Essexite, Nepheline Gabbro)
Teschenite - analcite only feldspathoid
Olivine Theralite - with olivine</td><td>Peridotite
Peridotite - clinopyroxene and olivine
Harzburgite - orthopyroxene and olivine
Picrite - pyroxene and olivine with some plagioclase
Dunite - olivine only
Pyroxenite - pyroxene only
Serpentine (Serpentinite) - chiefly serpentine</td><td>Missourite - pyroxene, olivine, and pseudoleucite
Ijolite - pyroxene and nepheline
Fergusite - pyroxene and pseudoleucite
Uncompahgrite (Melilite Pyroxenite) - pyroxene and melilite</td><td rowspan="2">Pegmatite - phanerocrystalline, normally silicic, dike rock (or small irregular mass) having a conspicuously coaser texture than parent.
Aplite - phanerocrystalline rock having sugary (fine-grained allotriomorphic-granular) texture.
Lamprophyre - dark dike rock with exclusive FeMg phenocrysts and or euhedral FeMg minerals in groundmass.</td></tr>
<tr><td rowspan="2">Porphyritic</td><td>Phaneritic Groudmass
Laccoliths, dikes, sills, plugs, small stocks, margins of larger masses.</td><td>Granite Porphyry</td><td>Syenite Porphyry</td><td>Nepheline Syenite Porphyry</td><td>Quartz Monzonite Porphyry</td><td>Monzonite Porphyry</td><td>Nepheline Monzonite Porphyry</td><td>Granodiorite Porphyry</td><td>Quartz Diorite Porphyry</td><td>Diorite Porphyry</td><td>Gabbro Porphyry</td><td>Theralite Porphyry</td><td>Peridotite Porphyry
Kimberlite - peridorite porphyry or breccia</td><td></td></tr>
<tr><td>Aphanitic Groudmass
Dikes, sills, laccoliths, surface flows, margins of larger masses, welded tuffs.</td><td>Rhyolite Porphyry</td><td>Trachyte Porphyry</td><td>Phonolite Porphyry</td><td>Quartz Latite Porphyry</td><td>Latite Porphyry</td><td>Nepheline Latite Porphyry</td><td colspan="2">Dacite Porphyry</td><td>Andesite Porphyry</td><td>Basalt Porphyry</td><td rowspan="2"></td><td>Tephrite Porphyry</td><td>Limburgite Porphyry</td><td></td><td rowspan="3">Trap - dark-colored aphanitic rock
Felsite - light-colored aphanitic rock</td></tr>
<tr><td rowspan="2">Aphanitic</td><td>Microcrystalline
Dikes, sills, surface flows, margins of larger masses, welded tuffs.</td><td>Rhyolite</td><td>Trachyte</td><td>Phonolite
Leucite Phonolite (leucite trachyte)- leucite only feldspathoid
Tinguaite-abundant aegirine
Wyomingite -leucite and phlogopite</td><td>Quartz Latite (Dellenite)</td><td>Latite (Trachy-andesite)</td><td>Nepheline Latite</td><td colspan="2">Dacite</td><td>Andesite</td><td>Basalt
Olivine Basalt - with olivine
Analcite Basalt - with analcite
Quartz Basalt - with quartz
Oceanite - with abundant olivine</td><td>Tephrite
Leucite Tephrite - leucite only feldspathoid
Basanite - with olivine
Leucite Basanite - with olivine and leucite</td><td>Limburgite</td><td>Nephelinite - pyroxene, and nepheline
Leucitite - pyroxene and leucite
Melilitite - pyroxene and melilite
Olivine Nephelinite (Nepheline Basalt) - pyroxene, nepheline, and olivine.
Etc.</td></tr>
<tr><td>Glassy
Surface flows, margins of dikes and sills, welded tuffs.</td><td colspan="14">Obsidian - black
Pitchstone - resinous
Vitrophyre - porphyritic
Perlite - concentric fractures
Pumice - finely cellular, light colored
Scoria - coarsely cellular, dark colored

Normally it is not possible to determine the composition of these rocks. They are customarily designated by the names at the left of this column. Basic glass is rare so rocks named, except scoria, will normally be silicic. If the approximate composition (by close association) or silica content (by refractive index or analysis), can be determined, the name may be prefixed by the name of the appropriate aphanitic rock, for example, "trachyte obsidian," or "latite vitrophyre." In general, scoria is basic; basic obsidian is called "tachylite"' and spherulitic tachylite is " variolite."

Frequency of occurrences:
This size type indicates Common Rocks.
This size type indicates Uncommon Rocks.
This size type indicates Rare Rocks</td></tr>
</table>

Figure G-8. Classification of igneous rocks (after Travis, 1955). This is the classification scheme used by the U.S. Forest Service.

Available Information

Rarely did the source-map authors describe either the methods of compositional estimation or the systems of classification they applied in defining and describing their igneous-map units. Different geologists, working in different parts of the study area at different times, probably applied different methods of compositional estimation and different classification schemes. Terms such as monzogranite, syenogranite, or alkali-feldspar granite indicate that the IUGS system was applied. However, the absence of these terms is non-diagnostic, unless the source map was made before 1973, when the IUGS classification system was introduced. In such areas, subsequent geologic maps or articles may apply IUGS nomenclature to mapped units. For example, the formally named Butte Quartz Monzonite has recently been shown to consist mostly of monzogranite, as classified according to the IUGS classification system (Lund and others, 2002).

Rules / Application

In general, we listed source-map terms for lithologies included in each igneous-map unit, and we generally named and symbolized igneous-map units on the basis of the predominant rock type in the unit. Where possible IUGS terminology was used for the list of lithology terms; this required some interpretation if the terms in the map-unit description were based on other igneous rock-classification schemes. For igneous map units that represent a wide range of rock types, we assigned a single name, indicating the central tendency of compositions, or we assigned multiple names, indicating the range of compositions included in the unit.

Many igneous map units consist largely of aphanitic or porphyro-aphanitic rocks that were only broadly characterized as felsic, intermediate, or mafic. Some units could only be characterized as ranging from mafic to intermediate, or intermediate to felsic. However, some predominantly felsic units could be divided into dacitic and rhyolitic sub-categories. The term “rhyodacite” was used on some source maps, but is not included in the IUGS classification system. We included “rhyodacite” in “felsic, dacitic.”

Some metamorphic rocks of inferred igneous origin are so metamorphosed that they are given a metamorphic name, with a note indicating their probable igneous origin. For example Archean amphibolite after mafic igneous rocks is labeled Aam~.

Summary – Convention for Creating Unique Igneous Map-Unit Names and Labels

Each igneous map unit has a unique name and a unique label, indicating the age, mode of occurrence, and lithologic classification of igneous rocks included in the map unit. Post-scripts to some map-unit names denote diagnostic minerals, or characteristics superimposed by dynamic or thermal metamorphism (table G-1).

The first set of words in the name, symbolized by upper case letters in the label, indicates geologic age or age span during which rocks of the unit formed (“Q” for Quaternary, “N” for Neogene, “T” for Tertiary, “K” for Cretaceous, “J” for Jurassic, “TR” for Triassic, “Z” for Late Proterozoic, “Y” for Middle Proterozoic, “X” for Early Proterozoic, and “A” for Archean).

The second set of words or letters indicates mode of occurrence (“s” for sedimentary, “vs” for volcaniclastic-sedimentary, “vc” for volcaniclastic, “v” for volcanic, and “i” for intrusive, subvolcanic or hypabyssal). Terms for phaneritic igneous rocks imply a plutonic origin, so “intrusive” is omitted from the map-unit names, and “i” is omitted from the igneous map-unit symbols for plutonic rocks.

The third set of words or letters indicate the lithologic composition of rock types included in the map unit. Abbreviations for breccia, migmatite and agmatite as well as post-scripted mineralogic modifiers are included. The abbreviations can be found in Table G-6. These mineral terms are listed in increasing order of abundance.

A fourth set of letters is added to some map-unit labels to abbreviate words in the name that indicate characteristics resulting from post-emplacement deformation or metamorphism. Examples are “f” for foliated, “my” for mylonitic, and “o” for orthogneissic. A post-scripted “~” indicates that the igneous rock is metamorphosed. Some meta-igneous rocks are so metamorphosed that their original mode of occurrence and composition can only be inferred. In such cases, an abbreviation for their metamorphic name is followed by a word about their possible igneous protolith. For example, Archean amphibolite after mafic igneous rock is symbolized “Aam~”.

Some igneous-map units represent parts of stratigraphically named assemblages of geologically related rocks. For example igneous-map units of the Neogene Columbia River Basalt Group (Nvcrb) are in ascending order: the Imnaha Fm (Nvcrb1), Grande Ronde Basalt (Nvcrb2), Wanapum Basalt (Nvcrb3), and Saddle Mountains Basalt (Nvcrb4). Similarly, igneous map units of the Archean Stillwater Complex (Asw) are in ascending order: the basal ultramafic unit (Aswum), lower-banded unit (Aswlb), middle-banded unit (Aswmb), and upper-banded unit (Aswub).

Map symbolization

We also developed a consistent approach to symbolization of map units, by applying consistent color ramps to rocks of closely related compositional affinity (purples for ultramafic rocks, and lavenders for syenitic intrusions; grays and dark greens for mafic rocks; grass-greens for intermediate intrusives, and pale greens for intermediate volcanics; oranges for tonalitic to granodioritic rock, and pale orange for felsic dacitic volcanics; reds for granitic intrusions, and pinks for rhyolitic volcanics. In general, these colors are brighter for younger and duller for older igneous rocks of the same composition. Finally, we added a “v” pattern for volcanic units, an inverted “y” pattern for volcaniclastic rocks, a dotted pattern for volcaniclastic-sedimentary units, and a pattern of “+” signs to distinguish intrusions of Tertiary age. The approach was implemented in the ArcGIS® lyr files ig_label_poly_igmu.lyr and ig_label_arc_igmu.lyr described in Appendix A of this report.

Discussion – Names for Igneous Intrusions and Volcanic Units

The North American stratigraphic code provides rules for naming of geologic units, including stratigraphic sequences of volcanic rocks, and igneous intrusions (North American Commission on Stratigraphic Nomenclature, 1983). All stratigraphic names are compound, and consist of a geographic name and a rank term or descriptive term. The geographic name is at or near the place where the stratigraphic unit is defined, and should be referable to an established geographic name printed on a map that shows names approved by the Board of Geographic Names (Hansen, 1991). Rank terms, in ascending order, are Member, Formation, Subgroup, Group, and Supergroup. Descriptive terms include lithologic names, and named types of geologic features, such as plutons.

Formal geologic names used in this report meet the requirements of the North American stratigraphic code, have been approved by the U.S. Geological Survey Geologic Names Unit, and are included in their lexicon of geologic names (GEOLEX (U.S. Geological Survey, 2004)). The first letter in each word of a formally named unit is capitalized. In ascending order of rank, the Priest Rapids Member of the Wanapum Basalt belongs to the Yakima Basalt Subgroup, which belongs to the Columbia River Basalt Group (table G-2). Stratigraphic ranking is more applicable to discontinuity-bounded stratigraphic sequences of strata (allostratigraphic units) than to igneous intrusions (lithodemic units), which may be discordant to the stratigraphic section. Nevertheless, a formal stratigraphic name, comprised of a geographic term and a descriptive term, can be applied to an intrusive rock type, such as the Uphill Creek Granodiorite, or to a body of igneous rocks, such as the Stillwater Complex.

Many intrusive bodies in the study area have been named informally in the geologic literature (table G-3). Informal geologic names meet some of the requirements of the North American stratigraphic code, but have not been approved by the U.S. Geological Survey Geologic Names Unit. For informal stratigraphic names, only proper geographic names are capitalized. The geographic name commonly follows the description for a lithologic term, as in rhyolite of Clear Creek, syenite of Gold Hill, or granodiorite of Wrenco. Alternatively, the geographic term may precede the lithologic term, as in Mount Spokane granite, but this less clearly indicates that the name is informal. The geographic name commonly precedes the descriptive term for an intrusion type, as in Idaho batholith, Atlanta lobe, White Cloud intrusive complex, Thompson Creek stock, Spirit pluton, Boise Basin dike swarm, or Crossport sills. The surface exposure of a stock is less than 100 km^2, whereas a batholith has more than 100 km^2 of more-or-less contiguous exposure area (Bates and Jackson, 1987). A batholithic assemblage includes non-contiguous intrusions that are interpreted to be geologically related to a nearby batholith of similar age and composition.

Named Bodies of Igneous Rock

Sequences of volcanic strata which occur in this compilation, either formally or informally named in the geologic literature, are listed in table G-2 and the ArcInfo® look-up tables NR_GEO.IGPNAM and NR_GEO.IGANAM. Named volcanic sequences are grouped at according to stratigraphic rank – supergroup (*vol_supgrp*), group (*vol_grp*), subgroup (*vol_subgrp*), formation (*vol_fm*), and member (*vol_mbr*). The names in the column ‘Informal name (*vol_infrml)*’, correspond to informally-named units. The named volcanic units were grouped into volcanic fields, provinces, or arc terranes in the column ‘Volcanic field name (*vol_field)*’. The units were then grouped in the column ‘Volcanic event name (*vol_event)*’ according to the processes responsible for causing the igneous activity– subduction related magmatic arcs or plume-related large magmatic events. *Vol_ctr* provides the name of calderas and grabens that form as a result of magmatic activity.

Table G-3 (and the ArcInfo® look-up tables NR_GEO.IGPNAM and NR_GEO.IGANAM) lists the named intrusions that occur in this compilation, as they are formally or informally named in the geologic literature. Named intrusions are grouped at three levels, of decreasing generality (in terms of size or complexity). Column ‘Named batholithic assemblage’ (and the item *name_bath* in the ArcInfo® look-up table NR_GEO.IGPNAM) lists named batholithic assemblages, column ‘Named intrusive complex, cluster, or suite’ (and the item *name_plut* in the ArcInfo® look-up table NR_GEO.IGPNAM) lists named intrusive complexes, clusters, or suites, and column ‘Named intrusion or part of intrusive complex’ (and the item *name_stk* in the ArcInfo® look-up table NR_GEO.IGPNAM) lists named intrusions and other named parts or zones of intrusive complexes.

Table G-4 (and the item *name_dksil* in the ArcInfo® look-up table NR_GEO.IGANAM) lists names for swarms of tabular dikes or sills that are too thin to be represented by polygons at the source-map scale, and are therefore represented by lines. Most of the names are new and informal. The name of each swarm is intended to indicate its general location, and the geologic age, form, or composition of dikes or sills that comprise the swarm.

In table G-5 we re-assign nearly every named intrusion from table G-3 to a grouping of geologically related intrusions, and to a regional assemblage of geologically related intrusions. Some of these groupings and assemblages were previously named, but we assigned additional intrusions to them. For example, we correlate the Thompson Creek stock with the Atlanta batholith and the Idaho batholithic assemblage, because of its age and composition, even though it lies well east of the contiguously exposed part of the batholith. Other groupings and assemblages are newly named. For example, we assign the syenite of Gold Hill to a newly named Gold Hill-Trout Creek belt of syenitic stocks, which we assign to a more regional Gold Hill – Libby syenitic assemblage, which also is newly named.

Such hierarchical grouping of named intrusions facilitates the making of maps that show nearly every named intrusion as a component of a geologically related group, and of more regionally extensive assemblage. The most general intrusion names appear in the column ‘Geologic assemblages of grouped intrusions' (and the item *intr_1name* in the ArcInfo® look-up table NR_GEO.IGPNAM); the most specific names in the hierarchy are in column 'Named intrusion' (and the item *intr_3name*). Nevertheless, a few named intrusions did not fit into a geologically related grouping or regional assemblage.

Estimated Depth of Emplacement

We estimated depth of emplacement for as many named plutons as possible, on the basis of depth-zone criteria described by Buddington (1959). We also compiled emplacement-depth estimates made by Mark Barton (written communication, 2002) on the basis of mineral assemblages in thermally metamorphosed and hydrothermally altered host rocks. Estimated emplacement-depth zones for named plutons are included in the item *depth_zone* in the ArcInfo® look-up table NR_GEO.IGPNAM.

Depth-Zone Criteria

Based on combinations of criteria described by Buddington (1959), we estimated depths of emplacement of igneous intrusions as upper epizonal (about 0 to 4 km), lower epizonal (about 4 to 8 km), epizonal to mesozonal (about 6 to 10 km), upper mesozonal (about 8 to 12 km), lower mesozonal (about 12 to 15 km), mesozonal to catazonal (about 14 to 16 km), and catazonal (about 15 to 20 km). We interpreted combinations of criteria indicative of more than one depth zone as indicative of emplacement under conditions transitional between the indicated depth zones.

Upper Epizone

We considered the following characteristics to indicate upper epizonal depths of emplacement: 1) intrusion into associated volcanic or volcaniclastic rocks, 2) discordant stocks, plugs, necks, and dikes, and concordant sills and laccoliths 3) porphyro-aphanitic textures, 4) miarolitic cavities, 5) aphanitic chilled margins 6) host rocks of low metamorphic grade (upper greenschist facies or less), 7) associated zones of hydrothermally altered rocks, epithermal to mesothermal veins, hydrothermal breccias, stockworks of veinlets, hornfels, skarn, or replacement deposits.

Lower Epizone

We considered the following characteristics to indicate lower epizonal depths of emplacement: 1) mostly discordant stocks and batholiths 2) phaneritic to porphyro-phaneritic textures, 3) lack of aphanitic chilled margins, 4) roof pendants, screens of inclusions, 5) host rocks metamorphosed to slates, phyllites of greenschist to lower amphibolite facies (Williams, Turner and Gilbert, 1954), 6) mesothermal to hypothermal (metamorphic-hydrothermal) polymetallic veins, low-sulfide gold-quartz veins, 7) skarns with relatively high-temperature, low-pressure assemblages of calc-silicate minerals, such as diopside and garnet.

Mesozone

We considered the following characteristics to indicate mesozonal depths of emplacement: 1) partly discordant, partly concordant plutons, 2) phaneritic to porphyro-phaneritic textures, commonly foliated as a result of upward movement or outward expansion of the pluton, 3) border zones of discordant dike injection to form agmatite (breccia-like mixture of host-rock fragments, cut by igneous dikes and dikelets), 4) schistose host rocks of lower to middle amphibolite facies.

Catazone

We considered the following characteristics to indicate catazonal depths of emplacement: 1) predominantly concordant intrusions, 2) extensive border zones of concordant, lit-par-lit injection of pegmatites in schist to form migmatite (mixed igneous and metamorphic rock), 3) schistose to gneissic host rocks of upper amphibolite facies (sillimanite-almandine subfacies) or higher, 4) presence of primary epidote, indicative of crystallization at high pressure (Zen, 1988), 5) metamorphic fabrics, indicating ductile deformation of the pluton (foliation, lineation, mylonitization), 6) anomalously young isotopic age determinations, indicating post-emplacement uplift through the blocking temperature of the dated material.

Summary of Estimated Emplacement-Depths

Concordant intrusions in migmatite of the Priest River metamorphic core complex, and primary epidote in many Cretaceous plutons in the Kaniksu batholith indicate multiple episodes of pre-Tertiary catazonal magmatism. However, Tertiary K-Ar age determinations on samples from phaneritic plutons in the Priest River metamorphic core complex indicate that Cretaceous catazonal plutons were unroofed during Eocene tectonic extensional uplift of the core complex. Mylonite and breccia zones along the margins of the core complex indicate a transition from ductile to brittle deformation during uplift from the catazone to the epizone (Miller and Engels, 1975; Doughty and Price, 1999).

Characteristics of the Bitterroot lobe of the Idaho batholith indicate plutonism at deep crustal levels (Hyndman and Foster, 1989). Along the eastern margin of the Bitterroot Mountains, mylonitic fabrics in Cretaceous plutonic rocks, and in the upper part of the Tertiary Paradise pluton indicate Tertiary uplift of catazonal Cretaceous plutonic rocks of the Bitterroot lobe of the Idaho batholith during Eocene uplift and emplacement of the Eocene Paradise pluton (Conyer and others, 2001).

East of the Bitterroot valley, many plutons in the Sapphire Mountains are epizonal on the basis of their contact metamorphic assemblages (Barton and others, 1988; Barton, unpub. data, 2001). The Sapphire Mountains are separated from the Bitterroot Mountains by a mylonitic detachment zone, exposed along the eastern margin of the Bitterroot lobe of the Idaho batholith. Some Cretaceous stocks in the Sapphire Mountains may therefore represent cupolas of the Idaho batholith, transported eastward above the Bitterroot detachment-fault zone (Alt and Hyndman, 1995). The tops of some intrusions within the Sapphire Mountains are also truncated by mylonite, indicating a higher Anaconda detachment zone, which probably dips eastward under the Deer Lodge valley, and possibly under the Boulder batholith (O'Neill and Lageson, 2003).

Characteristics of the western margin of the Atlanta lobe of the Idaho batholith indicate emplacement under deep-seated (catazonal) conditions, but characteristics of the eastern margin of the Atlanta lobe indicate later emplacement at much shallower (epizonal) depths (Buddington, 1959). Thus the older western margin of the Atlanta lobe has been more uplifted and deeply eroded than its younger eastern margin.

The Boulder batholith intrudes its associated volcanic field (the Elk Mountains Volcanics). This indicates that the Boulder batholith, regardless of its predominantly phaneritic textures, was emplaced to upper epizonal depths (Rutland and others, 1989). Thus, large plutons, emplaced to shallow levels, may crystallize gradually enough to result in phaneritic textures. Porphyro-aphanitic dikes associated with the Main Stage veins at Butte cut the Boulder batholith, but are too small to be represented at the 1:250,000 scale of source maps for the Butte and Dillon quadrangles, and are therefore not included in our compilation.

Some batholithic plutons of Tertiary age, such as the Sawtooth batholith, are predominantly phaneritic. However, many relatively small Tertiary plutons have porphyro-aphanitic textures, indicative of epizonal emplacement. Porphyro-aphanitic intrusions, emplaced into older volcanic rocks of the Challis, Absaroka, and Sanpoil volcanic fields were emplaced to upper epizonal (subvolcanic) levels.

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Table G-1. Explanation of igneous-map units, Northern Rocky Mountains study area.

[Item names in the ArcInfo® look-up table nr_geo.igmu are listed in parenthesis. [1] Map symbol abbreviates unique name for igneous-map unit. [2] Map-unit name indicates age, mode of occurrence, and lithology. Ages are from young to old, and lithologies in order of decreasing abundance. [3] Mode of occurrences describes the emplacement style of igneous rocks and derived sediments. Sedimentary includes cover and intravolcanic; extrusive includes volcanic and volcaniclastic; and intrusive includes hypabyssal and plutonic. Terms related to non-igneous sediments, sedimentary rocks, and metamorphic rocks are indicated by italics. [4] Lithologies included in each map unit (in order of generally decreasing abundance). Includes igneous rocks, meta-igneous rocks (denoted by ~), and sedimentary rocks interlayered with or derived from volcanic rocks. [5] Geologic features characteristic of the map unit, listed in order of generally decreasing abundance.]

Map-unit symbol[1] ***(ig_label)***	**Map-unit name[2]** ***(ig_name)***	**Mode of occurrence[3]** ***(ig_style)***	**Lithology[4]** ***(ig_lith)***	**Geologic feature[5]** ***(ig_feature)***
Qsvb	Quaternary *sediments*, volcanics, basaltic	*cover*	*alluvial sediments*, basaltic volcanics, undivided	*alluvial terraces*, *alluvial fans*, lava flows
Qvb	Quaternary volcanic rocks, basaltic	volcanic	basalt and related rocks	lava flows
Qvcr	Quaternary volcaniclastic rocks, rhyolitic	*volcaniclastic*	rhyolite tuffs	welded ash-flow tuffs
Qvr	Quaternary volcanic rocks, rhyolite	volcanic	rhyolite	lava flows
QNvb	Quaternary-Neogene volcanic rocks, basaltic	volcanic	basalt and related rocks	lava flows, scoria, and cinder cones
QNvbs	Quaternary-Neogene volcanic rocks, basaltic, and *sediments*	*alluvial*, volcanic	*alluvial sediments*, basaltic volcanics, undivided	*alluvial deposits*, lava flows
Nvb	Neogene volcanic rocks, basalt	volcanic	basalt	lava flows
Nvc	Neogene volcaniclastic rocks	volcaniclastic	tuff	ash-flow tuff, densely to partly welded
Nvcb	Neogene volcaniclastic rocks, basaltic	volcaniclastic	mafic tuffs, *tuffaceous sediments*	mafic tuffs, tuffaceous deposits
Nvcf	Neogene volcaniclastic rocks, felsic	volcaniclastic	felsic tuff	tuff, welded, non-welded
Nvcrb	Neogene volcanic rocks, Columbia River Basalt Group, undivided	volcanic	basalt	flood basalt flows, local pillow basalts, and local lenses of clay-rich lacustrine *sediments*, derived from erosion of saprolites
Nvcrb1	Neogene volcanic rocks, Columbia River Basalt, Imnaha Formation	volcanic and *sedimentary*	olivine- and plagioclase-phyric basalt	flood basalt flows, basal unit, filling previous drainage patterns

Map-unit symbol[1] (ig_label)	Map-unit name[2] (ig_name)	Mode of occurrence[3] (ig_style)	Lithology[4] (ig_lith)	Geologic feature[5] (ig_feature)
Nvcrb2	Neogene volcanic rocks, Columbia River Basalt, Grande Ronde Basalt	volcanic	aphanitic basalt	flood basalt flows, most widespread and thickest Columbia River Basalt unit
Nvcrb3	Neogene volcanic rocks, Columbia River Basalt, Wanapum Basalt	volcanic	olivine-phyric and feldspar-phyric basalts	flood basalt flows, relatively thin unit, covering most of central Columbia River Basalt basin
Nvcrb4	Neogene volcanic rocks, Columbia River Basalt, Saddle Mountains Basalt	volcanic	basalt	flood basalt flows, relatively thin uppermost unit, mostly along central axis of Columbia River Basalt basin, and filling canyons
Nvfmi	Neogene volcanic and volcaniclastic rocks, felsic, mafic and intermediate	volcanic, volcaniclastic	rhyolitic, basaltic, quartz latitic and ferrolatitic volcanic and volcaniclastic rocks	lava flows, ash-flow tuffs and ash-fall tuffs
Nvi	Neogene volcanic rocks, intermediate	volcanic	andesite to latite and related rocks	lava flows
Nvr	Neogene volcanic rocks, rhyolitic	volcanic, volcaniclastic	rhyolite, rhyolite tuff	lava flows, welded ash-flow tuff, non-welded air-fall tuff
Nib	Neogene intrusive rocks, basaltic	sub-volcanic	basalt and basaltic andesite	dikes
Tv	Tertiary volcanic rocks	volcanic	volcanic rocks, undivided	volcanic features, undivided
Tvbx	Tertiary volcanic breccia	volcaniclastic	megabreccia	caldera-wall slump debris
Tvc	Tertiary volcaniclastic rocks	volcaniclastic	tuffaceous rocks, undivided	welded, non-welded ash-flow, ash-fall tuffs, undivided
Tvcb	Tertiary volcaniclastic rocks, basaltic	volcaniclastic	basaltic scoria	cinder cone, ejectamenta, flows
Tvcd	Tertiary volcaniclastic rocks, dacitic	volcaniclastic	dacite to rhyodacite, quartz latite tuffs	welded, non-welded ash-flow, ash-fall tuffs, undivided
Tvcf	Tertiary volcaniclastic rocks, felsic	volcaniclastic	rhyodacitic and quartz latitic to rhyolitic tuffs, undivided	welded, non-welded ash-flow, ash-fall tuffs, undivided
Tvci	Tertiary volcaniclastic rocks, intermediate	volcaniclastic	andesite to latite tuff, feldspar-phyric tuff, *volcaniclastic sediments*	welded, non-welded ash-flow, ash-fall tuffs, undivided

Map-unit symbol[1] ***(ig_label)***	**Map-unit name**[2] ***(ig_name)***	**Mode of occurrence**[3] ***(ig_style)***	**Lithology**[4] ***(ig_lith)***	**Geologic feature**[5] ***(ig_feature)***
Tvcr	Tertiary volcaniclastic rocks, rhyolitic	volcaniclastic	rhyolite to rhyodacite, quartz latite tuffs	welded, non-welded ash-flow, ash-fall tuffs, undivided
Tvcs	Tertiary volcaniclastic rocks and sedimentary deposits	volcanic-*sedimentary*	tuffs and *tuffaceous volcaniclastic sedimentary* rocks	mixed tuffs and tuffaceous sedimentary strata
Tvcsi	Tertiary volcaniclastic rocks, intermediate, and derived sedimentary rocks	volcaniclastic-epiclastic	andesitic to dacitic volcaniclastic rocks, and *conglomeratic* to *tuffaceous sedimentary rocks*	volcanic-vent to *alluvial* facies
Tvd	Tertiary volcanic rocks, dacitic	volcanic	dacite, rhyodacite	lava flows, domes, ash-flow tuffs, undivided
Tvf	Tertiary volcanic rocks, felsic	volcanic	rhyolite, quartz latite, rhyodacite, undivided	lava flows, domes, ash-flow tuffs, mudflow breccias, undivided
Tvfi	Tertiary volcanic rocks, felsic to intermediate	volcanic	rhyolite, rhyodacite, dacite, quartz latite, latite, andesite, undivided	lava flows, domes, ash-flow tuffs, undivided
Tvi	Tertiary volcanic rocks, intermediate	volcanic	andesite, latite, intermediate lava and breccia	lava flows, volcanic breccias
Tvim	Tertiary volcanic rocks, intermediate to mafic	volcanic	andesite, basaltic andesite, basalt; latite lava and breccia, undivided	lava flows, flow breccias, subordinate interlayered mudflow deposits
Tvm	Tertiary volcanic rocks, mafic	volcanic	basalt, trachybasalt, mafic volcanic rocks	lava flows
Tvr	Tertiary volcanic rocks, rhyolitic	volcanic	rhyolite, flow-laminated rhyolite to quartz latite, perlite	lava flows, densely welded tuffs
Tvvci	Tertiary volcanic and volcaniclastic rocks, intermediate	volcanic-volcaniclastic	andesitic to dacitic volcanic, volcaniclastic, and *epiclastic breccia*	lava flows, flow breccias, and laharic epiclastic breccias
Tivf	Tertiary intrusive and volcanic rocks, felsic	hypabyssal to volcanic	rhyodacitic to felsic dacitic intrusive and volcanic rocks	plugs, dikes, sills, volcanic flows, tuffs, undivided
Ti	Tertiary intrusive rocks	hypabyssal	porphyro-aphanitic intrusive rocks	stocks, plugs, dikes, sills
Tiafm	Tertiary intrusive rocks, alkalic, felsic to mafic	hypabyssal	alkalic (sodic, silica-undersaturated) mafic to felsic porphyries	porphyritic stocks, plugs, dikes, sills, laccoliths

Map-unit symbol[1] (ig_label)	Map-unit name[2] (ig_name)	Mode of occurrence[3] (ig_style)	Lithology[4] (ig_lith)	Geologic feature[5] (ig_feature)
Tibx	Tertiary intrusive breccia	hypabyssal to volcanic	breccia with igneous-fragmental matrix	diatremes, pipes
Tid	Tertiary intrusive rocks, dacitic	hypabyssal	dacite, rhyodacite porphyries, undivided	porphyritic stocks, plugs, dikes, sills, laccoliths
Tif	Tertiary intrusive rocks, felsic	hypabyssal	porphyro-aphanitic rhyolite, rhyodacite, dacite, quartz latite, felsite; and porphyritic granite, granodiorite, quartz monzonite, undivided	porphyritic stocks, plugs, dikes, sills, laccoliths
Tifi	Tertiary intrusive rocks, felsic to intermediate	hypabyssal	rhyolitic to andesitic porphyries	porphyritic stocks, plugs, dikes, sills, laccoliths
Tii	Tertiary intrusive rocks, intermediate	hypabyssal	andesite, trachyandesite, latite porphyries; and porphyritic monzonite	porphyritic stocks, plugs, dikes, sills, laccoliths
Tiifm	Tertiary intrusive rocks, intermediate, felsic to mafic	hypabyssal	diorite to andesite, and rhyolite to basalt	radial dike swarm
Tiim	Tertiary intrusive rocks, intermediate to mafic	hypabyssal	basalt, shoshonite, andesite, diorite, lamprophyre, latite, dacite	porphyritic to aphanitic stocks, plugs, dikes, sills, laccoliths
Tim	Tertiary intrusive rocks, mafic	hypabyssal	diabase	porphyritic to aphanitic stocks, plugs, dikes, sills, laccoliths
Tir	Tertiary intrusive rocks, rhyolitic	hypabyssal	rhyolite to granite porphyries, aplites	porphyritic stocks, plugs, dikes, sills, laccoliths
Tgbm	Tertiary granitic rocks with biotite, muscovite	plutonic	biotite-muscovite granite, granodiorite	plutons
Tgqmd	Tertiary granitoid rocks, quartz monzodiorite suite	plutonic	granodiorite, monzogranite of quartz monzodiorite suite (with hornblende and biotite)	plutons, porphyritic stocks, dikes
Tm	Tertiary monzonite	plutonic	monzonite	stocks, dikes, sills
Tmg	Tertiary monzogranite suite	plutonic	monzogranite, subordinate syenogranite (with biotite + minor hornblende)	plutons, porphyritic stocks

Map-unit symbol[1] (ig_label)	Map-unit name[2] (ig_name)	Mode of occurrence[3] (ig_style)	Lithology[4] (ig_lith)	Geologic feature[5] (ig_feature)
Tqmd	Tertiary quartz monzodiorite suite	plutonic	quartz monzodiorite, monzogranite, granodiorite, subordinate quartz monzonite, monzodiorite, diorite, quartz diorite, undivided (with hornblende and biotite)	plutons, porphyritic stocks, dikes
Tsq	Tertiary syenite suite	plutonic	syenite, quartz syenite, syenogranite	plutons
TKvim	Tertiary-Cretaceous volcanic rocks, intermediate and mafic	volcanic	andesitic and basaltic volcanic rocks, undivided	lava flows
TKvtba	Tertiary-Cretaceous volcanic rocks, trachybasaltic, trachyandesitic	volcanic	trachybasalt, trachyandesite	lava flows, agglomerates
TKi	Tertiary-Cretaceous intrusive rocks	hypabyssal	porphyritic rocks of unspecified composition	dikes, plugs, sills
TKif	Tertiary-Cretaceous intrusive rocks, felsic	hypabyssal	granite, rhyolite, quartz latite, quartz monzonite, rhyodacite, and felsic dacite porphyries	stocks, dikes, sills
TKiif	Tertiary-Cretaceous intrusive rocks, intermediate to felsic	hypabyssal	andesite and intermediate to felsic intrusive rocks	dikes
TKim	Tertiary-Cretaceous intrusive rocks, mafic	hypabyssal	gabbroic, dioritic, lamprophyric aphanites, porphyries	dikes, sills,
TKita	Tertiary-Cretaceous intrusive rocks, trachyandesitic	hypabyssal	trachyandesite, andesite, trachybasalt	sills, dikes, irregular bodies
TKap	Tertiary-Cretaceous granitic aplite and pegmatite	plutonic	biotite-muscovite alaskite, pegmatite, aplite	dikes, sills, lenses, pods
TKgbm	Tertiary-Cretaceous granitic rocks with biotite, muscovite	plutonic	biotite-muscovite granite, granodiorite, quartz monzonite, alaskite, pegmatite, aplite	plutons
TKgd	Tertiary-Cretaceous granodioritic rocks	plutonic	granodiorite (ranges from quartz monzonite to monzogranite)	plutons
TKgdbh	Tertiary-Cretaceous granodiorite with biotite, hornblende	plutonic	hornblende-biotite granodiorite	plutons

Map-unit symbol[1] (ig_label)	Map-unit name[2] (ig_name)	Mode of occurrence[3] (ig_style)	Lithology[4] (ig_lith)	Geologic feature[5] (ig_feature)
TKmg	Tertiary-Cretaceous monzogranite	plutonic	monzogranite	plutons
TKgdbhf~	Tertiary-Cretaceous meta-granodiorite with biotite, hornblende, foliated	meta-plutonic	foliated biotite-hornblende granodiorite	foliated plutonic rocks
TKgdbmy~	Tertiary-Cretaceous granodiorite with biotite, mylonitic	meta-plutonic	biotite granodiorite, mylonitic	plutonic rocks with mylonitic fabric of detachment-fault zone
TKgdf~	Tertiary-Cretaceous meta-granodiorite, foliated	meta-plutonic	foliated granodiorite	foliated plutonic rocks
Kvcs	Cretaceous volcaniclastic and *sedimentary* rocks	pyroclastic, *sedimentary*	pyroclastic and volcaniclastic *sedimentary rocks* of unspecified compositions	tuff, ash-flow tuff, volcaniclastic sedimentary rocks
Kvfi	Cretaceous volcanic and volcaniclastic rocks, intermediate to felsic	volcanic, pyroclastic	rhyolite, rhyodacite, felsic quartz latite, felsic dacite	lava flows and tuffs, undivided
Kvi	Cretaceous volcanic and volcaniclastic rocks, intermediate	volcanic, pyroclastic, *sedimentary*	andesite, dacite, quartz latite, basalt; *volcaniclastic conglomerate, sandstone*	tuffs, breccias, lava flows, dikes, sedimentary interbeds, undivided
Kvts	Cretaceous volcanic trachyte, with *sedimentary* interlayers	volcanic, pyroclastic, *sedimentary*	trachyte, latite; tuffs; *conglomerate, sandstone*	lava flows, ash-flow tuffs, air-fall tuffs, sedimentary interbeds
Kid	Cretaceous intrusive rocks, dacitic	hypabyssal	felsic dacite, rhyodacite, quartz latite porphyries	intrusions
Kifi	Cretaceous intrusive rocks, felsic to intermediate	hypabyssal	rhyolite, rhyodacite, intermediate dacite porphyries	intrusions
Kii	Cretaceous intrusive rocks, intermediate	hypabyssal	diorite, hornblende granodiorite, and monzonite; andesite, trachyandesite, dacite, latite, monzonite porphyries, and lamprophyres	Subvolcanic stocks, plugs, dikes, sills
Kiim	Cretaceous intrusive rocks, intermediate to mafic	hypabyssal	intermediate to mafic lamprophyres	dikes
Kita	Cretaceous intrusive rocks, trachyandesitic	hypabyssal	trachyandesite, basaltic trachyandesite, trachyte	dikes, sills

Map-unit symbol[1] (ig_label)	Map-unit name[2] (ig_name)	Mode of occurrence[3] (ig_style)	Lithology[4] (ig_lith)	Geologic feature[5] (ig_feature)
Kdq	Cretaceous diorite, quartz diorite	plutonic	diorite, quartz diorite, gabbro to tonalite, undivided	plutons
Kg	Cretaceous granitic rocks	plutonic	granite, monzogranite, quartz monzonite, granodiorite	porphyritic to plutonic intrusions
Kgap	Cretaceous leucogranite, aplite, and pegmatite	plutonic	leucogranite, aplite, pegmatite, granophyre, alaskite	plutons, dikes, pods,
Kgb	Cretaceous gabbro	plutonic	gabbroic to diabasic rocks	small plutons, mafic margins on composite plutons
Kgbm	Cretaceous granitoid rocks with biotite, muscovite	plutonic	biotite-muscovite granite, granodiorite, trondhjemite, monzogranite, aplite, pegmatite, alaskite	plutons
Kgd	Cretaceous granodioritic rocks	plutonic	hornblende-biotite granodiorite, tonalite, and minor biotite-muscovite monzogranite, undivided	plutons
Kgdb	Cretaceous granodioritic rocks with biotite	plutonic	biotite granodiorite, tonalite, monzogranite	plutons
Kgdbh	Cretaceous granodioritic rocks with biotite, hornblende	plutonic	biotite-hornblende granodiorite, tonalite, trondhjemite, monzogranite, granite	plutons with phaneritic, megacrystic, and porphyritic textures
Kgmx	Cretaceous granitic migmatite	plutonic	granitic migmatite (mixed metamorphic and discordant granitic dikelets)	migmatite (brecciated schistose rocks, pervasively injected by abundant discordant granitic intrusions)
Kmd	Cretaceous monzodiorite suite	plutonic	monzodiorite, monzonite, quartz-bearing monzonite	plutons
Kmg	Cretaceous monzogranite	plutonic	monzogranite	plutons
Kmgbh	Cretaceous monzogranitic rocks with biotite, hornblende	plutonic	biotite-hornblende monzogranite, quartz monzonite	plutons

Map-unit symbol[1] (ig_label)	Map-unit name[2] (ig_name)	Mode of occurrence[3] (ig_style)	Lithology[4] (ig_lith)	Geologic feature[5] (ig_feature)
Kms	Cretaceous monzonite-syenite suite	plutonic	monzonite, quartz monzonite, leucomonzonite; syenite, alkali-feldspar syenite, quartz syenite	stocks, composite stocks
Kqdt	Cretaceous quartz diorite-tonalite suite	plutonic	quartz diorite, tonalite, trondhjemite	plutons
Kqm	Cretaceous quartz-monzonitic rocks	plutonic	quartz monzonite, monzogranite, quartz-bearing monzonite	plutons
Kspx	Cretaceous syenite-pyroxenite suite	plutonic	syenite, pyroxenite, biotite, vermiculite	composite intrusions
Kgbmf~	Cretaceous meta-granitic rocks with biotite, muscovite, foliated	meta-plutonic	biotite-muscovite granite, foliated, lineated, locally mylonitic	plutons, foliated, lineated, locally mylonitic
Kgbmo~	Cretaceous granitic rocks with biotite, muscovite, orthogneiss	meta-plutonic	biotite-muscovite granite, orthogneissic to mylonitic	plutons, orthogneissic to mylonitic
Kgdbf~	Cretaceous meta-granodiorite with biotite, foliated	meta-plutonic	biotite granodiorite, foliated	foliated plutonic rocks
Kgdbhf~	Cretaceous meta-granodiorite with biotite, hornblende, foliated	meta-plutonic	foliated biotite-hornblende granodiorite	foliated plutonic rocks
Kgdbmy~	Cretaceous granodiorite with biotite, mylonitic	meta-plutonic	biotite granodiorite, mylonitic	plutonic rocks with mylonitic fabric of detachment-fault zone
Kgdf~	Cretaceous meta-granodiorite, foliated	meta-plutonic	foliated granodiorite	foliated plutons
Kgdmy~	Cretaceous granodiorite, mylonitic	meta-plutonic	granodiorite, mylonitic	plutonic rocks with mylonitic fabric of detachment-fault zone
Kgo~	Cretaceous granitic orthogneiss	meta-plutonic	granitic orthogneiss	gneissic pluton
Ktf~	Cretaceous meta-tonalite, foliated	meta-plutonic	tonalite, foliated	foliated plutonic rocks
Ktgdmx~	Cretaceous tonalitic to granodioritic migmatite	meta-plutonic	tonalitic to granodioritic migmatite	mixed schist and concordant granodioritic lenses
Kto~	Cretaceous tonalite orthogneiss	meta-plutonic	tonalite orthogneiss (ranges from quartz diorite to granodiorite orthogneiss)	gneissic plutons in suture zone

Map-unit symbol[1] (ig_label)	Map-unit name[2] (ig_name)	Mode of occurrence[3] (ig_style)	Lithology[4] (ig_lith)	Geologic feature[5] (ig_feature)
KJgb~	Cretaceous-Jurassic meta-gabbro	meta-plutonic	meta-gabbro, norite	metamorphosed plutons
KJgd~	Cretaceous-Jurassic meta-granodiorite	meta-plutonic	meta-granodiorite, tonalite, minor albite granite	foliated to gneissic plutons
KJqd~	Cretaceous-Jurassic meta-quartz diorite suite	meta-plutonic	meta-quartz-diorite suite, undivided (includes quartz diorite, diorite, monzodiorite, quartz monzonite, granodiorite, tonalite, trondhjemite and gabbro)	foliated to gneissic plutons, commonly composite
KTRum~	Cretaceous-Triassic meta-ultramafic rocks	meta-plutonic	metamorphosed ultramafic rocks	metamorphosed ultramafic rocks
KPtmx~	Cretaceous-Permian tonalitic migmatite	meta-intrusive	tonalitic to granodioritic migmatite	migmatite (mylonitized schistose rocks, pervasively injected by abundant, mostly concordant, tonalitic to granodioritic intrusions)
KYim~	Cretaceous-Middle Proterozoic meta-intrusive rocks, mafic	meta-intrusive	amphibolite after mafic intrusive rocks	foliated amphibolitized dikes, sills, plugs
KYum~	Cretaceous-Middle Proterozoic meta-ultramafic rocks	meta-plutonic	serpentinite after ultramafic intrusive rocks	serpentinized ultramafic intrusions
KXivi~	Cretaceous-Early Proterozoic meta-intrusive or meta-volcanic rocks, intermediate	metavolcanic or meta-intrusive	foliated porphyritic meta-andesite, meta-dacite	foliated volcanic or hypabyssal intrusions
Jvci~	Jurassic greenstone after andesitic to latitic volcaniclastic and volcanic-derived sedimentary rocks	metavolcanic	greenstone after andesitic to latitic volcaniclastic and volcanic-derived sedimentary rocks	metamorphosed volcaniclastic and volcanic-derived sedimentary strata
Jvr~	Jurassic greenstone after rhyolitic volcanic rocks	metavolcanic	greenstone after rhyolitic metavolcanic rocks	rhyolitic metavolcanic layer
Jim~	Jurassic meta-intrusive rocks, mafic	meta-plutonic	meta-diabase, meta-gabbro	metamorphosed aphanitic intrusions, plutons
Jt~	Jurassic meta-tonalite	meta-plutonic	meta-tonalite, meta-trondhjemite	plutons

Map-unit symbol[1] (ig_label)	Map-unit name[2] (ig_name)	Mode of occurrence[3] (ig_style)	Lithology[4] (ig_lith)	Geologic feature[5] (ig_feature)
JTRms	Jurassic-Triassic monzonite to syenite	plutonic	monzonite, syenite	plutons
JTRqd~	Jurassic-Triassic meta-quartz diorite suite	meta-plutonic	meta-quartz diorite, diorite, gabbro, norite, albite granite	metamorphosed plutons
JPv~	Jurassic-Permian greenschist and amphibolite after mafic to felsic volcaniclastic and volcanic-derived metasedimentary rocks	metavolcanic	greenschist and amphibolite after mafic to felsic volcaniclastic rocks, and gray schist after volcanic-derived metasedimentary rocks	metamorphosed volcaniclastic and volcanic-derived sedimentary strata
TRgd	Triassic granodiorite	plutonic	granodiorite	plutons
TRv~	Triassic greenstone after andesitic to basaltic volcanic rocks	metavolcanic	greenstone after andesitic to basaltic volcanics	metavolcanic rocks
TRPgd	Triassic-Permian granodiorite	plutonic	granodiorite	plutons
TRPv~	Triassic-Permian metavolcanic greenstone after andesitic and keratophyric rocks	metavolcanic	basaltic to andesitic greenstone, keratophyre, and volcanic-derived metasedimentary rocks	metavolcanic and volcanic-derived meta-sedimentary rocks
TRPqd~	Triassic-Permian meta-quartz dioritic rocks	meta-plutonic	meta-quartz diorite and diorite, and minor associated gabbro, norite, and albite granite	metamorphosed plutons
Pqd	Permian quartz diorite	plutonic	quartz diorite	plutons
Pv~	Permian greenstone after volcanic and volcaniclastic rocks of intermediate to felsic composition	metavolcanic	greenstone after volcanic and volcaniclastic quartz-keratophyric rocks	meta-volcanic flows, and water-laid tuffs
Osy	Ordovician syenite suite	plutonic	syenite, subordinate gabbro, quartz syenite	plutons
Zsd	Late Proterozoic syenite-diorite suite	plutonic	syenite, diorite, quartz syenite, quartz diorite	plutons
Zimi	Late Proterozoic intrusive rocks, mafic to intermediate	plutonic	gabbro, diorite, quartz diorite	dikes, sills
ZYimi~	Late Proterozoic-Middle Proterozoic meta-intrusive rocks, mafic to intermediate	meta-plutonic	amphibolite after gabbroic to dioritic rocks	metamorphosed sills, dikes

Map-unit symbol[1] (ig_label)	Map-unit name[2] (ig_name)	Mode of occurrence[3] (ig_style)	Lithology[4] (ig_lith)	Geologic feature[5] (ig_feature)
ZXim~	Proterozoic meta-intrusive rocks, mafic	meta-intrusive	meta-diabase	metamorphosed sills, dikes
ZAam~	Late Proterozoic to Archean amphibolitic meta-intrusive rocks, mafic	meta-intrusive	meta-diabase, meta-gabbro	metamorphosed sills, dikes, irregular bodies
Yvm	Middle Proterozoic volcanic rocks, mafic	volcanic	alkaline basalt (amygdaloidal)	metamorphosed lava flows
Yii~	Middle Proterozoic meta-intrusive rocks, intermediate	meta-intrusive	meta-andesite, basaltic andesite, dacite, quartz diorite	metamorphosed sills, dikes in Belt strata
Yim~	Middle Proterozoic meta-intrusive rocks, mafic	meta-intrusive	amphibolite and hornblende gneiss after olivine meta-gabbro, diorite, trondhjemite and diabase, locally in gradational contact with comagmatic granite	metamorphosed sill complex, with thick, differentiated sills
Yan~	Middle Proterozoic meta-anorthosite	meta-plutonic	anorthosite	metamorphosed plutons, semi-concordant
Ygo~	Middle Proterozoic granitic gneiss	meta-plutonic	granitic augen gneiss, orthogneiss, porphyritic granite with local inclusions and rounded pillows of comagmatic diabase	metamorphosed plutons, thick dikes
Xg	Early Proterozoic granite	plutonic	granite	plutons
Xgb	Early Proterozoic gabbro	plutonic	gabbro	plutons
Xgo~	Early Proterozoic granitic gneiss	meta-plutonic	granitic orthogneiss	metamorphosed plutons
XAam~	Early Proterozoic-Archean amphibolite after mafic igneous rocks	meta-igneous	amphibolite, amphibole gneiss, after mafic intrusive and volcanic rocks	metamorphosed intrusions and volcanics
XAgdo~	Early Proterozoic-Archean granodioritic gneiss	meta-plutonic	granodiorite orthogneiss	metamorphosed plutons
XAum~	Early Proterozoic-Archean meta-ultramafic rocks	meta-plutonic	serpentinite	metamorphosed ultramafic rocks
Asw	Archean Stillwater Complex, undivided	hypabyssal	mafic to felsic rocks	layered intrusive complex

Map-unit symbol[1] *(ig_label)*	Map-unit name[2] *(ig_name)*	Mode of occurrence[3] *(ig_style)*	Lithology[4] *(ig_lith)*	Geologic feature[5] *(ig_feature)*
Aswub	Archean Stillwater Complex, Upper Banded series	hypabyssal	gabbro, anorthosite	layered intrusive complex
Aswmb	Archean Stillwater Complex, Middle Banded series	hypabyssal	gabbro, anorthosite	layered intrusive complex
Aswlb	Archean Stillwater Complex, Lower Banded series	hypabyssal	norite, gabbro	layered intrusive complex
Aswum	Archean Stillwater Complex, Basal and Ultramafic series	hypabyssal	harzburgite and bronzitite	layered intrusive complex
Aum~	Archean meta-ultramafic rocks	meta-intrusive	meta-ultramafic rocks, undivided	metamorphosed ultramafic rocks, probably intrusive
Aam~	Archean amphibolite after mafic igneous rocks	meta-igneous	meta-mafic rocks, including amphibolite, amphibole gneiss, meta-gabbro, and meta-norite after mafic intrusive and volcanic rocks	metamorphosed intrusions and volcanics
Ado~	Archean diorite gneiss	meta-plutonic	diorite gneiss	metamorphosed plutons
Agdo~	Archean granodiorite orthogneiss	meta-plutonic	granodiorite orthogneiss	metamorphosed plutons
Ago~	Archean granitic gneiss and schist	meta-plutonic	granitic gneiss, *schist*; quartzo-feldspathic gneiss, *schist*	metamorphosed plutons with inclusions of metamorphic rocks
Aqd~	Archean meta-quartz diorite	meta-plutonic	meta-quartz diorite	metamorphosed plutons
Atno~	Archean tonalitic gneiss	meta-plutonic	tonalitic orthogneiss	metamorphosed plutons

Table G-2. Named volcanic-stratigraphic sequences, Northern Rocky Mountains study area.

[Item names in the ArcInfo® look-up tables NR_GEO.IGPNAM and NR_GEO.IGANAM are listed in parenthesis]

Volcanic event name *(vol_event)*	Volcanic field name *(vol_field)*	Supergroup name *(vol_supgrp)*	Group name *(vol_grp)*	Subgroup name *(vol_subgrp)*	Formation name *(vol_fm)*	Member name *(vol_mbr)*	Informal name *(vol_infrml)*	Eruptive Center *(vol_ctr)*
Blue Mountains oceanic island arcs	Izee volcanic arc terrane				Weatherby Formation			
Blue Mountains oceanic island arcs	Olds Ferry volcanic arc terrane				Huntington Formation			
Blue Mountains oceanic island arcs	Wallowa volcanic arc terrance		Seven Devils Group		Doyle Creek Formation			
Blue Mountains oceanic island arcs	Wallowa volcanic arc terrance		Seven Devils Group					
Blue Mountains oceanic island arcs	Wallowa volcanic arc terrance		Seven Devils Group		Windy Ridge Formation			
Blue Mountains oceanic island arcs	Wallowa volcanic arc terrance		Seven Devils Group		Wild Sheep Creek Formation			
Blue Mountains oceanic island arcs	Wallowa volcanic arc terrance		Seven Devils Group		Hunsaker Creek Formation			
central Montana alkaline province continental magmatic arc	Adel Mountain volcanic field				Adel Mountain Volcanics			
Challis continental magmatic arc	Absaroka volcanic province	Absaroka Volcanic Supergroup	Washburn Group		Hyalite Peak Volcanics			

Volcanic event name *(vol_event)*	Volcanic field name *(vol_field)*	Supergroup name *(vol_supgrp)*	Group name *(vol_grp)*	Subgroup name *(vol_subgrp)*	Formation name *(vol_fm)*	Member name *(vol_mbr)*	Informal name *(vol_infrml)*	Eruptive Center *(vol_ctr)*
Challis continental magmatic arc	Absaroka volcanic province	Absaroka Volcanic Supergroup	Washburn Group		Sepulcher Formation	Fortress Mountain Member and Daly Creek Member, undivided		
Challis continental magmatic arc	Absaroka volcanic province	Absaroka Volcanic Supergroup	Washburn Group		Sepulcher Formation	Elk Creek Basalt Member		
Challis continental magmatic arc	Absaroka volcanic province	Absaroka Volcanic Supergroup					subvolcanic rocks, not named	
Challis continental magmatic arc	Absaroka volcanic province	Absaroka Volcanic Supergroup	Washburn Group		Golmeyer Creek Volcanics		subvolcanic rocks, not named	
Challis continental magmatic arc	Absaroka volcanic province	Absaroka Volcanic Supergroup	Washburn Group		Golmeyer Creek Volcanics		extrusive rocks, not named	
Challis continental magmatic arc	Absaroka volcanic province	Absaroka Volcanic Supergroup					extrusive rocks, not named	
Challis continental magmatic arc	Absaroka volcanic province	Absaroka Volcanic Supergroup	Washburn Group		Sepulcher Formation			
Challis continental magmatic arc	Absaroka volcanic province	Absaroka Volcanic Supergroup	Washburn Group		Sepulcher Formation	Lost Creek Tuff Member		
Challis continental magmatic arc	Challis volcanic field		Challis Volcanics					Thunder Mountain cauldron complex
Challis continental magmatic arc	Challis volcanic field		Challis Volcanics					Sun Valley caldera

Volcanic event name *(vol_event)*	Volcanic field name *(vol_field)*	Supergroup name *(vol_supgrp)*	Group name *(vol_grp)*	Subgroup name *(vol_subgrp)*	Formation name *(vol_fm)*	Member name *(vol_mbr)*	Informal name *(vol_infrml)*	Eruptive Center *(vol_ctr)*
Challis continental magmatic arc	Challis volcanic field		Challis Volcanics				extrusive rocks, not named	Van Horn Peak cauldron complex
Challis continental magmatic arc	Challis volcanic field		Challis Volcanics				extrusive rocks, not named	Twin Peaks caldera
Challis continental magmatic arc	Challis volcanic field		Challis Volcanics				subvolcanic rocks, not named	Van Horn Peak cauldron complex
Challis continental magmatic arc	Challis volcanic field		Challis Volcanics				subvolcanic rocks, not named	Twin Peaks caldera
Challis continental magmatic arc	Challis volcanic field		Challis Volcanics				subvolcanic rocks, not named	Panther Creek graben
Challis continental magmatic arc	Challis volcanic field		Challis Volcanics				extrusive rocks, not named	
Challis continental magmatic arc	Challis volcanic field						rhyolite of Clear Creek	
Challis continental magmatic arc	Challis volcanic field		Challis Volcanics				subvolcanic rocks, not named	Corral Creek cauldron segment
Challis continental magmatic arc	Challis volcanic field		Challis Volcanics				extrusive rocks, not named	Corral Creek cauldron segment
Challis continental magmatic arc	Challis volcanic field		Challis Volcanics				tuffs of Castle Rock	Castle Rock cauldron segment
Challis continental magmatic arc	Challis volcanic field		Challis Volcanics				tuff of Ellis Creek	Van Horn Peak cauldron complex

Volcanic event name (vol_event)	Volcanic field name (vol_field)	Supergroup name (vol_supgrp)	Group name (vol_grp)	Subgroup name (vol_subgrp)	Formation name (vol_fm)	Member name (vol_mbr)	Informal name (vol_infrml)	Eruptive Center (vol_ctr)
Challis continental magmatic arc	Challis volcanic field		Challis Volcanics				tuff of Eightmile Creek	Van Horn Peak cauldron complex
Challis continental magmatic arc	Challis volcanic field		Challis Volcanics				tuffs of Camas Creek-Black Mountain	Van Horn Peak cauldron complex
Challis continental magmatic arc	Challis volcanic field		Challis Volcanics					Withington Creek caldera
Challis continental magmatic arc	Challis volcanic field		Challis Volcanics				subvolcanic rocks, not named	
Challis continental magmatic arc	Challis volcanic field		Challis Volcanics				subvolcanic rocks, not named	Custer graben
Challis continental magmatic arc	Challis volcanic field		Challis Volcanics				extrusive rocks, not named	Custer graben
Challis continental magmatic arc	Challis volcanic field		Challis Volcanics				extrusive rocks, not named	Panther Creek graben
Challis continental magmatic arc	Hog Heaven volcanic field						volcanics of Hog Heaven mining district	
Challis continental magmatic arc	Kamiah volcanic field				Kamiah Volcanics			
Challis continental magmatic arc	Lowland Creek volcanic field		Bozeman Group		Renova Formation		Dillon volcanic member	
Challis continental magmatic arc	Lowland Creek volcanic field				Lowland Creek Volcanics			Lowland Creek graben

Volcanic event name *(vol_event)*	Volcanic field name *(vol_field)*	Supergroup name *(vol_supgrp)*	Group name *(vol_grp)*	Subgroup name *(vol_subgrp)*	Formation name *(vol_fm)*	Member name *(vol_mbr)*	Informal name *(vol_infrml)*	Eruptive Center *(vol_ctr)*
Challis continental magmatic arc	Lowland Creek volcanic field		Bozeman Group		Renova Formation			
Challis continental magmatic arc	Medicine Lodge volcanic field				Medicine Lodge Volcanics			
Challis continental magmatic arc	Potato Hill volcanic field						Potato Hill volcanics	
Challis continental magmatic arc	Sanpoil volcanic field				Sanpoil Volcanics			Republic graben
Challis continental magmatic arc	Virginia City volcanic field						volcanics of Virginia City	
Challis continental magmatic arc	volcanic field, not assigned						andesitic volcanics near Lincoln	
Challis continental magmatic arc	volcanic field, not assigned						rhyolitic volcanics near Lincoln	
Columbia River large magmatic event	Columbia River flood basalt province		Columbia River Basalt Group					
Columbia River large magmatic event	Columbia River flood basalt province		Columbia River Basalt Group	Yakima Basalt Subgroup				
Columbia River large magmatic event	Columbia River flood basalt province		Columbia River Basalt Group		Imnaha Basalt			
Columbia River large magmatic event	Columbia River flood basalt province		Columbia River Basalt Group	Yakima Basalt Subgroup	Grande Ronde Basalt			

Volcanic event name *(vol_event)*	Volcanic field name *(vol_field)*	Supergroup name *(vol_supgrp)*	Group name *(vol_grp)*	Subgroup name *(vol_subgrp)*	Formation name *(vol_fm)*	Member name *(vol_mbr)*	Informal name *(vol_infrml)*	Eruptive Center *(vol_ctr)*
Columbia River large magmatic event	Columbia River flood basalt province		Columbia River Basalt Group	Yakima Basalt Subgroup	Wanapum Basalt	Priest Rapids Member		
Columbia River large magmatic event	Columbia River flood basalt province		Columbia River Basalt Group	Yakima Basalt Subgroup	Wanapum Basalt	Roza Member		
Columbia River large magmatic event	Columbia River flood basalt province		Columbia River Basalt Group	Yakima Basalt Subgroup	Wanapum Basalt	Eckler Mountain Member		
Columbia River large magmatic event	Columbia River flood basalt province		Columbia River Basalt Group	Yakima Basalt Subgroup	Wanapum Basalt		basalt of Feary Creek	
Columbia River large magmatic event	Columbia River flood basalt province		Columbia River Basalt Group	Yakima Basalt Subgroup	Wanapum Basalt			
Columbia River large magmatic event	Columbia River flood basalt province		Columbia River Basalt Group	Yakima Basalt Subgroup	Saddle Mountains Basalt	Weissenfels Ridge Member		
Columbia River large magmatic event	Columbia River flood basalt province		Columbia River Basalt Group	Yakima Basalt Subgroup	Saddle Mountains Basalt		basalt of Weippe	Clearwater embayment
Columbia River large magmatic event	Columbia River flood basalt province		Columbia River Basalt Group	Yakima Basalt Subgroup	Saddle Mountains Basalt	Wilbur Creek Member		
Columbia River large magmatic event	Columbia River flood basalt province		Columbia River Basalt Group	Yakima Basalt Subgroup	Saddle Mountains Basalt	Grangeville Member		Clearwater embayment
Columbia River large magmatic event	Columbia River flood basalt province		Columbia River Basalt Group	Yakima Basalt Subgroup	Saddle Mountains Basalt		basalt of Lapwai	Clearwater embayment
Columbia River large magmatic event	Columbia River flood basalt province		Columbia River Basalt Group	Yakima Basalt Subgroup	Saddle Mountains Basalt	Asotin Member		

Volcanic event name ***(vol_event)***	**Volcanic field name** ***(vol_field)***	**Supergroup name** ***(vol_supgrp)***	**Group name** ***(vol_grp)***	**Subgroup name** ***(vol_subgrp)***	**Formation name** ***(vol_fm)***	**Member name** ***(vol_mbr)***	**Informal name** ***(vol_infrml)***	**Eruptive Center** ***(vol_ctr)***
Columbia River large magmatic event	Columbia River flood basalt province		Columbia River Basalt Group	Yakima Basalt Subgroup	Saddle Mountains Basalt			
event, not assigned	Timber Hill basalt flows		Bozeman Group		Sixmile Creek Formation		Timber Hill basalt member	
event, not assigned	volcanic field, not assigned							
event, not assigned	volcanic field, not assigned		Bozeman Group		Sixmile Creek Formation			
event, not assigned	Weiser embayment volcanic flows				Weiser Basalt		basaltic tuff of Weiser	Weiser embayment
event, not assigned	Weiser embayment volcanic flows				Weiser Basalt			Weiser embayment
event, not assigned	Weiser embayment volcanic flows						basalt of Cuddy Mountain	Weiser embayment
Laramide continental magmatic arc	Elkhorn Mountains volcanic field				Elkhorn Mountains Volcanics			Elkhorn Mountains eruptive center
Laramide continental magmatic arc	Elkhorn Mountains volcanic field and Livingston Group rocks		Livingston Group		Sedan Formation		ash-flow tuff assemblage	
Laramide continental magmatic arc	Sliderock Mountain volcanic field		Livingston Group				volcanic rocks of Sliderock Mountain	Sliderock Mountain stock eruptive center
Laramide continental magmatic arc	volcanic field, not assigned						volcanic-sedimentary rocks near Augusta	

Volcanic event name *(vol_event)*	Volcanic field name *(vol_field)*	Supergroup name *(vol_supgrp)*	Group name *(vol_grp)*	Subgroup name *(vol_subgrp)*	Formation name *(vol_fm)*	Member name *(vol_mbr)*	Informal name *(vol_infrml)*	Eruptive Center *(vol_ctr)*
Moyie large magmatic event	Purcell lava flows	Belt Supergroup	Missoula Group		Snowslip Formation	Purcell Lava Member		
Snake River plain - Yellowstone large magmatic event	Snake River Plain volcanic field		Snake River Group				basalt of Gowan Terrace	
Snake River plain - Yellowstone large magmatic event	Snake River Plain volcanic field		Snake River Group				basalt of Lava Creek	
Snake River plain - Yellowstone large magmatic event	Snake River Plain volcanic field		Snake River Group				basalt of Lucky Peak	
Snake River plain - Yellowstone large magmatic event	Snake River Plain volcanic field		Snake River Group				basalt of Smith Creek	
Snake River plain - Yellowstone large magmatic event	Snake River Plain volcanic field		Snake River Group				basalt, undivided	
Snake River plain - Yellowstone large magmatic event	Snake River Plain volcanic field		Snake River Group		Smith Prairie Basalt			

Volcanic event name (vol_event)	Volcanic field name (vol_field)	Supergroup name (vol_supgrp)	Group name (vol_grp)	Subgroup name (vol_subgrp)	Formation name (vol_fm)	Member name (vol_mbr)	Informal name (vol_infrml)	Eruptive Center (vol_ctr)
Snake River plain - Yellowstone large magmatic event	Snake River Plain volcanic field		Snake River Group		Steamboat Rock Basalt			
Snake River plain - Yellowstone large magmatic event	Snake River Plain volcanic field		Idavada Group, Idaho Group, and Snake River Group, undivided				Idavada volcanics; Banbury basalt; quartz latite of Magic Reservoir; ferrolatite of Square Mountain, undivided	central Snake River Plain and Magic Mountain eruptive center
Snake River plain - Yellowstone large magmatic event	Snake River Plain volcanic field		Snake River Group				basalt and gravel of Long Gulch	
Snake River plain - Yellowstone large magmatic event	Snake River Plain volcanic field		Snake River Group				basalt of Mores Creek	
Snake River plain - Yellowstone large magmatic event	Snake River Plain volcanic field		Snake River Group				basalt of Red Mountain	
Snake River plain - Yellowstone large magmatic event	Yellowstone Plateau volcanic field		Yellowstone Group		Madison River Basalt			Yellowstone Caldera

Volcanic event name *(vol_event)*	Volcanic field name *(vol_field)*	Supergroup name *(vol_supgrp)*	Group name *(vol_grp)*	Subgroup name *(vol_subgrp)*	Formation name *(vol_fm)*	Member name *(vol_mbr)*	Informal name *(vol_infrml)*	Eruptive Center *(vol_ctr)*
Snake River plain - Yellowstone large magmatic event	Yellowstone Plateau volcanic field		Yellowstone Group		Lava Creek Tuff		lower member	Yellowstone Caldera
Snake River plain - Yellowstone large magmatic event	Yellowstone Plateau volcanic field		Yellowstone Group		Lava Creek Tuff		upper member	Yellowstone Caldera
Snake River plain - Yellowstone large magmatic event	Yellowstone Plateau volcanic field						Big Bear Lake flow of the Mt. Jefferson rhyolite	
Snake River plain - Yellowstone large magmatic event	Yellowstone Plateau volcanic field		Yellowstone Group		Plateau Rhyolite	Central Plateau Member	lower Buffalo Lake flow	Yellowstone Caldera
Snake River plain - Yellowstone large magmatic event	Yellowstone Plateau volcanic field		Yellowstone Group		Plateau Rhyolite	Central Plateau Member	upper part	Yellowstone Caldera
Snake River plain - Yellowstone large magmatic event	Yellowstone Plateau volcanic field		Yellowstone Group		Huckleberry Ridge Tuff			Yellowstone Caldera
Snake River plain - Yellowstone large magmatic event	Yellowstone Plateau volcanic field		Yellowstone Group		Huckleberry Ridge Tuff		lower member	Yellowstone Caldera

Volcanic event name *(vol_event)*	Volcanic field name *(vol_field)*	Supergroup name *(vol_supgrp)*	Group name *(vol_grp)*	Subgroup name *(vol_subgrp)*	Formation name *(vol_fm)*	Member name *(vol_mbr)*	Informal name *(vol_infrml)*	Eruptive Center *(vol_ctr)*
Snake River plain - Yellowstone large magmatic event	Yellowstone Plateau volcanic field		Yellowstone Group		Huckleberry Ridge Tuff		upper member	Yellowstone Caldera
Snake River plain - Yellowstone large magmatic event	Yellowstone Plateau volcanic field		Yellowstone Group		Lava Creek Tuff			Yellowstone Caldera

Table G-3. Named igneous intrusions, Northern Rocky Mountains study area.

[Item names in the ArcInfo® look-up table NR_GEO.IGPNAM are listed in parenthesis]

Named batholithic assemblage ***(name_bath)***	**Named intrusive complex, cluster, or suite** ***(name_plut)***	**Named intrusion or part of intrusive complex** ***(name_stk)***
Anaconda batholithic assemblage, undivided	intrusive, not named	Hearst Lake stock
Anaconda batholithic assemblage, undivided	intrusive, not named	Seymour Creek stock
Anaconda batholithic assemblage, undivided	Pintlar Creek batholith	intrusive, not named
Boulder batholithic assemblage, undivided	Boulder batholith, potassic suite	Burton Park pluton
Boulder batholithic assemblage, undivided	Boulder batholith, potassic suite	Butte Quartz Monzonite or Butte Granite (monzogranite)
Boulder batholithic assemblage, undivided	Boulder batholith, potassic suite	intrusive, not named
Boulder batholithic assemblage, undivided	Boulder batholith, sodic suite	Rader Creek Granodiorite
Boulder batholithic assemblage, undivided	Boulder batholith, undivided	intrusive, not named
Boulder batholithic assemblage, undivided	Boulder batholith, undivided	Unionville Granodiorite
Boulder batholithic assemblage, undivided	Boulder batholithic assemblage, potassic suite	Butte Quartz Monzonite or Butte Granite (monzogranite)
Boulder batholithic assemblage, undivided	Boulder batholithic assemblage, sodic suite	Hell Canyon pluton
Boulder batholithic assemblage, undivided	Boulder batholithic assemblage, sodic suite	Moose Creek pluton
Boulder batholithic assemblage, undivided	Boulder batholithic assemblage, undivided	Blackfoot City stock
Boulder batholithic assemblage, undivided	Boulder batholithic assemblage, undivided	Broadwater stock
Boulder batholithic assemblage, undivided	Boulder batholithic assemblage, undivided	Butte Quartz Monzonite or Butte Granite (monzogranite)
Boulder batholithic assemblage, undivided	Boulder batholithic assemblage, undivided	intrusive, not named
Boulder batholithic assemblage, undivided	Boulder batholithic assemblage, undivided	Marysville stock
Boulder batholithic assemblage, undivided	Boulder batholithic assemblage, undivided	Scratch Gravel Hills stock
Boulder batholithic assemblage, undivided	Boulder batholithic assemblage, undivided	Trust-to-luck stock
Boulder batholithic assemblage, undivided	Boulder batholithic assemblage, undivided	Wilson Park stock
Flint Creek batholithic assemblage, undivided	intrusive, not named	Cable stock
Flint Creek batholithic assemblage, undivided	intrusive, not named	intrusive, not named
Flint Creek batholithic assemblage, undivided	Mount Powell batholith	intrusive, not named
Flint Creek batholithic assemblage, undivided	Philipsburg batholith	intrusive, not named
Flint Creek batholithic assemblage, undivided	Racetrack Creek intrusive and metamorphic complex	intrusive, not named

Named batholithic assemblage ***(name_bath)***	**Named intrusive complex, cluster, or suite** ***(name_plut)***	**Named intrusion or part of intrusive complex** ***(name_stk)***
Idaho batholithic assemblage, undivided	Atlanta batholithic assemblage	intrusive, not named
Idaho batholithic assemblage, undivided	Atlanta lobe (batholith)	intrusive, not named
Idaho batholithic assemblage, undivided	Atlanta lobe (batholith)	intrusive, not named
Idaho batholithic assemblage, undivided	Bitterroot batholithic assemblage	Brushy Fork stock
Idaho batholithic assemblage, undivided	Bitterroot batholithic assemblage	intrusive, not named
Idaho batholithic assemblage, undivided	Bitterroot batholithic assemblage	Moscow Mountain batholith
Idaho batholithic assemblage, undivided	Bitterroot batholithic assemblage	Skookum Butte stock
Idaho batholithic assemblage, undivided	Bitterroot batholithic assemblage	White Sand Creek stock
Idaho batholithic assemblage, undivided	Bitterroot lobe (batholith)	Canyon Lake pluton
Idaho batholithic assemblage, undivided	Bitterroot lobe (batholith)	intrusive, not named
Idaho batholithic assemblage, undivided	Bitterroot lobe (batholith)	White Sand Creek stock
Idaho batholithic assemblage, undivided	intrusive, not named	Croesus stock and McCoy Mine stock
Idaho batholithic assemblage, undivided	intrusive, not named	intrusive, not named
Idaho batholithic assemblage, undivided	White Cloud intrusive complex	Little Boulder Creek stock
Idaho batholithic assemblage, undivided	White Cloud intrusive complex	White Cloud stock
intrusive, not named	Chamberlain Basin, Bighorn Crags composite batholith	intrusive, not named
intrusive, not named	Gem stocks	Dago Peak stock
intrusive, not named	Gem stocks	Murray stock
intrusive, not named	Gem stocks	north Gem stock
intrusive, not named	Gem stocks	south Gem stock
intrusive, not named	intrusive, not named	Alder Creek stock
intrusive, not named	intrusive, not named	Arnett Creek pluton
intrusive, not named	intrusive, not named	Arrowrock Dam stock
intrusive, not named	intrusive, not named	Bad Luck Creek pluton
intrusive, not named	intrusive, not named	Banner Creek stock
intrusive, not named	intrusive, not named	Bear River stock
intrusive, not named	intrusive, not named	Beaver Creek pluton
intrusive, not named	intrusive, not named	Beaverhead Mountain stock
intrusive, not named	intrusive, not named	Big Eightmile stock
intrusive, not named	intrusive, not named	Big Smoky Creek stock
intrusive, not named	intrusive, not named	Big Spring Creek stock
intrusive, not named	intrusive, not named	Big Timber stock
intrusive, not named	intrusive, not named	Birch Flat stock, Little Falls stock
intrusive, not named	intrusive, not named	Boehls Butte anorthosite
intrusive, not named	intrusive, not named	Boise Basin stock
intrusive, not named	intrusive, not named	Boulder Baldy-Boulder Mountain composite stock

Named batholithic assemblage *(name_bath)*	Named intrusive complex, cluster, or suite *(name_plut)*	Named intrusion or part of intrusive complex *(name_stk)*
intrusive, not named	intrusive, not named	Boulder Mountains stock (Lewis and Killsgaard, 1991), or Boulder stock (Bennett and Knowles, 1985)
intrusive, not named	intrusive, not named	Bungalow pluton
intrusive, not named	intrusive, not named	Burnt Ridge pluton
intrusive, not named	intrusive, not named	Carmen stock
intrusive, not named	intrusive, not named	Casto pluton
intrusive, not named	intrusive, not named	Chief Joseph plutonic complex
intrusive, not named	intrusive, not named	Clifford Creek Granite
intrusive, not named	intrusive, not named	Complex of Fisher Mountain area
intrusive, not named	intrusive, not named	Coryell plutonic rocks and Sheppard Granite
intrusive, not named	intrusive, not named	Crooked Fork plug
intrusive, not named	intrusive, not named	Cumo stock
intrusive, not named	intrusive, not named	dacite of Haystack Butte
intrusive, not named	intrusive, not named	dacite porphyry of Fan and Lone Mountains
intrusive, not named	intrusive, not named	dacite porphyry of Henderson Mountain
intrusive, not named	intrusive, not named	dacite porphyry of Homestake mine area
intrusive, not named	intrusive, not named	dacite porphyry of Lulu Pass
intrusive, not named	intrusive, not named	Dalton Mountain stock
intrusive, not named	intrusive, not named	Deer Creek stock
intrusive, not named	intrusive, not named	diorite of Ibex Canyon
intrusive, not named	intrusive, not named	diorite of Scotch Bonnet Mountain
intrusive, not named	intrusive, not named	diorite of Silver Peak
intrusive, not named	intrusive, not named	Dry Creek stock
intrusive, not named	intrusive, not named	Echols Mountain stock
intrusive, not named	intrusive, not named	Enos Mountain stock
intrusive, not named	intrusive, not named	Falls Creek stock
intrusive, not named	intrusive, not named	Fisher Creek stock
intrusive, not named	intrusive, not named	Flowery Trail Granodiorite
intrusive, not named	intrusive, not named	Garnet Creek stock
intrusive, not named	intrusive, not named	Gilmore stock
intrusive, not named	intrusive, not named	Gird Point stock
intrusive, not named	intrusive, not named	gneiss of Laclede
intrusive, not named	intrusive, not named	Granite Butte stock
intrusive, not named	intrusive, not named	granite near Mount Spokane
intrusive, not named	intrusive, not named	granite of Mount Rathdrum
intrusive, not named	intrusive, not named	granite porphyry of Hellroaring Creek
intrusive, not named	intrusive, not named	granite stock of Ibex Canyon
intrusive, not named	intrusive, not named	granodiorite east of Trout Creek or Vermillion River stock
intrusive, not named	intrusive, not named	granodiorite of Lightning Creek
intrusive, not named	intrusive, not named	granodiorite of Priest Lake
intrusive, not named	intrusive, not named	granodiorite of Ruby Creek
intrusive, not named	intrusive, not named	granodiorite of the Skalkaho stock
intrusive, not named	intrusive, not named	granodiorite of Wrenco
intrusive, not named	intrusive, not named	granodiorite orthogneiss of Summit Lake
intrusive, not named	intrusive, not named	granodiorite porphyry of Emigrant Peak area
intrusive, not named	intrusive, not named	Haines Point pluton
intrusive, not named	intrusive, not named	Henderson Creek stock
intrusive, not named	intrusive, not named	Herrick stock
intrusive, not named	intrusive, not named	High Bridge stock
intrusive, not named	intrusive, not named	Horseshoe Lake stock
intrusive, not named	intrusive, not named	intrusive, not named

Named batholithic assemblage *(name_bath)*	Named intrusive complex, cluster, or suite *(name_plut)*	Named intrusion or part of intrusive complex *(name_stk)*
intrusive, not named	intrusive, not named	intrusive, not named
intrusive, not named	intrusive, not named	intrusive, not named
intrusive, not named	intrusive, not named	intrusive, not named
intrusive, not named	intrusive, not named	intrusive, not named
intrusive, not named	intrusive, not named	intrusive, not named
intrusive, not named	intrusive, not named	intrusive, not named
intrusive, not named	intrusive, not named	intrusive, not named
intrusive, not named	intrusive, not named	intrusive, not named
intrusive, not named	intrusive, not named	intrusive, not named
intrusive, not named	intrusive, not named	intrusive, not named
intrusive, not named	intrusive, not named	intrusive, not named
intrusive, not named	intrusive, not named	Jackson Peak stock
intrusive, not named	intrusive, not named	Kamiah Plutonic Complex
intrusive, not named	intrusive, not named	Knapp Peak stock
intrusive, not named	intrusive, not named	Lake Creek pluton
intrusive, not named	intrusive, not named	Lime Creek stock
intrusive, not named	intrusive, not named	Little Eightmile stock
intrusive, not named	intrusive, not named	Little Smoky Creek stock
intrusive, not named	intrusive, not named	Lodgepole pluton
intrusive, not named	intrusive, not named	Lolo Hot Springs batholith
intrusive, not named	intrusive, not named	Long Gulch stock
intrusive, not named	intrusive, not named	Lost Creek stock
intrusive, not named	intrusive, not named	Mackay stock
intrusive, not named	intrusive, not named	Maloney Basin stock
intrusive, not named	intrusive, not named	Marsh Creek stock
intrusive, not named	intrusive, not named	McKinley Gulch stock
intrusive, not named	intrusive, not named	Merton Creek stock
intrusive, not named	intrusive, not named	Mill Creek stock
intrusive, not named	intrusive, not named	Mineral Hill stock
intrusive, not named	intrusive, not named	Miners Gulch stock
intrusive, not named	intrusive, not named	Monumental Peak stocks
intrusive, not named	intrusive, not named	monzodiorite near Tumtum
intrusive, not named	intrusive, not named	monzodiorite of Independence district area
intrusive, not named	intrusive, not named	monzogranite of Big Meadows
intrusive, not named	intrusive, not named	monzogranite of Camden
intrusive, not named	intrusive, not named	monzogranite of Otter Creek
intrusive, not named	intrusive, not named	monzonite of Long Canyon
intrusive, not named	intrusive, not named	Mouat quartz monzonite
intrusive, not named	intrusive, not named	Mount Baldy stock; Mount Edith stock
intrusive, not named	intrusive, not named	Mount Fleecer stock
intrusive, not named	intrusive, not named	North Fork stock
intrusive, not named	intrusive, not named	North Sawtooth batholith
intrusive, not named	intrusive, not named	Ogden Mountain stock
intrusive, not named	intrusive, not named	orthogneiss of Coolwater Ridge
intrusive, not named	intrusive, not named	Owens Gulch stock
intrusive, not named	intrusive, not named	Painted Rocks pluton
intrusive, not named	intrusive, not named	Paradise pluton
intrusive, not named	intrusive, not named	Park Fork stock
intrusive, not named	intrusive, not named	Pine Creek stock
intrusive, not named	intrusive, not named	Pioneer Mountain stock
intrusive, not named	intrusive, not named	Piquett Creek pluton
intrusive, not named	intrusive, not named	pyroxenite, syenite of the Skalkaho alkalic intrusive complex

Named batholithic assemblage *(name_bath)*	Named intrusive complex, cluster, or suite *(name_plut)*	Named intrusion or part of intrusive complex *(name_stk)*
intrusive, not named	intrusive, not named	quartz monzodiorite of Ahern Meadows
intrusive, not named	intrusive, not named	quartz monzonite of Loon Lake
intrusive, not named	intrusive, not named	quartz monzonite of Trapper Peak
intrusive, not named	intrusive, not named	Ranger Creek stock
intrusive, not named	intrusive, not named	Rapid River stock
intrusive, not named	intrusive, not named	Red Mountain stock
intrusive, not named	intrusive, not named	Robie Creek stock
intrusive, not named	intrusive, not named	Rooks Creek stock
intrusive, not named	intrusive, not named	Roundtop pluton
intrusive, not named	intrusive, not named	Royal stock
intrusive, not named	intrusive, not named	Running Creek pluton
intrusive, not named	intrusive, not named	Savage Point pluton
intrusive, not named	intrusive, not named	Sawtooth batholith
intrusive, not named	intrusive, not named	Sheep Creek batholith
intrusive, not named	intrusive, not named	Short Peak stock
intrusive, not named	intrusive, not named	Silver Bell stock
intrusive, not named	intrusive, not named	Silver Point Quartz Monzonite
intrusive, not named	intrusive, not named	Sliderock Mountain stock
intrusive, not named	intrusive, not named	Smoky Dome stock
intrusive, not named	intrusive, not named	Soldier Mountains stock
intrusive, not named	intrusive, not named	Spout Creek stock
intrusive, not named	intrusive, not named	Storm Lake stock
intrusive, not named	intrusive, not named	Summit Creek stock
intrusive, not named	intrusive, not named	Susie Peak pluton
intrusive, not named	intrusive, not named	syenite of Bobtail Creek
intrusive, not named	intrusive, not named	syenite of Bovill
intrusive, not named	intrusive, not named	syenite of Gold Hill
intrusive, not named	intrusive, not named	syenite of Wall Mountain
intrusive, not named	intrusive, not named	Thompson Creek stock
intrusive, not named	intrusive, not named	Thorn Creek stock
intrusive, not named	intrusive, not named	tonalite, trondhjemite of Continental Mountain
intrusive, not named	intrusive, not named	Trinity Mountains stock
intrusive, not named	intrusive, not named	Virginia City diatreme
intrusive, not named	intrusive, not named	Wallace Creek stock
intrusive, not named	intrusive, not named	Warm Springs Creek stock
intrusive, not named	intrusive, not named	Welcome Creek stock
intrusive, not named	intrusive, not named	Whimstick Creek stock
intrusive, not named	intrusive, not named	Whistling Pig pluton
intrusive, not named	intrusive, not named	White Monument dioritic stock
intrusive, not named	intrusive, not named	Willow Creek pluton
intrusive, not named	intrusive, not named	Willow Creek stock
intrusive, not named	Middle Proterozoic mafic sills in Prichard Formation at Crosspor	intrusive, not named
intrusive, not named	Middle Proterozoic mafic sills in Prichard Formation at Crosspor	intrusive, not named
intrusive, not named	Middle Proterozoic mafic sills in Prichard Formation at Crosspor	intrusive, not named
intrusive, not named	Middle Proterozoic mafic sills in Prichard Formation at Crosspor	intrusive, not named
intrusive, not named	Middle Proterozoic mafic sills in Prichard Formation at Crosspor	intrusive, not named
intrusive, not named	Middle Proterozoic mafic sills in Prichard Formation at Perma	intrusive, not named

Named batholithic assemblage *(name_bath)*	Named intrusive complex, cluster, or suite *(name_plut)*	Named intrusion or part of intrusive complex *(name_stk)*
intrusive, not named	Middle Proterozoic mafic sills in Prichard Formation at Perma	intrusive, not named
intrusive, not named	Middle Proterozoic mafic sills in Prichard Formation at Perma	intrusive, not named
intrusive, not named	Sapphire batholith	Sapphire batholith, hornblende-biotite granodiorite of outer zone
intrusive, not named	Sapphire batholith	Sapphire batholith, muscovite-biotite granite of inner zone and hornblende-biotite granodiorite of outer zone
intrusive, not named	Stillwater Complex	intrusive, not named
intrusive, not named	Stillwater Complex	Stillwater Complex, Basal and Ultramafic series
intrusive, not named	Stillwater Complex	Stillwater Complex, Lower Banded series
intrusive, not named	Stillwater Complex	Stillwater Complex, Middle Banded series
intrusive, not named	Stillwater Complex	Stillwater Complex, Upper Banded series
intrusive, not named	Syenite of Goose Lake	syenite-monzonite-gabbro stock near Goose Lake
intrusive, not named	syenite-diorite complex of Ramey Ridge	Acorn Butte stock
intrusive, not named	syenite-diorite complex of Ramey Ridge	Ramey Ridge stock
intrusive, not named	syenite-diorite complex of Ramey Ridge	Rush Creek stock
intrusive, not named	Vermiculite Mountain intrusive complex	Rainy Creek pyroxenite stock of the Vermiculite Mountain complex
intrusive, not named	Vermiculite Mountain intrusive complex	syenite of the Vermiculite Mountain complex
Kaniksu batholithic assemblage, undivided	Kaniksu batholith	granitic and metamorphic rocks of Deep Creek
Kaniksu batholithic assemblage, undivided	Kaniksu batholith	granitic and metamorphic rocks of Lookout Mountain
Kaniksu batholithic assemblage, undivided	Kaniksu batholith	granitic and metamorphic rocks of Soldier Creek
Kaniksu batholithic assemblage, undivided	Kaniksu batholith	granitic rocks of Big Creek
Kaniksu batholithic assemblage, undivided	Kaniksu batholith	granitic rocks of Camels Prairie
Kaniksu batholithic assemblage, undivided	Kaniksu batholith	granodiorite of Caribou Creek
Kaniksu batholithic assemblage, undivided	Kaniksu batholith	granodiorite of Cavanaugh Bay
Kaniksu batholithic assemblage, undivided	Kaniksu batholith	granodiorite of Falls Creek
Kaniksu batholithic assemblage, undivided	Kaniksu batholith	granodiorite of Lucky Creek
Kaniksu batholithic assemblage, undivided	Kaniksu batholith	granodiorite of Marsh Lake
Kaniksu batholithic assemblage, undivided	Kaniksu batholith	granodiorite of Sawyer
Kaniksu batholithic assemblage, undivided	Kaniksu batholith	granodiorite of Search Lake
Kaniksu batholithic assemblage, undivided	Kaniksu batholith	granodiorite of Trapper Creek
Kaniksu batholithic assemblage, undivided	Kaniksu batholith	intrusive, not named

Named batholithic assemblage *(name_bath)*	Named intrusive complex, cluster, or suite *(name_plut)*	Named intrusion or part of intrusive complex *(name_stk)*
Kaniksu batholithic assemblage, undivided	Kaniksu batholith	leucocratic granitic rocks of Lost Creek
Kaniksu batholithic assemblage, undivided	Kaniksu batholith	monzogranite of Hunt Creek
Kaniksu batholithic assemblage, undivided	Kaniksu batholith	monzogranite of Klootch Mountain
Kaniksu batholithic assemblage, undivided	Kaniksu batholith	monzogranite of Shorty Peak
Kaniksu batholithic assemblage, undivided	Kaniksu batholith	tonalite of Snow Peak
Kaniksu batholithic assemblage, undivided	Kaniksu batholith	two-mica granitic rocks of Horton Creek
Kaniksu batholithic assemblage, undivided	Kaniksu batholith	two-mica rocks of Ball Creek
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	biotite granodiorite near Wellpinit
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	Blickensderfer Quartz Monzonite
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	Fan Lake Granodiorite
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	Galena Point Granodiorite
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	granite near Little Spokane River
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	granitic rocks of Algoma Lake
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	granitic rocks of Cabinet Mountains
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	granitic rocks of Jewel Lake
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	granodiorite of Bonners Ferry
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	granodiorite of Bunchgrass Meadows
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	granodiorite of Copeland
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	granodiorite of Dubius Creek
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	granodiorite of Hall Mountain
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	granodiorite of Kelly Pass
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	granodiorite of Kelso Lake
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	granodiorite of Le Clerc Creek
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	granodiorite of Mill Creek
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	granodiorite of Molybdenite Mountain
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	granodiorite of Rapid Lightning Creek
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	granodiorite of Reeder Creek

Named batholithic assemblage *(name_bath)*	Named intrusive complex, cluster, or suite *(name_plut)*	Named intrusion or part of intrusive complex *(name_stk)*
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	granodiorite of Road V-78
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	granodiorite of Salee Creek
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	granodiorite of Sema Meadows
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	granodiorite of Spring Valley
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	granodiorite of Whiskey Rock
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	granodiorite of Yocum Lake
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	granodiorite porphyry of Packsaddle Mountain
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	leucocratic granitic rocks of Scotia
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	monzogranite near Four Mound Prairie
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	monzogranite of Arden pluton
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	monzogranite of Blanchard Road
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	monzogranite of Blue Grouse Mountain
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	monzogranite of Gleason Mountain
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	monzogranite of Granite Pass
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	monzogranite of Hungry Mountain
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	monzogranite of Little Roundtop
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	monzogranite of Long Mountain
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	monzogranite of Middle Creek
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	monzogranite of Midnight Mine
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	monzogranite of Narcisse Creek
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	monzogranite of Sand Creek
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	monzogranite of Tango Creek
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	monzogranite of Twentymile Creek
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	monzogranite porphyry of Bodie Canyon
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	Mount Spokane granite
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	Newman Lake Gneiss
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	orthogneiss near Mount Spokane

Named batholithic assemblage *(name_bath)*	Named intrusive complex, cluster, or suite *(name_plut)*	Named intrusion or part of intrusive complex *(name_stk)*
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	Phillips Lake Granodiorite
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	porphyritic body of White Mud Lake
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	quartz monzodiorite of Lane Mountain
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	quartz monzonite near Mud Creek
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	quartz monzonite of Corkscrew Canyon
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	Spirit pluton
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	Starvation Flat Quartz Monzonite
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	tonalite of Clagstone
Kaniksu batholithic assemblage, undivided	Kaniksu batholithic assemblage	two-mica monzogranite of North Basin
Pioneer batholithic assemblage, undivided	Pioneer batholith	Doolittle Creek pluton
Pioneer batholithic assemblage, undivided	Pioneer batholith	Francis Creek pluton
Pioneer batholithic assemblage, undivided	Pioneer batholith	granodiorite of David Creek
Pioneer batholithic assemblage, undivided	Pioneer batholith	Grayling Lake Granite
Pioneer batholithic assemblage, undivided	Pioneer batholith	intrusive, not named
Pioneer batholithic assemblage, undivided	Pioneer batholith	Uphill Creek Granodiorite
Pioneer batholithic assemblage, undivided	Pioneer batholithic assemblage	Burnt Dam Ridge pluton
Pioneer batholithic assemblage, undivided	Pioneer batholithic assemblage	Granulated Mountain pluton
Pioneer batholithic assemblage, undivided	Pioneer batholithic assemblage	intrusive, not named
Pioneer batholithic assemblage, undivided	Pioneer batholithic assemblage	McCartney Mountain stock
Pioneer batholithic assemblage, undivided	Pioneer batholithic assemblage	Uphill Creek Granodiorite
Pioneer batholithic assemblage, undivided	Pioneer batholithic assemblage	Uphill Creek Granodiorite; Mount Fleecer stock

Table G-4. Named swarms of dikes or sills, Northern Rocky Mountains study area.

[Item names in the ArcInfo® look-up tables NR_GEO.IGANAM and NR_GEO.IGANAM are listed in parenthesis]

Named swarms of dikes or sills ***(name_dksil)***
andesitic intrusive breccia dike of Fishtail Butte
andesitic intrusive breccia dike of Nellies Twin Buttes
Big Timber radial dike swarm
Clearwater Mountains dike swarm
Crossport sill A
Crossport sill B
Crossport sill C
Crossport sill D
Crossport sill E
dacite porphyry of Fan and Lone Mountains
dikes and sills around Lodgepole pluton
Eocene dike swarm in the Skalkaho slab
intrusive, not named
Lemline Gulch sill
mafic sills, exposed in the Salmon River Arch
Middle Proterozoic mafic dike swarm of the Highland Mountains
Middle Proterozoic mafic dike swarm of the Ruby Mountains
Middle Proterozoic mafic dike swarm of the Tobacco Root Mountains
Middle Proterozoic mafic sills in Prichard Formation at Perma
Middle Proterozoic mafic sills in the Prichard Formation
Paradise sill
Plains sill
Precambrian mafic dikes of the Beartooth uplift
radial dike swarm of Sliderock Mountain
sills near North Fork Sun River
subvolcanic dikes and sills of the Absaroka volcanic field
Tertiary and Cretaceous dikes in the Bitterroot Dome and the Bargamin fault system
Tertiary and Cretaceous dikes of the Bargamin fault system
Tertiary Cayuse Creek dike swarm
Tertiary diabase-lamprophyre dike swarm
Tertiary dike swarms of the trans-Challis fault system
Tertiary dike swarms of the trans-Challis fault system, Boise Basin dike swarm
Tertiary dike swarms of the trans-Challis fault system, Grimes Creek fault zone
Tertiary dike swarms of the trans-Challis fault system, Mores Creek - Elk Creek fault zone
Tertiary dike swarms of the trans-Challis fault system, Pistol Creek dike swarm
Tertiary dike swarms of the trans-Challis fault system, Sawtooth dike swarm
Tertiary dikes in the Bitterroot Dome and the Bargamin fault system
Tertiary Pack River mafic dike swarm
Tertiary Profile Gap - Smith Creek dike swarm
Tertiary Sawtooth - Thorn Creek dike swarm
Tertiary-Cretaceous dike swarm in the Beartooth uplift
Whiskey Gulch sill
Wishards sills

Table G-5. Hierarchy of named igneous intrusions, Northern Rocky Mountains study area.

[Item names in the ArcInfo® look-up table NR_GEO.IGPNAM are listed in parenthesis]

Geologic assemblages of grouped intrusions ***(intr_1name)***	**Geologically-grouped intrusions** ***(intr_2name)***	**Named intrusion** ***(intr_3name)***
Archean intrusions	Archean granitoid intrusions	granite porphyry of Hellroaring Creek
Archean intrusions	Archean granitoid intrusions	granodiorite orthogneiss of Summit Lake
Archean intrusions	Archean granitoid intrusions	Mouat quartz monzonite
Archean intrusions	Stillwater layered intrusive complex	Stillwater Complex, Basal and Ultramafic series
Archean intrusions	Stillwater layered intrusive complex	Stillwater Complex, Lower Banded series
Archean intrusions	Stillwater layered intrusive complex	Stillwater Complex, Middle Banded series
Archean intrusions	Stillwater layered intrusive complex	Stillwater Complex, undivided
Archean intrusions	Stillwater layered intrusive complex	Stillwater Complex, Upper Banded series
Cretaceous Kaniksu batholithic assemblage	Cretaceous plutons, Spokane dome, Priest River core complex	Fan Lake Granodiorite
Cretaceous Kaniksu batholithic assemblage	Cretaceous plutons, Spokane dome, Priest River core complex	granite near Mount Spokane
Cretaceous Kaniksu batholithic assemblage	Cretaceous plutons, Spokane dome, Priest River core complex	granitic rocks of Algoma Lake
Cretaceous Kaniksu batholithic assemblage	Cretaceous plutons, Spokane dome, Priest River core complex	granitic rocks of Jewel Lake
Cretaceous Kaniksu batholithic assemblage	Cretaceous plutons, Spokane dome, Priest River core complex	granodiorite of Kelso Lake
Cretaceous Kaniksu batholithic assemblage	Cretaceous plutons, Spokane dome, Priest River core complex	granodiorite of Salee Creek
Cretaceous Kaniksu batholithic assemblage	Cretaceous plutons, Spokane dome, Priest River core complex	granodiorite of Sawyer
Cretaceous Kaniksu batholithic assemblage	Cretaceous plutons, Spokane dome, Priest River core complex	granodiorite of Spring Valley
Cretaceous Kaniksu batholithic assemblage	Cretaceous plutons, Spokane dome, Priest River core complex	granodiorite of Yocum Lake
Cretaceous Kaniksu batholithic assemblage	Cretaceous plutons, Spokane dome, Priest River core complex	leucocratic granitic rocks of Scotia
Cretaceous Kaniksu batholithic assemblage	Cretaceous plutons, Spokane dome, Priest River core complex	monzogranite of Blanchard Road
Cretaceous Kaniksu batholithic assemblage	Cretaceous plutons, Spokane dome, Priest River core complex	monzogranite of Camden
Cretaceous Kaniksu batholithic assemblage	Cretaceous plutons, Spokane dome, Priest River core complex	monzogranite of Little Roundtop
Cretaceous Kaniksu batholithic assemblage	Cretaceous plutons, Spokane dome, Priest River core complex	monzogranite of Long Mountain

Geologic assemblages of grouped intrusions *(intr_1name)*	Geologically-grouped intrusions *(intr_2name)*	Named intrusion *(intr_3name)*
Cretaceous Kaniksu batholithic assemblage	Cretaceous plutons, Spokane dome, Priest River core complex	monzogranite of Otter Creek
Cretaceous Kaniksu batholithic assemblage	Cretaceous plutons, Spokane dome, Priest River core complex	Mount Spokane granite
Cretaceous Kaniksu batholithic assemblage	Cretaceous plutons, Spokane dome, Priest River core complex	Newman Lake Gneiss
Cretaceous Kaniksu batholithic assemblage	Cretaceous plutons, Spokane dome, Priest River core complex	orthogneiss near Mount Spokane
Cretaceous Kaniksu batholithic assemblage	Cretaceous plutons, Spokane dome, Priest River core complex	Phillips Lake Granodiorite
Cretaceous Kaniksu batholithic assemblage	Cretaceous plutons, Spokane dome, Priest River core complex	tonalite of Clagstone
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached eastern satellite plutons	granitic rocks of Cabinet Mountains
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached eastern satellite plutons	granodiorite of Copeland
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached eastern satellite plutons	granodiorite of Kelly Pass
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached eastern satellite plutons	granodiorite of Lightning Creek
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached eastern satellite plutons	granodiorite of Rapid Lightning Creek
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached eastern satellite plutons	granodiorite of Road V-78
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached eastern satellite plutons	granodiorite of Whiskey Rock
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached eastern satellite plutons	granodiorite porphyry of Packsaddle Mountain
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached eastern satellite plutons	monzogranite of Twentymile Creek
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached plutons, Newport allochthon	Blickensderfer Quartz Monzonite
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached plutons, Newport allochthon	Galena Point Granodiorite
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached plutons, Newport allochthon	granodiorite of Bunchgrass Meadows
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached plutons, Newport allochthon	granodiorite of Dubius Creek
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached plutons, Newport allochthon	granodiorite of Hall Mountain

Geologic assemblages of grouped intrusions *(intr_1name)*	Geologically-grouped intrusions *(intr_2name)*	Named intrusion *(intr_3name)*
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached plutons, Newport allochthon	granodiorite of Le Clerc Creek
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached plutons, Newport allochthon	granodiorite of Marsh Lake
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached plutons, Newport allochthon	granodiorite of Mill Creek
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached plutons, Newport allochthon	granodiorite of Molybdenite Mountain
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached plutons, Newport allochthon	granodiorite of Priest Lake
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached plutons, Newport allochthon	granodiorite of Reeder Creek
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached plutons, Newport allochthon	granodiorite of Sema Meadows
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached plutons, Newport allochthon	monzogranite of Big Meadows
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached plutons, Newport allochthon	monzogranite of Gleason Mountain
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached plutons, Newport allochthon	monzogranite of Granite Pass
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached plutons, Newport allochthon	monzogranite of Hungry Mountain
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached plutons, Newport allochthon	monzogranite of Middle Creek
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached plutons, Newport allochthon	monzogranite of Sand Creek
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached plutons, Newport allochthon	monzogranite of Tango Creek
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, detached plutons, Newport allochthon	monzogranite porphyry of Bodie Canyon
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, western satellite plutons	biotite granodiorite near Wellpinit
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, western satellite plutons	granite near Little Spokane River
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, western satellite plutons	monzogranite near Four Mound Prairie
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, western satellite plutons	monzogranite of Arden pluton
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, western satellite plutons	monzogranite of Blue Grouse Mountain

Geologic assemblages of grouped intrusions *(intr_1name)*	Geologically-grouped intrusions *(intr_2name)*	Named intrusion *(intr_3name)*
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, western satellite plutons	monzogranite of Midnight Mine
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, western satellite plutons	monzogranite of Narcisse Creek
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, western satellite plutons	porphyritic body of White Mud Lake
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, western satellite plutons	quartz monzonite near Mud Creek
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, western satellite plutons	quartz monzonite of Corkscrew Canyon
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, western satellite plutons	Spirit pluton
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, western satellite plutons	Starvation Flat Quartz Monzonite
Cretaceous Kaniksu batholithic assemblage	Kaniksu batholithic assemblage, western satellite plutons	two-mica monzogranite of North Basin
Cretaceous Kaniksu batholithic assemblage	Kaniksu composite batholith, Selkirk crest, Priest River core complex	granitic and metamorphic rocks of Deep Creek
Cretaceous Kaniksu batholithic assemblage	Kaniksu composite batholith, Selkirk crest, Priest River core complex	granitic and metamorphic rocks of Lookout Mountain
Cretaceous Kaniksu batholithic assemblage	Kaniksu composite batholith, Selkirk crest, Priest River core complex	granitic and metamorphic rocks of Soldier Creek
Cretaceous Kaniksu batholithic assemblage	Kaniksu composite batholith, Selkirk crest, Priest River core complex	granitic rocks of Camels Prairie
Cretaceous Kaniksu batholithic assemblage	Kaniksu composite batholith, Selkirk crest, Priest River core complex	granodiorite of Bonners Ferry
Cretaceous Kaniksu batholithic assemblage	Kaniksu composite batholith, Selkirk crest, Priest River core complex	granodiorite of Caribou Creek
Cretaceous Kaniksu batholithic assemblage	Kaniksu composite batholith, Selkirk crest, Priest River core complex	granodiorite of Cavanaugh Bay
Cretaceous Kaniksu batholithic assemblage	Kaniksu composite batholith, Selkirk crest, Priest River core complex	granodiorite of Falls Creek
Cretaceous Kaniksu batholithic assemblage	Kaniksu composite batholith, Selkirk crest, Priest River core complex	granodiorite of Lucky Creek
Cretaceous Kaniksu batholithic assemblage	Kaniksu composite batholith, Selkirk crest, Priest River core complex	granodiorite of Ruby Creek
Cretaceous Kaniksu batholithic assemblage	Kaniksu composite batholith, Selkirk crest, Priest River core complex	granodiorite of Search Lake
Cretaceous Kaniksu batholithic assemblage	Kaniksu composite batholith, Selkirk crest, Priest River core complex	granodiorite of Trapper Creek

Geologic assemblages of grouped intrusions *(intr_1name)*	Geologically-grouped intrusions *(intr_2name)*	Named intrusion *(intr_3name)*
Cretaceous Kaniksu batholithic assemblage	Kaniksu composite batholith, Selkirk crest, Priest River core complex	Kaniksu batholith, undivided
Cretaceous Kaniksu batholithic assemblage	Kaniksu composite batholith, Selkirk crest, Priest River core complex	leucocratic granitic rocks of Lost Creek
Cretaceous Kaniksu batholithic assemblage	Kaniksu composite batholith, Selkirk crest, Priest River core complex	monzogranite of Hunt Creek
Cretaceous Kaniksu batholithic assemblage	Kaniksu composite batholith, Selkirk crest, Priest River core complex	monzogranite of Klootch Mountain
Cretaceous Kaniksu batholithic assemblage	Kaniksu composite batholith, Selkirk crest, Priest River core complex	monzogranite of Shorty Peak
Cretaceous Kaniksu batholithic assemblage	Kaniksu composite batholith, Selkirk crest, Priest River core complex	tonalite of Snow Peak
Cretaceous Kaniksu batholithic assemblage	Kaniksu composite batholith, Selkirk crest, Priest River core complex	two-mica granitic rocks of Horton Creek
Cretaceous Kaniksu batholithic assemblage	Kaniksu composite batholith, Selkirk crest, Priest River core complex	two-mica rocks of Ball Creek
Cretaceous plutons	Cretaceous granodioritic plutons	Big Spring Creek stock
Cretaceous plutons	Cretaceous granodioritic plutons	Blackfoot City stock
Cretaceous plutons	Cretaceous granodioritic plutons	Dalton Mountain stock
Cretaceous plutons	Cretaceous granodioritic plutons	Garnet Creek stock
Cretaceous plutons	Cretaceous granodioritic plutons	Granite Butte stock
Cretaceous plutons	Cretaceous granodioritic plutons	Henderson Creek stock
Cretaceous plutons	Cretaceous granodioritic plutons	Mineral Hill stock
Cretaceous plutons	Cretaceous granodioritic plutons	Miners Gulch stock
Cretaceous plutons	Cretaceous granodioritic plutons	Ogden Mountain stock
Cretaceous plutons	Cretaceous granodioritic plutons	Wallace Creek stock
Cretaceous plutons	Cretaceous granodioritic plutons, west-Idaho suture zone	Kamiah Plutonic Complex
Cretaceous plutons	Cretaceous monzonite-syenite suite	granodiorite of the Skalkaho Mountain stock
Cretaceous plutons	Cretaceous monzonite-syenite suite	Lemline Gulch sill
Cretaceous plutons	Cretaceous monzonite-syenite suite	pyroxenite, syenite of the Skalkaho Mountain stock
Cretaceous plutons	Cretaceous monzonite-syenite suite	syenite-monzonite-gabbro stock near Goose Lake
Cretaceous plutons	Cretaceous quartz monzodioritic intrusions	Storm Lake stock

Geologic assemblages of grouped intrusions *(intr_1name)*	Geologically-grouped intrusions *(intr_2name)*	Named intrusion *(intr_3name)*
Cretaceous plutons	Cretaceous quartz monzodioritic intrusions	Wilson Park stock
Gold Hill-Libby syenitic assemblage	Gold Hill-Trout Creek belt of syenitic stocks	Dago Peak stock
Gold Hill-Libby syenitic assemblage	Gold Hill-Trout Creek belt of syenitic stocks	granodiorite east of Trout Creek or Vermillion River stock
Gold Hill-Libby syenitic assemblage	Gold Hill-Trout Creek belt of syenitic stocks	Haines Point pluton
Gold Hill-Libby syenitic assemblage	Gold Hill-Trout Creek belt of syenitic stocks	Murray stock
Gold Hill-Libby syenitic assemblage	Gold Hill-Trout Creek belt of syenitic stocks	north Gem stock
Gold Hill-Libby syenitic assemblage	Gold Hill-Trout Creek belt of syenitic stocks	south Gem stock
Gold Hill-Libby syenitic assemblage	Gold Hill-Trout Creek belt of syenitic stocks	syenite of Gold Hill
Gold Hill-Libby syenitic assemblage	Vermiculite Mountain pyroxenite-syenite suite	Rainy Creek pyroxenite stock
Gold Hill-Libby syenitic assemblage	Vermiculite Mountain pyroxenite-syenite suite	syenite of Bobtail Creek
Gold Hill-Libby syenitic assemblage	Vermiculite Mountain pyroxenite-syenite suite	syenite of Vermiculite Mountain
intrusive, not named	intrusive, not named	Crooked Fork plug
intrusive, not named	intrusive, not named	dacite of Haystack Butte
intrusive, not named	intrusive, not named	intrusive, not named
intrusive, not named	intrusive, not named	Wishards sills
intrusive, not named	Paleogene - Cretaceous dike swarm	Clearwater Mountains dike swarm
intrusive, not named	Paleogene - Cretaceous dike swarm	Tertiary and Cretaceous dikes of the Bargamin fault system
intrusive, not named	Paleogene - Cretaceous intrusive complex	Chief Joseph plutonic complex
Laramide batholiths	Anaconda composite batholith in Sapphire allochthon	Beaverhead Mountain stock
Laramide batholiths	Anaconda composite batholith in Sapphire allochthon	Hearst Lake stock
Laramide batholiths	Anaconda composite batholith in Sapphire allochthon	Maloney Basin stock
Laramide batholiths	Anaconda composite batholith in Sapphire allochthon	Pintlar Creek batholith
Laramide batholiths	Anaconda composite batholith in Sapphire allochthon	Seymour Creek stock

Geologic assemblages of grouped intrusions *(intr_1name)*	Geologically-grouped intrusions *(intr_2name)*	Named intrusion *(intr_3name)*
Laramide batholiths	Anaconda composite batholith in Sapphire allochthon	Short Peak stock
Laramide batholiths	Boulder batholith, potassic suite	Burton Park pluton
Laramide batholiths	Boulder batholith, potassic suite	Butte Quartz Monzonite or Butte Granite
Laramide batholiths	Boulder batholith, potassic suite	potassic suite of Boulder batholith, undivided
Laramide batholiths	Boulder batholith, potassic suite	Unionville Granodiorite
Laramide batholiths	Boulder batholith, satellite stock	Broadwater stock
Laramide batholiths	Boulder batholith, satellite stock	Marysville stock
Laramide batholiths	Boulder batholith, satellite stock	Mill Creek stock
Laramide batholiths	Boulder batholith, satellite stock	Mount Fleecer stock; southwestern satellitic pluton of Boulder batholith
Laramide batholiths	Boulder batholith, satellite stock	Scratch Gravel Hills stock
Laramide batholiths	Boulder batholith, satellite stock	Trust-to-luck stock
Laramide batholiths	Boulder batholith, satellite stock	Welcome Creek stock
Laramide batholiths	Boulder batholith, sodic suite	Hell Canyon pluton
Laramide batholiths	Boulder batholith, sodic suite	Moose Creek pluton
Laramide batholiths	Boulder batholith, sodic suite	Rader Creek Granodiorite
Laramide batholiths	Boulder batholith, undivided	Boulder batholith, undivided
Laramide batholiths	Boulder batholith, volcanic carapace feeder	intrusives of Elkhorn volcanic field
Laramide batholiths	Boulder batholithic assemblage, undivided	Boulder batholithic assemblage, undivided
Laramide batholiths	Flint Creek batholithic assemblage, undivided	Flint Creek batholithic assemblage, undivided
Laramide batholiths	Flint Creek composite batholith in Sapphire allochthon	Cable stock
Laramide batholiths	Flint Creek composite batholith in Sapphire allochthon	Mount Powell batholith
Laramide batholiths	Flint Creek composite batholith in Sapphire allochthon	Philipsburg batholith
Laramide batholiths	Flint Creek composite batholith in Sapphire allochthon	Racetrack Creek intrusive complex
Laramide batholiths	Flint Creek composite batholith in Sapphire allochthon	Royal stock
Laramide batholiths	Pioneer composite batholith	Clifford Creek Granite
Laramide batholiths	Pioneer composite batholith	Doolittle Creek pluton

Geologic assemblages of grouped intrusions (intr_1name)	Geologically-grouped intrusions (intr_2name)	Named intrusion (intr_3name)
Laramide batholiths	Pioneer composite batholith	Francis Creek pluton
Laramide batholiths	Pioneer composite batholith	granodiorite of David Creek
Laramide batholiths	Pioneer composite batholith	Grayling Lake Granite
Laramide batholiths	Pioneer composite batholith	McCartney Mountain stock
Laramide batholiths	Pioneer composite batholith	Pioneer batholith, undivided
Laramide batholiths	Pioneer composite batholith	Uphill Creek Granodiorite
Laramide batholiths	Sapphire composite batholith in Sapphire allochthon	Sapphire batholith, hornblende-biotite granodiorite of outer zone
Laramide batholiths	Sapphire composite batholith in Sapphire allochthon	Sapphire batholith, muscovite-biotite granite of inner zone
Laramide batholiths	Tobacco Root batholith	Tobacco Root batholith, undivided
Laramide hypabyssal intrusions	Laramide sill swarms	dacite porphyry of Fan and Lone Mountains
Laramide hypabyssal intrusions	Livingston volcanic field, subvolcanic intrusions	Enos Mountain stock
Laramide hypabyssal intrusions	Livingston volcanic field, subvolcanic intrusions	Lodgepole pluton
Laramide hypabyssal intrusions	Livingston volcanic field, subvolcanic intrusions	Sliderock Mountain stock
Laramide hypabyssal intrusions	Livingston volcanic field, subvolcanic intrusions	Susie Peak pluton
Laramide plutons	alkalic plutons, central Montana alkalic province	Big Timber stock
Laramide plutons	alkalic plutons, central Montana alkalic province	Boulder Baldy-Boulder Mountain composite stock
Laramide plutons	alkalic plutons, central Montana alkalic province	High Bridge stock
Laramide plutons	alkalic plutons, central Montana alkalic province	Mount Baldy stock; Mount Edith stock
Laramide plutons	alkalic sills, central Montana alkalic province	trachyandesite porphyry sills near North Fork, Sun River
Laramide plutons	Flint Creek composite batholith in Sapphire allochthon	Owens Gulch stock
Laramide plutons	Laramide granitoid plutons	Dry Creek stock
Laramide plutons	Laramide quartz-monzodioritic plutons	Gird Point stock
Laramide plutons	Pioneer composite batholith	Burnt Dam Ridge pluton
Laramide plutons	Pioneer composite batholith	Granulated Mountain pluton
Laramide plutons	Pioneer composite batholith	Pioneer batholith, undivided

Geologic assemblages of grouped intrusions (intr_1name)	Geologically-grouped intrusions (intr_2name)	Named intrusion (intr_3name)
Laramide plutons	Pioneer composite batholith	Uphill Creek Granodiorite
Laramide plutons	Pioneer composite batholith	Uphill Creek Granodiorite; Mount Fleecer stock
Late Cretaceous Idaho batholithic complex	Atlanta batholith	Atlanta batholith, undivided
Late Cretaceous Idaho batholithic complex	Atlanta batholith, satellite stock	Arnett Creek pluton
Late Cretaceous Idaho batholithic complex	Atlanta batholith, satellite stock	Deer Creek stock
Late Cretaceous Idaho batholithic complex	Atlanta batholith, satellite stock	granitic rocks of Big Creek
Late Cretaceous Idaho batholithic complex	Atlanta batholith, satellite stock	McCoy Mine granodiorite stock
Late Cretaceous Idaho batholithic complex	Atlanta batholith, satellite stock	Rooks Creek stock
Late Cretaceous Idaho batholithic complex	Atlanta batholith, satellite stock	Thompson Creek stock
Late Cretaceous Idaho batholithic complex	Atlanta batholith, satellite stock	White Cloud intrusive complex, Little Boulder Creek stock
Late Cretaceous Idaho batholithic complex	Atlanta batholith, satellite stock	White Cloud intrusive complex, White Cloud stock
Late Cretaceous Idaho batholithic complex	Bitterroot batholith	Bitterroot batholith, undivided
Late Cretaceous Idaho batholithic complex	Bitterroot batholith	Bitterroot batholithic assemblage
Late Cretaceous Idaho batholithic complex	Bitterroot batholith	Brushy Fork stock
Late Cretaceous Idaho batholithic complex	Bitterroot batholith	Canyon Lake pluton
Late Cretaceous Idaho batholithic complex	Bitterroot batholith	Skookum Butte stock
Late Cretaceous Idaho batholithic complex	Bitterroot batholith	White Sand Creek stock
Late Cretaceous Idaho batholithic complex	Bitterroot batholith in Sapphire allochthon	Bitterroot batholith in Sapphire allochthon
Late Cretaceous Idaho batholithic complex	Bitterroot batholith in Sapphire allochthon	Burnt Ridge pluton
Late Cretaceous Idaho batholithic complex	Bitterroot batholith in Sapphire allochthon	Piquett Creek pluton
Late Cretaceous Idaho batholithic complex	Bitterroot batholith, satellite batholith	Moscow Mountain batholith

Geologic assemblages of grouped intrusions *(intr_1name)*	Geologically-grouped intrusions *(intr_2name)*	Named intrusion *(intr_3name)*
Late Cretaceous Idaho batholithic complex	Bitterroot batholith, satellite stock	orthogneiss of Coolwater Ridge
Late Cretaceous Idaho batholithic complex	Idaho batholithic assemblage, undivided	Idaho batholithic assemblage, undivided
Late Proterozoic intrusions	Windermere-rift-related syenite-diorite plutons	Acorn Butte stock
Late Proterozoic intrusions	Windermere-rift-related syenite-diorite plutons	Ramey Ridge stock
Late Proterozoic intrusions	Windermere-rift-related syenite-diorite plutons	Rush Creek stock
Mesozoic plutons	Jurassic-Triassic plutons in north Idaho	monzonite of Long Canyon
Mesozoic plutons	Jurassic-Triassic plutons in north Idaho	syenite of Wall Mountain
Mesozoic plutons	Jurassic-Triassic plutons in north Idaho	tonalite, trondhjemite of Continental Mountain
Mesozoic plutons	Jurassic-Triassic plutons in northeastern Washington	Flowery Trail Granodiorite
Mesozoic plutons	Jurassic-Triassic plutons in northeastern Washington	quartz monzodiorite of Lane Mountain
Mesozoic plutons, Blue Mountains accreted terranes	Cretaceous-Jurassic plutons in the Wallowa terrane	Echols Mountain stock
Mesozoic plutons, Blue Mountains accreted terranes	Cretaceous-Jurassic plutons in the Wallowa terrane	White Monument dioritic stock
Mesozoic plutons, Blue Mountains accreted terranes	Triassic plutons in the Izee terrane	Iron Mountain intrusive complex
Mesozoic plutons, Blue Mountains accreted terranes	Triassic plutons in the Olds Ferry terrane	Cuddy Mountains intrusive complex
Mesozoic plutons, Blue Mountains accreted terranes	Triassic plutons in the Olds Ferry terrane	Sturgill Peak intrusive complex
Middle Proterozoic intrusions	mafic sills in Lemhi Group	mafic sills, exposed in the Salmon River Arch
Middle Proterozoic intrusions	mafic sills in Prichard Formation at Crossport	Crossport sill A
Middle Proterozoic intrusions	mafic sills in Prichard Formation at Crossport	Crossport sill B
Middle Proterozoic intrusions	mafic sills in Prichard Formation at Crossport	Crossport sill C

Geologic assemblages of grouped intrusions *(intr_1name)*	Geologically-grouped intrusions *(intr_2name)*	Named intrusion *(intr_3name)*
Middle Proterozoic intrusions	mafic sills in Prichard Formation at Crossport	Crossport sill D
Middle Proterozoic intrusions	mafic sills in Prichard Formation at Crossport	Crossport sill E
Middle Proterozoic intrusions	mafic sills in Prichard Formation at Perma	Paradise sill
Middle Proterozoic intrusions	mafic sills in Prichard Formation at Perma	Plains sill
Middle Proterozoic intrusions	mafic sills in Prichard Formation at Perma	Whiskey Gulch sill
Proterozoic intrusions	Middle to Early Proterozoic anorthosite intrusive complex	Boehls Butte anorthosite
Proterozoic intrusions	Middle to Early Proterozoic felsic orthogneiss	gneiss of Laclede
Tertiary intrusions, Challis magmatic belt	Absaroka - Gallatin volcanic province, subvolcanic intrusions	Complex of Fisher Mountain area
Tertiary intrusions, Challis magmatic belt	Absaroka - Gallatin volcanic province, subvolcanic intrusions	dacite porphyry of Henderson Mountain
Tertiary intrusions, Challis magmatic belt	Absaroka - Gallatin volcanic province, subvolcanic intrusions	dacite porphyry of Homestake mine area
Tertiary intrusions, Challis magmatic belt	Absaroka - Gallatin volcanic province, subvolcanic intrusions	dacite porphyry of Lulu Pass
Tertiary intrusions, Challis magmatic belt	Absaroka - Gallatin volcanic province, subvolcanic intrusions	diorite of Scotch Bonnet Mountain
Tertiary intrusions, Challis magmatic belt	Absaroka - Gallatin volcanic province, subvolcanic intrusions	granodiorite porphyry of Emigrant Peak area
Tertiary intrusions, Challis magmatic belt	Absaroka - Gallatin volcanic province, subvolcanic intrusions	monzodiorite of Independence area
Tertiary intrusions, Challis magmatic belt	Paleogene dike swarms	Boise Basin dike swarm
Tertiary intrusions, Challis magmatic belt	Paleogene dike swarms	Tertiary dike swarms of the trans-Challis fault system
Tertiary intrusions, Challis magmatic belt	Paleogene dike swarms	Tertiary dike swarms of the trans-Challis fault system, Grimes Creek fault zone
Tertiary intrusions, Challis magmatic belt	Paleogene dike swarms	Tertiary dike swarms of the trans-Challis fault system, Mores Creek - Elk Creek fault zone
Tertiary intrusions, Challis magmatic belt	Paleogene dike swarms	Tertiary Sawtooth - Thorn Creek dike swarm
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Arrowrock Dam stock

Geologic assemblages of grouped intrusions *(intr_1name)*	Geologically-grouped intrusions *(intr_2name)*	Named intrusion *(intr_3name)*
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Bad Luck Creek pluton
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Banner Creek stock
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Bear River stock
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Beaver Creek pluton
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Boulder Mountains stock
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Bungalow pluton
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Cape Horn stocks
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Casto pluton
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Chamberlain Basin, Bighorn Crags composite batholith
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	granite stock of Ibex Canyon
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Horseshoe Lake stock
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Knapp Peak stock
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Lake Creek pluton
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Lolo Hot Springs batholith
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Lost Creek stock
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Mackay stock
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	North Sawtooth batholith
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Painted Rocks pluton
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Pioneer Mountain stock
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Ranger Creek stock

Geologic assemblages of grouped intrusions *(intr_1name)*	Geologically-grouped intrusions *(intr_2name)*	Named intrusion *(intr_3name)*
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Robie Creek stock
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Running Creek and Painted Rocks plutons
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Savage Point pluton
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Sawtooth batholith
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Sheep Creek batholith
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Smoky Dome stock
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Summit Creek stock
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Whimstick Creek stock
Tertiary intrusions, Challis magmatic belt	Paleogene monzogranite suite	Whistling Pig pluton
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, alkalic	Coryell plutonic rocks and Sheppard Granite
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, granitoid differentiates	Alder Creek stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, granitoid differentiates	Big Eightmile stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, granitoid differentiates	Big Timber stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, granitoid differentiates	Birch Flat stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, granitoid differentiates	Bobcat Gulch intrusive complex
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, granitoid differentiates	Boise Basin stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, granitoid differentiates	Cumo stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, granitoid differentiates	Falls Creek stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, granitoid differentiates	Gilmore stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, granitoid differentiates	Herrick stock

Geologic assemblages of grouped intrusions *(intr_1name)*	Geologically-grouped intrusions *(intr_2name)*	Named intrusion *(intr_3name)*
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, granitoid differentiates	Little Eightmile stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, granitoid differentiates	Merton Creek stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, granitoid differentiates	North Fork stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, granitoid differentiates	Park Fork stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, granitoid differentiates	Roundtop pluton
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, granitoid differentiates	Thorn Creek stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, granitoid differentiates, synkinematic with Priest River complex	granodiorite of Wrenco
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, granitoid differentiates, synkinematic with Bitterroot dome complex	Paradise pluton
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided	Big Smoky Creek stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided	Carmen stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided	diorite of Ibex Canyon
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided	diorite of Silver Peak
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided	Fisher Creek stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided	Jackson Peak stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided	Lime Creek stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided	Little Smoky Creek stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided	Long Gulch stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided	Marsh Creek stock (Lewis and Kiilsgaard, 1991), or diorite at Cape Horn Lakes (Bennett and Knowles, 1985)
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided	McKinley Gulch stock

Geologic assemblages of grouped intrusions *(intr_1name)*	Geologically-grouped intrusions *(intr_2name)*	Named intrusion *(intr_3name)*
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided	Monumental Peak stocks
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided	monzodiorite near Tumtum
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided	Pine Creek stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided	quartz monzodiorite of Ahern Meadows
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided	quartz monzonite of Loon Lake
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided	quartz monzonite of Trapper Peak
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided	Rapid River stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided	Red Mountain stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided	Silver Bell stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided	Soldier Mountains stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided	Spout Creek stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided	Trinity Mountains stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided	Warm Springs Creek stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided	Willow Creek pluton
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided	Willow Creek stock
Tertiary intrusions, Challis magmatic belt	Paleogene quartz monzodiorite suite, undivided, synkinematic with Priest River core complex	Silver Point Quartz Monzonite
Tertiary intrusions, Challis magmatic belt	Paleogene subvolcanic intrusives	intrusives of Absaroka volcanic field
Tertiary intrusions, Challis magmatic belt	Paleogene subvolcanic intrusives	Virginia City diatreme
Tertiary intrusions, Challis magmatic belt	Paleogene syenite suite	syenite of Bovill

Geologic assemblages of grouped intrusions *(intr_1name)*	**Geologically-grouped intrusions** *(intr_2name)*	**Named intrusion** *(intr_3name)*
Tertiary intrusions, Challis magmatic belt	Paleogene two-mica granites, synkinematic with Spokane dome complex	granite of Mount Rathdrum

Table G-6. Abbreviations for the lithologic composition of rock types and mineralogic modifiers for the third set of words or letters in the map unit label.

Abbreviation	Lithology
um	ultramafic
m	mafic
i	intermediate
f	felsic
b	basaltic
r	rhyolitic
d	dacitic
px	pyroxenite
gb	gabbro
d	diorite
md	monzodiorite
m	monzonite
sy	syenite
sq	syenite-quartz syenite suite
sd	syenite-diorite suite
qmd	quartz monzodiorite
qd	quartz diorite
t	tonalite
gd	granodiorite
qm	quartz monzonite
g	granitoid
gqmd	granitoid rocks of the quartz monzodiorite suite
mg	monzogranite
sg	syenogranite
gbm	granite, biotite-muscovite-bearing
ap	aplite-pegmatite
gdbh	granodiorite with biotite and hornblende
qdt	quartz diorite-tonalite suite
ms	monzonite-syenite suite
ta	trachyandesite
bx	breccia
mx	migmatite
xa	agmatite
b	biotitic
bm	biotite-muscovite-bearing
bh	biotite-hornblende-bearing

Appendix H. Base map

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Contents

Tables

Introduction

This appendix describes the spatial file NR_BASEMAP, a mosaic of digital raster graphic (DRG) images created to provide a topographic base map for the geologic map spatial database, NR_GEO. The base map is a raster geodatabase covering the same extent as NR_GEO. It can be brought into GIS software to display with the digital geology; however, the base map image cannot be queried, analyzed, or edited in a GIS environment.

NR_BASEMAP is provided in ERDAS IMAGINE® image format and represents a collection of files – the *.ige file stores the raster image, the *.img file is a header file that contains geospatial data, and the *.rrd (pyramid) file that contains coarser copies of the original image to increase drawing speed at different magnification levels. The *.xml file contains metadata for the spatial database. These files are provided in a single 'zip' compressed archive file.

Scale

The base map consists of mosaicked DRG images of either 1:100,000 or 1:250,000 scales (Table H-1). To be consistent with the individual maps used to compile the geology spatial database, NR_GEO, the base map combines DRG images that reflect the scale on which the individual source geologic maps were compiled. Consequently, the scale will vary according to the region of the image that is being viewed.

Those parts of the base map image that were derived from 1:100,000-scale topographic maps should be used or displayed at that scale, but not at a larger scale (for example 1:50,000). Similarly, those portions of the image that were derived from 1:250,000-scale topographic maps should be used or displayed at a scale of 1:250,000, but not at a larger scale (for example 1:100,000).

Table H-1. Digital raster graphic images used to create the base map mosaic.

[The table contains the name of each map tile in the spatial database, NR_GEO, and the DRG sources used to create the base map mosaic. Portions of the base map mosaic that were obtained from collarless DRG images also list the name of the USGS quadrangle(s) from which they were derived. Map scales that are followed by the letter "k" indicate "thousand", and should be read in the format "1:xxx,000." NRIS, Natural Resources Information System (Montana State Library); IDWR, Idaho Department of Water Resources; n/a, not applicable]

NR_GEO Spatial Database			Base Map Source Data			
Map_tile Name	**Geologic Map Scale**	**Geologic Map Base Scale**	**DRG file name**	**USGS Quadrangle Name**	**Scale**	**Source**
Big Timber 100k	100k	100k	f45109e1.tif	Big Timber	100k	NRIS
Butte 250k	250k	250k	c46112a1.tif	Butte	250k	NRIS
Challis 250k	250k	250k	drg250k_id_idwr.tif	n/a	250k	IDWR
Challis National Forest 250k	250k	250k	drg250k_id_idwr.tif	n/a	250k	IDWR
Choteau 250k	250k	250k	c47112a1.tif	Choteau	250k	NRIS
Coeur d'Alene 100k	100k	100k	f47116e1.tif	Coeur d'Alene	100k	NRIS
Cut Bank 250k	250k	250k	c48112a1.tif	Cut Bank	250k	NRIS
Dillon 250k	250k	250k	c45112a1.tif	Dillon	250k	NRIS
Elk City 100k	100k	100k	drg100k_id_idwr.tif	n/a	100k	IDWR
Ennis 100k	100k	100k	f45111a1.tif	Ennis	100k	NRIS
Gallatin National Forest 126k	126,720	250k	1) c45110a1.tif 2) c46110a1.tif	1) Bozeman 2) White Sulphur Springs	250k 250k	NRIS NRIS
Gardiner 100k	100k	100k	f45110a1.tif	Gardiner	100k	NRIS
Grangeville 100k	100k	250k	drg250k_id_idwr.tif	n/a	250k	IDWR
Hailey – Challis 100k	100k	100k	drg100k_id_idwr.tif	n/a	100k	IDWR
Hamilton (ID) 100k	100k	100k	f46114a1.tif	Hamilton	100k	NRIS
Hamilton (MT) 100k	100k	100k	f46114a1.tif	Hamilton	100k	NRIS
Headquarters 100k	100k	100k	f46115e1.tif	Headquarters	100k	NRIS
Hebgen Lake 100k	100k	100k	f44111e1.tif	Hebgen Lake	100k	NRIS
Helena National Forest 126k	126,720	250k	1) c46110a1.tif 2) c46112a1.tif 3) c47112a1.tif	1) White Sulphur Springs 2) Butte 3) Choteau	250k 250k 250k	NRIS NRIS NRIS
Idaho City 100k	100k	100k	drg100k_id_idwr.tif	n/a	100k	IDWR
Hailey – Idaho Falls 250k	250k	250k	drg250k_id_idwr.tif	n/a	250k	IDWR
Kalispell 250k	250k	250k	c48114a1.tif	Kalispell	250k	NRIS
Kooskia 100k	100k	100k	f46115a1.tif	Kooskia	100k	NRIS
Leadore (MT) 100k	100k	100k	f44113e1.tif	Leadore	100k	NRIS

Table H-1. Continued.

NR_GEO Spatial Database			Base Map Source Data			
Map_tile Name	**Geologic Map Scale**	**Geologic Map Base Scale**	**DRG file name**	**USGS Quadrangle Name**	**Scale**	**Source**
Lima (MT) 100k	100k	100k	f44112e1.tif	Lima	100k	NRIS
Livingston 100k	100k	100k	f45110e1.tif	Livingston	100k	NRIS
Missoula West (ID) 100k	100k	100k	f46114e1.tif	Missoula West	100k	NRIS
Missoula West (MT) 100k	100k	100k	f46114e1.tif	Missoula West	100k	NRIS
Nez Perce Pass (ID) 100k	100k	100k	f45114e1.tif	Nez Perce Pass	100k	NRIS
Nez Perce Pass (MT) 100k	100k	100k	f45114e1.tif	Nez Perce Pass	100k	NRIS
Payette National Forest 100k	100k	250k	drg250k_id_idwr.tif	n/a	250k	IDWR
Pullman (ID) 250k	250k	250k	drg250k_id_idwr.tif	n/a	250k	IDWR
Red lodge 100k	100k	100k	f45109a1.tif	Red Lodge	100k	NRIS
Riggins 100k	100k	250k	drg100k_id_idwr.tif	n/a	100k	IDWR
Rosalia 100k	100k	100k	drg100k_id_idwr.tif	n/a	100k	IDWR
Salmon National Forest 100k	100k	100k	drg100k_id_idwr.tif	n/a	100k	IDWR
Sandpoint 250k	250k	250k	c48116a1.tif	Sandpoint	250k	NRIS
Spokane 100k	100k	100k	drg100k_id_idwr.tif	n/a	100k	IDWR
St. Maries 100k	100k	100k	f47116a1.tif	Saint Maries	100k	NRIS
Thompson Falls (ID) 100k	100k	100k	f47115e1.tif	Thompson Falls	100k	NRIS
Wallace (ID) 100k	100k	100k	f47115a1.tif	Wallace	100k	NRIS
Wallace 250k	250k	250k	c47114a1.tif	Wallace	250k	NRIS

Base map creation

We wanted to create a custom topographic base map of the same spatial extent as NR_GEO to compliment the digital geology. In preparing the base map, we also wanted to maintain the disparate scales of the individual map tiles within NR_GEO, as well as each tile's specific shape. Because the scale can change between map tiles, each tile was processed separately prior to mosaicking them into a single ESRI® personal geodatabase.

Each original DRG image was obtained in georeferenced tiff format (geoTIFF) and converted to an ESRI® GRID format. In order to eliminate image overlap in the mosaic, the GRID files were clipped to the same extent and shape as the individual map tiles in the spatial database. The clipped GRID files were each converted to geoTIFF image format to facilitate loading into a raster dataset in a personal geodatabase. Loading multiple rasters into a single raster dataset in a personal geodatabase in effect mosaics the images into one dataset. Once the mosaicked DRG image had been created, the new image dataset was exported to an ERDAS IMAGINE® (NR_BASEMAP) file and compressed.

The process of clipping a GRID has the unwanted side effect of removing the colormap associated with the original image, as well as the spatial reference. NR_BASEMAP utilizes a colormap that was created to reflect the appearance of common USGS topographic DRG images. The base map contains 13 colors, each with a number between 0-12, which are identical to the original DRG colors. The RGB values for these colors are shown in table H-2.

Table H-2. NR_BASEMAP colormap definitions.

[The table contains definitions and descriptions of the colormap associated with NR_BASEMAP. Some features incorporate more than one color for proper appearance. The "not used" colors do not apply to any features in this base map, but are included to preserve the color scheme of the original DRG imagery]

Base Map Color Descriptions			Colormap RGB values		
Symbol	**Color**	**Feature**	**Red**	**Blue**	**Green**
0	black	text; roads; legal boundaries	0	0	0
1	white	background	255	255	255
2	teal	water	0	151	164
3	red	land grids; important roads	203	0	23
4	brown	topographic contours	131	66	37
5	green	vegetation	201	234	157
6	purple	not used	137	51	128
7	yellow	not used	255	234	0
8	blue	water	167	226	226
9	pink	topographic contours	255	184	184
10	lavender	not used	218	179	214
11	gray	text; boundaries; densely built up areas	209	209	209
12	tan	topographic contours	207	164	142

The actual symbology of NR_BASEMAP shows additional colors in the colormap which are not described in this table. These colors, symbolized as 100-215, do not represent actual colors or symbols in the base map. The multiple steps involved in the creation process, including conversion and clipping of the data, introduced artifacts which were not removed from the final product. Therefore, these additional colors are extraneous and do not affect the appearance or use of the base map image; they can be ignored.

The coordinate system of the NR_BASEMAP mosaic is set to an Albers Equal Area (NAD 1927) projection. The large areal extent of the base map dictated that we chose a spatial reference that minimized distortion over the entire image. Albers Equal Area is an appropriate projection for large areas in the conterminous United States, as areas and distances remain true and proportional to the Earth. In addition, we chose a central meridian that centered the image on the screen with minimal rotation at the edges. This spatial reference differs from the NR_GEO spatial database, which is presented in geographic coordinates.

Origin of Data

The original DRG images used to build this mosaic were obtained from the Idaho Department of Water Resources (IDWR) at the website: http://www.idwr.state.id.us/gisdata/gis_data.htm and the Montana State Library, Montana Natural Resources Information System (NRIS) at the website: http://nris.state.mt.us/gis/default.htm. All imagery used to compile this base map originated from one of these two sources based on their geographic location and/or availability on-line. Individual collarless DRG images of quadrangles in Montana and a few available quadrangles in Idaho were downloaded from Montana State Library, Montana Natural Resources Information System (NRIS). The remaining DRG images covering locations in Idaho were created by removing “cookie-cutter” pieces from one of two large geoTIFF images covering the entire state of Idaho. IDWR provides mosaicked 1:100,000- and 1:250,000-scale DRG images (geoTIFF files drg100k_id_idwr.tif and drg250k_id_idwr.tif, respectively).

Using the base map

The base map can be added to a GIS along with the spatial database coverage, NR_GEO. Add NR_BASEMAP to an ArcMap™ project containing the NR_GEO coverage to view the basemap as a layer with the spatial database, ensuring that the base map draws above the spatial database.

Two settings can be adjusted in the properties of NR_BASEMAP image while in the ArcMap™ environment to make it a more effective tool: the transparency and the color options. First, in order to view the underlying geology spatial database through NR_BASEMAP, it needs to be displayed as semi-transparent. A 50 percent transparency for NR_BASEMAP is recommended. Second, the white and green colors (colors 1 and 5, respectively, in the colormap) of the base map should be set to ‘null’ so that the colors of NR_BASEMAP will not conflict with the colored symbology of the spatial database. Null maintains the color value but renders the area transparent. Setting these two colors to null will allow map features such as, contours, roads, section lines, and so on, to remain visible, yet will not interfere with the intentional symbology of the spatial database.

Appendix I: Map-unit descriptions and related files

By J. Douglas Causey and Michael L. Zientek

Contents

Figures

Tables

Introduction

A digital compilation of 2,135 original geologic map-unit descriptions was created from the original geologic map sources. As the compiled spatial database was being constructed, relational database software (Microsoft® Access) and spreadsheet software (Microsoft® Excel) were used to manage most of the attribute information associated with the spatial objects. Subsets of this information were used to create many of the ArcInfo® look-up tables in this report. These descriptions are too long and complexly formatted to include as 320 character-length fields in an ArcInfo® look-up table. Because of their length, the map-unit descriptions are stored in a memo field in Microsoft® Access. This appendix describes how the map-unit descriptions were converted to digital format, how they are presented in this report, how this information can be imported into a relational database, and how to search these files.

Information capture and presentation

In most cases, the map-unit descriptions provided in this report are derived from explanations, pamphlets, and reports that accompanied the maps that make up this compilation. If these descriptions were available in a digital format (word processor files, databases, or spreadsheets), they were used for the compilation. If no digital files were available, optical character recognition (OCR) software was used to convert scanned images of the descriptions into editable text.

In all cases, these digital files were edited, consistently formatted, and imported into a memo field in a Microsoft® Access database. Extraneous text (such as headers) was removed from word processing files and the map unit label, map unit name, and map-unit description were formatted so that they could be imported into a spreadsheet. Paragraph formatting within the map-unit description was retained. Unique identification numbers (*mu_id*) were assigned to each map unit. For some maps, data tables (dbf files) were provided by the map author; however, the tables consisted of three 254 character text fields containing parts of the map-unit descriptions. If the complete map-unit description was longer than 762 characters, the description was truncated in the dbf file. Data in these fields were recombined into a single item and, if truncated, completed. All map-unit descriptions were spell-checked several times; corrections include OCR errors as well as misspellings in the original publication.

Spatial objects in the spatial databases for these geologic maps are commonly identified with a unit label and a unit name. In most cases, a labeled and named unit had a description that applied universally to all spatial objects on the map. On a few maps, polygons with the same name and map unit symbol had different map-unit descriptions for different areas of the map. For example, on the Lima map (Lonn and others, 2000), the Lodgepole Formation (map unit symbol Ml) has different descriptions for the Snowcrest Range versus the Red Rock Hills, Sage Creek Basin, and upper Blacktail region. Another example is on the Challis map (Fisher and others, 1992). Rhyolite intrusions (map unit symbol Tr) has different descriptions for the Thunder Mountain cauldron complex and environs, the northern part of the Van Horn Peak cauldron complex and Panther Creek graben, and the Custer graben area. The data could be restructured so that a unique description only applied to the appropriate group of polygons on the map. For the Challis map, 4 new map units with unique labels and names would have been created for rhyolite intrusions in different areas. However, the general geographic descriptions made it difficult to unambiguously assign spatial objects to the new units. For this compilation, we did not subdivide and create new named and labeled units that had unique descriptions for different geographic domains. All descriptions for a given map unit symbol and name were combined into a single map-unit description for this compilation. For these combined descriptions, the geographic area is listed followed by the appropriate description.

Some geologic units were not accompanied by a map-unit description. When possible, a description was obtained from other publications. For example, map-unit descriptions of Phanerozoic units in the Cut Bank 1:250,000-scale quadrangle map (Harrison and others, 1998) refer the reader to map-unit descriptions for the same units on the geologic map of the northern disturbed belt in Montana (Mudge and Earhart, 1983). For this compilation, the map-unit descriptions from Mudge and Earhart (1983) were appended to the descriptions provided by Harrison and others (1998). Usually, if a map unit consisted of two or more formations, no explanation was given for that unit. On a map explanation, it is easy for the reader to refer to the previous descriptions of the separate formations. In the database, the individual descriptions were combined to provide a description for the undivided unit. Forty-four map units do not have a description. The authors of this publication did not write new descriptions, nor were descriptions from adjoining maps used if descriptions were missing. Any material added to a map-unit description was taken from published literature and it is clearly identified as coming from a different source.

The map-unit descriptions contain hundreds of citations to literature. The reference list for each publication was captured in an editable form and compiled into a single comprehensive reference list that contains citations to the 43 published maps used for this compilation, the spatial databases for these maps, and the citations to literature in the map-unit descriptions. Duplicate entries were eliminated, incomplete citations were revised, and the format was standardized. Some map-unit descriptions use an “a”, “b”, “c” notation if the citation would otherwise be identical (for example, Authorname, 1974a; Authorname, 1974b, Authorname, 1974c). It was difficult to manage this style of notation for this compilation; the “a”, “b”, “c” notation is retained in the map-unit description; however, it is not used in the reference list. In this case, all Authorname (1974) citations are included in the reference list; the reader is referred to the original publication if the appropriate citation is not clear from the context in which it occurs.

Map-unit descriptions as delimited text files

A digital file containing the map-unit descriptions is provided with this report to allow users to incorporate that data into other projects. From the relational database, the key field *mu_id* and the corresponding map-unit description were exported to the ASCII text file, nr_geo_mud.txt. The character “|” was used to delimit fields in this file. Complex formatting of the map-unit description would not allow the use of tabs or commas as delimiters. The following discussion illustrates how this file can be imported into a memo field in Microsoft® Access:

1. Open a new or existing database in Microsoft® Access 2000 or newer.

2. From the **File** menu in Access, select **Import** (**File/Get External Data/Import**)

3. A window opens that allows you to navigate to the file. In the **File of type:** drop down list select “Text Files (*.txt;*.cvs.;*.tab;*.asc)” and then navigate to and select the text file, nr_geo_mud.txt, and then select the **Import** button.

4. A new window will open with the **Import Text Wizard** (fig. I-1**)**. Check the **Delimited** radio button and then the **Next>** button.

5. The wizard advances to a new window (fig. I-2). In the box **Choose the delimiter that separates your fields:**, select the radio button for **Other** and then enter the character | (shift + \) in the open box to the right of the button. Then check the box next to **First Row Contains Field Names**. In the **Text Qualifier**: drop down list, select the single quote character. Select the **Next>** button.

6. The wizard advances to a new window (fig. I-3). Store the information in a new table by selecting the radio button next to **In a New Table**.

7. Select the **Advanced…** button to see the file format and field information (fig. I-4). A new window opens. Change the Data Type from Text to Memo for the field name mu_desc. For the field name *mu_id*, change Indexed to Yes (No Duplicates). The settings should look like the example illustrated below. Select the **OK** button which returns you to the **Import Text Wizard**. Select the **Next>** button.

8. The wizard advances to a new window where you can specify information about each of the fields you are importing. Skip this window by selecting the **Next>** button.

9. The wizard advances to a new window where you can define a primary key for the new table (fig. I-5). Select the radio button next to **Choose my own primary** key and select *mu_id* from the drop down list. Select the **Next>** button.

10. The wizard advances to a new window. Name the new table in the box under **Import to Table** and select the **Finish** button.

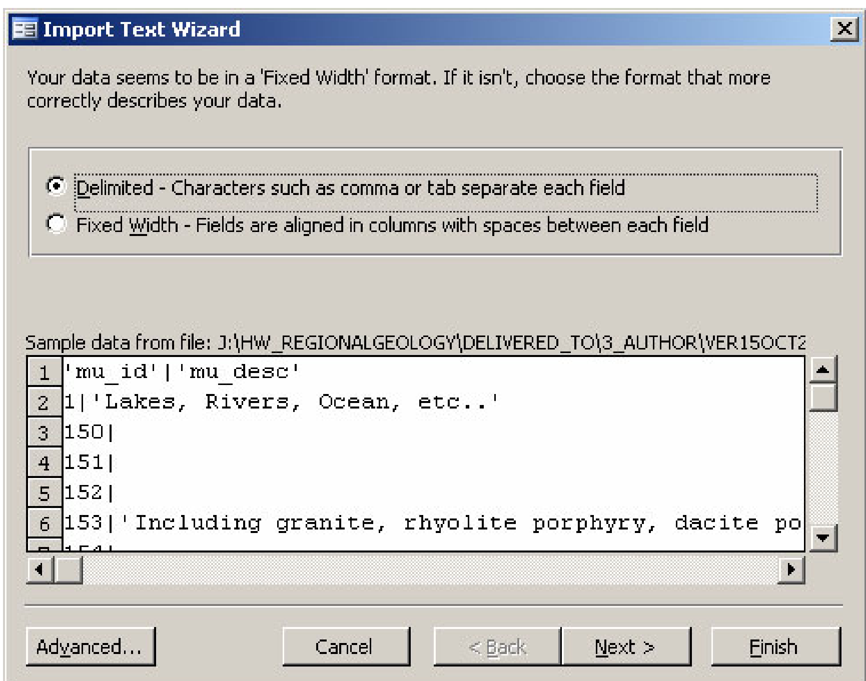


Figure I-1. A window image from Microsoft® Access showing the Delimited option selected in the first window of the Import Text Wizard.

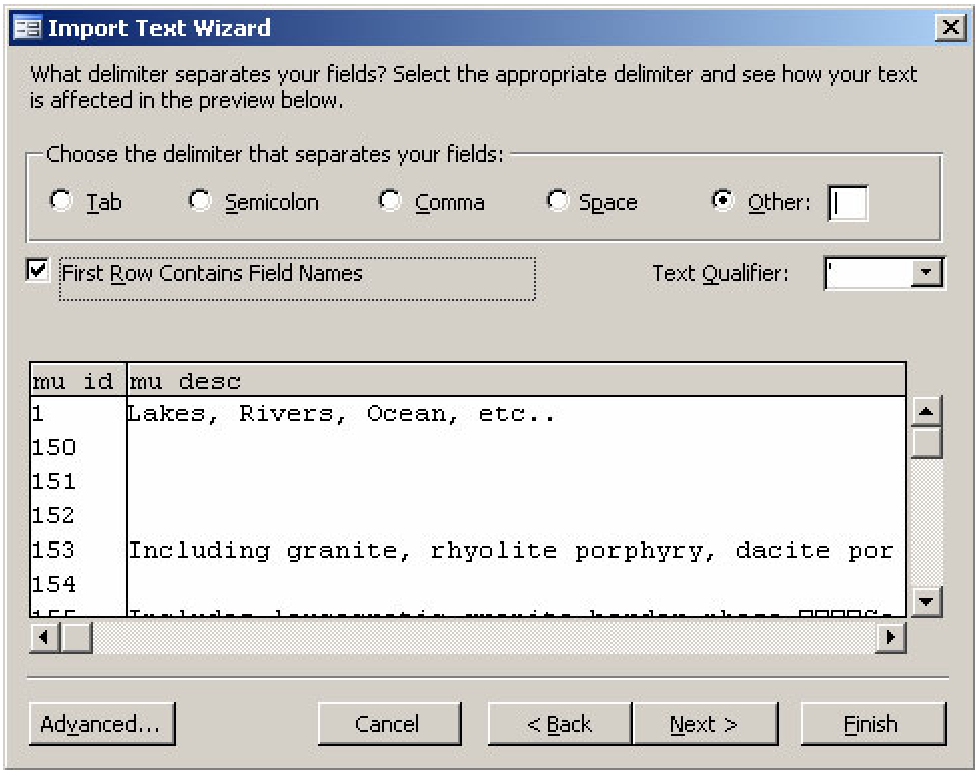


Figure I-2. A window image from Microsoft® Access showing field name, text qualifier, and delimiter options. The "|" character (shift+\) is chosen as the delimiter.

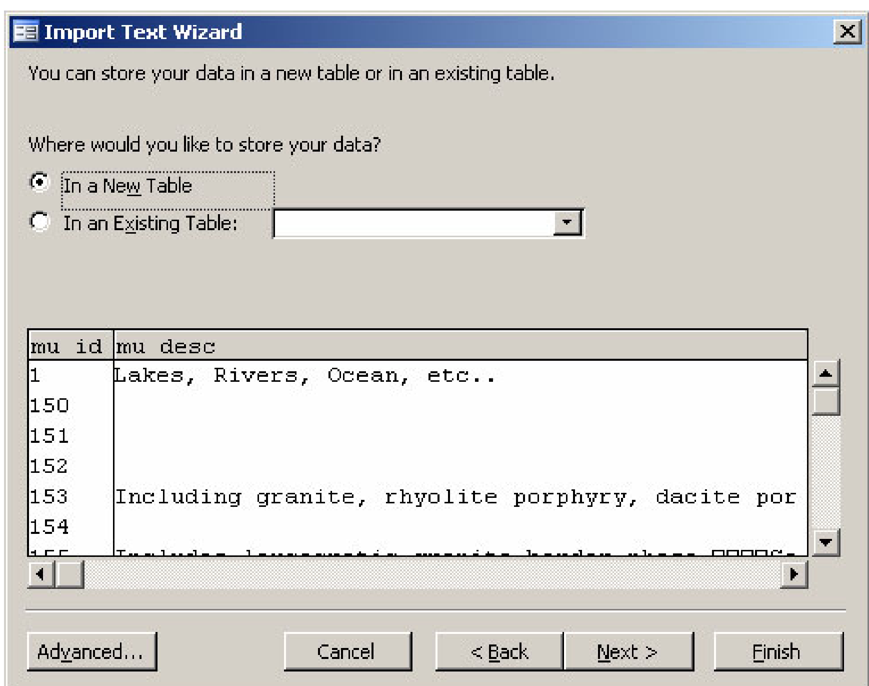


Figure I-3. A window image from Microsoft® Access showing options to store data in a new or existing table. The option, In a New Table, is selected.

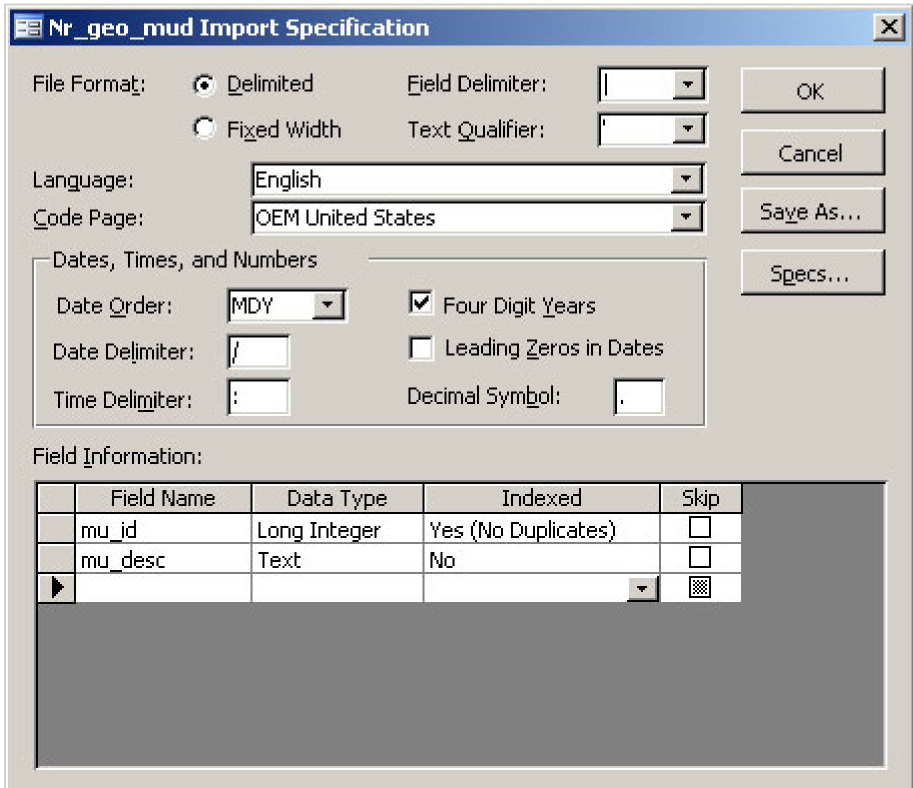


Figure I-4. A window image from Microsoft® Access showing the import specification dialog box. The field information for *mu_id* and *mu_desc* are specified in this window.

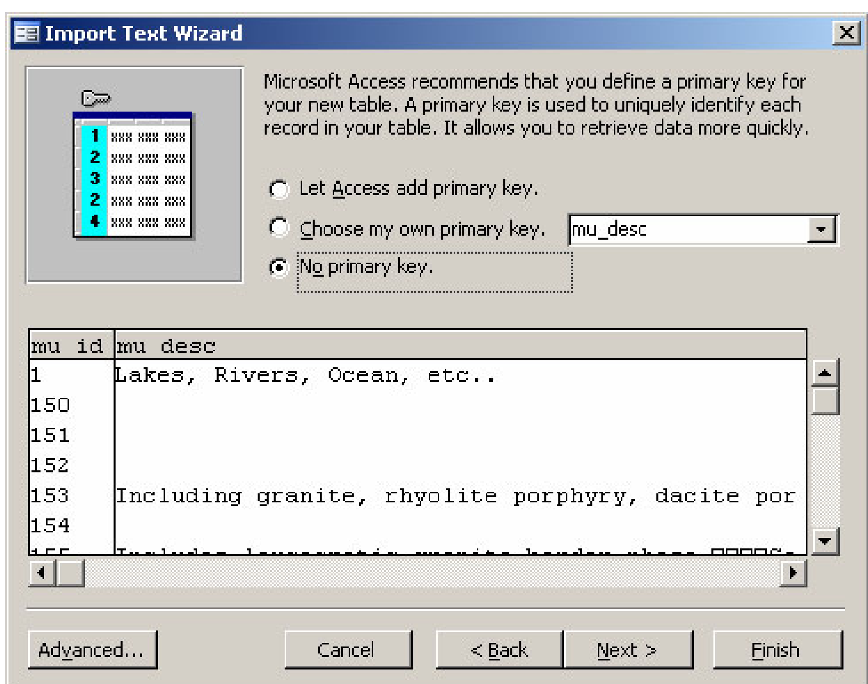


Figure I-5. A window image from Microsoft® Access showing options for selecting primary keys. *Mu_id* is selected as the primary key.

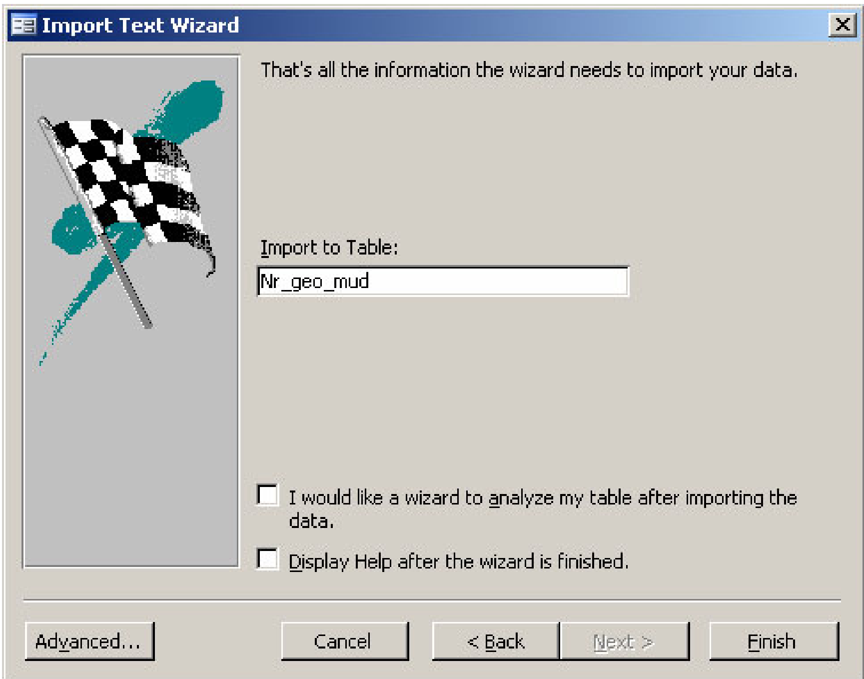
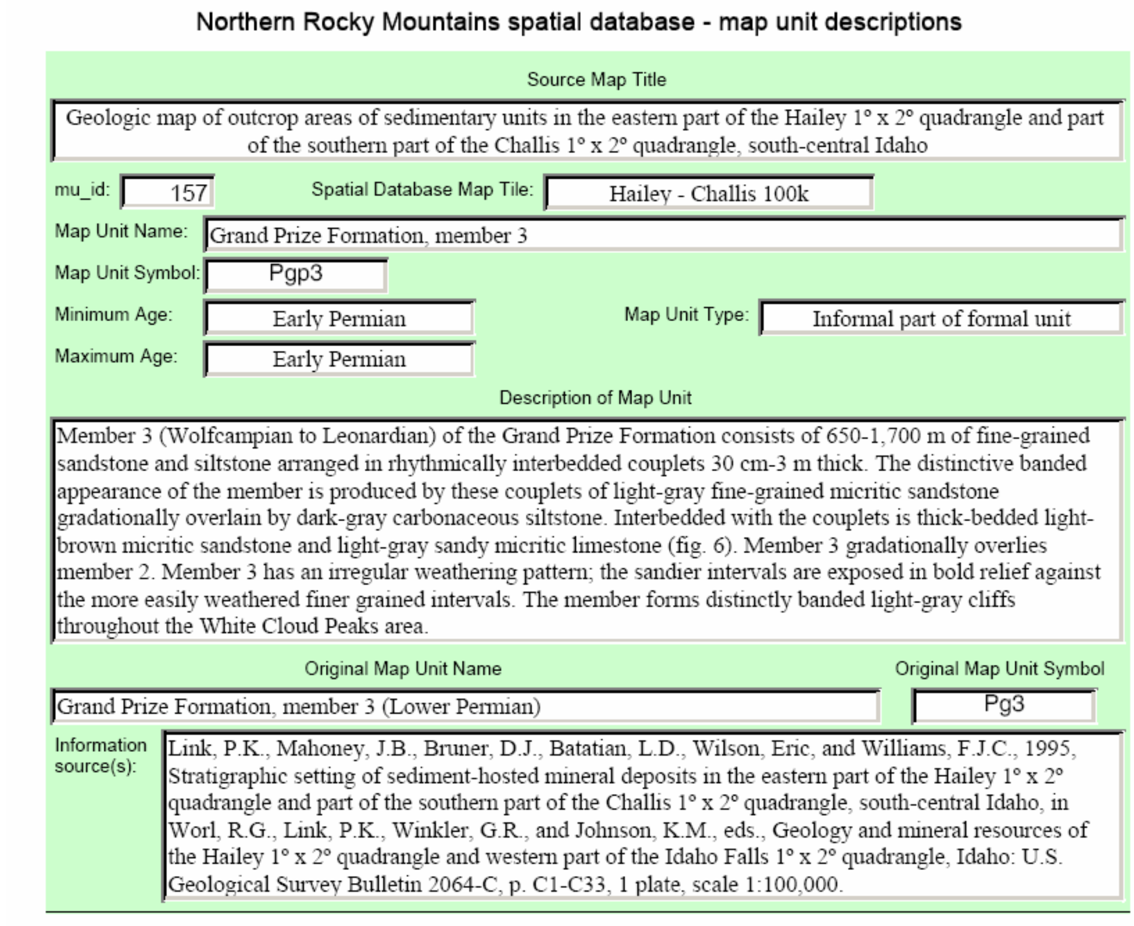


Figure I-6. A window image from Microsoft® Access showing option for naming the table.

Adobe® Portable Document Format file

Database tables optimized for storage and analysis are hard to read. Map-unit descriptions, along with selected attributes also reported in the ArcInfo® tables NR_GEO.PAT, NR_GEO.MU, and NR_GEO.BIB, were manipulated in a Microsoft® Access database to create a form that is easier to read. The results were exported into the Adobe® Portable Document Format file, nr_geo_mapunits.pdf. A typical form is shown in figure I-7. Caution – the file nr_geo_mapunits.pdf was developed to use online; be aware that it contains over 2000 pages if you plan to print this document. Table I-1 relates the captioned boxes on the form to fields in other tables in this report; the fields are described in table I-2.



Northern Rocky Mountains spatial database - map unit descriptions

Source Map Title

Geologic map of outcrop areas of sedimentary units in the eastern part of the Hailey 1° x 2° quadrangle and part of the southern part of the Challis 1° x 2° quadrangle, south-central Idaho

mu_id: 157

Spatial Database Map Tile: Hailey - Challis 100k

Map Unit Name: Grand Prize Formation, member 3

Map Unit Symbol: Pgp3

Minimum Age: Early Permian

Map Unit Type: Informal part of formal unit

Maximum Age: Early Permian

Description of Map Unit

Member 3 (Wolfcampian to Leonardian) of the Grand Prize Formation consists of 650-1,700 m of fine-grained sandstone and siltstone arranged in rhythmically interbedded couplets 30 cm-3 m thick. The distinctive banded appearance of the member is produced by these couplets of light-gray fine-grained micritic sandstone gradationally overlain by dark-gray carbonaceous siltstone. Interbedded with the couplets is thick-bedded light-brown micritic sandstone and light-gray sandy micritic limestone (fig. 6). Member 3 gradationally overlies member 2. Member 3 has an irregular weathering pattern; the sandier intervals are exposed in bold relief against the more easily weathered finer grained intervals. The member forms distinctly banded light-gray cliffs throughout the White Cloud Peaks area.

Original Map Unit Name

Grand Prize Formation, member 3 (Lower Permian)

Original Map Unit Symbol

Pg3

Information source(s):

Link, P.K., Mahoney, J.B., Bruner, D.J., Batatian, L.D., Wilson, Eric, and Williams, F.J.C., 1995, Stratigraphic setting of sediment-hosted mineral deposits in the eastern part of the Hailey 1° x 2° quadrangle and part of the southern part of the Challis 1° x 2° quadrangle, south-central Idaho, in Worl, R.G., Link, P.K., Winkler, G.R., and Johnson, K.M., eds., Geology and mineral resources of the Hailey 1° x 2° quadrangle and western part of the Idaho Falls 1° x 2° quadrangle, Idaho: U.S. Geological Survey Bulletin 2064-C, p. C1-C33, 1 plate, scale 1:100,000.

Figure I-7. A sample page from the file nr_geo_mapunits.pdf.

Table I-1. Relation between named boxes in the form and fields in ArcInfo® tables.

Caption on form	**Field name or item**	**ArcInfo® Table**
Source Map Title	--	--
Spatial database Map_Tile	*map_tile*	NR_GEO.PAT
mu_id	*mu_id*	NR_GEO.PAT, NR_GEO.AAT, NR_GEO.MU, NR_GEO.LITH, NR_GEO.UN
Map Unit Name	*name*	NR_GEO.MU
Map Unit Type	*unit_type*	NR_GEO.MU
Map Unit Symbol	*lab_gaf*	NR_GEO.MU
Minimum Age	*minage_or*	NR_GEO.MU
Maximum Age	*maxage_or*	NR_GEO.MU
Description of Map Unit	--	--
Original Map Unit Name	*name_or*	NR_GEO.MU
Original Map Unit Symbol	*lab_gaf_or*	NR_GEO.MU
Information source(s)	--	--

Table I-2. Northern Rocky Mountains data form description.

Name	Description
Source Map Title	Title of the geologic map
Spatial Database Map Tile	Short version of map name from the item *map_tile* in feature attribute tables NR_GEO.PAT and NR_GEO.AAT.
Mu_id	Unique number for each map unit. This integer relates rock unit descriptions in this file to the feature attribute tables NR_GEO.PAT and NR_GEO.AAT and the look-up tables NR_GEO.MU, NR_GEO.LITH, and NR_GEO.UN.
Map Unit Name	Name of unique regional geologic map unit used in the regional geology compilation.
Map Unit Type	The stratigraphic status of the geologic unit. Types are: Formal name, Informal part of formally-named unit, Informal name, Unconsolidated unit.
Map Unit Symbol	Map symbol, represented with GeoAgeFullAlpha font, used to label regional geologic units in the regional compilation.
Minimum Age	Youngest age given for a unit in the source maps used for the compilation.
Maximum Age	Oldest age given for a unit in the source maps used for the compilation.
Description of Map Unit	Description of the original map unit taken from the map explanations, pamphlets, and other sources.
Original Map Unit Name	Name of geologic map unit as used on original source map.
Original Map Unit Symbol	Map symbol, represented with GeoAgeFullAlpha font, for map unit as used on original source map.
Information source(s)	References for the information in Description of Map Unit.

Searching map-unit descriptions

Only terms for rock and sediment type were parsed from the map-unit descriptions into fields in the spatial database (Appendix E). Obviously, the map-unit descriptions contain additional information. The Search function in Acrobat Reader can be used to look for additional information in the file nr_geo_mapunits.pdf. Data in the map-unit descriptions can also be queried if the file nr_geo_mud.txt is imported into database software.

Word lists were developed to facilitate searching the map-unit descriptions. The map-unit descriptions were indexed, creating a unique list of all words that appear. From this master list, specific word lists for age, color, geology, minerals, and paleontology were developed. These word lists are presented as text files (wordlist_age.txt, wordlist_color.txt, wordlist_geology.txt, wordlist_minerals.txt, wordlist_rocks.txt, and wordlist_paleo.txt). The file, author_terms.txt, is a list of unique rock and sediment names derived from the items *name_major*, *name_majr1*, *name_majr2*, *name_minor*, and *name_other* in the ArcInfo® look-up tables NR_GEO.LITH and NR_GEO.UN.

References cited

Fisher, F.S., McIntyre, D.H., and Johnson, K.M., 1992, Geologic map of the Challis 1° x 2° quadrangle, Idaho: U.S. Geological Survey Miscellaneous Investigations Series Map I-1819, 39 p., 1 sheet, scale 1:250,000.

Harrison, J.E., Whipple, J.W., and Lidke, D.J., 1998, Geologic map of the western part of the Cut Bank 1° x 2° quadrangle, northwestern Montana: U.S. Geological Survey Geologic Investigations Map I-2593, 1 sheet, scale 1:250,000.

Lonn, J.D., Skipp, Betty, Ruppel, E.T., Janecke, S.U., Perry Jr., W.J., Sears, J.W., Bartholomew, M.J., Stickney, M.C., Fritz, W.J., Hurlow, H.A., and Thomas, R.C., 2000, Preliminary geologic map of the Lima 30' x 60' quadrangle, southwest Montana: Montana Bureau of Mines and Geology Open File Report 408, 54 p. (parts A, B, and C), 1 sheet, scale 1:100000.

Mudge, M.R., and Earhart, R.L., 1983, Bedrock geologic map of part of the northern disturbed belt, Lewis and Clark, Teton, Pondera, Glacier, Flathead, Cascade, and Powell Counties, Montana: U.S. Geological Survey Miscellaneous Investigations Series Map 1-1375, scale 1:125,000.