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A Classification of Geologic Materials for Web Display of National and Regional-Scale Mapping

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The Geologic Mapping Act of 1992 mandates the U.S. Geological Survey (USGS) and Association of American State Geologists (AASG) to design and build a National Geologic Map Database (NGMDB), as an archive of map-based, standardized geoscience information. The science and technical standards for this archive have been under development since that time, and mostly consist of revisions and modifications to standards that have evolved in the geosciences since the 1800s. Numerous reports of progress have been included in previous Proceedings of the Digital Mapping Techniques workshops and elsewhere (see, for example, Soller and Stamm, this volume).

The NGMDB project delivers geoscience information in several ways including via a Geoscience Catalog which provides, for each of ~80,000 publications, one or more web links to the publishing agency and in many cases to downloadable data and images (*http://ngmdb.usgs.gov/ngmdb/ngm_catalog.ora.html*). In a recent initiative made feasible after the development of certain science and technical standards, the project began to design a Web-mapping portal (the NGMDB “Data Portal,” *http://maps.ngmdb.us/dataviewer/*, see Soller, 2008) where the full richness and variability of map information content is managed by the publishing agencies or other repositories, with a subset of the information made available in a standardized and coherent fashion via this Portal, for browsing and querying and, in the future and on a limited basis, for downloading.

In this paper I address, but do not presume to solve, a particularly challenging task—that is, how to effectively portray many geologic maps together, in a coherent fashion, via a Web-mapping system. Geologic maps vary significantly in content owing to factors including the purpose (e.g., mineral exploration, economic development, groundwater modeling), map scale, geologic terrane, and the geologic concepts in use when the map was made. Even if we examine the most recent intermediate- to detailed-scale maps for a region, the differences among them commonly are sufficient to limit the effectiveness of standard rock classifications for bringing the maps together into a synoptic view. Fault doesn’t lie with the classifications but with their application to a situation for which they were not designed—that is, interactive, dynamic Web display of multiple and disparate geologic maps.

Because the geologic classification described in this paper was developed specifically for application in a Web-mapping system, and because those systems are relatively new and unevolved, it may be somewhat unconventional. Suggestions for improvement to this classification and how it is applied on the Web are welcome; I do not suppose the classification to be ideal, but it is clear that more effective methods for cartographic display of geologic information in Web-mapping systems are needed.

From my limited personal experience, I find the process of developing a classification to be difficult, fraught with ambiguities and second-guessing. It gives me newfound respect for those who have done it successfully. This paper describes how the classification was developed, in order to place it in context and to lend some small measure of insight into the process.

Design Assumptions and Principles for the NGMDB Data Portal

The design of the NGMDB Data Portal and its geologic classification is the outcome of numerous observations, assumptions, and principles regarding how people use the Web, and the type of geoscience information that is contained in geologic maps. Some are discussed below.

Complement, Don't Compete—A "Website Nonproliferation Agreement"

People who visit geoscience websites, whether professional geologists or the general public, want to quickly find the information they need; as emphasized in their emailed comments, they clearly do not want to grope amongst many similar websites, unsure which site is "best" and has the most authoritative content. This user preference is in opposition to a strongly positive aspect of the Web – that is, the unrestricted ability to "publish" information by posting it to a website. And so a natural tension exists between users and website providers. This tension can be healthy when it motivates those legally responsible for information to develop better Web-based methods of communicating it, but it obviously becomes counterproductive when the user is faced with multiple websites offering what appears at first glance to be the same content.

In designing the NGMDB Data Portal, we specifically try to complement rather than compete with, or duplicate, the Web services and information provided by the Nation's geological surveys. For example, the Portal shows a national view of bedrock and surficial geology and, with increasing levels of zoom into a given region, provides a generalized view of the geology and links to the State geological surveys where more detailed geologic mapping is available. The function of the NGMDB is, then, not a "better" dissemination of a State geological survey's published maps, but an integration of geology across the Nation, as both an educational tool and a means to find the original, detailed information.

Is Web "Publishing" Really Different from Paper? Yes and No

The intended audience for a product guides the method that is selected to convey it. For example, is it a formal, printed publication intended for professional geologists? Or perhaps is it for non-geologists who guide public decision-making? Is it a website that contains an electronic copy of a conventionally designed geologic map, and/or a geologic map database intended for downloading? Or, is it a Web-mapping system that contains formally published and/or unofficial information postings (e.g., geologic map information that has not received agency approval), designed to be interactively queried and viewed in order to address a variety of questions posed by the tax-paying general public? Web-mapping systems increasingly are a means by which the public obtains geologic map information. Although in some respects it is a fundamentally different product than a traditional map, in at least one important respect it is the same – high-quality, effective cartography remains essential.

Geologic maps convey complex and somewhat unfamiliar concepts and imprecise information, and the presentation must be done with careful thought and art, especially on the Web. This is partly because users tend to spend less time studying and learning information presented in a Web browser than they do for the printed page or map sheet. Also, because the Web interface is small in size when compared to a conventionally designed printed or electronic map sheet, methods of portrayal must be especially informative and compelling; the user will not long endure the process of clicking on a map unit, reading the information in a popup window or a mouse-over display, committing that information to memory, and then moving to another map unit and repeating the process. More complex and informative queries of the map database, specified interactively by the user, are quite challenging and expensive to design, and are not commonly found in Web-mapping systems implemented for geologic maps. Therefore, comprehension of geologic map information is still best achieved by viewing and querying the entire map in the user's local environment, hence the continued demand for downloadable GIS data and map images. For the NGMDB, and perhaps for other sites and other agencies as well, the most effective role for Web presentation of geologic maps, at least in the near-term, is to provide a quick overview with simple queries that either satisfies the user's general curiosity or encourages the user to download or purchase the printed map(s).

Good Cartography Remains Essential

"…the [geologic] maps are designed not so much for the specialist as for the people, who justly look to the official geologist for a classification, nomenclature, and system of convention so simple and expressive as to render his work immediately [understandable]…" (USGS Director, John W. Powell, 1888). These words are as relevant today as when they were written. Information on a geologic map must be readily comprehensible, and clearly presented.

For a Web-mapping system (and, in general, for any geologic map) it is critically important to portray the various rock units in a manner that highlights their similarities and differences; this is the art of cartography. By using similar colors and patterns for geologically related map units, the geologic features and relationships deemed by the author to be most significant are made more visible, thereby aiding map comprehension. Conversely, if the colors of adjacent map units are too similar, or are randomly assigned by the system, important details of geologic materials, structure, and history may not be readily discernible. The changing set of conditions under which the map, or group of source maps, is displayed in the user's browser presents a real challenge to Web-mapping system design. For example, user-specified changes in the area viewed (pan or zoom) cause a different set of geologic map units to be visible on-screen. How will those specific units be symbolized to optimally convey the geology? Will the map legend dynamically change to show just those units or will it be a static legend that shows all units in the map database?

Source versus Derived Information

Geologic mapping begins with fieldwork that includes the description of rocks and sediments (which generally are few in number and confined to points of observation). These field observations and interpretations then are mentally assembled into a conceptual 3D model that permits the extrapolation of observation points to the entire map area, thereby producing the geologic map. In general, geologic maps show an organization of rocks and sediments into stratigraphic packages or units. In many cases these stratigraphically defined units are directly usable (e.g., to predict the occurrence of oil-bearing units outside the areas where oil has been mapped). However, not uncommonly the public wants to know the nature of the material at a particular location, rather than how the geologist organized the materials into map units. For this reason, maps of lithology, geologic age, and other factors are derived from the geologic map. These derivatives are common in Web-mapping systems and can be created by a database query and dynamic display of the results or can be created by the system at any time and later displayed as static objects.

Commonly, the derivative information is created by someone other than the map author. Typically, relevant information is identified in the Description of Map Units (DMU) and, if available, in the accompanying pamphlet or report. This information is used directly to prepare the derivative map or is parsed into free-text or controlled-term database fields in order to make the information available to others. Despite the utility, and at times it seems the imperative, of deconstructing and parsing geologic map unit descriptions into various database fields, the process causes some information loss. This is true whether or not standard terminologies are used. Because the parsed information is an interpretation, derived in turn from the interpretations that are provided in the DMU, it is not equivalent in content to the direct field observations from which the geologic map and DMU were created (Figure 1). If the parsed information is derived from a pre-existing map database, it is even further removed from the actual observations. These realities guided decisions on the Data Portal's design, regarding what information would be parsed from the source maps and stored in the Portal's database, and what would be displayed in the Web browser.

A database can store multiple descriptions or science terms for any given characteristic of a map unit, derived from the DMU or the source map's database. For example, numerous lithologies can occur within a mapped unit, and each of these can be recorded in the database with an indication of the lithology's proportion. The NGMDB Portal's database uses this approach, storing information for each lithology in each map unit. However, such information is difficult to portray in a single map view, and so it is common to identify and show a single characteristic such as the dominant lithology. A derivative map such as this can be extremely useful where map units are relatively homogenous in composition; but in many areas this is the exception, not the rule. A somewhat randomly selected map of the U.S. Midcontinent includes a unit well known for its homogeneity (St. Peter Sandstone), and a notably heterogenous, cyclothemic unit (Tradewater Formation); their map unit descriptions are shown in Figure 2. How would a dominant lithology be identified for the Tradewater Formation? For this Portal, in which many maps are to be integrated into a coherent view, it was decided to minimize the "distance" between field observations and Web display by classifying and displaying information that more closely characterizes the nature of the entire map unit as defined by the original authors.

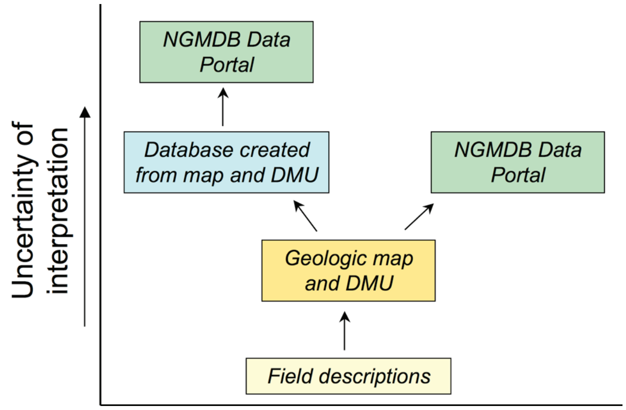
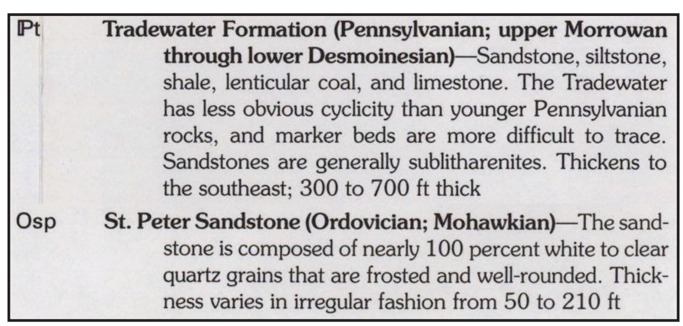


Figure 1. Diagram showing accumulation of uncertainty in the interpretation of geologic information. The most certain information is directly recorded in field observations, and on the resulting geologic maps. Uncertainty in parsing geologic map unit descriptions into database fields, whether free-text or controlled-term, increases at each process step removed from the source map. For purposes of the diagram, nuances such as the structure and content of a database directly associated with the source map are not addressed.



IPt **Tradewater Formation (Pennsylvanian; upper Morrowan through lower Desmoinesian)**—Sandstone, siltstone, shale, lenticular coal, and limestone. The Tradewater has less obvious cyclicity than younger Pennsylvanian rocks, and marker beds are more difficult to trace. Sandstones are generally sublitharenites. Thickens to the southeast; 300 to 700 ft thick

Osp **St. Peter Sandstone (Ordovician; Mohawkian)**—The sandstone is composed of nearly 100 percent white to clear quartz grains that are frosted and well-rounded. Thickness varies in irregular fashion from 50 to 210 ft

Figure 2. Comparison of lithologic descriptions for two units found in the Paducah 1° x 2° quadrangle, Illinois, Indiana, Kentucky, and Missouri (Nelson, 1998). The St. Peter Sandstone (Ordovician) is the product of repeated reworking of older sediments, whereas the Tradewater Formation is a typical product of cyclic sedimentation common in the Midcontinent region during the Pennsylvanian.

Classifications can be Comprehensive, or Selective

For the past decade, the NGMDB project and many colleagues in the U.S. and international community (for example, see Appendix A in Soller and Stamm, this volume) have steadily worked to define science and technical standards that build upon the works of many predecessors (for example, Powell, 1888). These standards address cartography, map database design, and science terminology (e.g., a list of terms and definitions for lithology). Particularly noteworthy here is the North American Data Model Steering Committee's Science Language Technical Team (SLTT) report on development of a proposed standard terminology for describing the lithology of rocks and sediments (2004; *http://pubs.usgs.gov/of/2004/1451/nadm/*). The SLTT report is the principal component of the NGMDB's lithology term list, which is part of the project's evolving set of science terminology standards (see Richard and Soller, this volume). This lithology term list then was reduced to a limited, more general set of terms appropriate for national and regional applications such as this Data Portal, where it serves as a principal attribute in the Portal's database. The restricted set of terms also was recently incorporated into the GeoSciML standard lithology terms and definitions (*https://www.seegrid.csiro.au/twiki/bin/view/CGIModel/GeoSciML*).

The SLTT classification is a comprehensive, detailed, hierarchical list of terms and definitions. It serves as a useful compendium from which classifications can be tailored to suit a region's geology and the requirements of a map or Web-mapping system. Because the Data Portal shows an overview of the Nation's geology, its classification of geologic materials must concisely reflect the relative proportion of the various rock and sediment types found therein. In other words, the most commonly occurring materials must be classified or subdivided to a greater extent than those that are less common. To do otherwise would unduly emphasize relatively insignificant rock types at the expense of materials that cover broad expanses of the country. In a Web-mapping system in which cartographic display of map units on many separately published maps is quite technically challenging, this is especially important. In the conterminous U.S., sedimentary rocks underlie about 80 percent of the area (information derived from provisional database of Reed and others (2005) Geologic Map of North America). If surficial deposits were to be included in the estimate, the proportion of land underlain by sedimentary materials likely would be 90 percent or more. Further, given the relative heterogeneity of surficial materials and of interbedded sedimentary rocks as compared to other major rock types, and the fact that the majority of U.S. residents live on sediments or sedimentary rocks, it was imperative they be well represented in the Portal's classification by subdividing sedimentary materials to a greater extent than other rock types.

Geologic Materials Classification

General Process

There are three principal aspects to any classification: the names or terms, their definitions, and the structure within which they are organized. The first step taken was empirical – an inventory of the principal types of geologic materials and geologic map units encountered in the U.S. Next, these types were organized in a hierarchical classification according to principal criteria by which each particular class of materials commonly is classified. Through numerous iterations, the classification emerged (Appendix A provides a recent version). The current version is maintained at *http://ngmdb.usgs.gov/Info/standards/NGMDBvocabs/*; it includes the classification criteria, which could be used in structured searches. The final step in the classification process was to assign a name to each geologic material type, and to write its definition.

Based on the design principles and assumptions described above, the classification is:

- hierarchical and includes about 90 geologic material types,
- intended to characterize the general nature of the various geologic materials comprising each map unit shown on typical geologic maps,
- designed specifically for Web display of national- to regional-scale (e.g., 1:100,000) maps, and therefore may be inappropriate for more detailed maps,
- based mostly on familiar, commonly used terms, and
- supported by definitions intended for the general public.

The selection of names proved to be a difficult process in part because many names have ambiguous or multiple definitions, depending on the geologic context in which they are used and the geologist who is using them. Name selection was further complicated because of space limitations imposed by Web browsers. For example, the space available for a map legend at a website is, realistically, restricted to perhaps 1 - 2 inches in width. The traditional DMU must therefore be deconstructed – for example, a set of terse names in a map legend box might be supplemented by pop-up windows or mouseovers containing the full name and related information such as the name's definition, the map unit description, and geologic attributes (Figure 3 and Appendix B).

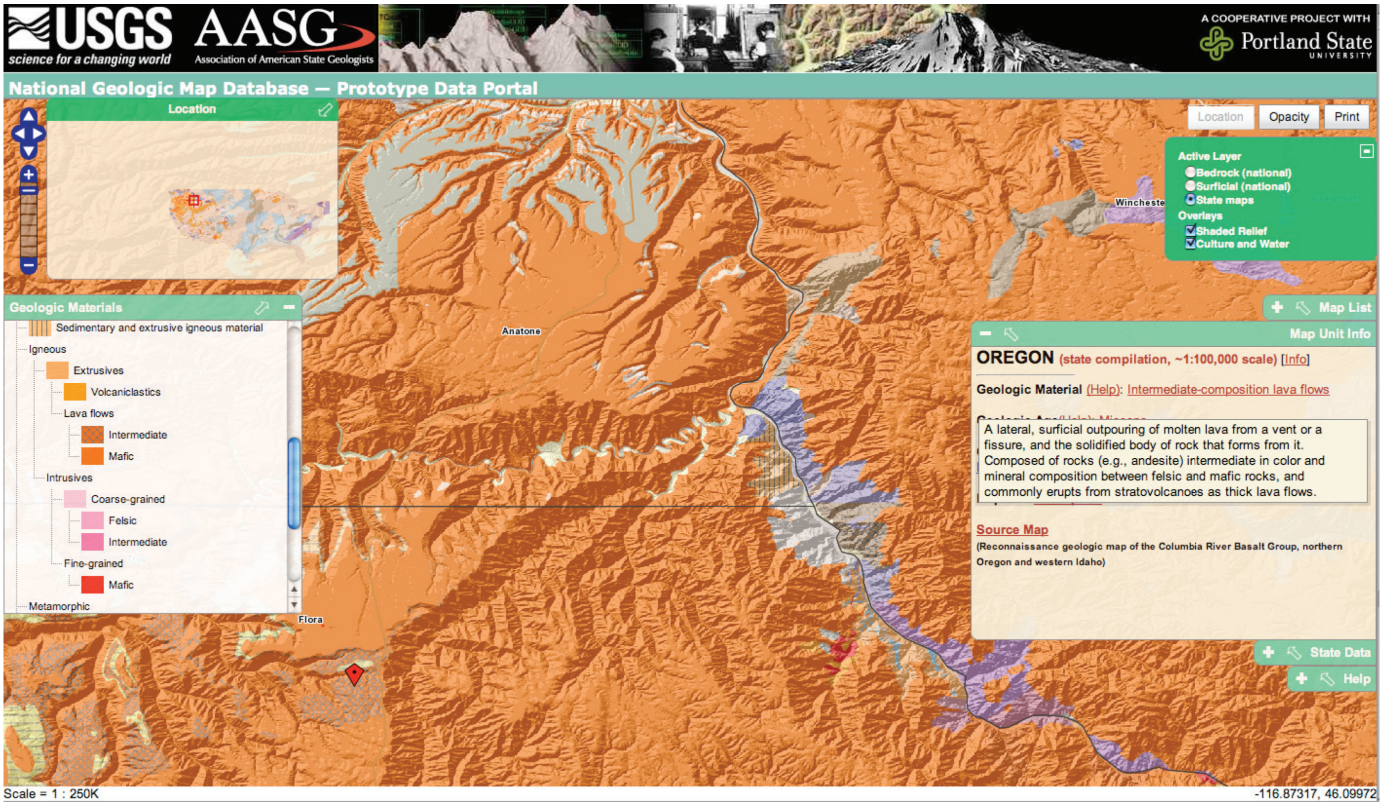


Figure 3. Screenshot of the NGMDB Data Portal, showing State-scale geologic map data of Washington, Oregon, and Idaho. Small red icon in lower left part of map marks location of a "MapUnitInfo" query, whose results are shown in pop-up box on right side of Portal window. The map unit's geologic material is named "Intermediate-composition lava flows"; the definition ("A lateral, surficial outpouring…") is obtained by mousing-over the name. The map unit is symbolized as hachured orange, and the name is shown in an abbreviated fashion in the hierarchical arrangement of the GeologicMaterials legend ("Igneous / Extrusives / Lava flows / Intermediate"). By mousing-over the abbreviated name "Intermediate," the full name "Intermediate-composition lava flows" is displayed. This approach was taken in order to restrict the legend to 1 – 2 inches in width and to provide the hierarchical context for each name.

What's a Good Definition?

For geologic material names used in this classification, definitions abound. Among the various definitions for a name, significant differences are not uncommon. In some cases these differences have a scientific basis, whereas in other cases they simply are a matter of scope or writing style. When writing a definition, authors carefully consider the intended audience and the format in which the definition will be presented. Clearly, in a general-interest publication or website, those definitions need to consist of more generalized terminology than might be useful for professional geologists; the definitions convey the general essence of name but may not be sufficiently precise for operational use by a field geologist. For example, "felsic" as defined for the public might describe the light color exemplified by the term, whereas the field geologist would be more interested in the specific minerals, the bulk chemistry, and the color index. The definitions in this classification are intended for the general public, for reasons stated above.

But definitions also must be written in a style appropriate to how they will be presented. For example, the definitions in the AGI Glossary (Neuendorf and others, 2005) are succinct and use terminology that may be unfamiliar. Nevertheless, because those terms also are contained in the Glossary, they may in turn be read and understood. A Web encyclopedia or glossary (e.g., see geologic terms in Wikipedia) uses the same strategy, with hyperlinks to related terms. This is an effective method for creating a concise yet informative definition. However, it is not always feasible or practical to use this approach, and in such cases the definitions must be more comprehensive. In the Data Portal, the definitions are intended for display when a user clicks on, or mouses-over, a name (Figure 3). Hyperlinks from such displays would be cumbersome for the user (not to mention, at least in our situation, the expense of software design), and so a "standalone" definition was needed.

Significant Decisions and Points of Contention

Here are brief comments on a few aspects of this classification and naming of geologic materials. These comments are not comprehensive but serve to indicate some of the significant decisions and points of contention. Comments are organized by geologic material classes or by classification criteria.

Clastic sediment – because the depositional environments and geomorphology of the various surficial materials have proven to be a common and reliable criteria for mapping and for delineation of map units, these materials do not neatly fit into classification schemes designed for rocks. For example, the ubiquitous map unit "alluvium," when classified in terms of lithologic-based criteria commonly applied to sedimentary rocks, might be generalized to simply "clastic sediment"; the fundamental nature and characteristics that we associate with "alluvium" are, so to speak, lost in translation. This classification therefore adopts terms that are in common use for describing and mapping surficial materials. However, two groups of these materials deserve further comment. First, although the term "Coastal zone sediment" is not uncommon as a general descriptor, it is not a familiar term in lithologic classifications. Based on a previous integration of surficial materials of the United States (Soller and Reheis, 2004), I found it useful to include here. Second, the names for mass movement deposits are unfamiliar. After much consideration, I chose these names because they seem clear and descriptive, but acknowledge that some users might not agree.

Clastic sedimentary rock – seldom is a geologic map unit, of any origin, composed solely of one lithology. In this group of rocks, multiple lithologies within a map unit can be particularly common and areally widespread, for example in the cyclothemic rocks deposited on the stable craton of the midcontinent. For this reason, and because sedimentary rocks cover a large area of the country, two geologic material types were defined specifically for map units that contain numerous lithologies. These two names are verbose, perhaps excessively so (Figure 4). However, the names are descriptive and use familiar terms. A third group of materials of this general type was identified, composed dominantly of carbonate rock

○ **Mostly sandstone, interbedded with other sedimentary rocks which locally may include conglomerate and finer grained clastics (mudstone), carbonates, and/or coal** -- This area is underlain by sequences of various sedimentary rocks that, for this generalized map depiction, are too complex to be shown separately.

Figure 4. A clastic sedimentary rock such as the Tradewater Formation (Figure 2) is composed of various geologic materials and not distinctly dominated by any one. These rock types are common throughout the United States, especially in the Mississippian-Pennsylvanian and Cretaceous. Rather than name these rocks according to a term that has strong geologic-process connotation (e.g., cyclothem) that may not apply to all rocks of this type, it was decided to simply name it according to its common constituents.

interbedded with (clastic) sedimentary rock, and is classified under the parent, sedimentary rock.

Felsic-, Intermediate-, and Mafic-composition igneous rocks – the bulk composition of igneous rocks and the minerals of which they are composed, as well as the resulting rock color, commonly have been a basis for classification. For example, the terms felsic, intermediate, and mafic composition (emphasizing the color of the rock and predominant minerals), or acidic, intermediate, and basic (emphasizing the bulk chemistry). Both classification systems are widely used. Geologists describing extrusive rocks seem to prefer the chemistry-based names. For all igneous rocks I opted for the mineral composition and color-based system, which I sense is somewhat more widely used and familiar. Differences of opinion exist in the literature regarding whether certain rocks (e.g., syenite, dacite) should be classified as felsic or intermediate, but the dominant usage seems to be felsic and is so reflected in the classification.

Fine-grained intrusive igneous rock, *Mafic-composition air-fall tephra, and Felsic-composition lava flows* – the classification strives to restrict the number of rock and sediment types, for reasons discussed above. However, for the sake of parallel construction, these three relatively uncommon rock types were included.

Applying the Classification

Dynamic Reclassification and Symbolization

The classification includes about 90 types of geologic materials. Displaying all of these on a traditional map and DMU is feasible. But in a Web-mapping system it is far too cumbersome – when a map is displayed in a browser, the user struggles to comprehend complex geologic map patterns. Aggregation of map units, into perhaps 10-20 geologic materials classes, is more appropriate for Web display. This presents a technical challenge because the user specifies the map area to be shown. To most effectively display the geology each time the user pans or zooms, the system should dynamically change the aggregation scheme, the DMU, and the symbolization.

This first iteration of the NGMDB Data Portal approximates that goal by generating different aggregation schemes and symbolizations for various types of maps shown (e.g., national maps, State maps) and for the various levels of detail of a given map that are shown as the user zooms in or out. In future iterations, we anticipate addressing differences in aggregating and symbolizing among geologic regions.

Currently, the system functions as follows:

- The initial view is of a national bedrock or surficial geologic map, at 1:15 million scale. The aggregation scheme for each map emphasizes the (approximately) 10 most areally extensive geologic material classes.

- The first level of display detail (1:7.5 million scale) uses a somewhat less extensive aggregation of the 90 material types. As noted, in the future we intend to vary the aggregation regionally, but for this version we strove for a single scheme that results in perhaps 20 or fewer material types displayed for any given map area. As the user pans across the U.S., the symbolization remains fixed but the DMU or map legend is updated dynamically to show only the geologic materials that actually occur within the field of view.
- At more detailed levels of display (1:3 million and 1:1.5 million) the full classification is used without aggregation. At these levels, the user is given the option to view State-level geologic mapping instead of the national-scale maps. Symbolization of the State maps is somewhat different than for the national maps, and is reflected in the map legend.
- Additional levels of zoom are provided, but because generally they exceed the compilation scale of State geologic maps, the option is provided to access more detailed geologic maps via the NGMDB Map Catalog.

Simple and Clear Presentation

Web presentation of information is a relatively new issue, and with it new challenges have arisen. In the NGMDB Data Portal we address some of these, within the very real limits of our experience, artistic judgment, and funding. Our focus has been the timeless need for simple, clear presentation of generalized geologic information, adapted to a relatively new medium. Suggestions for improved clarity are welcomed.

Acknowledgments

Foremost, I humbly thank the geologists who, in years past, attempted to create order from seeming chaos. Struggling to define this classification, I have even more respect for their intellectual exertions and classifications. I also gratefully acknowledge these NGMDB project members: David Percy (Portland State University), who focused on implementation of the Data Portal itself as well as provided advice and guidance during the process of classifying; Morgan Harvey (Portland State University), for his software development work on the Portal, specifically the dynamic legend; Stephen Richard (Arizona Geological Survey), who provided significant advice and suggestions on classification and definitions; and Nancy Stamm (USGS), who significantly advised me on classification systems in general, and in particular the imperative for simple and clear terminology. Finally, I thank David Sherrod (U.S. Geological Survey) for his scientific expertise and for his guidance in classifying the volcanic rocks; the resulting classification benefited greatly from my opportunity to obtain his views, but responsibility (or blame) for the result rests with me.

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Appendix A. Terms and Definitions for the NGMDB Geologic Materials Classification

The terms in this classification are intended to describe a geologic map unit as a whole. The classification is not intended for application to separate, lithologically distinct bodies of rock or sediment that may be observable but undifferentiated, within a map unit. It is designed for display of regional- and national-scale geologic maps in applications such as the National Geologic Map Database's Data Portal (*http://maps.ngmdb.us/dataviewer/*), and so may be inappropriate for use with more detailed maps. The definitions are intended for the general public as well as for geologists (see source for definitions, at end of this Appendix). The current version of this classification is maintained at *http://ngmdb.usgs.gov/Info/standards/NGMDBvocabs/*; it includes the classification criteria, which could be used in structured searches.

- **Sedimentary material** -- An aggregation of particles deposited by gravity, air, water, or ice, or as accumulated by other natural agents operating at Earth's surface such as chemical precipitation or secretion by organisms. May include unconsolidated material (sediment) and/or sedimentary rock. Does not here include sedimentary material directly deposited as a result of volcanic activity.
    - **Sediment** -- Unconsolidated material (sediment) composed of particles deposited by gravity, air, water, or ice, or as accumulated by other natural agents operating at Earth's surface such as chemical precipitation or secretion by organisms. Does not here include sedimentary material directly deposited as a result of volcanic activity.
        - **Clastic sediment** -- A sediment formed by the weathering and erosion of preexisting rocks or minerals; the eroded particles or "clasts" are transported and deposited by gravity, air, water, or ice.
            - **Clastic sediment of unspecified origin** -- A sediment formed by the weathering and erosion of preexisting rocks or minerals; the eroded particles or "clasts" are transported and deposited by gravity, air, water, or ice.
                - **Sand and gravel of unspecified origin** -- A sediment, composed mostly of sand and/or gravel, formed by the weathering and erosion of preexisting rocks or minerals; the eroded particles or "clasts" are transported and deposited by gravity, air, water, or ice.
                - **Silt and clay of unspecified origin** -- A sediment, composed mostly of silt and/or clay, formed by the weathering and erosion of preexisting rocks or minerals; the eroded particles or "clasts" are transported and deposited by gravity, air, water, or ice.
            - **Alluvial sediment** -- Unconsolidated material deposited by a stream or other body of running water, as a sorted or semi-sorted sediment in the bed of the stream or on its floodplain or delta, or as a cone or fan at the base of a mountain slope. Grain size varies from clay to gravel.
                - **Alluvial sediment, mostly coarse-grained** -- Unconsolidated material deposited by a stream or other body of running water, as a sorted or semi-sorted sediment in the bed of the stream or on its floodplain or delta, or as a cone or fan at the base of a mountain slope. This sediment is mostly sand and gravel, but may contain some mud and/or cobbles and boulders.
                - **Alluvial sediment, mostly fine-grained** -- Unconsolidated material deposited by a stream or other body of running water, as a sorted or semi-sorted sediment in the bed of the stream or on its floodplain or delta, or as a cone or fan at the base of a mountain slope. This sediment is mostly silt and clay, but may contain some coarser material (e.g., sand, gravel).
            - **Glacial till** -- Mostly unsorted and unstratified material, generally unconsolidated, deposited directly by and underneath a glacier without subsequent reworking by meltwater, and consisting of a heterogeneous mixture of clay, silt, sand, gravel, and boulders ranging widely in size and shape.
                - **Glacial till, mostly sandy** -- Mostly unsorted and unstratified material, generally unconsolidated, deposited directly by and underneath a glacier without subsequent reworking by meltwater, and consisting of clay, silt, sand, gravel, and boulders ranging widely in size and shape. Relatively sandy in texture.

- **Glacial till, mostly silty** -- Mostly unsorted and unstratified material, generally unconsolidated, deposited directly by and underneath a glacier without subsequent reworking by meltwater, and consisting of a heterogeneous mixture of clay, silt, sand, gravel, and boulders ranging widely in size and shape. Relatively loamy (silty) in texture.
- **Glacial till, mostly clayey** -- Mostly unsorted and unstratified material, generally unconsolidated, deposited directly by and underneath a glacier without subsequent reworking by meltwater, and consisting of a heterogeneous mixture of clay, silt, sand, gravel, and boulders ranging widely in size and shape. Relatively clayey in texture.

- **Ice-contact and ice-marginal sediment** -- Mostly sand, silt, and gravel-sized particles or “clasts” derived from rock or preexisting sediment eroded and transported by glaciers. As the ice melted, this material was deposited by running water essentially in contact with glacial ice, or was transported and deposited by glacially fed streams. Includes sediment deposited into water bodies adjacent to the glacial ice margin.
  - **Ice-contact and ice-marginal sediment, mostly coarse-grained** -- Mostly sand and gravel-sized particles or “clasts,” with lesser silt and clay, derived from rock or preexisting sediment eroded and transported by glaciers. As the ice melted, this material was deposited by running water essentially in contact with glacial ice, or was transported and deposited by glacially fed streams. Includes sediment deposited into water bodies adjacent to the glacial ice margin.
  - **Ice-contact and ice-marginal sediment, mostly fine-grained** -- Mostly silt and clay-sized particles or “clasts,” with lesser sand and gravel, derived from rock or preexisting sediment eroded and transported by glaciers. As the ice melted, this material was deposited by running water essentially in contact with glacial ice, or was transported and deposited by glacially fed streams. Includes sediment deposited into water bodies adjacent to the glacial ice margin.
- **Eolian sediment** -- Silt- and sand-sized sediment deposited by wind.
  - **Dune sand** -- Mostly sand-sized sediment deposited by wind. Typically characterized by various dune landforms.
  - **Loess** -- Silty material deposited by winds near the glacial margin.
- **Lacustrine sediment** -- Mostly well sorted and well bedded material ranging in grain size from clay to gravel, deposited in perennial to intermittent lakes. Much of the sediment is derived from material eroded and transported by streams. Includes deposits of lake-marginal beaches and deltas.
  - **Lacustrine sediment, mostly coarse-grained** -- Mostly well-sorted and well-bedded material, generally sand- and gravel-sized with lesser silt and clay, deposited in perennial to intermittent lakes. Much of the sediment is derived from material eroded and transported by streams. Includes deposits of lake-marginal beaches and deltas.
  - **Lacustrine sediment, mostly fine-grained** -- Mostly well-sorted and well-bedded material, generally silt- and clay-sized with lesser sand and gravel, deposited in perennial to intermittent lakes. Much of the sediment is derived from material eroded and transported by streams. Includes deposits of lake-marginal beaches and deltas.
- **Playa sediment** -- Fine-grained sediment and evaporite salts deposited in ephemeral lakes in the centers of undrained basins. Includes material deposited in playas, mudflats, salt flats, and adjacent saline marshes. Generally interbedded with eolian sand and with lacustrine sediment deposited during wetter climatic periods; commonly intertongue upslope with sediment deposited by alluvial fans.
- **Coastal zone sediment** -- Mud and sandy sediment deposited in beach, barrier island, nearshore marine deltaic, or in various low-energy shoreline (mud flat, tidal flat, sabka, algal flat) settings.
  - **Coastal zone sediment, mostly coarser grained** -- Mostly sand-, silt-, and gravel-sized sediment deposited on beaches and dunes, and in shallow marine and related alluvial environments.

        - **Coastal zone sediment, mostly fine-grained** -- Mostly clay- and silt-sized sediment deposited in lagoons, tidal flats, backbarriers, and coastal marshes.
      - **Marine sediment** -- Mud and sandy sediment deposited in various marine settings. Sediment may originate from erosion of rocks and sediments on land, or from marine organisms (of carbonate or siliceous composition).
        - **Marine sediment, mostly coarser grained** -- Mud and sandy sediment derived from erosion or rocks and sediment on land, transport by streams, and deposition on marine deltas and plains. Sediment therefore is mostly siliceous in composition.
        - **Marine sediment, mostly fine-grained** – Mostly clay- and silt-sized sediment deposited in relatively deep, quiet water, far removed from areas where coarser grained clastic sediments are washed into the marine environment. Includes sediment derived from marine organisms.
      - **Mass movement of geologic materials, downslope** -- Formed by downslope transport of particles or "clasts" produced by weathering and breakdown of the underlying rock, sediment, and/or soil. Composed of poorly sorted and poorly stratified material ranging in size from clay to boulders. Includes colluvium, landslides, talus, and rock avalanches.
        - **Colluvium and other widespread mass-movement sediment** -- Formed by relatively widespread and slow downslope transport of particles or "clasts" produced by weathering and breakdown of the underlying rock, sediment, and/or soil. Composed of poorly sorted and poorly stratified material ranging in size from clay to boulders.
        - **Debris flows, landslides, and other localized mass-movement sediment** -- Formed by relatively localized downslope transport of particles or "clasts" produced by weathering and breakdown of the underlying rock, sediment, and/or soil. Composed of poorly sorted and poorly stratified material ranging in size from clay to boulders. Commonly, the slopes on which this material occurs fail because of water, earthquake, or volcanic activity, and this material is then transported and deposited downslope. The speed of sediment transport ranges from rapid to imperceptible.
    - **Residual material** -- Unconsolidated material presumed to have developed in place, by weathering of the underlying rock or sediment. Usually forms a relatively thin surface layer that conceals the unweathered or partly altered source material below, and is the material from which soils are formed.
    - **Carbonate sediment** -- A sediment formed by the biotic or abiotic precipitation from aqueous solution of carbonates of calcium, magnesium, or iron; e.g., limestone and dolomite.
    - **Peat and muck** -- An unconsolidated material principally composed of plant remains, with lesser amounts of generally fine-grained clastic sediment. Deposited in a water-saturated environment such as a swamp, marsh, or bog. It is an early stage or rank in the development of coal.
  - **Sedimentary rock** -- Consolidated material (rock) composed of particles deposited by gravity, air, water, or ice, or as accumulated by other natural agents operating at Earth's surface such as chemical precipitation or secretion by organisms. Does not here include sedimentary material directly deposited as a result of volcanic activity.
    - **Clastic sedimentary rock** -- Sedimentary rock that is composed dominantly of particles or "clasts" derived by erosion, weathering, or mass-wasting of preexisting rock, and deposited by gravity, air, water, or ice.
      - **Conglomerate** -- Sedimentary rock that is composed dominantly of particles or "clasts" derived by erosion and weathering of preexisting rock, and containing more than 30 percent gravel-sized particles.
      - **Sandstone** -- Sedimentary rock that is composed dominantly of particles or "clasts" derived by erosion and weathering of preexisting rock, consisting mostly of sand-sized particles, with or without a fine-grained matrix of silt or clay.
      - **Mostly sandstone, interbedded with other sedimentary rocks which locally may include conglomerate and finer grained clastics (mudstone), carbonates, and/or coal** -- This area is underlain by sequences of various sedimentary rocks that, for this generalized map depiction, are too complex to be shown separately.
      - **Sandstone and mudstone** -- Approximately equal (or unspecified) proportion of sandstone and mudstone (which includes shale and siltstone).

        - **Mudstone** -- Sedimentary rock that is composed dominantly of particles or "clasts" derived by erosion and weathering of preexisting rock, consisting mostly of mud (silt- and clay-sized particles). Includes shale and siltstone.
        - **Mostly mudstone, interbedded with other sedimentary rocks which locally may include coarser grained clastics (sandstone, conglomerate), carbonates, and/or coal** -- This area is underlain by sequences of various sedimentary rocks that, for this generalized map depiction, are too complex to be shown separately.
    - **Carbonate rock** -- A sedimentary rock such as limestone or dolomite, consisting chiefly of carbonate minerals.
    - **Mostly carbonate rock, interbedded with clastic sedimentary rock** -- This area is underlain by sequences of various sedimentary rocks that, for this generalized map depiction, are too complex to be shown separately.
    - **Evaporitic rock** -- Sedimentary rock composed primarily of minerals produced by evaporation of a saline solution. Examples include gypsum, anhydrite, other diverse sulfates, halite (rock salt), primary dolomite, and various nitrates and borates.
    - **Iron-rich sedimentary rock** -- Sedimentary rock in which at least 50 percent of the observed minerals are iron-bearing (hematite, magnetite, limonite-group, siderite, iron sulfides).
    - **Coal and lignite** -- Organic rich sedimentary rock formed from the compaction and alteration of plant remains. Coal is a consolidated, hard black organic rock, whereas lignite is a semiconsolidated brown to black, earthy material, which may contain large particles of recognizable plant parts and tends to crack upon drying.
- **Sedimentary and extrusive igneous material** -- This area is underlain either by (1) sedimentary rock and/or unconsolidated material (sediment) and by extrusive igneous material (volcanic rock and/or sediment) or (2) by volcanic rock and/or sediment and by such material after erosion and redeposition.
- **Igneous rock** -- Rock that solidified from molten or partly molten material (i.e., magma).
    - **Extrusive igneous material** -- Molten material that was erupted onto the surface of the Earth, fusing into rock or remaining as unconsolidated particles. Includes lava flows and pyroclastic material such as volcanic ash.
        - **Volcaniclastic (fragmental) material** -- Rock and unconsolidated material consisting of particles or "clasts" that were formed by volcanic explosion or aerial expulsion from a volcanic vent.
            - **Pyroclastic flows** -- An avalanche of hot ash, pumice, rock fragments, and volcanic gas that rushes down the side of a volcano as fast as 100 km/hour or more. Once deposited, the ash, pumice, and rock fragments may deform (flatten) and weld together because of the intense heat and the weight of the overlying material.
                - **Felsic-composition pyroclastic flows** -- An avalanche of hot ash, pumice, rock fragments, and volcanic gas that rushes down the side of a volcano as fast as 100 km/hour or more. Once deposited, the ash, pumice, and rock fragments may deform (flatten) and weld together because of the intense heat and the weight of the overlying material. Composed of light-colored rocks (e.g., rhyolite, dacite) which, because of their high-silica content and resulting high viscosity, tend to erupt explosively.
                - **Intermediate-composition pyroclastic flows** -- An avalanche of hot ash, pumice, rock fragments, and volcanic gas that rushes down the side of a volcano as fast as 100 km/hour or more. Once deposited, the ash, pumice, and rock fragments may deform (flatten) and weld together because of the intense heat and the weight of the overlying material. Composed of rocks (e.g., andesite) intermediate in color and mineral composition between felsic and mafic rocks. Andesite magma commonly erupts from stratovolcanoes as thick lava flows but also can generate strong explosive eruptions to form pyroclastic flows.
                - **Mafic-composition pyroclastic flows** -- An avalanche of hot ash, pumice, rock fragments, and volcanic gas that rushes down the side of a volcano as fast as 100 km/hour or more. Once deposited, the ash, pumice, and rock fragments may deform (flatten) and weld together because of the intense heat and the weight of the overlying material. Composed of dark-colored rocks (e.g., basalt) which, because of their low-silica content and resulting low viscosity, tend to erupt gently as lava flows rather than more forcefully as pyroclastic flows.

- **Air-fall tephra** -- Fragments of volcanic rock and lava, of various sizes, are known as "tephra." This material is blasted into the air by explosions or carried upward by hot gases in eruption columns or lava fountains. As tephra falls to the ground with increasing distance from a volcano, the average size of the individual rock particles and the thickness of the resulting deposit decrease. At some distance from a volcano, the deposit is known as volcanic ash.
  - **Felsic-composition air-fall tephra** -- Fragments of volcanic rock and lava, of various sizes, are known as "tephra." This material is blasted into the air by explosions or carried upward by hot gases in eruption columns or lava fountains. As tephra falls to the ground with increasing distance from a volcano, the average size of the individual rock particles and the thickness of the resulting deposit decrease. Composed of light-colored rocks (e.g., rhyolite, dacite) which, because of their high-silica content and resulting high viscosity, tend to erupt explosively, readily forming pumice and volcanic ash.
  - **Intermediate-composition air-fall tephra** -- Fragments of volcanic rock and lava, of various sizes, are known as "tephra." This material is blasted into the air by explosions or carried upward by hot gases in eruption columns or lava fountains. As tephra falls to the ground with increasing distance from a volcano, the average size of the individual rock particles and the thickness of the resulting deposit decrease. Composed of rocks (e.g., andesite) intermediate in color and mineral composition between felsic and mafic rocks. Andesite magma commonly erupts from stratovolcanoes as thick lava flows but also can generate strong explosive eruptions, readily forming pumice and volcanic ash.
  - **Mafic-composition air-fall tephra** -- Fragments of volcanic rock and lava, of various sizes, are known as "tephra." This material is blasted into the air by explosions or carried upward by hot gases in eruption columns or lava fountains. As tephra falls to the ground with increasing distance from a volcano, the average size of the individual rock particles and the thickness of the resulting deposit decrease. Composed of dark-colored rocks (e.g., basalt) which, because of their low-silica content and resulting low viscosity, tend to erupt gently as lava flows rather than more forcefully, and so these deposits are uncommon.

▪ **Lava flows** -- A lateral, surficial outpouring of molten lava from a vent or a fissure, and the solidified body of rock that forms when it cools. Composed generally of fine-grained, dark-colored rocks (e.g., basalt), and tends to form extensive sheets with generally low relief except in the vent areas where cinder cones or shield volcanoes may form. Includes basaltic shield volcanoes, which may become very large (e.g., Hawaii).

- **Felsic-composition lava flows** -- A lateral, surficial outpouring of molten lava from a vent or a fissure, and the solidified body of rock that forms when it cools. Composed of fine-grained, light-colored rocks (e.g., rhyolite, dacite) which, because of their high-silica content and resulting high viscosity, tend to erupt explosively, and so these deposits are uncommon.
- **Intermediate-composition lava flows** -- A lateral, surficial outpouring of molten lava from a vent or a fissure, and the solidified body of rock that forms when it cools. Composed of fine-grained rocks (e.g., andesite) intermediate in color and mineral composition between felsic and mafic rocks, and commonly erupts from stratovolcanoes as thick lava flows.
- **Mafic-composition lava flows** -- A lateral, surficial outpouring of molten lava from a vent or a fissure, and the solidified body of rock that forms when it cools. Composed of fine-grained, dark-colored rocks (e.g., basalt), and tends to form extensive sheets with generally low relief. Includes basaltic shield volcanoes, which may become very large (e.g., Hawaii).

- **Intrusive igneous rock** -- Rock that solidified from molten or partly molten material (i.e., magma), forming below the Earth's surface.

▪ **Coarse-grained intrusive igneous rock** -- Rock that solidified from molten or partly molten material (i.e., magma). It formed at some depth beneath the Earth's surface, thereby cooling slowly enough for mineral crystals to grow to a size large enough to be visible to the naked eye.

        - **Coarse-grained, felsic-composition intrusive igneous rock** -- Rock that solidified from molten or partly molten material (i.e., magma). It formed at some depth beneath the Earth's surface, thereby cooling slowly enough for mineral crystals to grow to a size large enough to be visible to the naked eye. Composed mostly of light-colored minerals (e.g., quartz, feldspars, feldspathoids, muscovite). Includes granitic and syenitic rock.
        - **Coarse-grained, intermediate-composition intrusive igneous rock** -- Rock that solidified from molten or partly molten material (i.e., magma). It formed at some depth beneath the Earth's surface, thereby cooling slowly enough for mineral crystals to grow to a size large enough to be visible to the naked eye. Intermediate in color and mineral composition between felsic and mafic igneous rock. Includes dioritic rock.
        - **Coarse-grained, mafic-composition intrusive igneous rock** -- Rock that solidified from molten or partly molten material (i.e., magma). It formed at some depth beneath the Earth's surface, thereby cooling slowly enough for mineral crystals to grow to a size large enough to be visible to the naked eye. Composed mostly of one or more ferromagnesian, dark-colored minerals. Includes gabbroic rock.
        - **Ultramafic intrusive igneous rock** -- Rock that solidified from molten or partly molten material (i.e., magma). It formed at some depth beneath the Earth's surface, thereby cooling slowly enough for mineral crystals to grow to a size large enough to be visible to the naked eye. Composed mostly of mafic minerals, e.g., monomineralic rocks composed of hypersthene, augite, or olivine.
    - **Fine-grained intrusive igneous rock** -- Rock that solidified from molten or partly molten material (i.e., magma). It formed at shallow depths beneath the Earth's surface, thereby cooling quickly. These rocks generally are fine-grained, but may contain large mineral crystals (phenocrysts), and they occur as tabular dikes or sills.
        - **Fine-grained, felsic-composition intrusive igneous rock** -- Rock that solidified from molten or partly molten material (i.e., magma). It formed at shallow depths beneath the Earth's surface, thereby cooling quickly. These rocks generally are fine-grained, but may contain large mineral crystals (phenocrysts), and they occur as tabular dikes or sills. Composed mostly of light-colored minerals (e.g., quartz, feldspars, feldspathoids, muscovite). Includes rhyolitic, dacitic, and trachytic rock.
        - **Fine-grained, intermediate-composition intrusive igneous rock** -- Rock that solidified from molten or partly molten material (i.e., magma). It formed at shallow depths beneath the Earth's surface, thereby cooling quickly. These rocks generally are fine-grained, but may contain large mineral crystals (phenocrysts), and they occur as tabular dikes or sills. Intermediate in color and mineral composition between felsic and mafic igneous rock. Includes andesitic rock.
        - **Fine-grained, mafic-composition intrusive igneous rock** -- Rock that solidified from molten or partly molten material (i.e., magma). It formed at shallow depths beneath the Earth's surface, thereby cooling quickly. These rocks generally are fine-grained, but may contain large mineral crystals (phenocrysts), and they occur as tabular dikes or sills. Composed mostly of one or more ferromagnesian, dark-colored minerals. Includes basaltic rock.
    - **Exotic-composition intrusive igneous rock** -- Rock that solidified from molten or partly molten material (i.e., magma), forming below the Earth's surface and having exotic mineralogical, textural, or field setting characteristics. These rocks typically are dark colored with abundant phenocrysts. Includes kimberlite, lamprophyre, lamproite, and foiditic rocks.
- **Igneous and metamorphic rock** -- Consists of coarse-grained intrusive igneous rocks and generally medium to high-grade metamorphic rocks. This area is not dominantly either igneous or metamorphic.
- **Metamorphic rock** -- A rock derived from preexisting rocks by mineralogical, chemical, or structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, shearing stress, and chemical environment, generally at depth in the Earth's crust.
    - **Regional metamorphic rock, of unspecified origin** -- A rock derived from preexisting rocks by mineralogical, chemical, or structural changes, essentially in the solid state, in response to marked regional changes in temperature, pressure, shearing stress, and chemical environment, generally at depth in the Earth's crust. In this area, the origin of the preexisting rock (e.g., igneous, sedimentary) is not known.

        - **Medium and high-grade regional metamorphic rock, of unspecified origin** -- A rock which is derived from preexisting rocks by mineralogical, chemical, or structural changes, essentially in the solid state, in response to relatively intense regional changes in temperature, pressure, shearing stress, and chemical environment, generally at depth in the Earth's crust. In this area, the origin of the preexisting rock (e.g., igneous, sedimentary) is not known. Includes rocks such as amphibolite, granulite, schist, and gneiss.
        - **Contact-metamorphic rock** -- Rock that originated by local processes of thermal metamorphism, genetically related to the intrusion and extrusion of magmas and taking place in rocks at or near their contact with a body of igneous rock. Metamorphic changes are effected by the heat and fluids emanating from the magma and by some deformation because of emplacement of the igneous mass.
        - **Deformation-related metamorphic rock** -- A rock derived from preexisting rocks by mineralogical, chemical, or structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, shearing stress, and chemical environment. Generally forms in narrow, planar zones of local deformation (e.g., along faults) and characterized by foliation or alignment of mineral grains. Includes mylonite.
    - **Metasedimentary rock** -- A rock derived from preexisting sedimentary rocks by mineralogical, chemical, or structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, shearing stress, and chemical environment, generally at depth in the Earth's crust.
        - **Slate and phyllite, of sedimentary rock origin** -- A fine-grained rock derived from preexisting sedimentary rocks by mineralogical, chemical, or structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, shearing stress, and chemical environment, generally at depth in the Earth's crust. Includes phyllite and slate, which is a compact, fine-grained rock that possesses strong cleavage and hence can be split into slabs and thin plates. Mostly formed from fine-grained material such as mudstone.
        - **Schist and gneiss, of sedimentary rock origin** -- A foliated rock derived from preexisting sedimentary rocks by mineralogical, chemical, or structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, shearing stress, and chemical environment, generally at depth in the Earth's crust. Includes schist (characterized by such strong foliation or alignment of minerals that it readily splits into flakes or slabs) and gneiss (characterized by alternating, irregular bands of different mineral composition). Mostly formed from fine-grained material such as mudstone.
        - **Marble** -- A rock derived from preexisting (commonly carbonate) sedimentary rocks by mineralogical, chemical, or structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, shearing stress, and chemical environment, generally at depth in the Earth's crust. Characterized by recrystallization of the carbonate minerals in the source rock.
        - **Quartzite** -- A rock derived from preexisting (commonly sandstone) sedimentary rocks by mineralogical, chemical, or structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, shearing stress, and chemical environment, generally at depth in the Earth's crust. Characterized by recrystallization of quartz in the source rock.
    - **Metaigneous rock** -- A rock derived from preexisting igneous rocks (mostly extrusive in origin) by mineralogical, chemical, or structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, shearing stress, and chemical environment, generally at depth in the Earth's crust. Mafic and ultramafic schists and gneisses are common.
- **Other materials:**
    - **Rock and sediment** -- Various rocks and sediment, not differentiated.
    - **Rock** -- Various rock types, not differentiated.
    - **"Made" or human-engineered land** -- Modern, unconsolidated material known to have human-related origin.
    - **Water or ice**
    - **Unmapped area**

Definitions were adapted from a variety of published and unpublished works, including:

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North American Geologic Map Data Model Steering Committee Science Language Technical Team, 2004, Report on Progress to Develop a North American Science-Language Standard for Digital Geologic-Map Databases, *in* Soller, D.R., ed., Digital Mapping Techniques '04 – Workshop Proceedings: U.S. Geological Survey Open-File Report 2004-1451, p. 85-94 and 4 appendices containing the science terminologies, *http://pubs.usgs.gov/of/2004/1451/nadm/*.

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USGS Photo glossary of volcanic terms, 2008, U.S. Geological Survey Volcano Hazards Program website, *http://volcanoes.usgs.gov/images/pglossary/index.php*.

Appendix B. Terse, Hierarchical Notation Shown in Map Legend, and the Corresponding Full Names

The terse names are necessitated by the page-size limitations imposed by the Web browser. These names are placed in the context by the hierarchical display, and comprehension is supported by the display of full names within the Data Portal's query results (Figure 3).

Terse, hierarchical notation shown in Map Legend	Full name, as shown in query results and definition
Sedimentary	Sedimentary material
Sediment	Sediment
Clastic sediment	Clastic sediment
Unspecified origin	Clastic sediment of unspecified origin
Sand, gravel	Sand and gravel of unspecified origin
Silt, clay	Silt and clay of unspecified origin
Alluvium	Alluvial sediment
Mostly coarse-grained	Alluvial sediment, mostly coarse-grained
Mostly fine-grained	Alluvial sediment, mostly fine-grained
Glacial till	Glacial till
Mostly sandy	Glacial till, mostly sandy
Mostly silty	Glacial till, mostly silty
Mostly clayey	Glacial till, mostly clayey
Ice-marginal	Ice-contact and ice-marginal sediment
Mostly coarse-grained	Ice-contact and ice-marginal sediment, mostly coarse-grained
Mostly fine-grained	Ice-contact and ice-marginal sediment, mostly fine-grained
Eolian	Eolian sediment
Sand	Dune sand
Loess	Loess
Lacustrine	Lacustrine sediment
Mostly coarse-grained	Lacustrine sediment, mostly coarse-grained
Mostly fine-grained	Lacustrine sediment, mostly fine-grained
Playa	Playa sediment
Coastal zone	Coastal zone sediment
Mostly coarser grained	Coastal zone sediment, mostly coarser grained
Mostly fine-grained	Coastal zone sediment, mostly fine-grained
Marine	Marine sediment
Mostly coarser grained	Marine sediment, mostly coarser grained
Mostly fine-grained	Marine sediment, mostly fine-grained
Mass movement	Mass movement of geologic materials, downslope
Widespread	Colluvium and other widespread mass-movement sediment
Localized	Debris flows, landslides, and other localized mass-movement sediment
Residual	Residual material
Carbonate	Carbonate sediment
Peat	Peat and muck
Rock	Sedimentary rock
Clastic rock	Clastic sedimentary rock
Conglomerates	Conglomerate
Sandstones	Sandstone
Mostly sandstone	Mostly sandstone, interbedded with other sedimentary rocks which locally may include conglomerate and finer grained clastics (mudstone), carbonates, and/or coal
Sandstone and mudstone	Sandstone and mudstone
Mudstones	Mudstone

Mostly mudstone	Mostly mudstone, interbedded with other sedimentary rocks which locally may include coarser grained clastics (sandstone, conglomerate), carbonates, and/or coal
Limestones	Carbonate rock
Mostly limestones	Mostly carbonate rock, interbedded with clastic sedimentary rock
Evaporites	Evaporitic rock
Iron-rich	Iron-rich sedimentary rock
Coal	Coal and lignite
Sedimentary and extrusive igneous material	Sedimentary and extrusive igneous material
Igneous	Igneous rock
Extrusives	Extrusive igneous material
Volcaniclastics	Volcaniclastic (fragmental) material
Pyroclastic flows	Pyroclastic flows
Felsic	Felsic-composition pyroclastic flows
Intermediate	Intermediate-composition pyroclastic flows
Mafic	Mafic-composition pyroclastic flows
Air-fall tephra	Air-fall tephra
Felsic	Felsic-composition air-fall tephra
Intermediate	Intermediate-composition air-fall tephra
Mafic	Mafic-composition air-fall tephra
Lava flows	Lava flows
Felsic	Felsic-composition lava flows
Intermediate	Intermediate-composition lava flows
Mafic	Mafic-composition lava flows
Intrusives	Intrusive igneous rock
Coarse-grained	Coarse-grained intrusive igneous rock
Felsic	Coarse-grained, felsic-composition intrusive igneous rock
Intermediate	Coarse-grained, intermediate-composition intrusive igneous rock
Mafic	Coarse-grained, mafic-composition intrusive igneous rock
Ultramafic	Ultramafic intrusive igneous rock
Fine-grained	Fine-grained intrusive igneous rock
Felsic	Fine-grained, felsic-composition intrusive igneous rock
Intermediate	Fine-grained, intermediate-composition intrusive igneous rock
Mafic	Fine-grained, mafic-composition intrusive igneous rock
Exotics	Exotic-composition intrusive igneous rock
Igneous and metamorphic rock	Igneous and metamorphic rock
Metamorphic	Metamorphic rock
Unspecified origin	Regional metamorphic rock, of unspecified origin
Medium to High-grade	Medium and high-grade regional metamorphic rock, of unspecified origin
Contact	Contact-metamorphic rock
Deformation	Deformation-related metamorphic rock
Metasedimentary	Metasedimentary rock
Slate and phyllite	Slate and phyllite, of sedimentary rock origin
Schist and gneiss	Schist and gneiss, of sedimentary rock origin
Marble	Marble
Quartzite	Quartzite
Metaigneous	Metaigneous rock
Rock and sediment	Rock and sediment
Rock	Rock
“Made” land	“Made” or human-engineered land
Water or ice	Water or ice
Unmapped	Unmapped